MEMORANDUM

To: Suzanne Kocchi, USEPA Headquarters, Mail Code: 6207J, Washington, DC

From: Ruth Mead, Jason Huckaby, and Darcy Wilson, Eastern Research Group, Inc., Morrisville, NC

Date: June 6, 2008

Subject: **Review of Existing Programs**

Addendum dated February 12, 2009: Note that this memorandum is dated June 6, 2008. The information it contains reflects program information that was available as of spring 2008 when EPA technical working groups conducted the reviews of existing greenhouse gas reporting programs and protocols. For example, the California mandatory reporting rule was adopted in December 2008 and The Climate Registry implemented a pilot reporting program in 2008 after completion of this memo. These and other changes between June 2008 and proposal of the EPA mandatory GHG reporting rule are not reflected in this memorandum or its attachments.

The purpose of this memorandum is to document the EPA technical working group reviews of existing greenhouse gas (GHG) reporting programs and protocols. The information reviewed for each source category and applicable reporting program included:

- Coverage (gases or fuels)
- Coverage thresholds
- Level of reporting (e.g., source category, facility, unit)
- Point of monitoring
- Monitoring methods and GHG calculation methods
- Program purpose (e.g., mandatory, voluntary)
- Data inputs needed to implement GHG methods
- Information to be reported
- Quality assurance/quality control procedures

The reporting programs and GHG protocols reviewed varied by source category, but the following programs were reviewed for most source categories:

- California Climate Action Registry General Reporting Protocol (CCAR)
- California Mandatory GHG Reporting Rule
- Department of Energy 1605(b) Voluntary Reporting Program
- EPA Climate Leaders
- Inventory of U.S. GHG Emissions and Sinks 1990-2005
- European Union Emissions Trading System (EU ETS)
- 2006 IPCC Guidelines (IPCC)
- Regional Greenhouse Gas Initiative (RGGI)

- The Climate Registry (TCR)
- World Resources Institute/ World Business Council for Sustainable Development GHG Protocol Corporate Standard (WRI/WBCSD)
- Industry trade groups (e.g., API, NCASI, International Aluminum Institute)

In several cases, the EPA technical working groups were aware of additional GHG protocols that pertained specifically to their source categories and included these on the tables. In other cases, working groups determined that some of the reporting programs listed above were not relevant to a source category (or did not add substantive information for the given source category) and therefore did not list the program in the table (e.g., if a program didn't contain a methodology for the source category or provided only a general reference to IPCC).

The attachment to this memorandum provides the review of existing program details for each source category, in the following order:

1. General stationary fuel combustion sources
2. Adipic acid production
3. Aluminum production
4. Ammonia manufacturing
5. Cement production
6. Electronics manufacturing
7. Ferroalloy production
8. Glass production
9. HCFC-22 production and HFC-23 destruction
10. Hydrogen production
11. Iron and steel production
12. Lead production
13. Lime manufacturing
14. Magnesium production
15. Miscellaneous uses of carbonates
16. Nitric acid manufacturing
17. Oil and natural gas systems
18. Petrochemical production
19. Petroleum refineries
20. Phosphoric acid production
21. Pulp and paper manufacturing
22. Silicon carbide production
23. Soda ash manufacturing
24. Sulfur hexafluoride (SF_6) from electrical equipment
25. Titanium dioxide production
26. Underground coal mines
27. Zinc production
28. Landfills
29. Wastewater treatment
30. Manure management
31. Suppliers of coal and coal-based liquid fuels
32. Suppliers of petroleum products

33. Suppliers of natural gas and natural gas liquids
34. Suppliers of industrial greenhouse gases
35. Suppliers of carbon dioxide
36. Mobile sources

Separate program reviews were not conducted for the ethanol production and food production source categories. Ethanol and food production facilities would report GHG emissions from stationary fuel combustion, landfills, and wastewater treatment. See the reviews for those source categories.

The program review for the fluorinated greenhouse gas production source category is included in the review for "suppliers of industrial greenhouse gases".

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Coverage (GHGs)	Coverage (Stationary Source Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (CEMS or Calculation - what is monitored including frequency and equipment; what data are used to calculate GHG emissions)	Supported Program Type (e.g., mandatory reporting, voluntary reporting, etc.)
California ARB Mandatory Reporting Rule (Proposed)	All fuels	CO_2, CH_4, N_2O	All combustion equipment at affected facilities	De minimis sources	Facility	Facility or unit fuel supply	May estimate emissions by using alternative methods of operator's choosing, subject to verification team concurrence.	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	Biomass fuel, municipal waste	CO_2	All combustion equipment at affected facilities	All except de minimis sources	Facility	Facility or unit steam line	Calculation: 1) Measure steam output and convert to energy input by a factor equal to design heat input BTU/design output lbs steam, and combine with default emission factors. 2) Fuels or fuel mixtures ≥ 5% biomass by weight and not pure biomass, except waste-derived fuels < 30% by weight of total fuels combusted for the year, shall determine biomass portion of CO_2 emissions based on carbon age using ASTM D6866-06a, measuring for at least 24 consecutive hours every three months. Ratio developed from tests multiplied by emissions to apportion emissions.	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	Refinery fuel gas, other low Btu gases	CO_2, CH_4, N_2O	All combustion equipment at affected facilities	All except de minimis sources	Facility	Facility or unit fuel line	Calculation: 1) Daily gas consumption and measure refinery gas carbon content 3 times per day (every 8 hours) or flexi-coker gas once per day. 2) Daily or weekly measured fuel consumption, carbon content, and heat content for each fuel gas system. May use in-line continuous monitor for carbon content and either use hourly average or the hour the sample was taken. Daily or weekly schedule based on refinery size. For CH4 and N2O use fuel consumption and default emission factor based on heat content if measured, or default heat content.	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	Fuel Oil	CO_2, CH_4, N_2O	All non-CEMS combustion equipment at affected facilities	All except de minimis sources	Facility	Facility or unit fuel supply	Calculation: Measure and record fuel consumption at receipt of each new fuel shipment/delivery, or monthly. 1) Measure carbon content monthly or 2) Measure heat content for each shipment or monthly. Emissions calculated based on 1) carbon content and fuel consumption, 2) heat content, fuel consumption, and ARB default emission factor. May also calculate emissions based on annual fuel combustion and default heat content and emission factors.	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	Solid fuels	CO_2	All non-CEMS combustion equipment at affected facilities	All except de minimis sources	Facility	Facility or unit fuel as fired	Calculation: Monthly measure fuel as-fired carbon or heat content based on a composite sample of four weekly samples (use specified ASTM methods). Combine with measurements of monthly fuel burned and emission factor based on measured carbon content, or default factor if only measuring heat content. Use fuel consumption and default emission factor based on heat content if measured, or default heat content for CH_4 and N_2O .	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	Natural gas	CO_2, CH_4, N_2O	All combustion equipment at affected facilities	All except de minimis sources	Facility	Facility or unit fuel line	Calculation: Natural gas consumption and heat content measured monthly, and may use suppliers heat content if within GCV range of 975 to 1100 Btu/scf. If GCV outside of range of 975 to 1100 Btu/scf, then use carbon content method and measure monthly. Use default emission factor or measured monthly carbon content (carbon content not relevant to CH_4 and N_2O). Use fuel consumption and default emission factor based on heat content if measured, or default heat content for CH_4 and N_2O .	Mandatory

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	IPCC or WRI/WBCSD Elements	Source
California ARB Mandatory Reporting Rule (Proposed)	All fuels	Fuel burned or other operating parameters.	Annually separately identify and include emissions designated as de minimis	De minimis estimates subject to third party verification.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	Biomass fuel, municipal waste	Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	Refinery fuel gas, other low Btu gases	Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	Fuel Oil	Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	Solid fuels	Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	Natural gas	Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Coverage (GHGs)	Coverage (Stationary Source Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (CEMS or Calculation - what is monitored including frequency and equipment; what data are used to calculate GHG emissions)	Supported Program Type (e.g., mandatory reporting, voluntary reporting, etc.)
California ARB Mandatory Reporting Rule (Proposed)	Biomass fuel, municipal waste, other waste	CO_2	Combustion equipment with CEMS subject to ARB or 40 CFR Parts 60 or 75	All except de minimis sources	Facility	Stack	CEMS: CEMS Units with diluent and flow CEMS required by CARB or federal programs shall determine emissions based on Part 75 (See Part 75). If a mix of fossil and non-fossil fuels are burned then CO_2 emissions are separately apportioned by 1) determine fossil fuel CO_2 emissions by calculation method and subtract from CEMS emissions, or 2) Fuels or fuel mixtures ≥ 5% biomass by weight and not pure biomass, except waste-derived fuels < 30% by weight of total fuels combusted for the year, shall determine biomass portion of CO_2 emissions based on carbon age using ASTM D6866-06a measuring for at least 24 consecutive hours every three months. Ratio developed from tests shall be multiplied by emissions to apportion emissions.	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	Biomass fuel, municipal waste, other solid waste	CO_2, CH_4, N_2O	All combustion equipment at affected facilities	All except de minimis sources	Facility	Stack	Source test: In lieu of CEMS, non-fossil solid fuel fired units may use ARB approved emission factors based on annual source tests.	Mandatory
California ARB Mandatory Reporting Rule (Proposed)	All fossil fuels	CO_2	Combustion equipment with CEMS subject to ARB or 40 CFR Parts 60 or 75	All except de minimis sources	Facility	Stack or facility or unit fuel supply.	Units with CEMS under 40 CFR Parts 60 or 75 shall determine emissions based Part 75, and non-CEMS Part 75 units shall also meet Part 75 requirements (See Part 75). Plus there is additional net energy output monitoring, and non-CEMS Part 60 equipment shall meet general stationary source combustion requirements (See ARB specific fuel rows).	Mandatory
California Climate Action Registry (CCAR)	All fuels	CO_2, CH_4, N_2O	All combustion equipment at organization's facilities	De minimis sources	Entity-level required, facility or sub-entity level encouraged	Facility or unit fuel supply.	Calculation: First year and every three years unless changes in de minimis activities. Same calculation methods (see above) as for significant sources except power/utility entities can estimate by using operating parameters other than fuel (hours) and conservative assumptions.	Voluntary
California Climate Action Registry (CCAR)	All fuels	CO_2	All EGUs at power/utility entities	Significant sources	Entity-level required, facility or sub-entity level encouraged	Stack CEMS or Facility or unit fuel supply.	CEMS or calculations methods as used in 40 CFR Part 75 (See Part 75). If a mix of fossil and non-fossil fuels are burned then CO_2 emissions are separately apportioned by using a fuel calculation approach for the biomass fuel. Additional calculations for efficiency metrics in terms of emissions per energy output and fossil fuel input, and CHP energy output allocations as described above.	Voluntary

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	IPCC or WRI/WBCSD Elements	Source
California ARB Mandatory Reporting Rule (Proposed)	Biomass fuel, municipal waste, other waste	Stack gas concentration and flow. Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	Biomass fuel, municipal waste, other solid waste	Fuel burned. Electric output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - 1) Uses some IPCC emission factors, 2) Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California ARB Mandatory Reporting Rule (Proposed)	All fossil fuels	Stack gas concentration and flow, fuel burned, plus net energy output for EGUs.	Annual direct GHG emissions, amount of fuel burned by type; for electricity generating facilities: average high heat value by fuel type (if measured), average carbon content by fuel type (if measured); indirect energy usage, net energy output.	Establish, document, implement, and maintain data acquisition and handling activities for the calculation and reporting of emissions. Implement systems of internal audit, quality assurance, and quality control for the reporting program and the data reported. Employ measurement procedures for fuel activity data (mass or volume flow) that have an uncertainty of not more than ±5 percent. All fuel activity measurement devices shall be maintained and calibrated in a manner and at a frequency required to maintain this level of measurement uncertainty. Third party verification required.	IPCC - Requires third party verification.	http://www.arb.ca.gov/cc/ccei.htm
California Climate Action Registry (CCAR)	All fuels	Fuel burned or other operating parameters.	Report de minimis sources and emissions for the first year of program. Report in subsequent years only if there are changes.	GHG Management Plan, and third party certification.	IPCC - 1) May use IPCC emission factors, 2) Requires third party verification. The CCAR General Reporting Protocol's accounting and reporting principles are consistent with the WRI/WBCSD GHG Protocol Initiative.	http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html
California Climate Action Registry (CCAR)	All fuels	Fuel burned	Annual. Entities must report at least 95% of direct emissions from stationary combustion. CO_2 emissions at a minimum must be reported for CA or the US for the first three years, and from fourth year, all Kyoto GHGs must be reported. Data submitted using CARROT tool.	GHG Management Plan, and third party certification. Third party certifier's estimates of GHG emissions for the entire inventory must not differ from participant's by > 5%.	IPCC - 1) May use IPCC emission factors, 2) Requires third party verification. The CCAR General Reporting Protocol's accounting and reporting principles are consistent with the WRI/WBCSD GHG Protocol Initiative.	http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Coverage (GHGs)	Coverage (Stationary Source Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (CEMS or Calculation - what is monitored including frequency and equipment; what data are used to calculate GHG emissions)	Supported Program Type (e.g., mandatory reporting, voluntary reporting, etc.)
California Climate Action Registry (CCAR)	All fuels	CO_2, CH_4, N_2O	All combustion equipment at organization's facilities	Significant sources	Entity-level required, facility or sub-entity level encouraged	Stack or facility or unit fuel supply.	Use CEMS emissions data or make estimate of emissions. Calculation: Fuel direct measurement according to industry approved methods, recording fuel purchases, or sales invoices measuring any stock change combined with specified or source derived emission factors. CHP facilities may calculate emissions associated with each energy product stream using three methods (1. efficiency method, 2. energy content method, and 3. work potential method).	Voluntary
The Climate Registry (TCR)	All fuels	CO_2, CH_4, N_2O	All combustion equipment at organization's facilities	All, no de minimis	Facility	Stack or facility or unit fuel supply.	CEMS: Should use data if measured in accordance with 40 CFR Part 75 (See Part 75). Calculation: Preferably measure each unit's fuel use, but may use purchase records. Measure fuel heat and carbon content on a frequency determined by fuel variability to develop emission factors. May also use default fuel based emission factors. Optional method for CHP facilities to apportion emissions to electric and heat output. To calculate CH_4 and N_20 emissions, multiply fuel burned by a default emission factor.	Voluntary
Chicago Climate Exchange (CCX)	All fuels	CO_2, CH_4, N_2O	On-site combustion of fossil fuels	Incomplete Information	Incomplete Information	Stack or facility or unit fuel supply.	CEMS, WRI/WBCSD protocols, and CCX developed protocols.	Voluntary
Regional Greenhouse Gas Initiative (RGGI)	Biomass fuel (sustainably harvested woody and herbaceous fuel sources that are available on a renewable or recurring basis (excluding old growth timber). Does not include biomass mixed with other waste.	CO_2	Fossil fuel-fired (>50% of heat input from fossil fuel) EGUs serving a generator with nameplate capacity ≥ 25 MW	All except LME	Unit	Stack or unit fuel supply.	Same as 40 CFR Part 75 (See Part 75), plus additional biomass fuel and net energy output monitoring. Additional biofuel measurements include: 1) sampling and analysis of each shipment received fro carbon content, heating value, and moister content, 2) mass or volumetric measurement of fuel burned, 3) operating hours. Sampling and analysis per methods in the New York State Renewable Energy Portfolio Standard Biomass Guidebook, May 2006. As fired biomass CO_2 emissions shall be the lower of the CEMS when biomass fired alone, or calculation method when combined with other fuels.	Mandatory
Regional Greenhouse Gas Initiative (RGGI)	Fossil fuels	CO_2	Fossil fuel-fired (>50% of heat input from fossil fuel) EGUs serving a generator with nameplate capacity ≥ 25 MW	All except LME	Unit	Stack or unit fuel supply.	Same as 40 CFR Part 75 (See Part 75), plus additional net energy output monitoring.	Mandatory
Regional Greenhouse Gas Initiative (RGGI)	Natural gas, fuel oil, Refinery fuel gas, blast furnace gas, other fossil fuel derived gases	CO_2	Fossil fuel-fired (>50% of heat input from fossil fuel) EGUs serving a generator with nameplate capacity ≥ 25 MW	Low mass emitters (LME)	Unit	Unit fuel supply	Same as 40 CFR Part 75 (See Part 75), plus additional net energy output monitoring.	Mandatory
U.S. DOE 1605B	Natural gas	CO_2, CH_4, N_2O	All combustion equipment	Large emitters	Entity	Facility or unit fuel line.	Calculation: Fuel burned based on measured purchases or consumption. May use measured, contractual, or default calorific values (GCV). Default emission factors, except reporters burning natural gas with a Btu content < 975 Btu/scf or >1,100 Btu/scf, should develop emission factor based on gas analysis.	Voluntary
U.S. DOE 1605B	Refinery fuel gas	CO_2, CH_4, N_2O	All combustion equipment	Large emitters	Entity	Facility or unit fuel line.	Calculation: Fuel burned based on measured purchases or consumption. Use EIA default emission factors for refinery gas or develop CO_2 emission factor based on gas analysis.	Voluntary

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	IPCC or WRI/WBCSD Elements	Source
California Climate Action Registry (CCAR)	All fuels	Fuel burned and EIA default emissions factors. Source can use alternative emission factor if this will result in a more accurate measurement of emissions. In order to use alternative factors, potential for increased accuracy must be demonstrated to and accepted by certifier.	Annual. Entities must report at least 95% of direct emissions from stationary combustion. CO_2 emissions at a minimum must be reported for CA or the US for the first three years, and from fourth year, all Kyoto GHGs must be reported. Data submitted using CARROT tool.	GHG Management Plan, and third party certification. Third party certifier's estimates of GHG emissions for the entire inventory must not differ from participant's by > 5%.	IPCC - 1) May use IPCC emission factors, 2) Requires third party verification. The CCAR General Reporting Protocol's accounting and reporting principles are consistent with the WRI/WBCSD GHG Protocol Initiative.	http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html
The Climate Registry (TCR)	All fuels	Fuel burned or CEMS data.	Annual entity and facility GHG emissions by source category (stationary combustion), and quantification methodologies and tier level for each source. Optional performance metrics (energy intensity) may be reported. Data submitted using the CRIS tool.	Inventory Quality Management System: quality management team, quality management plan, perform generic and category specific quality checks (e.g., compare source developed emission factors to generic factors). CEMS units must meet Part 75 QA/QC requirements. Third party verification is required.	IPCC - Uses tier approach for measurement methods, and requires third party verification. TCR General Reporting Protocol's accounting and reporting principles are consistent with the WRI/WBCSD GHG Protocol Initiative. The inventory quality guidance is from the WRI/WBCSD GHG Protocol Corporate Standard (Revised Edition), Chapter 7.	http://www.theclimateregistry.org/reference.html
Chicago Climate Exchange (CCX)	All fuels	CEMS data or fuel burned.	Annual emissions report.	Third party verification by Financial Agency Regulatory Authority (FINRA).	WRI/WBCSD - Uses measurement protocols and emission factors.	http://www.chicagoclimatex.com/content.jsf?id=74
Regional Greenhouse Gas Initiative (RGGI)	Biomass fuel (sustainably harvested woody and herbaceous fuel sources that are available on a renewable or recurring basis (excluding old growth timber). Does not include biomass mixed with other waste.	Same as 40 CFR Part 75 (See Part 75) plus net energy output.	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data. For biomass also report quarterly biomass burned (mass/volume and mmBtus), biomass emission factor, biomass oxidation factor, and biomass CO_2 emissions.	CO_2 budget and net energy output monitoring plan, and other QA/QC as required by 40 CFR Part 75 (See Part 75 below).	No	http://www.rggi.org/modelrule.htm
Regional Greenhouse Gas Initiative (RGGI)	Fossil fuels	Same as 40 CFR Part 75 (See Part 75) plus net energy output.	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	CO_2 budget and net energy output monitoring plan, and other QA/QC as required by 40 CFR Part 75 (See Part 75 below).	No	http://www.rggi.org/modelrule.htm
Regional Greenhouse Gas Initiative (RGGI)	Natural gas, fuel oil, Refinery fuel gas, blast furnace gas, other fossil fuel derived gases	Same as 40 CFR Part 75 (See Part 75) plus net energy output.	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	CO_2 budget and net energy output monitoring plan, and other QA/QC as required by 40 CFR Part 75 (See Part 75 below).	No	http://www.rggi.org/modelrule.htm
U.S. DOE 1605B	Natural gas	Fuel burned	Annual GHG emissions, estimation methods and information sources, entity boundaries.	No requirement. Implied documentation of data and methods with sufficient transparency for potential third party verification.	IPCC: Ordinal rating system for emissions calculations ("A" for CEMS, "B" or "C" for actual measures, "D" for application of EIA default factors).	http://www.pi.energy.gov/enhancingGHGregistry/technical guidelines.html
U.S. DOE 1605B	Refinery fuel gas	Fuel burned	Annual GHG emissions, estimation methods and information sources, entity boundaries.	No requirement. Implied documentation of data and methods with sufficient transparency for potential third party verification.	IPCC: Ordinal rating system for emissions calculations ("A" for CEMS, "B" or "C" for actual measures, "D" for application of EIA default factors).	http://www.pi.energy.gov/enhancingGHGregistry/technical guidelines.html

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Coverage (GHGs)	Coverage (Stationary Source Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (CEMS or Calculation - what is monitored including frequency and equipment; what data are used to calculate GHG emissions)	Supported Program Type (e.g., mandatory reporting, voluntary reporting, etc.)
U.S. DOE 1605B	Fuel Oil	CO_2, CH_4, N_2O	All combustion equipment	Large emitters	Entity	Facility or unit fuel supply.	CEMS or Calculation: Fuel burned based on measured purchases or consumption. May use measured, contractual, or default calorific values (GCV) provided in the guidelines by oil type. stand.	Voluntary
U.S. DOE 1605B	Biomass fuel, municipal waste, other waste	CO_2, CH_4, N_2O	All combustion equipment	Large emitters	Entity	Facility or unit fuel supply	CEMS or Calculation: Fuel burned based on measured purchases or consumption. May use measured, contractual, or default calorific values (GCV). Default emission factors may be used from AP42 or IPCC Revised Guidelines. Do not estimate CO_2 emissions for biomass fuels. Estimate biomass fraction of municipal solid waste or landfill gas by sampling and analysis or EIA default factors.	Voluntary
U.S. DOE 1605B	Coal, petroleum coke	CO_2, CH_4, N_2O	All combustion equipment	Large emitters	Entity	Stack CEMS, or facility/unit fuel supply	CEMS: If CEMS used in compliance with 40 CFR Part 75, use CEMS data. Otherwise, do mass balance calculation. Using fuel burned (determined by weight or heating value), carbon content, and a measure of the fraction combusted, calculate carbon emissions. For petroleum coke, use CEMS (preferred). If not in place, use measured consumption of petroleum coke and actual carbon content composition of coke based on periodic samples if available; otherwise use consumption estimates and/or default emissions factors. To calculate CH_4 and N_20 emissions, multiply fuel burned by a default emission factor (factors prepared by EPA and IPCC).	Voluntary
U.S. DOE 1605B	All fuels	CO_2, CH_4, N_2O	All combustion equipment in single activity	Small emitters <10,000 tonnes/yr CO_2e may elect to report on emissions for a single, chosen "activity".	Single chosen activity.	Facility or unit fuel line/supply.	Same as for Large Emitters	Voluntary
U.S. EPA 40 CFR Part 75	Fuel Oil	CO_2	Combustion units subject to U.S. Emission Trading Programs	All, except LME	Unit	Facility or unit fuel line.	Calculation Methods: 1) Sample each fuel oil shipment or delivery and monitor fuel flow to calculate CO_2, 2) Use %C content (alternatively fuel GCV, and F-factor) and mass fuel flow, 3) Use F factor and hourly heat input to calculate CO_2.	Mandatory
U.S. EPA 40 CFR Part 75	Refinery fuel gas, blast furnace gas, other fossil fuel derived gases	CO_2	Combustion units subject to U.S. Emission Trading Programs	All, except LME	Unit	Facility or unit fuel line.	Calculation: Daily or hourly fuel sampling for GCV and carbon content (monthly if demonstrates low GCV variability) and fuel flow monitoring. May use on-line GCV calorimeter or gas chromatograph. Use carbon content (alternatively GCV, and F-factor) combined with daily mass fuel flow to calculate daily emissions.	Mandatory
U.S. EPA 40 CFR Part 75	Coal, petroleum coke	CO_2	Combustion units subject to U.S. Emission Trading Programs	All, except LME	Unit	Unit (non-CEMS)	Calculation: Fuel sampling and fuel flow monitoring: %C content (alternatively fuel GCV, and F-factor) and mass fuel flow.	Mandatory
U.S. EPA 40 CFR Part 75	Natural gas	CO_2	Combustion units subject to U.S. Emission Trading Programs	All, except LME	Unit	Facility or unit fuel line.	Calculation: Monthly fuel sampling for GCV and carbon content and fuel flow monitoring. Use carbon content (alternatively GCV, and F-factor) combined with daily mass fuel flow to calculate daily emissions.	Mandatory
U.S. EPA 40 CFR Part 75	All fuels	CO_2	Combustion units subject to U.S. Emission Trading Programs	All, except LME	Unit	Stack CEMS	CEMS: CO_2 or O_2 diluent CEMS and a stack flow monitor.	Mandatory
U.S. EPA 40 CFR Part 75	Refinery fuel gas, blast furnace gas, other fossil fuel derived gases	CO_2	Combustion units subject to U.S. Emission Trading Programs	Low mass emitters (LME)	Unit	Facility or unit fuel line.	Calculation: Derive a carbon based F-factor through fuel sampling and analysis as specified in Appendix F, measure fuel flow, and calculate hourly CO_2 using equation G-4 in Appendix G.	Mandatory
U.S. EPA 40 CFR Part 75	Natural gas or fuel oil	CO_2	Combustion units subject to U.S. Emission Trading Programs	Low mass emitters (LME)	Unit	Facility or unit fuel line/supply or shipment.	Calculation: Use default or sampled fuel GCV and quantity of fuel burned to determine heat input, then use heat input and default or measured emission factor to calculate CO_2	Mandatory
U.S. EPA Climate Leaders	Biomass fuel, municipal waste, other waste	CO_2, CH_4, N_2O	All combustion equipment	All, no de minimis	Corporate	Stack or facility or unit fuel supply.	CEMS: May use data if measured in accordance with 40 CFR Part 75 (See Part 75). Otherwise use calculation method based on fuel use and emission factors. Preferable to sample and analyze waste fuels to determine waste fuel emission factors instead of provided default factors. Part 75 units should use Part 75 non-CEMS methods (See Part 75). Other units should collect amount of fuel burned, and use suppliers or sampled energy content data.	Voluntary

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	IPCC or WRI/WBCSD Elements	Source
U.S. DOE 1605B	Fuel Oil	Fuel burned	Annual GHG emissions, estimation methods and information sources, entity boundaries.	No requirement. Implied documentation of data and methods with sufficient transparency for potential third party verification.	IPCC: Ordinal rating system for emissions calculations ("A" for CEMS, "B" or "C" for actual measures, "D" for application of EIA default factors).	http://www.pi.energy.gov/enhancingGHGregistry/technical guidelines.html
U.S. DOE 1605B	Biomass fuel, municipal waste, other waste	Fuel burned	Annual GHG emissions, estimation methods and information sources, entity boundaries. Do not report biomass CO_2.	No requirement. Implied documentation of data and methods with sufficient transparency for potential third party verification.	IPCC - References IPCC Revised Guidelines as a source of emission factors.	http://www.pi.energy.gov/enhancingGHGregistry/technical guidelines.html
U.S. DOE 1605B	Coal, petroleum coke	For coal: Fuel burned (weight or heating value), carbon content, fraction combusted. For Petroleum coke: Fuel burned, carbon content and/or default emissions factors.	Annual GHG emissions, estimation methods and information sources, entity boundaries.	No requirement. Implied documentation of data and methods with sufficient transparency for potential third party verification.	IPCC: Ordinal rating system for emissions calculations ("A" for CEMS, "B" or "C" for actual measures, "D" for application of EIA default factors).	http://www.pi.energy.gov/enhancingGHGregistry/technical guidelines.html
U.S. DOE 1605B	All fuels	Fuel burned	Annual GHG emissions, estimation methods and information sources, entity boundaries.	No requirement. Implied documentation of data and methods with sufficient transparency for potential third party verification.	IPCC: Ordinal rating system for emissions calculations ("A" for CEMS, "B" or "C" for actual measures, "D" for application of EIA default factors).	http://www.pi.energy.gov/enhancingGHGregistry/technical guidelines.html
U.S. EPA 40 CFR Part 75	Fuel Oil	Fuel burned, carbon content, hourly heat input	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA 40 CFR Part 75	Refinery fuel gas, blast furnace gas, other fossil fuel derived gases	Fuel burned	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA 40 CFR Part 75	Coal, petroleum coke	Fuel feed rate, carbon content (result of periodic fuel sampling and analysis)	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA 40 CFR Part 75	Natural gas	Fuel burned	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA 40 CFR Part 75	All fuels	Stack gas concentration and flow.	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA 40 CFR Part 75	Refinery fuel gas, blast furnace gas, other fossil fuel derived gases	Fuel burned	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA 40 CFR Part 75	Natural gas or fuel oil	Fuel burned	Quarterly electronic reports with emissions, operating parameters, and quality assurance test data.	Monitoring plan, performance specifications, certification and on-going quality assurance test requirements.	No	http://www.epa.gov/airmarkets/emissions/rules.html
U.S. EPA Climate Leaders	Biomass fuel, municipal waste, other waste	CEMS data or fuel burned.	Annual GHG emissions by source category. (Fossil-based CO_2-equivalent emissions data must be reported and are included in inventory for goal-tracking purposes, biomass-based CO_2-equivalent emissions data must be reported but are not included in inventory.)	GHG Inventory Management Plan, and EPA review or third party verification. CEMS should be quality assured per Part 75 (See Part 75 below).	IPCC - Uses third party verification concept. WRI/WBCSD - Uses measurement protocols and emission factors.	http://www.epa.gov/stateply/resources/cross-sector.html

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Coverage (GHGs)	Coverage (Stationary Source Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (CEMS or Calculation - what is monitored including frequency and equipment; what data are used to calculate GHG emissions)	Supported Program Type (e.g., mandatory reporting, voluntary reporting, etc.)
U.S. EPA Climate Leaders	All commercial fossil fuels	CO_2, CH_4, N_2O	All combustion equipment	All, no de minimis	Corporate	Stack CEMS or Unit	Use CEMS or non-CEMS (Appendix G) data if measured in accordance with 40 CFR Part 75 (See Part 75). Otherwise use calculation method based on fuel burned, heating value of fuel (energy content) and emission factors. To calculate CH4 and N_2O emissions, multiply fuel burned by U.S. EPA fuel-type and sector-specific default factors.	Voluntary
Australian National GHG and Energy Reporting System (Proposed)	Fossil and non-fossil fuels	CO_2, CH_4, N_2O	All combustion equipment at affected facilities	All except de minimis facilities (<2% of group inventory, <3,000 tonnes CO_2e, consumes or produces <12 Tj, and total of all de minimis <5% of entity GHG).	Entity and Facility (if facility emissions > 25,000 tonnes)	Facility or unit fuel supply	CEMS or Calculation: Measure facility or unit fuel consumed and combine with emission factors. May sample fuel to develop facility specific factors. Methods are rated from 1 - 4 to assess quality of emission estimate. Highest quality is 1- CEMS, next 2 - emission factor based on direct sampling and analysis conforming to Australian standards or equivalent, 3 - emission factor based on representative bias free method but not conforming to a standard, and 4 - default emission factors.	Mandatory
Canadian GHG National Reporting Program	Biomass fuels	CO_2, CH_4, N_2O	All combustion equipment	All, no de minimis	Facility	Facility or unit fuel supply, unit stack.	Calculation: References Annex FCCC/CP/ 2002/8, IPCC Inventory Guidelines and Good Practices. Measure facility or unit fuel consumed and combine with an emission factor (default or source derived). This is a Tier 3 approach. CEMS: May be used for CO_2 when CO_2 diluent monitor installed for measurements of other pollutants, also a Tier 3 approach. Biomass CO_2 emissions must be separated if blended fuels are burned.	Mandatory
Canadian GHG National Reporting Program	Fossil fuels	CO_2, CH_4, N_2O	All combustion equipment	All, no de minimis	Facility	Facility or unit fuel line, unit stack	Calculation: References Annex FCCC/CP/ 2002/8, IPCC Inventory Guidelines and Good Practices. Measure facility or unit fuel consumed and combine with an emission factor. This is a Tier 3 approach. CEMS: May be used for CO_2 when CO_2 diluent monitor installed for measurements of other pollutants, also a Tier 3 approach.	Mandatory
EU Emissions Trading Scheme	Solid fuel and non-commercial gaseous or liquid fuels	CO_2	All combustion equipment at affected facilities	All affected sources except low emissions facilities and de minimis sources.	Facility	Facility or unit fuel line.	Calculation: Fuel consumption determined over the year within a maximum uncertainty based on facility size from 5 - 1.5%, Heat content measured by operator, or contracted laboratory, and sampling procedure and frequency designed to ensure annual average has a maximum uncertainty of less than 1/3 of the maximum uncertainty required by the approved activity data tier level.. Country specific emission factors may be used for sources with $CO_2 \leq 500{,}000$ tonnes/year. CEMS: May use CO_2 CEMS combined with flow monitor or flow determined by mass balance if demonstrated that CEMS achieves greater accuracy than highest tier calculation approach. Also perform supplementary calculation or mass balance based emissions estimate to compare with CEMS results.	Mandatory
EU Emissions Trading Scheme	Commercial gaseous and liquid fuels	CO_2	All combustion equipment at affected facilities	All affected sources except low emissions facilities and de minimis sources.	Facility	Facility or unit fuel line.	Calculation: Fuel consumption determined over the year within a maximum uncertainty based on facility size from 5 - 1.5%, NCV from fuel supplier provided it is based on accepted standards, or country specific factors as reported in latest UNFCCC inventory. Country specific emission factors, or derive based on measurements using a standardized method that limits sampling and measurement bias and has a known level of uncertainty. CEMS: May use CO_2 CEMS combined with flow monitor or flow determined by mass balance if demonstrated that CEMS achieves greater accuracy than highest tier calculation approach. Also perform supplementary calculation or mass balance based emissions estimate to compare with CEMS results.	Mandatory

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	IPCC or WRI/WBCSD Elements	Source
U.S. EPA Climate Leaders	All commercial fossil fuels	CEMS data or fuel burned with heating value of fuel.	Annual GHG emissions by source category.	GHG Inventory Management Plan, and EPA review or third party verification. CEMS should be quality assured per Part 75 (See Part 75 below).	IPCC - Uses third party verification concept. WRI/WBCSD - Uses measurement protocols and emission factors.	http://www.epa.gov/stateply/resources/cross-sector.html
Australian National GHG and Energy Reporting System (Proposed)	Fossil and non-fossil fuels	Fuel burned.	Annual amount of each fuel consumed, amount of energy produced, and GHG emissions.	Estimation of facility-specific emission factors should be conducted in accordance with existing recognized standards (Australian, ISO, ASTM).	IPCC - 1) Facility methods are based on those Australia uses for its national greenhouse gas emissions inventory, 2) measurement approaches are rated similar to tiers, 3 third party audits. WRI/WBCSD - Emission category basis (Scope 1 direct, Scope 2 indirect, Scope 3 indirect).	http://www.greenhouse.gov.au/inventory/methodology/index.html
Canadian GHG National Reporting Program	Biomass fuels	Fuel burned, or stack gas	Annual emissions of each GHG by source category (stationary combustion). CO_2 emissions from biomass combustion are reported separately and not included in GHG totals. Requires certification statement.	IPCC - Use standard measurement methods (e.g., ISO methods), calibrate and maintain measurement equipment, and have a QA/QC process. Canada Phase I Guide - Emissions should be verifiable, and documentation to allow verification should be maintained.	IPCC - Requires methodologies in UNFCCC Decision 18/ CP.8 and Annex FCCC/CP/ 2002/8, which reference Inventory Guidelines and Good Practices.	http://canadagazette.gc.ca/partI/2008/20080216/html/notice-e.html#d108
Canadian GHG National Reporting Program	Fossil fuels	Fuel burned, or stack gas	Annual emissions of each GHG by source category (stationary combustion). CO_2 emissions from biomass combustion are reported separately and not included in GHG totals. Requires certification statement.	IPCC - Use standard measurement methods (e.g., ISO methods), calibrate and maintain measurement equipment, and have a QA/QC process. Canada Phase I Guide - Emissions should be verifiable, and documentation to allow verification should be maintained.	IPCC - Requires methodologies in UNFCCC Decision 18/ CP.8 and Annex FCCC/CP/ 2002/8, which reference Inventory Guidelines and Good Practices.	http://canadagazette.gc.ca/partI/2008/20080216/html/notice-e.html#d108
EU Emissions Trading Scheme	Solid fuel and non-commercial gaseous or liquid fuels	Fuel burned and heat content derived from operator measurement or default factors.	Annual report for all sources or source streams of all CO_2 emissions that includes total emissions, chosen measurement approach and tier, activity data, heat content and emission factors. If CEMS approach include annual CO_2 emissions and supplementary emission calculation or mass balance. Also report any change in method tiers or the installation.	1) Monitoring plan submitted and approved prior to reporting period, 2) Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Check against measurement standards traceable to international standards when available. 3) Establish an effective data control system and document data flow activities. 4) Laboratory used to determine the emission factor, net calorific value, oxidation factor, carbon content, the biomass fraction or composition data should be accredited according to EN ISO 17025:2005. 5) Third party verification process and report submitted with annual report.	IPCC - 1) Applies monitoring method uncertainty tiers similar to IPCC based on facility size (emissions), 2) uses IPCC emission factors, 3) Requires third party verification.	http://ec.europa.eu/environment/climat/emission/mrg_en.htm
EU Emissions Trading Scheme	Commercial gaseous and liquid fuels	Fuel burned and heat content from fuel supplier or derived from operator measurement.	Annual report for all sources or source streams of all CO_2 emissions that includes total emissions, chosen measurement approach and tier, activity data, heat content and emission factors. If CEMS approach include annual CO_2 emissions and supplementary emission calculation or mass balance. Also report any change in method tiers or the installation.	1) Monitoring plan submitted and approved prior to reporting period, 2) Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Check against measurement standards traceable to international standards when available. 3) Establish an effective data control system and document data flow activities. 4) Laboratory used to determine the emission factor, net calorific value, oxidation factor, carbon content, the biomass fraction or composition data should be accredited according to EN ISO 17025:2005. 5) Third party verification process and report submitted with annual report.	IPCC - 1) Applies monitoring method uncertainty tiers similar to IPCC based on facility size (emissions), 2) uses IPCC emission factors, 3) Requires third party verification.	http://ec.europa.eu/environment/climat/emission/mrg_en.htm

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Coverage (GHGs)	Coverage (Stationary Source Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (CEMS or Calculation - what is monitored including frequency and equipment; what data are used to calculate GHG emissions)	Supported Program Type (e.g., mandatory reporting, voluntary reporting, etc.)
EU Emissions Trading Scheme	Biomass fuel (non-fossilized and biodegradable organic material originating from plants, animals, and micro-organisms: specifically identifies fuels in guidelines)	CO_2	All combustion equipment at affected facilities	All affected sources except low emissions facilities and de minimis sources.	Facility	Facility or unit fuel supply	Calculation: Fuel consumption for blended fuels (fossil combined with biomass) are determined over the year within a maximum uncertainty similar to fossil fuels based on facility size from 5 - 1.5%. Activity or fuel content measurements must be done using a standardized method that limits sampling and measurement bias and has a known level of uncertainty. Pure biomass (≤3% non-biomass) source streams may use non-tier methods, and has an emission factor of zero. Mixed fuel streams (biomass and fossil) shall identify biomass portion through approved sampling methods using CEN, ISO, or national standards. Biomass portion uses a zero emission factor. If determination of the biomass portion is not feasible, assume 100% fossil. CEMS: May use CO_2 CEMS combined with flow monitor or flow determined by mass balance if demonstrated that CEMS achieves greater accuracy than highest tier calculation approach. Must apportion biomass fraction of CEMS emissions. Also perform supplementary calculation or mass balance based emissions estimate to compare with CEMS results.	Mandatory
EU Emissions Trading Scheme	All fuels	CO_2	All combustion equipment at affected facilities	De minimis sources (selected by operator that emit ≤ 1000 tonne/yr, or contribute < 2% of total annual emissions (up to 20,000 tonnes))	Facility	Facility or unit fuel line.	Facility may use its own non-tier methods.	Mandatory
EU Emissions Trading Scheme	All fuels	CO_2	All combustion equipment at affected facilities	Low Emissions Installations (<25,000 tonnes/yr)	Facility	Facility or unit fuel supply.	Same method as for larger installations (see above), except that member states may allow lower tier methods (Tier 1 minimum - 5% uncertainty). Fuel use may be based on purchases or stock changes without further consideration of uncertainty.	Mandatory

Stationary Fuel Combustion GHG Methods

Reporting Program/Guidance	Fuel	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	IPCC or WRI/WBCSD Elements	Source
EU Emissions Trading Scheme	Biomass fuel (non-fossilized and biodegradable organic material originating from plants, animals, and micro-organisms: specifically identifies fuels in guidelines)	Fuel burned and heat content from fuel supplier or derived from operator measurement.	Annual report for all sources or source streams of all fossil CO_2 emissions: includes total emissions, chosen measurement approach and tier, activity data, heat content and emission factors. For biomass fuel provide amount of fuel burned. If CEMS approach include annual biomass CO_2 emissions, biomass fraction if blended fuel, and supplementary emission calculation or mass balance to verify CEMS based emissions. Also report any change in method tiers or the installation.	1) Monitoring plan submitted and approved prior to reporting period, 2) Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Check against measurement standards traceable to international standards when available. 3) Establish an effective data control system and document data flow activities. 4) Laboratory used to determine the emission factor, net calorific value, oxidation factor, carbon content, the biomass fraction or composition data should be accredited according to EN ISO 17025:2005 5) Third party verification process and report submitted with annual report.	IPCC - 1) Applies monitoring method uncertainty tiers similar to IPCC based on facility size (emissions), 2) uses IPCC emission factors, 3) Requires third party verification.	http://ec.europa.eu/environment/climat/emission/mrg_en.htm
EU Emissions Trading Scheme	All fuels	Not specified	Annual report for all sources or source streams of all fossil CO_2 emissions: includes total emissions, chosen measurement approach and tier, activity data, heat content and emission factors. For biomass fuel provide amount of fuel burned. If CEMS approach include annual biomass CO_2 emissions, biomass fraction if blended fuel, and supplementary emission calculation or mass balance to verify CEMS based emissions. Also report any change in method tiers or the installation.	Member states may allow simplified monitoring plans, waive lab accreditation, and proof of calibration requirement addressing uncertainty.	IPCC - 1) Applies monitoring method uncertainty tiers similar to IPCC based on facility size (emissions), 2) uses IPCC emission factors, 3) Requires third party verification.	http://ec.europa.eu/environment/climat/emission/mrg_en.htm
EU Emissions Trading Scheme	All fuels	Fuel burned and heat content.	Annual report for all sources or source streams of all fossil CO_2 emissions: includes total emissions, chosen measurement approach and tier, activity data, heat content and emission factors. For biomass fuel provide amount of fuel burned. If CEMS approach include annual biomass CO_2 emissions, biomass fraction if blended fuel, and supplementary emission calculation or mass balance to verify CEMS based emissions. Also report any change in method tiers or the installation.	Member states may allow simplified monitoring plans, waive lab accreditation, and proof of calibration requirement addressing uncertainty.	IPCC - 1) Applies monitoring method uncertainty tiers similar to IPCC based on facility size (emissions), 2) uses IPCC emission factors, 3) Requires third party verification.	http://ec.europa.eu/environment/climat/emission/mrg_en.htm

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006	Adipic Adipic Production	N2O	Industrial Process - process emissions from adipic acid production	N/A	National		**IPCC 2006 Tier 2,3 Methodology:** For two production plants, 1990 to 2002 emission estimates were obtained directly from the plant engineer and account for reductions due to control systems in place at these plants during the time series (Childs 2002, 2003). These estimates were based on continuous emissions monitoring (CEM) equipment installed at the two facilities. Reported emission estimates for 2003 to 2006 were unavailable and, thus, were calculated by applying 4.4, 4.2, 0.0, and 0.0 percent national production growth rates, respectively. For the other two plants, N2O emissions were calculated by multiplying adipic acid production by an IPCC 2006 emission factor (i.e., N2O emitted per unit of adipic acid produced) and adjusting for the percentage of N2O released as a result of plant specific emission controls. Emissions are estimated using the following equation: N2O emissions = (production of adipic acid [metric tons {MT} of adipic acid]) × (0.3 MT N2O / MT adipic acid) × (1 − [N2O destruction factor × abatement system utility factor])	Meet the reporting requirements for Parties to the UNFCCC

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006	Adipic Adipic Production	For 1990 to 2003, plant-specific production data was estimated where direct emission measurements were not available. In order to calculate plant-specific production for the two plants, national adipic acid production was allocated to the plant level using the ratio of their known plant capacities to total national capacity for all U.S. plants. For 2004 and 2006, actual plant production data were obtained for these two plants and used for emission calculations. For 2005, interpolated national production was used. National adipic acid production data for 1990 through 2002 were obtained from the American Chemistry Council (ACC 2003). Production for 2003 was estimated based on linear interpolation of 2002 and 2004 reported production. Production for 2004 and 2006 were obtained from Chemical Week, Product Focus: Adipic Acid (CW 2005, 2007). Plant capacities for 1990 through 1994 were obtained from Chemical and Engineering News, "Facts and Figures" and "Production of Top 50 Chemicals" (C&EN 1992 through 1995). Plant capacities for 1995 and 1996 were kept the same as 1994 data. The 1997 plant capacities were taken from Chemical Market Reporter "Chemical Profile: Adipic Acid" (CMR 1998). The 1998 plant capacities for all four plants and 1999 plant capacities for three of the plants were obtained from Chemical Week, Product Focus: Adipic Acid/Adiponitrile (CW 1999). Plant capacities for 2000 for three of the plants were updated using Chemical Market Reporter, "Chemical Profile: Adipic Acid" (CMR 2001). For 2001 through 2005, the plant capacities for these three plants were kept the same as the year 2000 capacities. Plant capacity for 1999 to 2005 for the one remaining plant was kept the same as 1998. For 2004 to 2006, although plant capacity data are available (CW 1999, CMR 2001, ICIS 2007), they are not used to calculate plant-specific production for these years because plant-specific production data for 2004 and 2006 are also available and are used in our calculations instead (CW 2005, CW 2007).	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	The overall uncertainty associated with the 2006 N2O emission estimate from adipic acid production was calculated using the IPCC Guidelines for National Greenhouse Gas Inventories (2006) Tier 2 methodology.	http://epa.gov/climatechange/emissions/downloads/08_Industrial.pdf

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Adipic Acid Production	N2O	Industrial Process - process emissions from adipic acid production	N/A	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company") (Page 18, Federal Register document)	"A" rated method: continuous emissions monitoring at plant-level.	**"A" rated approach - Continuous emission monitoring (CEM):** Continuous emission monitoring (CEM) or estimates based on periodic, direct measurements. **"B" rated approach** - product of IPCC default emission factors and production: If plant-level data is not available, use known destruction and abatement factor values in conjunction with the IPCC 2000 default emission factor. Equation: N2O Emissions = Emission factor * Adipic Acid production * [1 - (N2O Destruction factor * Abatement system utilization factor)]. **"C" rated approach** - product of other emission factors and production: IPCC 2000 default destruction and abatement system utilization factors in conjunction with IPCC 2000 default emission factor.	Voluntary reporting

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Adipic Acid Production	**"A" rated approach:** Continuous emission monitoring data, or Direct, periodic measurement data to establish emission rate. **"B" rated approach:** Production; IPCC 2000 default emission factor; known N2O destruction and abatement system utilization factor. **"C" rated approach:** Production; IPCC 2000 default emission factor; IPCC 2000 default destruction and abatement system utilization factor.	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and sub entity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf; Federal Register Document http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf (Pages 18, 87-88)

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Adipic Acid Production	N2O	Industrial Process - process emissions from adipic acid production	N/A	National		Emissions are estimated as follows: **Tier 1: Product of emission factor and production** EN2O = EF * AAP Where: EN2O = N2O emissions, kg EF = N2O emission factor (default), kg N2O/tonne adipic acid produced AAP = adipic acid production, tonnes Notes: When applying the Tier 1 method, assume no abatement of N2O emissions and use the highest default emission factor based on technology type (default emission factors presented below). **Tier 2: Uses plant-level production data disaggregated by technology type and default emission factors classified by technology type**. Emissions are calculated as follows: EN2O = SUM[(EFi * AAPi *(1-DFj * ASUFj)] Where: EN2O = emissions of N2O, kg EFi = N2O emission factor for technology type i, kg N2O/tonne adipic acid produced AAPi = adipic acid production from technology type i, tonnes DFj = destruction factor for abatement technology type j, fraction ASUFj = abatement system utilization factor for abatement technology type j, fraction **Tier 3: Plant-level production data is disaggregated by technology type and plant level emission factors that are obtained from direct measurement of emissions.** These may be derived from irregular sampling of emissions of N2O or periodic emissions monitoring of N2O undertaken over a period(s) that reflects the usual pattern of operation of the plant. IPCC 2006 default emission factors, destruction factors, and utilization factors are provided in Note 3 in the notes sheet.	National Inventory Guidelines

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Adipic Acid Production	**Tier 1:** national production of adipic acid. **Tier 2**: plant-level production data disaggregated by technology type and abatement system type. **Tier 3**: plant-level production data disaggregated by technology and abatement system; however, production data are not used to estimate emissions where continuous emissions monitoring data (CEM) are available.	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	If emissions are calculated using data from individual nitric acid plants (Tier 2/3 bottom-up approach), estimates are compared to emissions calculated using national production data (top-down approach). Results should be recorded and unexplained discrepancies investigated. Where plant-level data is used, an independent review of the time series of emissions beginning in the base year, and an explanation of trends in emissions when making historical comparisons is necessary. Also, confirm that internationally recognized, standard methods were used. compare plant-based factors to the IPCC defaults to ensure that the plant-specific factors are reasonable. Explain and document any differences between plant-specific factors and default factors, particularly any differences in plant characteristics that might lead to these differences.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
WRI/WBCSD Protocol	Adipic acid production	N2O	Industrial process emissions from adipic acid production	N/A	Corporate/Facility		Where plant-specific direct monitoring data is not available: N2O Emissions = (Adipic Acid Production x Emission Factor) x (1 – Fraction Abated x Utilization Factor) Where: Adipic Acid Production (metric tons) Emission Factor (metric tons of N2O/metric ton of adipic acid produced). Fraction Abated (%) – percent of emissions abated by reduction technologies and practices. Utilization Factor (%)– percent of time the abatement technology was in use. All factors are from IPCC 2006.	Voluntary reporting
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Adipic Acid Production	N20	Industrial Process - adipic acid production	3% of total emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries. For example semiconductor manufacturing emissions would include not only process emissions, but other direct emissions (including transportation, on-site energy, etc).	Facility-level		IPCC 2006, Equation 3.8, N2O Emissions from Adipic Acid Production, Tier 2. Mass Balance Method equation: N2O Emissions = (Adipic Acid Production x N2O Emission Factor) x (1 - Destruction factor x Abatement system utilization factor) (see Note 1 for emissions factors)	Voluntary reporting

Review of Selected Programs Relevant to Source - Adipic Acid Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
WRI/WBCSD Protocol	Adipic acid production	(1) amount of adipic acid produced (tonnes). (2) abatement technology used and abatement system utilization factor (IPCC 2006 defaults referenced).	N/A	**1. Emissions comparisons:** Compare the emissions data obtained with emissions data calculated for the same facility in previous years. A calculation error is probable if differences between current data and data from previous years cannot be explained by changes in activity levels or changes in production technologies employed. **2. Order of magnitude checks:** If you have used Approaches 1 or 2 to calculate your emissions, you can employ the method proposed in Approach 3 to check whether your results are in the correct range.	http://www.ghgprotocol.org/calculation-tools/sector-toolsets
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Adipic Acid Production	Adipic acid production, N2O emission factor, destruction factor, abatement system utilization factor. Tier A2 uses plant-specific emission, utilization and destruction factors; Tier B uses a mix of default and plant-specific factors; Tier C uses default emission, utilization and destruction factors. Default emissions factors = IPCC 2006 emissions factors.	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source (see Note 1), including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources. (see Note 2 for additional reporting requirements that may apply)	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	Page 39 (Reporting Requirements), Pages 96-97 (Adipic Acid Production) http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Review of Selected Programs Relevant to Source - Adipic Acid Production

Note 1.

Direct Process N2O Emissions from Adipic Acid Production		
Tier	**Method**	**Emission Factors**
A1	Continuous emissions monitoring	n/a
A2	Mass Balance	Plant-specific factors: • Actual destruction and utilization factors for an abatement technology • Actual N2O emissions factor based on direct measurements
B	Mass Balance	Mix of default and plant-specific factors
C	Mass Balance	Default factors: • Default destruction and utilization factors for an abatement technology • Default N2O emissions factor

Mass Balance Method
Source: WRI/WBCSD, Calculating N2O Emissions from the Production of Adipic Acid, 2001 (Consistent with IPCC 2006, Equation 3.8, N2O Emissions from Adipic Acid Production, Tier 2)
N2O Emissions = (Adipic Acid Production x N2O Emission Factor) x (1 - Destruction factor x Abatement system utilization factor)
Where:
N2O emissions = N2O emissions, metric tons
N2O emissions factor = N2O emission factor by technology type, metric tons of N2O/metric ton of adipic acid produced
N2O destruction factor = fraction of emissions abated by reduction technologies
Abatement system utilization factor = fraction of time the abatement system was in use

Note 2. Additional reporting requirements:
if applicable, a list of de minimis sources and estimated emissions from each source; for those reporting on a control basis, information on equity investments, including a list of all entities and jointly owned projects in which the entity has an ownership share but does not have control, the entity's equity share in each listed entity or project, the identity of the legal entity that has control over each listed entity or project, and a brief qualitative description of each listed entity or project's emitting activities and emissions profile; for those reporting on an equity-share basis, an indication as to whether the organization has financial control and operational control over each of the facilities or operations; for reporters that are subsidiaries, the identity of the parent company and an organizational chart that makes clear the reporting subsidiary's relationship to its parent(s) and other subsidiaries.

Note 3.

Default factors for adipic acid production:

TABLE 3.4
DEFAULT FACTORS FOR ADIPIC ACID PRODUCTION

Production Process	**N_2O Generation Factor[a,d]**	**Uncertainty Estimate**
Nitric Acid Oxidation	300 kg/tonne adipic acid (uncontrolled)	± 10% (based on expert judgement). The range of 300 kg ± 10% encompasses the variability from pure ketone to pure alcohol feedstocks, with most manufacturers somewhere in the middle.[a]
Abatement Technology	**N_2O Destruction Factor[b]**	**Uncertainty Estimate**
Catalytic Destruction	92.5%	90-95% (based on expert judgement). Manufacturers known to employ this technology include: BASF (Scott, 1998), and DuPont (Reimer, 1999b).
Thermal Destruction	98.5%	98-99% (based on expert judgement). Manufacturers known to employ this technology include: Asahi, DuPont, Bayer, and Solutia (Scott, 1998).
Recycle to Nitric Acid	98.5%	98-99% (based on expert judgement). Manufacturers known to employ this technology include: Alsachemie (Scott, 1998).
Recycle to feedstock for Adipic Acid	94%	90-98% (based on expert judgement). Solutia implemented this technology around 2002.
Abatement System	**Utilisation Factor[d]**	**Uncertainty Estimate**
Catalytic Destruction	89%	80-98% (based on expert judgement)[c].
Thermal Destruction	97%	95-99% (based on expert judgement)[c].
Recycle to Nitric Acid	94%	90-98% (based on expert judgement)[c].
Recycle to Adipic Acid	89%	80-98% (based on expert judgement)[c].

[a] With regard to a value from the Japan Environment Agency (1995) (282 kg N_2O/tonne adipic acid), it is believed that this manufacturer uses oxidation of pure cyclohexanol (alcohol), instead of a ketone-alcohol mixture (Reimer *et al.*, 1999). This is the only plant known to use this method.

[b] The destruction factor (that represents the technology abatement efficiency) should be multiplied by an abatement system utility factor.

[c] Note that these default values are based on expert judgement and not industry-supplied data or plant-specific measurements. In the first 1-5 years of the abatement technology implementation, the utilisation factor tends to be at the lower end of the range. Lower utility of the equipment typically results because of the need to learn how to operate the abatement system and because more maintenance problems occur during the initial phase. After 1-5 years, the operating experience improves and the utilisation factor would tend to be at the high end of the range.

Source:
[d] Thiemans and Trogler (1991).
[e] Reimer (1999b).

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Aluminum Production	CO2	Industrial Process - aluminum production	N/A	National		**CO2 emissions:** Mass balance approach assuming the carbon content of net anode consumption or paste consumption is ultimately emitted as CO2. The equation differs depending on the technology used: **Prebake**: - *Electrolysis emissions*: ECO2 = NAC * MP * (100 - Sa - Asha)/100 *44/12 Where: ECO2 = CO2 emissions from prebaked anode consumption, metric tons CO2 MP = total metal production, metric tons Al NAC = net prebaked anode consumption per tonne of aluminium, metric tons C/ tonne Al Sa = sulphur content in baked anodes, wt % Asha = ash content in baed anodes, wt % 44/12 = CO2 molecular mass: carbon atomic mass ratio, dimensionless - *Baking furnace emissions*: (1) Emissions from pitch volatiles combustion: ECO2 = (GA -Hw - BA- WT) * 44/12 Where ECO2 = CO2 emissions from pitch volatiles combustion, metric tons CO2 GA = initial weight of green anodes, metric tons Hw = hydrogen content in green anodes, metric tons BA = baked anode production, metric tons WT = waste tar collected, metric tons (2) Emissions from combustion of bake furnace packing material: ECO2 = PCC * BA * (100-Spc -Ashpc)/100 * 44/12 Where: ECO2 = CO2 emissions from bake furnace packing material, metric tons CO2 PCC = packing coke consumption, metric tons/metric ton BA BA = baked anode production, metric tons Spc = sulphur content in packing coke, wt % Ashpc = ash content in packing coke, wt %	Meet the reporting requirements for Parties to the UNFCCC

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Aluminum Production	**Tier 1**: Aluminum production from Prebake process and from Soderberg process, IPCC 2006 emission factors (see Note 1) **Tier 2 and 3**: - Metal production and net anode consumption (for prebake cells) or paste consumption (for other cells) (individual facility records) - Other parameters (as listed in the equations): Tier 2 uses industry typical values (see Notes 2 to 5), Tier 3 individual facility records	The supporting information necessary to ensure transparency in reported emissions estimates is shown in IPCC 2006 table 4.17 (see Note 8)	Facility CO2 emission factors per t aluminium should be compared with the expected range of variation. Interannual changes in emissions of carbon dioxide per tonne aluminium should not exceed +/- 10 percent based on the consistency of the underlying processes that produce CO2.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Aluminum Production	CO2	Industrial Process - aluminum production	N/A	National		**Soderberg:** ECO2 = (PC * MP - CSM * MP/1000 - BC/100 * PC * MP * (Sp + Ashp + Hp)/100 - (100 - BC)/100 * PC * MP * (Sc + Ashc)/100 - MP * CD) *44/12 Where: ECO2 = CO2 emissions from paste consumption, metric tons CO2 MP = total metal production, metric tons Al PC = paste consumption, tons/ton Al CSM = emissions of cyclohexane soluble matter, kg/metric ton Al BC = binder content in paste, wt % Sp = sulphur content in pitch, wt % Ashp = ash content in pitch, wt % Hp = hydrogen content in pitch, wt % Sc = sulphur content in calcined coke, wt% Ashc = ash content in calcined coke, wt % CD = carbon in skimmed dust from Soderberg cells, ton C/ton Al 44/12 = CO2 molecular mass: carbon atomic mass ratio, dimensionless **Tier 1** uses industry-wide emission factors by process technology (see Table 4.10 in Note 1) (not recommended). **Tier 2** uses typical industry values for impurities (see Tables 4.11, 4.12, 4.13, and 4.14 in Notes 2 to 5) **Tier 3** uses actual concentrations of impurities	Meet the reporting requirements for Parties to the UNFCCC

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Aluminum Production	**Tier 1**: Aluminum production from Prebake process and from Soderberg process, IPCC 2006 emission factors (see Note 1) **Tier 2 and 3**: - Metal production and net anode consumption (for prebake cells) or paste consumption (for other cells) (individual facility records) - Other parameters (as listed in the equations): Tier 2 uses industry typical values (see Notes 2 to 5), Tier 3 individual facility records	The supporting information necessary to ensure transparency in reported emissions estimates is shown in IPCC 2006 table 4.17 (see Note 8)	Facility CO2 emission factors per t aluminium should be compared with the expected range of variation. Interannual changes in emissions of carbon dioxide per tonne aluminium should not exceed +/- 10 percent based on the consistency of the underlying processes that produce CO2.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Aluminum Production	PFCs	Industrial Process - aluminum production	N/A	National		**PFC emissions:** **Tier 1 method (not recommended):** Uses technology-based default emission factors for the four main production types: Centre-Worked Prebake (CWP), Side-Worked Prebake (SWP), Horizontal Stud Soderberg (HSS), and Vertical Stud Soderberg (VSS) ECF4 = ∑(EFCF4,i * MPi) and EC2F6 = ∑(EFC2F6,i * MPi) Where: ECF4 = emissions of CF4 from aluminium production, kg CF4 EC2F6 = emissions of C2F6 from alumninium production, kg C2F6 EFCF4,i = default emissions factor by cell technology type i for CF4, kg CF4/metric ton Al EFC2F6,i = default emissions factor by cell technology type i for C2F6, kg C2F6/metric ton Al MPi = metal production by cell technology type i, metric tons Al **Tier 2 and 3 methods:** based on anode effect performance. Depending on the type of anode effect process data recorded, one the following methods should be used: *Slope method*: ECF4 = SCF4 * AEM * MP and EC2F6 = ECF4 * FC2F6/CF4 Where: ECF4 = emissions of CF4 from aluminium production, kg CF4 EC2F6 = emissions of C2F6 from aluminium productiom, kg C2F6 SCF4 = slope coefficient for CF4 (kg CF4/metric ton Al)(AE-Mins/cell-day) AEM = anode effect minute per cell-day, AE-Mins/cell-day MP = metal production, metric ton Al FC2F6/CF4 = weight fraction of C2F6/CF4, kg C2F6/kg CF4	Meet the reporting requirements for Parties to the UNFCCC

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Aluminum Production	**Tier 1:** Aluminum production from each cell technology type, IPCC 2006 emission factors for each cell technology type (see Note 6) **Tier 2**: - metal production and anode effect minutes per cell-day or anode effect overvoltage: individual facility records - other parameters: technology specific values (see Note 7) **Tier 3:** - metal production and anode effect minutes per cell-day or anode effect overvoltage: individual facility records - other parameters: individual facility measurements	The supporting information necessary to ensure transparency in reported emissions estimates is shown in IPCC 2006 table 4.17 (see Note 8)	Significant differences between calculated coefficients based on PFC measurements and industry average Tier 2 coefficients should be investigated	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Aluminum Production	PFCs	Industrial Process - aluminum production	N/A	National		*Overvoltage method* **:** ECF4 = OVC * AEO/(CE/100) * MP and EC2F6 = ECF4 * FC2F6/CF4 Where: ECF4 = emissions of CF4 from aluminium production, kg CF4 EC2F6 = emissions of C2F6 from aluminium production, kg C2F6 OVC = Overvoltage coefficient for CF4 (kg CF4/metric ton Al)/mV AEO = anode effect overvoltage, mV CE = aluminium production process current efficiency expressed, percent MP = metal production, metric tons Al FC2F6/CF4 = weight fraction of C2F6/CF4, kg C2F6/kg CF4 **Tier 2** uses average coefficient from measurement at numerous facilities **Tier 3** is based on periodic or continuous measurements of PFCs at the individual facility, consistent with established measurement practices (US EPA and IAI, 2003) and the International Aluminium Institute GHG Protocol (IAI, 2005)	Meet the reporting requirements for Parties to the UNFCCC

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Aluminum Production	**Tier 1:** Aluminum production from each cell technology type, IPCC 2006 emission factors for each cell technology type (see Note 6) **Tier 2**: - metal production and anode effect minutes per cell-day or anode effect overvoltage: individual facility records - other parameters: technology specific values (see Note 7) **Tier 3:** - metal production and anode effect minutes per cell-day or anode effect overvoltage: individual facility records - other parameters: individual facility measurements	The supporting information necessary to ensure transparency in reported emissions estimates is shown in IPCC 2006 table 4.17 (see Note 8)	Significant differences between calculated coefficients based on PFC measurements and industry average Tier 2 coefficients should be investigated	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
International Aluminium Institute	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Corporate/ Facility		**CO2 and PFC process emissions**: see 2006 IPCC Guidelines. The use of Tier 3 methods is strongly recommended. An alternative method for calculating process CO2 based on raw material purchases is proposed. CO2 emissions are calculated from the carbon content of carbon containing materials consumed. It is assumed that all carbon except verifiable carbon output is converted to CO2 during the process. This assumes that any CO2 produced is further oxidized in the atmosphere to CO2. Fuels and electrical energy used are not included in the calculation. ECO2 = [(TPC * PC)/100 + (coke * CC)/100 + (TPCC * PCC)/100 - TWC + (PA * PAC)/100 - (SA * SAC)/100] * 44/12 Where ECO2 = CO2 emissions in metric tons per year TPC = Total pitch consumed, metric tons pitch per year PC = Carbon content of pitch, wt % Coke = Total coke consumed, metric tons coke per year CC = Carbon content of coke, wt % TPCC = Total packing coke consumed, metric tons packing coke per year PCC = Carbon content of packing coke, wt % TWC = Total carbon by-products or waste, metric tons carbon per year PA = Total mass of purchased anodes, tonnes purchased anodes per year PAC = Carbon content of purchased anodes, wt % SA = Total mass of sold anodes, tonnes sold anodes per year	Voluntary

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
International Aluminium Institute	Aluminum Production	See 2006 IPCC Guidelines for CO2 and PFC process emissions. **Coke calcination**: - Green coke feed (individual facility records) - Other parameters (as listed in the equations): Tier 2 uses industry typical values (see Note 9), Tier 3 individual facility records **Soda ash use**: - Quantity of soda ash used (individual facility records) - Purity of soda ash consumed: Tier 2 uses industry typical values (0.95), Tier 3 individual facility records **Lime production**: - Quantity of quick and slaked lime produced (individual facility records) - Purity of quick and slaked lime: Tier 2 uses industry typical values (0.95), Tier 3 individual facility records	CF4 and C2F6 emissions should be reported separately on a mass basis, as well as in CO2-eq.	If custom emissions factors are used, they should be compared with the corresponding default value.	http://www.world-aluminium.org/cache/fl0000127.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
International Aluminium Institute	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Corporate/ Facility		SAC = Carbon content of sold anodes, wt % 44/12 = CO2 Molecular Mass : Carbon Atomic Mass Ratio, dimensionless In addition, the protocol provides CO2 emissions calculation methods for production facilities that have coke calcining operations, use soda ash, and produce lime. **Coke calcination:** ECO2 = [[[GC * (100 - H2Ogc - Vgc - S gc)/100]-[(CC + UCC + DE) * (100-Scc)/100)]]*44/12]+[GC * 0.035 * 44/16] Where: ECO2 = CO2 emissions in tonnes per year GC = Green coke feed, tonnes green coke per year H2Ogc = Humidity in green coke, wt % Vgc = Volatiles in green coke, wt % Sgc = Sulphur content in green coke, wt % CC = Calcinated coke produced, metric tons calcined coke per year UCC = Under-calcined coke collected, metric tons under-calcined coke per year DE = Coke dust emissions, metric tons coke dust per year Scc = Sulphur content in calcinated coke, wt % 44/12 = CO2 Molecular Mass : Carbon Atomic Mass ratio, dimensionless 44/16 = CO2 Molecular Mass: CH4 Molecular Mass Ratio, dimensionless **Tier 2** uses typical industry values for parameters **Tier 3** uses facility specific parameters	Voluntary

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
International Aluminium Institute	Aluminum Production	See 2006 IPCC Guidelines for CO2 and PFC process emissions. **Coke calcination**: - Green coke feed (individual facility records) - Other parameters (as listed in the equations): Tier 2 uses industry typical values (see Note 9), Tier 3 individual facility records **Soda ash use**: - Quantity of soda ash used (individual facility records) - Purity of soda ash consumed: Tier 2 uses industry typical values (0.95), Tier 3 individual facility records **Lime production**: - Quantity of quick and slaked lime produced (individual facility records) - Purity of quick and slaked lime: Tier 2 uses industry typical values (0.95), Tier 3 individual facility records	CF4 and C2F6 emissions should be reported separately on a mass basis, as well as in CO2-eq.	If custom emissions factors are used, they should be compared with the corresponding default value.	http://www.world-aluminium.org/cache/fl0000127.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
International Aluminium Institute	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Corporate/ Facility		**Soda Ash Use:** ECO2 = Qsoda_ash * Psoda_ash * 44/106 Where: ECO2 = CO2 emissions in tonnes per year Qsoda_ash = Quantity of soda ash consumed, tonnes soda ash per year Psoda_ash = Purity of soda ash consumed, decimal fraction 44/106 = CO2 Molecular Mass: Na2CO3 Molecular Mass Ratio, dimensionless **Tier 2** uses typical industry values for purity **Tier 3** uses facility specific parameters **Lime Production:** ECO2 = (Ql * Pl * 44/56) + (Qs * Ps * 44/74) Where: ECO2 = CO2 emissions in metric tons per year Ql = Quantity quick lime produced, metric tons quick lime per year Pl = Purity of quick lime, decimal fraction Qs = Quantity of slaked lime produced, metric tons slaked lime per year Ps = Purity slaked lime, decimal fraction 44/56 = CO2 Molecular Mass : CaO Molecular Mass Ratio, dimensionless 44/74 = CO2 Molecular Mass : Ca(OH)2 Molecular Mass ratio, dimensionless **Tier 2** uses typical industry values for purity **Tier 3** uses facility specific parameters	Voluntary

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
International Aluminium Institute	Aluminum Production	See 2006 IPCC Guidelines for CO2 and PFC process emissions. **Coke calcination**: - Green coke feed (individual facility records) - Other parameters (as listed in the equations): Tier 2 uses industry typical values (see Note 9), Tier 3 individual facility records **Soda ash use**: - Quantity of soda ash used (individual facility records) - Purity of soda ash consumed: Tier 2 uses industry typical values (0.95), Tier 3 individual facility records **Lime production**: - Quantity of quick and slaked lime produced (individual facility records) - Purity of quick and slaked lime: Tier 2 uses industry typical values (0.95), Tier 3 individual facility records	CF4 and C2F6 emissions should be reported separately on a mass basis, as well as in CO2-eq.	If custom emissions factors are used, they should be compared with the corresponding default value.	http://www.world-aluminium.org/cache/fl0000127.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
WRI/WBCSD GHG Protocol	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Corporate/ Facility		Refers to the Aluminium Sector GHG Protocol (Addendum to the WRI/WBCSD GHG Protocol), International Aluminium Institute, 2006 for process emissions: see International Aluminium Institute	Voluntary
EPA Climate Leaders	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Corporate/ Facility		Similar to International Aluminium Institute, except does not mention the alternative method for calculating process CO2 based on raw material purchases. The use of site or company specific data is strongly encouraged. See International Aluminium Institute.	Voluntary

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
WRI/WBCSD GHG Protocol	Aluminum Production	See International Aluminium Institute		see International Aluminium Institute	http://www.ghgprotocol.org/calculation-tools/aluminum-sector
EPA Climate Leaders	Aluminum Production	See International Aluminium Institute	Partners are required to complete the Climate Leaders Reporting Requirements for aluminium production, to report past year emissions annually, and to report the following information (documentation source is included in brackets): - Material produced including lime, aluminium, calcined coke, baked anodes (financial records, production reports) - Material consumption including anodes, packing coke, paste, green coke, soda, ash, consumption (purchase receipts, delivery receipts, contract purchase or firm purchase records, stock inventory documentation, maintenance records) - Material properties such as sulfur, ash, hydrogen, and purity contents (vendor analysis or specifications, facility lab analysis) - Slope and overvoltage coefficients (facility specific measurements of PFC based on the PFC measurement protocol)	EPA Review, QA/QC guidelines: Checks should ensure the best and most accurate emission factors are being used. If custom emission factors are available, any significant differences with the default numbers? What methodology used to compute company or site-specific emission factors? Has site documented sources for all emission factors? Plant and company wide data should be checked to ensure there is no double counting, specifically between this sector and the stationary combustion sector. Only fuels that cross the boundaries of the facility should be considered.	http://www.epa.gov/climateleaders/documents/resources/review_aluminum_sector_protocol.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Voluntary Aluminium Industrial Partnership	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Corporate		Uses the 2006 IPCC slope method (see 2006 IPCC)	Voluntary
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	Facility-level		**CO2 emissions**: See 2006 IPCC: - **Tier A** corresponds to IPCC Tier 3 - **Tier B** corresponds to IPCC Tier 2 **PFC emissions**: See 2006 IPCC - **Tier A** corresponds to IPCC Tier 3 - **Tier B** corresponds to IPCC Tier 2 - **Tier C** corresponds to IPCC Tier 1	Voluntary

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Voluntary Aluminium Industrial Partnership	Aluminum Production	See 2006 IPCC	- Annual production - Anode effect frequency - Anode effect duration - Anode effect minutes per cell day - Slope coefficients for CF4 and C2F6	EPA Review	http://www.epa.gov/aluminum-pfc/join.html
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Aluminum Production	See 2006 IPCC	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. The entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	Page 39 (Reporting Requirements), Pages 98-101 (CO2 Emissions from Aluminum Production), Pages 102-104 (PFC Emissions from Aluminum Production), http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Aluminum Production	CO2, PFCs and SF6	Industrial Process - aluminum production	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company") (Page 18, Federal Register document)		**CO2 emissions** No specific method required (reporters may use estimation methods identified by IPCC, WRI/WBCSD, etc.) **Method rating A**: mass balance based on quantity and composition of reducing agents consumed **Method rating B**: mass balance based on default anode composition values and data on quantity of reducing agent consumed **Method rating C**: default emissions factors **PFC emissions** No specific method required (reporters may use estimation methods identified by IPCC, WRI/WBCSD, etc.) **Method rating A** : smelter-specific slope factors based on representative fields measurements **Method rating B** : technology specific slope factors (or over-voltage coefficients), anode effect frequency and duration (or anode effect over voltage), and production data **Method rating C**: inference method based on most recent IPCC default emissions factors **SF6 emissions** **Method rating A:** Inference method using purchase data SF6 Emissions = SF6 Consumption	Voluntary

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Aluminum Production	**CO2 emissions:** Quantity and composition of the reducing agents consumed. **PFC emissions:** Aluminium production, anode effect minutes per cell day or anode effect over-voltage, and smelter specific slope factors or over-voltage coefficients **SF6 emissions:** SF6 consumption (from purchase data)	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Pages 2-32 (Reporting Guidelines), Pages 88-92 (Aluminum Production) http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf; Federal Register Document http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf (Pages 18, 106, 114)

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
US Inventory	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	National		**PFC emissions** PFC emissions from aluminum production were estimated using a per unit production emission factor that is expressed as a function of operating parameters (anode effect frequency and duration), as follows: PFC (CF4 or C2F6) emission factor (kg/metric ton Al) = S x Anode Effect Minutes/Cell-Day where: S = Slope coefficient (kg PFC/metric ton Al/(Anode Effect minutes/cell day)) Anode Effect Minutes/Cell-Day = Anode Effect Frequency/Cell-Day x Anode Effect Duration (minutes) **Slope Coefficient** Smelter-specific slope coefficients based on field measurements yield the most accurate results, and are used where possible. These estimates have been obtained from the EPA-funded smelter measurement campaigns of 1995/96, 1999 and 2003. For smelters in which no smelter-specific slope coefficient are available, technology-specific slope coefficients from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (see 2006 IPCC) were applied.	National inventory

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
US Inventory	Aluminum Production	**PFC emissions** For each smelter: - Aluminium production - Slope coefficients (site specific or 2006 IPCC default value for appropriate technology when not available) - Anode Effect (AE) Minutes/Cell-Day or - AE Frequency/Cell-Day - Average AE Duration **CO2 emissions** For each smelter: - Production - Type of technology used	**PFC emissions** - National CF4 emissions (in tCO2-eq and tC-eq) - National C2F6 emissions (in tCO2-eq and tC-eq) - National PFC emissions (in tCO2-eq and tC-eq) - Absolute emissions (in tCO2-eq and tC-eq) - Relative emissions (in tCO2-eq/tonne product and tC-eq/metric ton product) **CO2 emissions** VAIP and Aluminium industry totals: - Absolute emissions (in tCO2-eq) - Relative emissions (in tCO2-eq/tonne product)	Production figures provided by companies are confirmed using different sources (IAI, USGS) Facility-specific emission factors are compared to default factors	http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
US Inventory	Aluminum Production	CO2 and PFCs	Industrial Process - aluminum production	All (no deminimis)	National		**Anode Effect Data** The slope coefficients were combined with smelter-specific anode effect data, collected by aluminum companies and reported to the VAIP, to estimate emission factors over time. Where smelter-specific anode effect data were not available industry averages were used, or values were kept constant at prior year levels. Industry averages are based on data from IAI (2000). **Aluminium Production** For all smelters, emission factors were multiplied by annual production to estimate annual emissions at the smelter level. Smelter-specific production data was used where available; for the remaining, production estimates are based on national aluminum production and capacity data (USGS). **CO2 emissions** Based on 2006 IPCC methods, using a combination of different tiers (see 2006 IPCC). Each smelter reports annual input data which allows emission estimates to be smelter specific.	National inventory

Review of Existing Programs Relevant to Source - Aluminum Production

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
US Inventory	Aluminum Production	For partner companies smelters: *Prebake* - Net carbon consumption - Baked Anode sulphur, ash and impurities % *Anode baking* - Weight of green and baked anode - Pitch content in anode - Hydrogen content in pitch - Recovered tar - Packing coke consumption - Sulphur and ash content of packing coke *Soderberg* - Weight of paste used - Average binder content in paste - Pitch properties (sulphur, hydrogen, ash %) - Calcinated coke properties (sulphur, ash %) - Emissions of benzene soluble matter	**PFC emissions** - National CF4 emissions (in tCO2-eq and tC-eq) - National C2F6 emissions (in tCO2-eq and tC-eq) - National PFC emissions (in tCO2-eq and tC-eq) - Absolute emissions (in tCO2-eq and tC-eq) - Relative emissions (in tCO2-eq/tonne product and tC-eq/metric ton product) **CO2 emissions** VAIP and Aluminium industry totals: - Absolute emissions (in tCO2-eq) - Relative emissions (in tCO2-eq/tonne product)	Production figures provided by companies are confirmed using different sources (IAI, USGS) Facility-specific emission factors are compared to default factors	http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf

Aluminum Production - Notes

Note 1: IPCC 2006

TABLE 4.10 TIER 1 TECHNOLOGY SPECIFIC EMISSION FACTORS FOR CALCULATING CARBON DIOXIDE EMISSIONS FROM ANODE OR PASTE CONSUMPTION

Technology	Emission Factor (tons CO2/ton Al)	Uncertainty (+/-%)
Prebake	1.6	10
Søderberg	1.7	10

Source: International Aluminium Institute, Life Cycle Assessment of Aluminium (IAI, 2000).

Note 2: IPCC 2006

TABLE 4.11 DATA SOURCES AND UNCERTAINTIES FOR PARAMETERS USED IN TIER 2 OR 3

Parameter	Tier 2 Method		Tier 3 Method	
	Data Source	Uncertainty (+/-%)	Data Source	Uncertainty (+/-%)
MP: total metal production (metric tons aluminium per year)	Individual facility records	2	Individual facility records	2
NAC: net anode consumption per metric ton of aluminium (tons per ton Al)	Individual facility records	5	Individual facility records	5
Sa: sulphur content in baked anodes (wt %)	Use industry typical value, 2	50	Individual facility records	10
Asha: ash content in baked anodes (wt %)	Use industry typical value, 0.4	85	Individual facility records	10

Source: IAI (2005b).

Note 3: IPCC 2006

TABLE 4.12 DATA SOURCES AND UNCERTAINTIES FOR PARAMETERS USED IN TIER 2 OR 3

Parameter	Tier 2 Method		Tier 3 Method	
	Data Source	Uncertainty (+/-%)	Data Source	Uncertainty (+/-%)
GA: initial weight of green anodes processed (metric tons green anode per year)	Individual facility records	2	Individual facility records	2
Hw: Hydrogen content in green anodes (metric tons)	Use industry typical value, 0.005 • GA	50	Individual facility records	10
BA: Baked anode production (metric tons per year)	Individual facility records	2	Individual facility records	2
WT: Waste tar collected (tonnes) a) Riedhammer furnaces b) All other furnaces	typical value, a) 0.005 • GA b) insignificant	50	Individual facility records	20

Source: IAI (2005b).

Note 4: IPCC 2006

TABLE 4.13 DATA SOURCES AND UNCERTAINTIES FOR PARAMETERS USED IN TIER 2 OR 3

Parameter	Tier 2 Method		Tier 3 Method	
	Data Source	Uncertainty (+/-%)	Data Source	Uncertainty (+/-%)
PCC: Packing coke consumption (ton per ton BA)	Use industry typical value, 0.015	25	Individual facility records	2
BA: Baked anode production (metric tons per year)	Individual facility records	2	Individual facility records	2
Spc: Sulphur content in packing coke (wt %)	Use industry typical value, 2	50	Individual facility records	10
Ashpc: Ash content in packing coke (wt %)	Use industry typical value, 2.5	95	Individual facility records	10

Source: IAI (2005b).

Note 5: IPCC 2006

TABLE 4.14 DATA SOURCES AND UNCERTAINTIES FOR PARAMETERS USED IN TIER 2 OR 3

Parameter	Tier 2 Method		Tier 3 Method	
	Data Source	Data Uncertainty (+/-%)	Data Source	Data Uncertainty (+/-%)
MP: total metal production (metric tons Al/year)	Individual facility records	2	Individual facility records	2
PC : paste consumption (tons per ton Al)	Individual facility records	2-5	Individual facility records	2-5
CSM: emissions of cyclohexane soluble matter (kg per metric ton Al)	Use industry typical value, HSS – 4.0 VSS – 0.5	30	Individual facility records	15
BC: binder content in paste (wt %)	typical value, Dry Paste – 24 Wet Paste – 27	25	Individual facility records	5
Sp: sulphur content in pitch (wt %)	Use industry typical value, 0.6	20	Individual facility records	10
Ashp: ash content in pitch (wt %)	Use industry typical value, 0.2	20	facility records	10
Hp: hydrogen content in pitch (wt %)	Use industry typical value, 3.3	50	Individual facility records	10
Sc: sulphur content in calcined coke (wt %)	Use industry typical value, 1.9	20	Individual facility records	10
Ashc: ash content in calcined coke (wt %)	Use industry typical value, 0.2	50	Individual facility records	10
CD: carbon in dust from anode (tonnes of carbon in skim per metric ton Al)	Use industry typical value, 0.01	99	Individual facility records	30

Note 6: IPCC 2006

TABLE 4.15 DEFAULT EMISSION FACTORS AND UNCERTAINTY RANGES FOR THE

Technology	CF4		C2F6	
	EFCF4 (kg/tonne Al)a	Uncertainty Range (%)b	EFC2F6 (kg/tonne Al)c	Uncertainty Range (%)d
CWPB	0.4	-99/+380	0.04	-99/+380
SWPB	1.6	-40/+150	0.4	-40/+150
VSS	0.8	-70/+260	0.04	-70/+260
HSS	0.4	-80/+180	0.03	-80/+180

a Default CF4 values calculated from median anode effect performance from 1990 IAI survey data (IAI, 2001).

b Uncertainty based on the range of calculated CF4 specific emissions by technology from 1990 IAI anode effect survey data (IAI, 2001)

c Default C2F6 values calculated from global average C2F6:CF4 ratios by technology, multiplied by the default CF4 emission factor.

d Uncertainty range based on global average C2F6:CF4 ratios by technology, multiplied by calculated minimum and maximum specific CF4 emissions from 1990 IAI survey data (IAI, 2001).

Note: These default emission factors should only be used in the absence of Tier 2 or Tier 3 data.

Note 7: IPCC 2006
TABLE 4.16 TECHNOLOGY SPECIFIC SLOPE AND OVERVOLTAGE COEFFICIENTS FOR THE

	Slope Coefficient b, c [(kg PFC/tAl) / (AE-Mins/cell-day)]		Overvoltage Coefficientb, c, d [(kg CF4/tAl) / (mV)]		Weight Fraction C2F6 / CF4	
Technologya	CF4	Uncertainty (+/-%)	CF4	Uncertainty (+/-%)	C2F6/CF4	Uncertainty (+/-%)
CWPB	0.143	6	1.16	24	0.121	11
SWPB	0.272	15	3.65	43	0.252	23
VSS	0.092	17	NR	NR	0.053	15
HSS	0.099	44	NR	NR	0.085	48

a Centre Worked Prebake (CWPB), Side Worked Prebake (SWPB), Vertical Stud Søderberg (VSS), Horizontal Stud Søderberg (HSS).

b Source: Measurements reported to IAI, US EPA sponsored measurements and multiple site measurements (U.S. EPA and IAI, 2003).

c Embedded in each Slope and Overvoltage coefficient is an assumed emissions collection efficiency as follows: CWPB 98%, SWPB 90%, VSS 85%, HSS 90%. These collection efficiencies have been assumed based on measured PFC collection fractions, measured fluoride gas collection efficiencies and expert opinion.

d The noted coefficients reflect measurements made at some facilities recording positive overvoltage and others recording algebraic overvoltage. No robust relationship has yet been established between positive and algebraic overvoltage. Positive overvoltage should provide a better correlation with PFC emissions than algebraic overvoltage. Overvoltage coefficients are not relevant (NR) to VSS and HSS technologies.

Note 8: IPCC 2006

TABLE 4.17 GOOD PRACTICE REPORTING INFORMATION FOR CALCULATING CO2 AND PFC

Data	Tier 3	Tier 2	Tier 1
PFCs			
Annual national production (by CWPB, SWPB, HSS, or VSS technology)			X
Annual production by smelter (by CWPB, SWPB, HSS, or VSS technology)	X	X	
Anode Effect minutes per cell-day or Anode Effect Overvoltage (mV)	X	X	
Facility specific emission coefficients linked to anode effect performance	X		
Technology specific emission coefficients linked to anode effect performance		X	
Default technology emission coefficients			X
Supporting documentation	X	X	X
CO2			
Annual national production (by Prebake or Søderberg technology)			X
Annual production by smelter (by Prebake or Søderberg technology)	X	X	
Net anode consumption for Prebake cells or paste consumption for Søderberg cells	X	X	
Carbon material impurity levels and carbon dust for Søderberg cells	X		

Note 9: International Aluminium Institute

Table 6 Data Sources for Parameters Used in Tier 2 or 3 Methods for Carbon

Parameter	Tier 2 Method Data Source	Tier 3 Method Data Source
GC: green coke feed (metric tons per year)	Individual Facility Records	Individual Facility Records
H2O: humidity in green coke (wt %)	Use industry typical value, 10	Individual Facility Records
Vgc: volatiles in green coke (wt %)	Use industry typical value, 10	Individual Facility Records
Sgc: sulphur content in green coke (wt %)	Use industry typical value, 3	Individual Facility Records
CC: calcinated coke produced (metric tons per year)	Use industry typical value, 0.8 * GC	Individual Facility Records
UCC: under calcinated coke collected (metric tons per year)	Use industry typical value, 0	Individual Facility Records
DE: coke dust emissions (metric tons per year)	typical value, 0.075 * GC	Individual Facility Records
Scc: sulphur content in calcinated coke (wt %)	Use industry typical value, 2.5	Individual Facility Records

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Ammonia Production	CO_2	Energy and Process (Includes Fuel and Feedstock in Emission Factors)	N/A	National	N/A	**Tier 1: Default values and national statistics** Emissions = [PRODamm x FR x CCF x COF x 44/12] - RECco2 **Where:** PRODamm = ammonia production, tons FR = fuel requirement per unit of production, GJ/ton ammonia production CCF = C content of fuel used, kg C/GJ COF = C oxidation factor of fuel used, fraction RECco2 = CO_2 recovered for downstream use (e.g., urea production), kg **Default Values:** Default values for FR, CCF, and COF are provided in the Notes section	National Inventory Guidelines for Mandatory GHG Reporting
2006 IPCC Guidelines	Ammonia Production	CO_2	Energy and Process (Includes Fuel and Feedstock in Emission Factors)	N/A	National	N/A	**Tier 2: Facility-specific output data disaggregated by fuel input and process type with default values** Emissions = [Σ (TFR x CCF x COF x 44/12) for each fuel type] - RECco2 **Where:** TFR = total fuel requirement for each fuel type, GJ (see calculation below) CCF = carbon content factor for each fuel type, kg C/GJ COF = carbon oxiation factor for each fuel type, fraction RECco2 = CO2 recovered for downstream use (e.g., urea production), kg Note: CO2 recovery includes CO2 for urea production and carbon capture and storage (CCS) only. Fuel amounts should be deducted from the Energy estimates to avoid double counting. TFR = Σ (PRODamm x FR) for each fuel type and process type **Where:** PRODamm = ammonia production for each fuel type and process type, tons FR = fuel requirement for each fuel type and process type, GJ/ton ammonia production Default Values: Default values for FR, CCF, and COF are provided in the Notes section	National Inventory Guidelines for Mandatory GHG Reporting

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Ammonia Production	**Tier 1: Default values and national statistics** Ammonia production CO_2 recovered	Base year and subsequent annual GHG emissions.	Check that emission factors are within the range of default emission factors provided by IPCC. Ensure that emission factors are consistent with the process chemistry.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf
2006 IPCC Guidelines	Ammonia Production	**Tier 2:** Facility-specific output data disaggregated by fuel input and process type with default values Ammonia production Total fuel requirements CO_2 Recovered	Base year and subsequent annual GHG emissions.	Check that emission factors are within the range of default emission factors provided by IPCC. Ensure that emission factors are consistent with the process chemistry.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Ammonia Production	CO_2	Energy and Process (Includes Fuel and Feedstock in Emission Factors)	N/A	National	N/A	**Tier 3: Facility-specific output data disaggregated by fuel input and process type, without default values** Emissions = [Σ (TFR x CCF x COF x 44/12) for each fuel type] - RECco2 **Where:** TFR = total fuel requirement for each fuel type and for each plant, GJ CCF = carbon content factor for each fuel type, kg C/GJ COF = carbon oxiation factor for each fuel type, fraction RECco2 = CO2 recovered for downstream use (e.g., urea production), kg Note: CO2 recovery includes CO2 for urea production and carbon capture and storage (CCS) only. Fuel amounts should be deducted from the Energy estimates to avoid double counting. **Default Values:** An entity may use either facility-specific values (Tier A2) or default values, as provided by the IPCC in the Notes tab (Tier B)	National Inventory Guidelines for Mandatory GHG Reporting

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Ammonia Production	**Tier 3:** Facility-specific output data disaggregated by fuel input and process type, without default values	Base year and subsequent annual GHG emissions.	Check that emission factors are within the range of default emission factors provided by IPCC. Ensure that emission factors are consistent with the process chemistry. For Tier 3 approach, ensure that datasets provided are complete-containing fuel requirement data, ammonia production data, calculations, methods used, assumptions, carbon contents, oxidation factors, and CO2 recovered.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
WRI/WBCSD Protocol	Ammonia Production	CO_2	Energy and Process	N/A	Corporate/Facility	N/A	**Approach: IPCC Tier 2; IPCC Tier 3 if sufficient data is available** Emissions = [Σ (TFR x CCF x COF x 44/12) for each fuel type] - RECco2 **Where:** TFR = total fuel requirement for each fuel type and for each plant, GJ CCF = carbon content factor for each fuel type, kg C/GJ COF = carbon oxiation factor for each fuel type, fraction RECco2 = CO2 recovered for downstream use (e.g., urea production), kg Note: CO2 recovery includes CO2 for urea production and carbon capture and storage (CCS) only. Fuel amounts should be deducted from the Energy estimates to avoid double counting. **Default Values:** Default values for FR, CCF, and COF are provided in the Notes section	Voluntary
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Ammonia Production	CO2	Process	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company") (Page 18, Federal Register document)	N/A	See Note 1 for ratings of various methods. **"A" rated method:** Direct measurement of emissions, including CEM and periodic direct measurements ("A" rating). **"B" rated method**: Based on calculation, using measurement of feedstock fuel and its carbon content Mass balance approach based on the carbon content and consumption data for feedstock fuel (see Note 2 for equation). Reporters can use default carbon content values from EIA 2003 if plant-specific data is not availabe (see Note 3). **"C" rated method**: Based on calculation, using quantity of ammonia produced If no plant-specific information is available, reporters can use default emission factor of 1.26 TCO_2/T ammonia produced.	Voluntary

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
WRI/WBCSD Protocol	Ammonia Production	Fuel carbon contents	N/A	Compare resutls with emissions data calculated for same facility in previous years. Compare fuel consumption data to fuel purchasing data. Compare emission estimates from CEMS with estimated emissions. Compare fuel-supplier provided emission factors to those provided by national and international default emission factors.	http://www.ghgprotocol.org/calculation-tools/ammonia
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Ammonia Production	Carbon oxidation factors CO2 recovered **"C" rated method:** Amount of ammonia produced.	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO_2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. A is the best available practice, and D is the least accurate practice. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Pages 2-32 (Reporting Guidelines), Pages 92-94 http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf; Federal Register Document http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf (Pages 18, 106, 114)

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Ammonia Production	CO_2	Process	All (no deminimis)	Facility	N/A	**Tier A1:** Uses direct measurement, either through CEM or periodic direct measurements **Tier A2:** Mass Balance Approach Emissions = [Σ (TFR x CCF x COF x 44/12) for each fuel type] - RECco2 **Where:** TFR = total fuel requirement for each fuel type, GJ (see calculation below) CCF = carbon content factor for each fuel type, kg C/GJ COF = carbon oxiation factor for each fuel type, fraction RECco2 = CO2 recovered for downstream use (e.g., urea production), kg Note: CO2 recovery includes CO2 for urea production and carbon capture and storage (CCS) only. Fuel amounts should be deducted from the Energy estimates to avoid double counting. TFR = Σ (PRODamm x FR) for each fuel type and process type **Where:** PRODamm = ammonia production for each fuel type and process type, tons FR = fuel requirement for each fuel type and process type, GJ/ton ammonia production **Default Values:** Default values for FR, CCF, and COF are provided in the Notes section	Voluntary

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Ammonia Production	**Tier A1:** Direct measurement, either continuous emissions monitoring or periodic direct measurements. **Tier A2:** Plant-specific fuel requirements Fuel carbon contents Carbon oxidation factors CO2 recovered	Annual GHG emissions (CO2 equivalents), including the base year Activity and throughput data for each facility. Whether or not the entity is participating as a transitional reporter The consolidation approach(es) employed (i.e., operational control, financial control, equity share) Estimation methodology Recalculations discussion Detailed description of each facility and its emission sources	Independent third-party verification system	http://www.theclimateregistry.org/downloads/GRP.pdf

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Inventory of U.S. Greenhouse Gas Emissions and Sinks	Ammonia Manufacture	CO_2	Process	N/A	National Level	N/A	The U.S. Inventory estimates emissions for ammonia production according to the following equation, where CC is the abbreviation for carbon content. CO2 Emissions = {(Ammonia Production from Petroleum Coke x Ammonia Production from Pet. Coke CC) + (Ammonia Production from Natural Gas x Ammonia Prod. from Nat. Gas CC) **Where:** Ammonia Production from Petroleum Coke CC = 3.57 ton CO2/ton ammonia produced Ammonia Production from Natural Gas CC = 1.2 ton CO2/ton ammonia produced The U.S. Inventory also estimates emissions from urea consumed for industrial processes (does not include urea applied to agricultural lands) and reports this estimate along with the ammonia production estimate.	Mandatory National Reporting to UNFCCC

Review of Existing Programs Relevant to Source - Ammonia Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Inventory of U.S. Greenhouse Gas Emissions and Sinks	Ammonia Manufacture	Activity Data: Total U.S. Ammonia Production and total ammonia produced using petroleum coke.	Base year and subsequent annual GHG emissions, as well as activity data.	QAQC Procedures include completing a QAQC plan that follows the IPCC QAQC Approach which includes, comparing emission factors and carbon contents to IPCC defaults. Checking for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consulting industry experts for third party reviews.	U.S. EPA (2008) U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2006. Available online at http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Review of Existing Programs Relevant to Source - Ammonia Production

Note 1. IPCC Guidelines

Production Process	TFR	CCF	COF	EF
Conventional reforming - natural gas	30.2	15.3	1	1.694
Excess air reforming - natural gas	29.7	15.3	1	1.666
Autothermal reforming - natural gas	30.2	15.3	1	1.694
Partial oxiation	36.0	21.0	1	2.772
Average value - natural gas	37.5	15.3	1	2.104
Average value - partial oxiation	42.5	21.0	1	3.273

Source: IPCC 2006 Guidelines for National Greenhouse Gas Inventories, Chapter 3.
Available online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Note 2. The Climate Registry

Natural Gas Default Values

Heat Content (HHV Btu per Standard Cubic Foot)	Carbon Content (kg C / MMBtu)	Oxidation Factor
975 - 1,000	14.73	1.0
1,000 - 1,025	14.43	1.0
1,025 - 1,050	14.47	1.0
1,050 - 1,075	14.58	1.0
1,075 - 1,100	14.65	1.0
> 1,100	14.92	1.0
Unspecified (Weighted U.S. Average)	14.47	1.0

Source: The Climate Registry General Reporting Protocol v1.0.
Available online at
http://www.theclimateregistry.org/downloads/GRP.pdf

Notes for Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program

Note 1. **Table 1.E.6. Rating of Estimation Methods for Carbon Dioxide Emissions from Ammonia Manufacturing**

Estimation Method	Rating
Continuous emission monitoring or periodic direct measurement	A
Mass balance when carbon content of feedstock fuel is known	B
Mass balance using default carbon content value	B
Default emissions factor of 1.26 tons carbon dioxide per ton ammonia produced	C

Note 2. **Estimated carbon dioxide emissions from ammonia production:**

$$CO2\ emissions = Consumption_{Feedstock\ fuel} * Carbon\ content_{Feedstock\ fuel} * CO2 / carbon\ ratio$$

Where: CO2 / Carbon ratio = 44/12

Note 3. **Table 1.E.5. Carbon Dioxide Emissions Coefficients for U.S. Natural Gas**

HHV Btu Content per Standard Cubic Foot	Emissions Coefficient (metric tons per billion Btu)	
	CO2	Carbon
975 – 1,000	54.01	14.73
1,000 – 1,025	52.91	14.43
1,025 – 1,050	53.06	14.47
1,050 – 1,075	53.46	14.58
1,075 – 1,100	53.72	14.65

Source: Energy Information Administration, Documentation for Emissions of Greenhouse Gases in the United States 2003 (May, 2005), web site: www.eia.doe.gov/oiaf/1605/ggrpt/documentation/pdf/0638(2003).pdf.

Abbreviations Key

General

EF	Emission Factor
PROD	Production
CF	Consumption Factor
IM	Imports
EX	Exports
FR	Fraction
CONS	Consumption
SR	Stoichiometric
CC	Carbon Content

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
2006 IPCC Guidelines	Cement Production	CO_2	Process	N/A	National	N/A	**Tier 1: Estimating clinker production through cement production** Emissions = [Σ (PRODcem x FRcli) - IM + EX for each cement type] x EFcem **Where:** PRODcem = cement production, tons FRcli = clinker fraction for each cement type, fraction IM = clinker imports, tons EX = clinker exports, tons EFcem = emission factor for cement, tons CO_2/ton cement **Default Values**: EFcem: 0.525, tons CO_2/ton cement Note: the EFcem default value corrects for cement kiln dust (CKD) **Tier 2: Use of clinker production data** Emissions = PRODcli x EFcli x CFckd **Where:** PRODcli = clinker production, tons EFcli = emission factor for clinker, tons CO_2/ton clinker CFckd = correction factor for CKD, dimensionless **Default Values:** EFcli: 0.51, tons CO_2/ton clinker CFckd: 1.02, dimensionless **Tier 3: Use of carbonate input data** Emissions = Σ (EFcarb x CONScarb x FRcarb) - Mckd x FRckdcarb x (1 - FRckdcalc) + (CONSnonfuel x FRnonfuel x EFnonfuel) for each carbonate type **Where:** EFcarb = emission factor of each carbonate type, tons CO_2/ton carbonate CONScarb = consumption of each carbonate type, tons FRcarb = fraction of calcination achieved for each carbonate type, fraction Mckd = mass of CKD not recycled in the kiln, tons FRckdcarb = fraction of original carbonate not recycled in the kiln, fraction FRckdcalc = calcination fraction of CKD not recycled in the kiln, fraction CONSnonfuel = consumption of each C-bearing nonfuel raw material type, tons FRnonfuel = fraction of C in each C-bearing nonfuel raw material type, tons EFnonfuel = emission factor of each C-bearing nonfuel raw material type, tons CO_2/ton carbonate

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat	**Tier 1:** Cement production Clinker fraction of cement Clinker imports for consumption Clinker exports. Tier 2: Clinker production Country-specific EF if available Tier 3: Carbonate consumption CKD produced Weight of other carbon-bearing nonfuel raw materials	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers. Comparisons between default and calculated emission factors. Site-specific activity data check.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
U.S. Inventory of Greenhouse Gas Emissions and Sinks	Cement Production	CO_2	Industrial Processes process emissions from cement production	N/A	National	N/A	**Approach: IPCC Tier 2** Emissions = PRODcli x EFcli x CFckd **Where:** PRODcli = clinker production, tons EFcli = emission factor for clinker, tons CO2/ton clinker CFckd = correction factor for CKD, dimensionless **Default Values:** EFcli: 0.51, tons CO_2/ton clinker CFckd: 1.02, dimensionless
WRI/WBCSD Protocol (Cement Sustainability Initiative)	Cement Production	CO_2	Process	N/A	Corporate/Facility	N/A	**Approach 1: Clinker-based production data with a facility-specific EF if available** Emissions = PRODcli x EFcli, where EFcli = [(FRcao x SRcao) + (FRmg x SRmg)] **Where:** PRODlcli = clinker production, tons EFcli = emission factor for the clinker, tons CO_2/ton clinker FRcao = CaO content of the clinker, fraction SRcao = stoichiometric weight ratio of CO2 to CaO, dimensionless FRmg = MgO content of the clinker, fraction SRmg = stoichiometric weigh ratio of CO2 to MgO, dimensionless **Default Values:** SRcao: 0.7848, dimensionless SRmg: 1.0918, dimensionless EFcli: 0.525, tons CO_2/ton clinker Additional formulas for calculating facility-specific EFs are available in the Notes section **Approach 2: Cement-based** Emissions = PRODcem x FRcli x FRrm x FRcaco3 x SRcaco3 **Where:** PRODcem: total amount of cement produced, tons FRcli: fraction ot clinker in the cement, fraction FRrm: fraction of raw material in the clinker, fraction FRcaco3: fraction of $CaCO_3$ in the clinker, fraction SRcaco3: ctoichiometric ratio of CO_2 to $CaCO_3$, = atomic weight of CO_2 (44 g) / atomic weight of $CaCO_3$ (100 g). Note: this method does not provide a correction for cement kiln dust (CKD)

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
U.S. Inventory of Greenhouse Gas Emissions and Sinks	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat	National clinker production data	Base year and subsequent annual GHG emissions, as well as activity data. A National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers, especially between Tiers 1/2 (a national, top-down approach) and Tiers 3 (a bottom-up approach). Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	U.S. EPA (2008) U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2006. Available online at http://www.epa.gov/climatechange/emissions/usinventoryreport.html
WRI/WBCSD Protocol (Cement Sustainability Initiative)	Voluntary Reporting	**Approach 1**: Clinker production CaO and MgO content of clinker (if available) **Approach 2**: Cement production Clinker content of cement Raw material content of the clinker	N/A	General data collection and calculation suggestions. Compare emission estimates using different methodologies. Compare default and calculated emission factors.	http://www.ghgprotocol.org/calculation-tools/cement-sector

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Climate Leaders	Cement Production	CO_2	Process	N/A	Corporate	N/A	**Approach 1: WRI/WBCSD Clinker-based** Emissions = Clinker Emissions + Bypass Dust Emissions + CKD Emissions + Raw Material Emissions, where: Clinker Emissions = Σ (PRODcli x EFcli) for each clinker type, where EFcli = [(CONTcao x SRcao) + (CONTmg x SRmg)] Bypass Dust Emissions = PRODbpd x EFcli CKD Emissions = PRODckd x EFckd Raw Material Emissions = TOCrm x SRco2 x CONScarb x FRcalc **Where:** PRODlcli = clinker production, tons PRODbpd = bypass dust produced, tons PRODckd = CKD produced, tons EFcli = emission factor for the clinker, tons CO_2/ton clinker EFckd = emissions factor for CKD, tons CO_2/ton CKD CONTcao = CaO content of the clinker, % by mass SRcao = stoichiometric weight ratio of CO_2 to CaO, dimensionless CONTmg = MgO content of the clinker % by mass SRmg = stoichiometric weigh ratio of CO_2 to MgO, dimensionless CONScarb = carbonate consumed, tons FRcalc = fraction of carbonate calcined, fraction **Default Values:** SRcao: 0.785, dimensionless SRmg: 1.09, dimensionless EFcli: 0.525, tons CO_2/ton clinker Additional formulas for calculating facility-specific EFs are available in the Notes section

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Climate Leaders	Voluntary Reporting	**Approach 1:** Clinker production (ideally by type) Bypass dust produced CaO and MgO content of clinker (if available) calcination fractions (if available) CKD disposed	Baseline and subsequent annual GHG emissions, broken out by source type (core direct, core indirect, and optional) for domestic and international sources Activity data Clinker content ratios	EPA review and option for third-party review. Comparison of emission factors. Loss on Ignition tests. Amount of CKD discarded.	1) http://www.climateregistry.org/resources/docs/protocols/industry/cement/EPA_Climate_Leaders_Cement_Protocol.pdf 2) http://www.ghgprotocol.org/calculation-tools/cement-sector

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Climate Leaders	Cement Production	CO_2	Process	N/A	Corporate	N/A	**Approach 2: Cement-based** Emissions = PRODcem x FRcli x FRraw x FRcarb x SRcaco3 x SRmgco3 **Where:** PRODcem = cement production, tons FRcli = fraction of clinker in cement, fraction FRraw = fraction of clinker in raw materials, fraction FRcarb = fraction of carbonate in raw materials, fraction SRcaco3 = stoichiometric weight ratio of CO2 to $CaCO_3$, dimensionless SRmgco3 = stoichiometric weigh ratio of CO2 to $MgCO_3$, dimensionless **Approach 3: Carbonate Inputs** Emissions = Carbonate Emissions + CKD Emissions + Non-carbonate Input Emissions, where: Carbonate Emissions = Σ (CONScarb x EFcarb x FRcalc) for each carbonate type CKD Emissions = PRODckd x EFckd x FRckd x (1 - FRcalcckd) Non-carbate Input Emissions = Σ (EFnonc x CONSnonc x (FRtoc x SRco2) for each input type **Where:** CONScarb = consumption of each carbonate type, tons CONSnonc = consumption of each non-carbate input, tons PRODckd = produced CKD, tons EFcarb = emission factor for each carbonate type, tons CO_2/ton carbonate EFckd = emission factor for CKD, tons CO_2/ton CKD EFnonc = emission factor for non-carbonate inputs, tons CO_2/ton input FRcalc = fraction of calcination achieved for each carbonate type, fraction FRckd = fraction of orginal carbonate in CKD, fraction FRcalcckd = fraction of calcination achieved for CKD, fraction FRtoc = fraction of TOC in non-carbate inputs, fraction SRco2 = stoichiometric ratio of CO_2 to carbon, ratio **Default Values:** See the WRI/WBCSD default values, provided above and in the Notes tab. Note: These approaches should account for imports and exports in production data. An approach for alternative fuels is also included.

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Climate Leaders	Voluntary Reporting	**Approach 2:** Cement production (ideally by cement type, and to include imports/exports) Clinker and carbonate fractions (if available) **Approach 3**: Input consumption (both carbonates and non-carbonates) CKD production Calcination fraction (if available) MgO and Ca	Baseline and subsequent annual GHG emissions, broken out by source type (core direct, core indirect, and optional) for domestic and international sources Activity data Clinker content ratios	EPA review and option for third-party review. Comparison of emission factors. Loss on Ignition tests. Amount of CKD discarded.	1) http://www.climateregistry.org/resources/docs/protocols/industry/cement/EPA_Climate_Leaders_Cement_Protocol.pdf 2) http://www.ghgprotocol.org/calculation-tools/cement-sector

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
New Mexico Mandatory GHG Reporting	Cement Production	CO_2	Process and combustion	N/A	Facility	N/A	**Approach 1**: CEMS, including emissions by fuel type. **Approach 2: Clinker-based** Emissions = (PRODcli x EFcli) + (PRODckd x EFckd) + (TOCrm x RM x SRco2) **Where:** PRODcli = clinker production, tons EFcli = emission factor for clinker, tons CO_2/ton clinker PRODckd = produced CKD, tons EFckd = emission factor for CKD, tons CO_2/ton CKD TOCrm = Total Organic Carbon (TOC) content of raw materials, fraction RM = amount of raw material consumed, tons SRco2 = stoichiometric ratio of CO_2 to C, = 44/12 **Default Values:** TOCrm: 0.2% See WRI/WBCSD note on the Notes page for calculating EFs
EU ETS 1st Reporting Period	Cement Production	CO_2	Process and combustion	> 500 tons of cement production per day	Facility	N/A	**Calculation Method A: Carbonates** Emissions = Σ (PRODcarb x EFcarb X CFcarb) for each carbonate type **Where:** PRODcarb = carbonate production, tons EFcarb = emission factor for carbonate, tons CO_2/ton carbonate CFcarb = conversation factor to account for C not converted into CO_2, dimensionless **Carbonate Method Tier 1:** Activity data: Amount of pure carbonates in process input are metered with maximum permissible uncertainty of less than +-5% uncertainty **Carbonate Method Tier 2:** Activity data: Amount of pure carbonates in process input are metered with maximum permissible uncertainty of less than +-2.5% uncertainty **Default Values:** EFcarb: 0.440 ($CaCO_3$), 0.522 ($MgCO_3$), tons CO_2/ton carbonate CFcarb: 1.0, dimensionless
EU ETS 1st Reporting Period	Cement Production	CO_2	Process and combustion	> 500 tons of cement production per day	Facility	N/A	**Calculation Method B: Clinker** Emissions = Σ [Clinker emissions - CKD emissions] for each clinker and CKD type, where Clinker emissions = PRODcli x EFcli X CFcli and CKD emissions = PRODckd x EFckd X CFckd **Where:** PRODcli = clinker production, tons PRODckd = cement kiln dust (CKD) produced, tons EFcli = emission factor for clinker, tons CO_2/ton clinker EFckd = emission factor for CKD, tons CO_2/ton CKD CFcli = conversion factor for clinker, dimensionless CFckd = conversion factor for CKD, dimensionless **Clinker Method Tier 1:** Activity data: Amount of clinker in process output are metered with maximum permissible uncertainty of less than +-5% uncertainty Activity data: Amount of CKD in process output are metered with maximum permissible uncertainty of less than +-10% uncertainty **Clinker Method Tier 2:** Activity data: Amount of clinker in process output are metered with maximum permissible uncertainty of less than +-2.5% uncertainty Activity data: Amount of CKD in process output are metered with maximum permissible uncertainty of less than +-5% uncertainty

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
New Mexico Mandatory GHG Reporting	Mandatory Reporting	**Approach 1:** Direct emissions monitoring **Approach 2:** Clinker production CKD Raw material	Annual Emissions Data Report, which includes total CO_2 emissions, process CO_2 emissions, TOC in raw material, and stationary combustion emissions		http://www.nmenv.state.nm.us/aqb/GHG/documents/NM_GHGEI_quantif_proced2008.pdf
EU ETS 1st Reporting Period	Mandatory Reporting	**Calculation Method A:** Carbonte consumption	Emissions Chosen tiers and methods (if applicable) Activity data Emission factor(s) Oxidation / Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU ETS 1st Reporting Period	Mandatory Reporting	**Calculation Method B:** Clinker production CKD production	Emissions Chosen tiers and methods (if applicable) Activity data Emission factor(s) Oxidation / Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
EU ETS 1st Reporting Period	Cement Production	CO_2	Process and combustion	> 500 tons of cement production per day	Facility	N/A	**Clinker Method Tier 3:** Activity data: Amount of clinker in process output are metered with maximum permissible uncertainty of less than +-1.5% uncertainty and is measured by multiplying cement production by a clinker/cement ratio **Default Values:** EFcli and EFckd: 0.525 (Tier 1), calculated using the WRI/WBCSD formula found in the notes section (Tier 2), tons CO2/ton clinker or CKD CFcli and CFckd: 1.0, dimensionless **Calculation Method A: Kiln Input** Emissions = Σ (INPUTkiln x EFkiln X CFkiln) for each kiln input **Where:** INPUTkiln = kiln input, tons EFkiln = emission factor for carbonate, tons CO2/ton input CFkiln = conversation factor for each input, dimensionless Note: threes tiers exists for estimating INPUTkiln; tier 1 is within 7.5% uncertainty, tier 2 is within 5.0% uncertainty, and tier 3 is within 2.5% uncertainty **Kiln Method Tier 1:** Activity data: Amount of process input is metered with maximum permissible uncertainty of less than +-7.5% uncertainty **Kiln Method Tier 2:** Activity data: Amount of process input is metered with maximum permissible uncertainty of less than +-5.0% uncertainty **Kiln Method Tier 3:** Activity data: Amount of process input is metered with maximum permissible uncertainty of less than +2.5% uncertainty **Default Values:** CFkiln: 1.0 (Tier 1), 0 ≤ CFkiln ≤ 1 (Tier 2), dimensionless

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU ETS 1st Reporting Period	Mandatory Reporting		Emissions Chosen tiers and methods (if applicable) Activity data Emission factor(s) Oxidation / Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
EU Emissions Trading System 2nd reporting period	Cement Production	CO_2	Process and combustion	> 500 tons of cement production per day	Facility	N/A	**Calculation Method A: Kiln Input** Emissions = Σ (INPUTkiln x EFkiln X CFkiln) for each kiln input Where: INPUTkiln = kiln input, tons EFkiln = emission factor for carbonate, tons CO2/ton input CFkiln = conversation factor for each input, dimensionless Note: threes tiers exists for estimating INPUTkiln; tier 1 is within 7.5% uncertainty, tier 2 is within 5.0% uncertainty, and tier 3 is within 2.5% uncertainty **Kiln Method Tier 1:** Activity data: Amount of process input is metered with maximum permissible uncertainty of less than +-7.5% uncertainty **Kiln Method Tier 2:** Activity data: Amount of process input is metered with maximum permissible uncertainty of less than +-5.0% uncertainty **Kiln Method Tier 3:** Activity data: Amount of process input is metered with maximum permissible uncertainty of less than +2.5% uncertainty **Default Values:** CFkiln: 1.0 (Tier 1), 0 ≤ CFkiln ≤ 1 (Tier 2), dimensionless
EU Emissions Trading System 2nd reporting period	Cement Production	CO_2	Process and combustion	> 500 tons of cement production per day	Facility	N/A	**Calculation Method B: Clinker** Emissions = Σ [Clinker emissions - CKD emissions - raw material emissions] for each clinker and CKD type, where Clinker emissions = PRODcli x EFcli X CFcli, CKD emissions = PRODckd x EFckd X CFckd, and non-carbonate emissions = CONSrm x EFrm x CFrm Where: PRODcli = clinker productions, tons PRODckd = CKD produced, tons CONSrm = consumption of non-carbonate raw material, tons EFcli = emission factor for clinker, tons CO2/ton clinker EFckd = emission factor for CKD, tons CO2/ton CKD EFrm = emissions factor for non-carbonate raw material, tons CO2/ton raw material CFcli = conversion factor for clinker, dimensionless CFckd = conversion factor for CKD, dimensionless Note: two tiers exist for PRODcli; tier 1 is within 5% uncertainty and tier 2 is within 2.5% uncertainty Clinker Method Tier 1: Activity data: Amount of clinker in process output are metered using industry best-practices guidelines Activity data: Consumption of non-carbonate raw materials is metered with maximum permissible uncertainty of less than +-15% uncertainty Clinker Method Tier 2: Activity data: Amount of clinker in process output are metered with maximum permissible uncertainty of less than +-7.5% uncertainty Activity data: Consumption of non-carbonate raw materials is metered with maximum permissible uncertainty of less than +-7.5% uncertainty Default Values: EFcli and EFckd: 0.525 (Tier 1), calculated using a UNFCCC country-specific emissions factor (Tier 2), or calculated using the WRI/WBCSD formula found in the notes section (Tier 3) EFrm: industry best practices (Tier 1), using the WRI/WBCSD formula found in the notes section (Tier 2) CFcli and CFckd: 1.0 (Tier 1), 0 ≤ CF ≤ 1 (Tier 2, calculated using facility-specific data) CFrm: 1.0 (Tier 1), 0 ≤ CF ≤ 1 (Tier 2, calculated using industry best practices)

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Mandatory Reporting	Reporting requirements for all sources (in addition to emissions): - Chosen tiers and methods - Activity data - Emission factor - Conversion factor	Emissions Chosen tiers and methods (if applicable) Activity data Emission factor(s) Oxidation / Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF
EU Emissions Trading System 2nd reporting period	Mandatory Reporting	Reporting requirements for all sources (in addition to emissions): - Chosen tiers and methods - Activity data - Emission factor - Conversion factor	Emissions Chosen tiers and methods (if applicable) Activity data Emission factor(s) Oxidation / Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Department of Energy 1605(b) Voluntary Reporting Program	Cement Production	CO_2	Clinker Production	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	N/A	**"A" rated method (best practice):** CO2 emissions = (calcination emission factor x clinker produced) + (magnesium emission factor x clinker produced) The calcination emission factor is calculated "by multiplying the measured CaO content of clinker, as a percent, by the molecular ratio of CO2 to CaO" (which is 0.785). The magnesium emissions factor is calculated "by multiplying the measured magnesium oxide content of the clinker, as a percent, by the molecular ratio of CO2 to MgO" (which is 1.092). **Alternate "A" rated method and "B" method (next best practice):** Use knowledge of raw material composition with the equation provided in Cement Note 2. If this is calculated specific to each plant, it is an "**A**" rated estimate. If composition is not known for each plant, use the IPCC 2000 clinker composition defaut values, for a "**B**" rated estimate. Alternatively, use a default emissins factor of 0.525 MT of CO2 for each metric ton of clinker produced. **This is rated "B"**. **"C" rated method**: If reliable data on raw material composition and amounts are not available, use a default emissions factor of 0.499 tons CO2 per ton cement produced.

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Department of Energy 1605(b) Voluntary Reporting Program	Voluntary	**"A" rated**: percent CaO and MgO contents of clinker **"A" rated**: plant-specific measurement of raw material composition. **"B" rated**: measurement of clinker produced. **"C" rated**: measurement of cement produced.	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. A is the best accepted method, and D is the least accurate method. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place. (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Section 1.E.4.1.4.1 of http://www.pi.energy.gov/enhancingGHGregistry/technicalguidelines.html and 10 CFR 300 (p 106 and 114) at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Department of Energy 1605(b) Voluntary Reporting Program	Cement Production	CO_2	Discarded Bypass/Cement Kiln Dust (CKD) - "Emissions from discarded CKD should not be included in cement manufacturers' emission inventories, provided it is discarded outside the entity's organizational boundaries."	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	**"A" rated method**: direct measurement of CO2 emissions at disposal site.	**"A" rated method:** direct measurement of emissions at disposal site

Review of Existing Programs Relevant to Source - Cement Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Department of Energy 1605(b) Voluntary Reporting Program	Voluntary	**"A" rated method**: CO2 emissions are measured directly.	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. A is the best accepted method, and D is the least accurate method. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Section 1.E.4.1.4.2 of http://www.pi.energy.gov/enhancingGHGregistry/technicalguidelines.html. Also see www.ghgprotocol.org. Also 10 CFR 300 (p 106 and 114) available at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf.

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Department of Energy 1605(b) Voluntary Reporting Program	Cement Production	CO_2	Discarded Bypass/Cement Kiln Dust (CKD) - "Emissions from discarded CKD should not be included in cement manufacturers' emission inventories, provided it is discarded outside the entity's organizational boundaries."	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	**"B" rated method**: Calculated from inputs and clinker production emission factors, measuring portion of CKD that is calcined, the weight fraction of carbonate CO2 in the CKD, and the weight fraction of carbonate CO2 in the raw materials **"C" rated method**: Calculated from clinker production inputs	**"B" rated method:** If plant-specific clinker emission factors and data on the portion of CKD that is calcined are available, consult the WRI/WBCSD GHG Protocol. This Protocol effectively uses the formula below, applied to plant-specific data: CO2 emission from CKD = (CKD) (EFckd) where CKD is the amount of CKD discarded and EFckd is the emission factor, explained in CCAR Cement Notes 2 and 3. **"C" rated method**: assume that CO2 emissions from discarded CKD are 2 percent of the CO2 emissions from clinker production, per IPCC 2000.
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Cement Production	CO_2	Direct Process	3% of a facility's total CO_2-equivalent emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries.	Facility-level	N/A	**Method 1: Clinker Method** Emissions = (PRODcli x EFcli) + (PRODckd x EFckd) + (FRtoc x RM x SRco2) Where: PRODcli = clinker production, tons EFcli = emission factor for clinker, tons CO2/ton clinker PRODckd = produced CKD, tons EFckd = emission factor for CKD, tons CO2/ton CKD FRtoc = Total Organic Carbon (TOC) content of the raw material, fraction SRco2 = stiochiometric ratio of CO2 to C, = 44/12 RM = amount of raw material consumed, tons **Clinker Method Tier A:** Facility-specific values for inputs **Clinker Method Tier B:** Default values for inputs Default Values: FRtoc: 0.2% See WRI/WBCSD note on the Notes page for calculating EFs
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Cement Production	CO_2	Direct Process	3% of a facility's total CO_2-equivalent emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries.	Facility-level	N/A	**Method 2: Carbonate Method** Emissions = Σ (EFcarb x CONScarb x FRcarb) - Mckd x FRckdcarb x (1 - FRckdcalc) + (CONSnonfuel x FRnonfuel x EFnonfuel) for each carbonate type **Where:** EFcarb = emission factor of each carbonate type, tons CO_2/ton carbonate CONScarb = consumption of each carbonate type, tons FRcarb = fraction of calcination achieved for each carbonate type, fraction Mckd = mass of CKD not recycled in the kiln, tons FRckdcarb = fraction of original carbonate not recycled in the kiln, fraction FRckdcalc = calcination fraction of CKD not recycled in the kiln, fraction CONSnonfuel = consumption of each C-bearing nonfuel raw material type, tons FRnonfuel = fraction of C in each C-bearing nonfuel raw material type, tons EFnonfuel = emission factor of each C-bearing nonfuel raw material type, tons CO2/ton carbonate Default Values: FRcarb: 1.0, fraction FRckdcalc: 1.0, fraction EFcarb: 0.43971 (calcite/aragonite), 0.52917 (MgCO3), 0.47732 (dolomite), 0.37987 (siderite), 0.40822 - 0.47572 (ankenite), 0.38286 (rhodochrosite), 0.41492 (sodium carbonate/soda ash), tons CO2/ton carbonate

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Department of Energy 1605(b) Voluntary Reporting Program		**"B" rated method**: clinker emission factors calculated from plant-specific data on MgO and CaO content of clinker. Data on portion of CKD calcined is used. **"C" rated method**: clinker production emissions are used.			
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Voluntary	**Method 1:** Clinker Production CKD Raw Material	Annual GHG emissions (CO_2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	http://www.theclimateregistry.org/downloads/Draft_GRP.pdf
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Voluntary	**Method 2:** Carbonate consumption CKD produced Weight of other carbon-bearing nonfuel raw materials	Annual GHG emissions (CO_2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
California Climate Action Registry (CCAR) - Cement Reporting Protocol	Cement Production	CO_2	Cement Mfg	95% (5% can be deminimis and only estimated baseline year)	Entity (Facility/source level encouraged)	Production of clinker	Process: Cement-based. Cement-based calculates CO2 emissions based on raw materials and their carbonate content. Data collected on cement production, the raw material ratio to produce clinker and the CaCO3 equivalent content of the raw materials. Clinker-based: CO2 emissions based on the volume and composition of clinker produced as well as the amount of cement kiln dust (CKD) not recycled to the kiln. CO2 emissions = [(Cli) (EFCli) + (CKD) (EFCKD)]. EF may be plant specific or default emission factor of 525 kg CO2/metric ton of clinker Total Organic Carbon (TOC) CO2 emissions = (TOCR.M.) x (R.M.) x (3.664), assuming TOC =0.2 (or plant specific) CKD- CO2 emissions from CKD not recycled to the kiln are estimated by determining the amount of CKD produced and the calcination rate of CKD; the CKD emission factor is calculated from the clinker emission factor and the degree of calcination. May use 2% default for CKD EF CKD = {[(Clinker EF/(1+ClinkerEF) x D)]/[1-(Clinker EF/(1+Clinker EF)) x D]}
California Climate Action Registry (CCAR) - Cement Reporting Protocol	Cement Production	CO_2	from total organic carbon in raw materials	95% (5% can be deminimis and only estimated baseline year)	Entity (Facility/source level encouraged)	Consumption of raw material	Monitor weight of raw material consumed. CO2 emissions from TOC in raw materials = (TOCrm x RM x SRco2) **Where:** TOCrm = Total Organic Carbon (TOC) content of raw materials, fraction RM = amount of raw material consumed, tons SRco2 = stoichiometric ratio of CO2 to C, = 44/12 **Default Values:** TOCrm: 0.2% See WRI/WBCSD note on the Notes page for calculating EFs
California Climate Action Registry (CCAR) - General Reporting Protocol v. 2.2	Cement Production	HFCs	Fugitive - refrigerant system leaks	95% (5% can be deminimis and only estimated baseline year)	Entity (Facility/source level encouraged)	Beginning and end of year inventory, any point of HFC acquisition or disbursement	Mass balance approach. Monitor: types of refrigerant, changes in base inventory, changes to nameplate capacity of equipment (at beginning of year and end of year), purchases/acquisitions, sales/disbursements (throughout the year). (see note 5 for full calculation method)
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates **(please see note A for important information regarding this protocol)**	Cement Production	CO_2	cement mfg	All (if deminimis [= <3%] can be calculated more simply)	Facility	Production of clinker	Calculate CO_2 emissions based on the volume and composition of clinker produced as well as the amount of CKD (cement kiln dust) discarded during the manufacturing process. Each plant must calculate plant-specific clinker and CKD emission factors. (notes 1 and 2)
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	Cement Production	CO_2	from total organic carbon in raw materials	All (if deminimis [= <3%] can be calculated more simply)	Facility	Consumption of raw material	Monitor weight of raw material consumed. CO_2 emissions based on assumption of 0.2% TOC in raw material. (note 3)
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	Cement Production	CH_4	Fugitive - from coal storage	All (often can be calculated as de minimis using alternative methods selected by the operator)	Facility	Time of coal purchase	Monitor amount of coal purchased (tons). CH_4 emissions based on default emission factor.

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
California Climate Action Registry (CCAR) - Cement Reporting Protocol	Voluntary	Mass of clinker produced, % CaO content of clinker, % MgO content of clinker, mass non-carbonate CaO, mass non-carbonate MgO, mass of discarded CKD not recycled (all company collected data). Clinker and CKD emission factors derived from above (company calculated), unless CaO/MgO content is lacking then use default emission factor of 525 kg CO2/ton of clinker produced (given in cement protocol).	Base year and annual GHG emissions (CO2 equivalents).	3rd party certification (approved cement sector certifiers)	http://www.climateregistry.org/resources/docs/protocols/industry/cement/Cement_Reporting_Protocol_1205.pdf
California Climate Action Registry (CCAR) - Cement Reporting Protocol	Voluntary	Tons raw material consumed in report year Organic carbon content of raw material	Base year and annual GHG emissions (CO2 equivalents).	3rd party certification (approved cement sector certifiers)	http://www.climateregistry.org/resources/docs/protocols/industry/cement/Cement_Reporting_Protocol_1205.pdf
California Climate Action Registry (CCAR) - General Reporting Protocol v. 2.2	Voluntary	Inventory at beginning and end of year Purchases of HFCs HFCs returned to the site after offsite recycling Returns to supplier HFCs taken from storage and/or equipment and disposed of HFCs taken from storage and/or equipment and sent offsite for recycling or reclamation Total full charge of new equipment Total full charge of retiring equipment	Base year and annual GHG emissions (CO_2 equivalents). Note: HFC leaks are often deminimis; if so, reports only needed for baseline year and in years with significant changes	3rd party certification (approved cement sector certifiers)	http://www.climateregistry.org/resources/docs/protocols/grp/GRPV2March2007_web.pdf
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates **(please see note A for important information regarding this protocol)**	Mandatory	Quantity of clinker produced CaO % content of clinker MgO % content of clinker Non-carbonate CaO % Non-carbonate MgO % Clinker emission factor (calculated by plant) CKD emission factor (calculated by plant) Plant specific CKD calcination rate using the fraction of carbonate CO_2 in the CKD and raw material (calculated by plant) Quantity of CKD discarded	Annual emissions Clinker emission factor CKD emission factor.	Verification by 3rd party (private firm or air district) trannually due to relatively stable emissions and straightforward quantification	http://www.arb.ca.gov/regact/2007/ghg2007/isor.pdf
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	Mandatory	Metric tons raw material consumed in report year (not specified), organic carbon content of raw material (not specified).	Annual GHG emissions (CO_2 from TOC in raw materials) Metric tonnes raw material consumed in the report year Organic carbon content of raw material (%).	Verification by 3rd party (private firm or air district) triannually due to relatively stable emissions and straightforward quantification	http://www.arb.ca.gov/regact/2007/ghg2007/isor.pdf
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	Mandatory	Tons of purchased coal type (not specified), emission factor in scf CH4/metric ton (default by coal type from Appendix A, section 5f of reporting guidelines).	Annual GHG emissions (fugitive CH4 emissions from coal storage).	Verification by 3rd party (private firm or air district) triannually due to relatively stable emissions and straightforward quantification	http://www.arb.ca.gov/regact/2007/ghg2007/isor.pdf

Notes on GHG Calculation Methods and Procedures for Cement Production

General Abbreviations Used:
EF: Emission Factor
PROD: Production
CF: Consumption Factor
IM: Imports
EX: Exports
FR: Fraction
CONS: Consumption
SR: Stoichiometric Ratio

Note 1: 2006 IPCC Guidelines. It is acceptable to set Carbonate in CKD FR equal to the CaCO3 ratio of raw kiln material. Also, if the heat contribution from other C-bearing nonfuel (e.g., kerogen, fly ash) is < 5% of total fuel heat, these emissions may be ignored.

Note 2: WRI/WBCSD
CKD Emission Factor
Efckd = {[(EFcli)/(1+Efcli)]xd} / [1 - {[(EFcli)/(1+Efcli)]xd}]
Where:
EFckd = CKD Emission Factor
EFcli = Clinker Emission Factor
d = CKD Calcination Rate

Plant-specific CKD Calcination Rate
d = [1 - {[fCO2ckd x (1 - fCO2rm)] / [(1 - fCO2ckd) x fCO2rm]}]
Where:
fCO2ckd = weight fraction of carbonate CO2 in the CKD
fCO2rm = weight fraction of carbonate CO2 in the raw material

The calcination rate, “d”, should be based on loss-on-ignition data from each plant; it reflects the amount of CO2 associated with creating CKD and expressed as a fraction of the total carbonate CO2 in the raw materials. Alternatively, the Registry suggests using a default value of 1, which is conservative.

If companies have inadequate data to calculate a plant-specific CKD emission factor the Registry recommends assuming that the CO2 emissions from CKD equal 2% of clinker CO2 emissions.

Note 3: **WRI/WBCSD**
Clinker emission factor calculation
EFCli = [(CaO content – non-carbonate CaO) x Molecular ratio of CO2/CaO]+ [(MgO Content – non-carbonate MgO) x Molecular Ratio of CO2/MgO]
Where:
CaO Content (by weight) = CaO content of Clinker (%)
Molecular Ratio of CO2/CaO = 44g/56g = 0.785
MgO Content (by weight) = MgO content of Clinker (%)
Molecular Ratio of CO2/MgO = 44g/40g = 1.092
Non-carbonate CaO (by weight) = Non-carbonate CaO of Clinker (%)
Non-carbonate MgO(by weight) = Non-carbonate MgO of Clinker (%)

Note 4: CCAR
TOC Content in Raw Materials
CO2 emissions = (TOCR.M.) x (R.M.) x (3.664)
Where:
TOCR.M = 0.2% = Organic carbon content of raw material (%)
R.M. = The amount of raw material consumed (metric tonnes/yr)
3.664 = The CO2 to carbon molar ratio

Note 5: CCAR
Calculating fugitive HFC from refrigerant leaks
Method is from CCAR General Reporting Protocol, Part III, Chapter 11

HFC *Emissions = A - B + (C1 + C2) - (D1 +D2 + D3) + (E1 -E2)*
Where:
A = HFC in inventory (beginning of year)
B = HFC in inventory (end of year)
C1 = purchases of HFCs (including HFCs in new equipment)
C2 = HFCs returned to the site after offsite recycling
D1 = returns to supplier
D2 = HFCs taken from storage and/or equipment and disposed of
D3 = HFCs taken from storage and/or equipment and sent offsite for recycling or reclamation
E1 = total full charge of new equipment
E2 = total full charge of retiring equipment
ALL IN KGS

HFC should then be converted to metric tonnes of CO2e using IPCC SAR GWPs

Notes on GHG Calculation Methods and Procedures for CA Mandatory GHG Reporting Program

Note A *: From CA ARB website: "On December 6, 2007, the Air Resources Board (ARB) approved a regulation for the mandatory reporting of greenhouse gas emissions from major sources, pursuant to the California Global Warming Solutions Act of 2006. ARB staff was directed by the Board to make specified modifications to the proposed regulation that was released on October 19, 2007. Staff anticipates that the revised version of the mandatory reporting regulation, with the board directed changes, will be made available in early April 2008. Upon release of the revised regulation, ARB staff will invite all stakeholders to provide comments during a 15-day comment period.*

Following the 15-day comment period, staff will prepare a final statement of reasons addressing all comments received during the initial 45-day comment period and the additional 15-day comment period. "

This document has been updated best as possible to reflect the 12/06/07 revision suggestions of the CA Air Resources Board. However, please note that the regulation should not be considered official until the final statement of reasons is released (likely to occur 2nd quarter 2008).

Note 1: Process CO2 emissions calculation uses the CCAR/CSI clinker-based method.
The clinker emission factor is based on the percent of lime and magnesium oxide content of the clinker. The CKD emission factor must be calculated only when cement plant operators do not recycle CKD back to the kiln. There are at least two cement plants in California that discard CKD; these facility operators would also calculate a plant-specific CKD calcination rate.
Clinker-Based Methodology. Operators of cement plants shall calculate CO_2 emissions from clinker production using a plant-specific clinker emission factor and a plant-specific cement kiln dust (CKD) emission factor
as specified in this section, 95110(c)(1).

Clinker-Based Methodology
CO2 Emissions (metric tonnes) = [(Cli) x (EFCli) + (CKD) x (EFCKD)]
Where: Cli = Quantity of clinker produced, metric tonnes, EFCli = Clinker emission factor, metric tonnes CO2/metric tonnes clinker computed as specified in section 95110(b)(1)(A), CKD = Quantity CKD discarded, metric tonnes, EFCKD = CKD emission factor, computed as specified in section 95110(c)(1)(B)

Clinker Emission Factor:
EFCli = [(CaO content – non-carbonate CaO) x Molecular ratio of CO2/CaO]+ [(MgO Content – non-carbonate MgO) x Molecular Ratio of CO2/MgO]
Where: CaO Content (by weight) = CaO content of Clinker (%), Molecular Ratio of CO2/CaO = 44g/56g = 0.785, MgO Content (by weight) = MgO content of Clinker (%), Molecular Ratio of CO2/MgO = 44g/40g = 1.092, Non-carbonate CaO (by weight) = Non-carbonate CaO of Clinker (%), Non-carbonate MgO(by weight) = Non-carbonate MgO of Clinker (%)

Note 2: CKD Emission Factor
Efckd = {[(EFcli)/(1+Efcli)]xd} / [1 - {[(EFcli)/(1+Efcli)]xd}]
Where:
EFckd = CKD Emission Factor
EFcli = Clinker Emission Factor
d = CKD Calcination Rate

Plant-specific CKD Calcination Rate
d = [1 - {[fCO2ckd x (1 - fCO2rm)] / [(1 - fCO2ckd) x fCO2rm]}]
Where:
fCO2ckd = weight fraction of carbonate CO2 in the CKD
fCO2rm = weight fraction of carbonate CO2 in the raw material

Note 3: TOC Content in Raw Materials
CO2 emissions = (TOCR.M.) x (R.M.) x (3.664)
Where:
TOCR.M = 0.2% = Organic carbon content of raw material (%)
R.M. = The amount of raw material consumed (metric tonnes/yr)
3.664 = The CO2 to carbon molar ratio

Note 4: Method for Calculating Fugitive CH4 Emissions from Coal Storage
*CH4 = PC * EF * CF1 / CF2*
Where:
CH4 = CH4 emissions in the report year, metric tonnes
PC = Purchased coal in the report year, tons
EF = Default emission factor for CH4 based on coal origin and mine type provided in Appendix A, scf CH4/ton
CF1 = Conversion factor equals 0.04228, lbs CH4/scf
CF2 = Conversion factor equals 2,204.6, lbs/metric ton

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	PFCs (e.g., CF4, C2F6, CHF3, C3F8), NF3, and SF6 gases; heat transfer fluids (e.g., C6F14)	Industrial Process--Electronics Manufacturing	All (no deminimis)	Facility, company, or country level.		**Tier 1: Product of Emission Factor and Area of Substrate Processed:** For Semiconductors and TFT-FPDs: E(FC)i = EFi x Cu x Cd (i = 1...n) For PV-Cells: E(FC)i = EFi x Cu x Cd x Cpv (i = 1...n) where, E(FC)i = emissions of FC gas i, mass of gas i EFi = emission factor of FC gas i [mass of gas i/m2 of substrate] Cu = annual production capacity utilization fraction Cd = annual production capacity Cpv = fraction of PV manufacture that use FCs	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	PFCs (e.g., CF4, C2F6, CHF3, C3F8), NF3, and SF6 gases; heat transfer fluids (e.g., C6F14)	Industrial Process--Electronics Manufacturing	All (no deminimis)	Facility, company, or country level.		**Tier 2a: Process Gas-Specific Parameters:** Company-specific data on gas consumption and emission control technology is combined with default industry parameters on gas left in cylinders (i.e., heel), gas utilization rates, by-product formation rates, and abatement Desctruction or Removal Efficiency (DRE) (see Equation below). 1) E(FC)i = (1-h) x FCi x (1-Ui) x (1 - ai x di) (i = 1...n) 2) B(FC)j,i = (1-h) x Bj,i x FCi X (1 - ai x dj) (i = 1...n) & (j = 1...m) where, For Equation 1-- E(FC)i = emissions of FC gas i, kg FCi = consumption of FC gas i, kg h = fraction of gas remaining in shipping container Ui = process utilization rate for gas i ai = fraction of gas i used in processes with abatement devices di = fraction of gas i destroyed in abatement devices For Equation 2-- B(FC)j,i = by-product emission of gas j from gas i usage, kg h = fraction of gas remaining in shipping container Bj,i = fraction of gas j created during gas i usage FCi = consumption of FC gas i, kg ai = fraction of gas i used in processes with abatement devices dj = fraction of gas j destroyed in abatement devices	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	**Tier 1 Inputs** Required non-default input values: (1) Manufacturing design capacity; (2) annual capacity utilization; (3) fraction of PV manufacture that use FCs (if estimating emissions from PV). Default values: IPCC Tier 1 default emission factors by gas type.		General QA/QC procedures outlined national inventory compiler	(1) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_6_Ch6_Electronics_Industry.pdf; (2) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	**Tier 2a Inputs** Required non-default input values: (1) Company gas consumption; (2) fraction of gas entering an abatement device. Default values: (1) Gas process utilization rate; (2) by-product formation rate; (3) Abatement DRE; (4) heel		General QA/QC procedures outlined national inventory compiler	(1) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_6_Ch6_Electronics_Industry.pdf; (2) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	PFCs (e.g., CF4, C2F6, CHF3, C3F8), NF3, and SF6 gases; heat transfer fluids (e.g., C6F14)	Industrial Process--Electronics Manufacturing	All (no deminimis)	Facility, company, or country level.		**Tier 2b: Process Type-Specific Parameters:** Company-specific data on gas consumption by process (i.e., chemical vapor deposition (CVD) chamber clean or etch) and emission control technology is combined with either default industry or company specific parameters on gas heel, gas utilization rates, by-product formation rates, and abatement Desctruction or Removal Efficiency (DRE) (see Equation below). 1) E(FC)i = (1 - h) x [FCi,etch x (1 - Ui,etch) x (1 - ai,etch x di,etch) + FCi,cvd x (1 - U,cvd) x (1 - ai,cvd x di,cvd)] where, the subcripts etch and cvd refer to parameters for etch or CVD chamber clean process types, respetively. Similarly Equation 2 from Tier 2a would be the following: 2) B(FC)i = (1-h) x [Bj,i,etch x FCi,etch x (1 - ai,etch x dj,cvd) = Bj.i,cvd x FCi,cvd x (1 - ai,cvd x dj,cvd)] where, For Equation 1-- E(FC)i = emissions of FC gas i, kg FCi,etch/cvd = consumption of FC gas i for etch/cvd processes, kg h = fraction of gas remaining in shipping container Ui,etch/cvd = process utilization rate for gas i in etch/cvd processes ai,etch/cvd = fraction of gas i used in etch/cvd processes with abatement devices di,etch/cvd = fraction of gas i destroyed in abatement devices connected to etch/cvd process tools For Equation 2-- B(FC)j,i = by-product emission of gas j from gas i usage, kg h = fraction of gas remaining in shipping container Bj,i,etch/cvd = fraction of gas j created during gas i usage in etch/cvd processes FCi,etch/cvd = consumption of FC gas i for etch/cvd processes, kg ai,etch/cvd = fraction of gas i used in etch/cvd processes with abatement devices dj,etch/cvd = fraction of gas j destroyed in abatement devices connected to etch/cvd process tools	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	**Tier 2b Inputs** Required non-default input values: (1) company gas consumption by process; (2) fraction of gas entering an abatement device Default values: (1) Gas process utilization rate (by process type); (2) by-product formation rate (by process type); (3) Abatement DRE; (4) heel		General QA/QC procedures outlined national inventory compiler	(1) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_6_Ch6_Electronics_Industry.pdf; (2) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	PFCs (e.g., CF4, C2F6, CHF3, C3F8), NF3, and SF6 gases; heat transfer fluids (e.g., C6F14)	Industrial Process--Electronics Manufacturing	All (no deminimis)	Facility, company, or country level.		**Tier 3: Process-Specific Methods:** Company-specific data is used for all parameters including data on gas consumption by process, emission control technology and Destruction or Removal Efficiency (DRE) of abatement systems, gas heel, gas utlization rates, and by-product formation rates (See Equation below). 1) E(FC)i = (1 - h) x [FCi,etch x (1 - Ui,etch) x (1 - ai,etch x di,etch) + FCi,cvd x (1 - U,cvd) x (1 - ai,cvd x di,cvd)] where, the subcripts etch and cvd refer to parameters for etch or chemical vapor deposition (CVD) chamber clean process types, respetively. Similarly Equation 2 from Tier 2a would be the following: 2) B(FC)i = (1-h) x [Bj,i,etch x FCi,etch x (1 - ai,etch x dj,cvd) = Bj.i,cvd x FCi,cvd x (1 - ai,cvd x dj,cvd)] where, For Equation 1-- E(FC)i = emissions of FC gas i, kg FCi,etch/cvd = consumption of FC gas i for etch/cvd processes, kg h = fraction of gas remaining in shipping container Ui,etch/cvd = process utilization rate for gas i in etch/cvd processes ai,etch/cvd = fraction of gas i used in etch/cvd processes with abatement devices di,etch/cvd = fraction of gas i destroyed in abatement devices connected to etch/cvd process tools For Equation 2-- B(FC)j,i = by-product emission of gas j from gas i usage, kg h = fraction of gas remaining in shipping container Bj,i,etch/cvd = fraction of gas j created during gas i usage in etch/cvd processes FCi,etch/cvd = consumption of FC gas i for etch/cvd processes, kg ai,etch/cvd = fraction of gas i used in etch/cvd processes with abatement devices dj,etch/cvd = fraction of gas j destroyed in abatement devices connected to etch/cvd process tools	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	**Tier 3 Inputs** Required non-default values: (1) company gas consumption by process; (2) fraction of gas entering an abatement device; (3) gas process utilization rate (by process type); (4) by-product formation rate (by process type); (5) Abatement DRE; (6) heel		General QA/QC procedures outlined national inventory compiler	(1) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_6_Ch6_Electronics_Industry.pdf; (2) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	PFCs (e.g., CF4, C2F6, CHF3, C3F8), NF3, and SF6 gases; heat transfer fluids (e.g., C6F14)	Industrial Process--Electronics Manufacturing	All (no deminimis)	Facility, company, or country level.		**Heat Transfer Fluid Emissions During Semiconductor Manufacturing:** **2006 IPCC Tier 1: Product of Emission Factor and Area of Substrate Processed:** A default emission factor is used to estimate heat transfer fluid emissions from semiconductor manufacturing (note--no HTF emissions from PV-Cell or TFT-FPD manufacture). E(FC) = EF x Cu x Cd where, E(FC) = Total liquid FC emissions as expressed in terms of C6F14 [Mt C6F14] EF = Liquid FC emission factor expressed in terms of C6F14 [Mt C6F14/Gm2] Cu = annual production capacity utilizataion fraction Cd = annual production capacity **2006 IPCC Tier 2a:** Process Gas-Specific Parameters, Tier 2b: Process Type-Specific Parameters, and Tier 3: Process-Specific Methods. A mass balance approach is used to estimate heat transfer fluid emissions from semiconductor manufacturing (note--no HTF emissions from PV-Cell or TFT-FPD manufacture). E(FCi) = density x [Ii,o + Pi,t - Ni,t + Ri,t - Ii,t - Di,t] where, E(FCi) = Emissions of liquid FCi [kg] density = density of liquid FCi [kg/liter] Ii,o = Inventory of liquid FCi at the end of previuos period [liters] Pi,t = Net purchases of liquid FCi during the current period [liters] Ni,t = Total nameplate capacity [charge] of installed liquid FCi equipment [liters] Ri,t = Total nameplate capacity [charge] on retired liquid FCi equipment [liters] Ii,t = Inventory of liquid FCi at the end of current period [liters] Di,t = Amount of liquid FCi recovered and sent offsite during current period [liters]	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.
U.S. National Inventory	Semiconductor Manufacturing	PFCs, NF3, and SF6 gases	Industrial Process--Semiconductor Manufacturing	All (no deminimis)	Country level.		U.S. semiconductor emissions estimates follow two methodologies: one for Partners of the PFC Reduction/Climate Partnership for Semiconductors and another for non-Partners. Partners emissions are estimated using a methodology at least as accurate as Tier 2a (see 2006 IPCC guidelines). Non-Partners emissions are estimated using an emission factor developed based on Partner reported data on emissions from the 1996 to 1999 reporting period.	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.
WRI	Semiconductor Manufacturing	PFCs, NF3, and SF6 gases	Industrial Process--Semiconductor Manufacturing	All (no deminimis)	Facility or company level.		Semiconductor emissions are estimated using a methodology equivalent to the Tier 2c guidelines in the IPCC Good Practice Guidance in Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2001). WRI default parameters have not been updated to the 2006 IPCC numbers, but remain as 2000 IPCC values (from Good Practice Guidance).	Voluntary

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Semiconductor, Photovoltaics (PV), and Thin Film Transistor-Flat Panel Display (TFT-FPD) Manufacturing	**Heat Transfer Fluid Emissions Inputs for Semiconductors:** Tier 1-- (1) Manufacturing design capacity; (2) annual capacity utilization; (3) emission factors (default IPCC Tier 1); Tier 2a,2b, and 3: (1) Inventory at end of previous year; (2) Inventory at end of current year; (3) net purchases; (4) total nameplate capacity of new equipment; (5) total nameplate capacity of sold or retired equipment; (6) amount recovered from retiring equipment and set offsite.		General QA/QC procedures outlined national inventory compiler	(1) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_6_Ch6_Electronics_Industry.pdf; (2) http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/1_Volume1/V1_6_Ch6_QA_QC.pdf
U.S. National Inventory	Semiconductor Manufacturing	**For non-Partners:** (1) Manufacturing design capacity; (2) wafer size produced; (3) geometry (i.e., linewidth) of wafers. These three inputs are used to estimate the total manufactured layer area of each semiconductor, which is the unit of activity used to estimate non-Partner emissions. **For Partners:** Partners use method at least as accurate as the 2006 IPCC Tier 2a guidelines, and therefore, should have at least the following inputs-- Required non-default input values: (1) Company gas consumption; (2) fraction of gas entering an abatement device. Default values: (1) Gas process utilization rate; (2) by-product formation rate; (3) Abatement DRE; (4) heel	National emissions inventory for all GHGs reported to the UNFCCC.	General QA/QC procedures outlined national inventory compiler	http://www.epa.gov/semiconductor-pfc/
WRI	Semiconductor Manufacturing	(1) Gas consumption; (2) Fraction of gas that goes to abatement (monitoring process tools); (3) Number and diameter of wafers produced.	None	Not specified	http://www.ghgprotocol.org/calculation-tools/semiconductors

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
PFC Reduction/Climate Change Partnership for Semiconductors	Semiconductor Manufacturing	PFCs, NF3, and SF6 gases	Industrial Process--Semiconductor Manufacturing	All (no deminimis)	Company level		Companies use a method at least as accurate as the IPCC 2006 Tier 2a guidelines; however, some companies use methods of greater accuracy (i.e., equivalent to Tier 2b and 3). Default factors from the IPCC 2000 guidelines (e.g., Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories) are used instead of the more recent IPCC 2006 default factors.	Voluntary
The Climate Registry	Semiconductor Manufacturing	PFCs, NF3, and SF6 gases	Industrial Process--Semiconductor Manufacturing	3% of total emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries. For example semiconductor manufacturing emissions would include not only process emissions, but other direct emissions (including transportation, on-site energy, etc).	Company level		Suggests consulting the 2006 IPCC Tier 2b and Tier 3 approaches. **"A" Rating** = When company-specific factors developed for each individual process in the 2006 IPCC Tier 3 Equation (e.g., plasma enhanced chemical vapor deposition (PECVD) tool chamber cleaning or silicon nitride etching). **"B" Rating** = When company-specific parameters are used for each process type in the 2006 IPCC Tier 3 Equation (e.g., etching or CVD chamber cleaning) **"C" Rating =** When some or all of IPCC 2006 default parameters are used in 2006 IPCC Tier 2b Equation.	Voluntary

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
PFC Reduction/Climate Change Partnership for Semiconductors	Semiconductor Manufacturing	For Partners: Partners use method at least as accurate as the 2006 IPCC Tier 2a guidelines, and therefore, should have at least the following inputs-- Required non-default input values: (1) Company gas consumption; (2) fraction of gas entering an abatement device. Default values: (1) Gas process utilization rate; (2) by-product formation rate; (3) Abatement DRE; (4) heel	Reports are submitted to Latham and Watkins (third party) and are made available to the EPS upon request. No standard reporting format is required, although, reporting guidelines are suggested and include--showing example calculations, citing the methodology used (e.g., IPCC 2000 Tier 2a), stating all assumptions, and citing all sources.	Not specified	http://www.epa.gov/semiconductor-pfc/
The Climate Registry	Semiconductor Manufacturing	Required non-default values for each individual process: (1) gas consumption by specific process (e.g., silicon nitride etching or plasma enhanced chemical vapor deposition (PECVD) tool chamber cleaning); (2) fraction of gas entering an abatement device for each specific process; (3) gas process utilization rate (for each specific process); (4) by-product formation rate (for each specific process); (5) Abatement DRE; (6) heel Required company-specific non-default values: (1) company gas consumption by process; (2) fraction of gas entering an abatement device; (3) gas process utilization rate (by process type); (4) by-product formation rate (by process type); (5) Abatement DRE; (6) heel Required non-default input values: (1) company gas consumption by process; (2) fraction of gas entering an abatement device Default values: (1) Gas process utilization rate (by process type); (2) by-product formation rate (by process type); (3) Abatement DRE; (4) heel	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approaches) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
DOE 1605b	Semiconductor Manufacturing	PFCs, NF3, and SF6 gases	Industrial Process--Semiconductor Manufacturing	All (no deminimis)	Facility or company level. (Reporters must set reporting boundaries consistently across all reporting years.)		Suggests consulting the 2000 IPCC Tier 2a (equivalent to Tier 3 in IPCC 2006), 2b (equivalent to IPCC 2006 tier 2b), and 2c (equivalent to IPCC 2006 tier 2a) approaches. **"A" Rating** = 2000 IPCC Tier 2a	Voluntary
							"B" Rating = 2000 IPCC Tier 2b OR WRI spreadsheet when plant-specific factors are used	
							"C" Rating = 2000 IPCC Tier 2c (equivalent to IPCC 2006 tier 2a) OR WRI spreadsheet with default factors are used	

Review of Existing Programs Relevant to Source - Semiconductors, Electronics, Photovoltaic Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
DOE 1605b	Semiconductor Manufacturing	Required non-default values: (1) company gas consumption by process; (2) fraction of gas entering an abatement device; (3) gas process utilization rate (by process type); (4) by-product formation rate (by process type); (5) Abatement DRE; (6) heel Required non-default input values: (1) company gas consumption by process; (2) fraction of gas entering an abatement device Default values: (1) Gas process utilization rate (by process type); (2) by-product formation rate (by process type); (3) Abatement DRE; (4) heel Required non-default input values: (1) Company gas consumption; (2) fraction of gas entering an abatement device. Default values: (1) Gas process utilization rate; (2) by-product formation rate; (3) Abatement DRE; (4) heel	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf

Summary of GHG Reporting Programs and Protocols for Ferroalloy Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Ferroalloy production		No protocol given for ferroalloy production				
Canada Mandatory GHG Reporting	Ferroalloy production	CO2, CH4	Phase 1: Consistent with IPCC.	100,000 metric tons CO2e	Facility	NA (activity data records)	Phase 1: No prescribed estimation methods, but should be consistent with IPCC (prioritize by Tier-method based on emissions levels).
Australia National Mandatory GHG Reporting Program	Ferroalloy production	CO2	Process emissions from production of ferroalloys	Registration and reporting required for corporations if: they control facilities that emit at least 25,000 metric tons of CO2e, or produce or consume at least 100 terajoules of energy; or their corporate group emits at least 125,000 metric tons CO2e, or it produces or consumes at least 500 terajoules of energy.	Facility	NA (activity data records)	NGA default method: Based on carbon reductant usage (A), energy content of reductant (EC), and emission factor (EF) for reductant. E = ∑A * EC * EF / 1000 (See attached sheet for EC and EF default values.) Higher-order method: Facility-specific emission factors.

Summary of GHG Reporting Programs and Protocols for Ferroalloy Production

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Ferroalloy production				[a] Industry trade groups include: International Lead and Zinc Study Group, International Zinc Association, American Foundry Society, Natural Resources Canada - Minerals and Metals, Non-Ferrous Founders' Society (NFFS), and Centre for Sustainable Resource Processing
Canada Mandatory GHG Reporting	Ferroalloy production	Mandatory	Annual emissions data (in CO2e).	Phase 1: Information should be verifiable. No third party verification required.	C:\GHG Reporting Rule\Review of Existing Rules\Canada\page2.mht
Australia National Mandatory GHG Reporting Program	Ferroalloy production	Mandatory	NGA default method: Annual production and amount of carbon reductant consumed. Higher-order method: Annual production, amount of carbon reductant consumed, facility-specific emission factors, and emissions.	QA/QC procedures developed by inventory compiler. Rating system for emission estimation methods and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf

Summary of GHG Reporting Programs and Protocols for Ferroalloy Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
IPCC	Ferroalloy production	CO2	Process emissions from production of ferrosilicon (45, 65, 75, 90% Si), ferromanganese (7,1 % C), silicomanganese, silicon metal, and ferrochromium	NA	Tier 1: Source category Tier 2: Source category or facility Tier 3: Facility	NA (activity data records)	Tier 1: Based on production-based emission factors. Tier 2: Based on reducing agent usage. Tier 3: Based on carbon content in reducing agents, electrode paste, ores, slag forming materials, and products. (See attached sheet for factors and equations.)
IPCC	Ferroalloy production	CH4	Process emissions from production of ferrosilicon (65, 75, 90% Si), silicon metal	NA	Tier 1: Source category Tier 2: Source category or furnace type Tier 3: Facility	NA (activity data records)	Tier 1: Based on production-based emission factors. Tier 2: Based on operation-specific emission factors. (See attached sheet for factors and equations.) Tier 3: Based on direct measurements (method does not contain any details on point and method of monitoring).
US Inventory	Ferroalloy production	CO2, CH4	Process emissions from production of ferrosilicon (25-55% silicon), ferrosilicon (56-95% silicon) silicon metal, and miscellaneous alloys	NA	Source category	NA (activity data records)	IPCC emission factors (see attached sheet for factors and equations)

Summary of GHG Reporting Programs and Protocols for Ferroalloy Production

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
IPCC	Ferroalloy production		NA, not an industry-reporting program	National inventory compiler reponsible for QA/QC (Guidance on QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
IPCC	Ferroalloy production		NA, not an industry-reporting program	National inventory compiler reponsible for QA/QC (Guidance on QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
US Inventory	Ferroalloy production	National Inventories	NA, not an industry-reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf

Summary of GHG Reporting Programs and Protocols for Ferroalloy Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
NESHAP	Ferroalloy production	HAP	Ferromanganese and silicomanganese production process emissions from submerged arc furnaces, metal oxygen refining process, crushing and screening operatons, fugitive dust sources.	Major sources (>25 tons total HAP/yr or >10 tons of single HAP/yr)	Facility (furnace, process, or equipment)	Air pollution control devices or vent stacks	The rule contains PM emission limits (as a surrogate for metal HAP). It requries annual PM emission tests and monitoring of control device (e.g., baghouse) operating parameters, but these are not useful for calculating GHG emissions.
NSPS	Ferroalloy production	PM, CO	Process emissions from elecric submerged arc furnaces producing listed ferroallow products, dust-handling equipment		Facility	Furnace, pollution control devices	The rule contains PM and CO emission limits. It requires emission testing, continuous opacity monitoring,continuous monitoring of furnace power input, and monitoring of emissions capture and control system operating parameters.

Summary of GHG Reporting Programs and Protocols for Ferroalloy Production

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
NESHAP	Ferroalloy production	Mandatory compliance	NA. Required reports are not useful for GHG calculation		40 CFR Part 63 Subpart XXX
NSPS	Ferroalloy production	Mandatory compliance	NA, monitoring and recordkeeping requirements only (except for report of initial emissions test).		40 CFR Part 60 Subpart Z

IPCC Emission Factors and Calculation Methods for Ferroalloys

Tier 1. Generic CO2 Emission Factors Based on Production

Type of Ferroalloy	CO2 Emission Factor (ton/ton product)
Ferrosilicon 45% Si	2.5
Ferrosilicon 65% Si	3.6
Ferrosilicon 75% Si	4.0
Ferrosilicon 90% Si	4.8
Ferromanganese 7% C	1.3
Ferromanganese 1% C	1.5
Silicomanganese	1.4
Silicon metal	5.0
Ferrochromium	1.3 (1.6 w/sinter plant)

Tier 2. CO2 Emission Factors based on Reducing Agents

Reducing Agent (usage)	CO2 Emission Factor (ton/ton reducing agent)
Coal (for FeSi and Si-metal)	3.1
Coal (for other ferroalloys)	*
Coke (for FeMn and SiMn)	3.2-3.3
Coke (for Si and FeSi)	3.3-3.4
Coke (for other ferroalloys)	*
Prebaked electrodes	3.54
Electrode paste	3.4
Petroleum coke	3.5

Tier 3. CO2 Emission Estimation Method

$$E_{CO2} = \sum (M_{reducing\ agent,i} * EF_{reducing\ agent,i}) + \sum(M_{ore,h} * Ccontent_{ore,h}) * 44/12$$
$$+ \sum (M_{slag\ forming\ material,j} * Ccontent_{slag\ forming\ material,j}) * 44/12$$
$$- \sum (M_{product,k} * Ccontent_{product,k}) * 44/12$$
$$- \sum (M_{non\text{-}product\ outgoing\ stream,l} * Ccontent_{non\text{-}product\ outgoing\ stream,l}) * 44/12$$

Tier 1. Generic CH4 Emission Factors Based on Production

Alloy	CH4 Emission Factor (kg/metric ton product)
Si-metal	1.2
FeSi 90	1.1
FeSi 75	1.0
FeSi 65	1.0

Tier 2. Operation-specific CH4 Emission Factors

Alloy	CH4 Emission Factor (kg/metric ton product)		
	Operation of Furnace		
	Batch-charging	Sprinkle-charging	Sprinkle-charging and >750^{oC}
Si-metal	1.5	1.2	0.7
FeSi 90	1.4	1.1	0.6
FeSi 75	1.3	1.0	0.5
FeSi 65	1.3	1.0	0.5

Summary of GHG Reporting Programs and Protocols for Glass Production and Other Uses of Carbonates

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
2006 IPCC Guidelines	Limestone and Dolomite Use	CO2	Glass Production	NA	Tier 1: Source category Tier 2: Source category Tier 3: Facility	NA (activity data records)	Tier 1: Based on production-based emission factors and cullet (recycled scrap glass) ratios. (See attached glass methods sheet for factors, cullet ratios, and equations.) Tier 2: Based on production-based emission factors and cullet ratios. (See attached glass methods sheet for factors, cullet ratios, and equations.) Tier 3: Based on input based emission factors. (See attached glass methods sheet for factors.)
2006 IPCC Guidelines	Limestone and Dolomite Use	CO2	Other Process Uses (including fluxes and slagging agents in metallurgy, flue gas desulfurization, etc.)	NA	Tier 1: Source category Tier 2: Source category Tier 3: Facility	NA (activity data records)	Tier 1: Based on consumption-based emission factors. (See attached "other process use" sheet for factors.) Tier 2: Based on consumption-based emission factors. (See attached "other process use" sheet for factors.) Tier 3: Based on consumption-based emission factors. (See attached "other process use" sheet for factors.)
US Inventory	Limestone and Dolomite Use	CO2	Flux stone, flue gas desulfurization, and other (chemical stone, mine dusting or acid water treatment, acid neutralization, and sugar refining).	NA	Source category	NA (activity data records)	IPCC emission factors (see attached "other process use" sheet for factors and equations)
EU Emissions Trading Scheme - 1st/2nd Period Monitoring Guidelines	Limestone and Dolomite Use	CO2	Glass Manufacture	NA	Facility	NA (activity data records)	Calculation method A: Based on consumption-based emission factors. (See attached glass methods sheet for factors.) Calculation method B: Based on output-based emissions factors. (See attached glass methods sheet for factors.)
DOE 1605(b) Voluntary Reporting Program	Limestone and Dolomite Use	CO2	Other Industries	NA	Facility	NA (activity data records)	Based on consumption-based emission factors. (See attached "other process use" sheet for factors.)
Australian National Mandatory GHG Reporting Program	Limestone and Dolomite Use	CO2	Other Industries (metallurgy, glass manufacture, magnesia production, agriculture, construction, environmental pollution control)	Emit >25,000 metric tons CO2e or use >100 terajoules of energy; or their corporate group emits at least 125,000 metric tons eCO2, or it produces or consumes at least 500 terajoules of energy.	Facility	NA (activity data records)	Default method: Based on consumption (carbonate materials). (See attached "other process use" sheet for factors.) Higher order method: Based on consumption (pure carbonates). (See attached "other process use" sheet for factors.)

Summary of GHG Reporting Programs and Protocols for Glass Production and Other Uses of Carbonates

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Limestone and Dolomite Use	National Inventories	Tier 1: Production data and cullet ratios. Tier 2: Production data and cullet ratios. Tier 3: Input data.	NA, not an industry reporting program	National inventory compiler responsible for QA/QC (guidance for QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (Section 2.4)
2006 IPCC Guidelines	Limestone and Dolomite Use	National Inventories	Tier 1: Consumption data. Tier 2: Consumption data. Tier 3: Consumption data.	NA, not an industry reporting program	National inventory compiler responsible for QA/QC (guidance for QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf (Section 2.5)
US Inventory	Limestone and Dolomite Use	National Inventories	National production data. Source: USGS Minerals Yearbook	NA, not an industry-reporting program	Emission inventories are subject to EPA QAP	http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf (Section 4.5)
EU Emissions Trading Scheme - 1st/2nd Period Monitoring Guidelines	Limestone and Dolomite Use	Mandatory	Calculation method A: Carbonate consumption. Calculation method B: Alkali earth/oxide conversion quantity.	Report to Member States the type of material, activity data, emission factor, conversion factor, and annual CO2 emission estimates.	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF (Annex IX)
DOE 1605(b) Voluntary Reporting Program	Limestone and Dolomite Use	Voluntary reportin	Consumption data	Annual	Not explicitly specified (QA/QC procedures are the responsibility of the inventory compiler or reporter)	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf (Section 1.E.4.1.8)
Australian National Mandatory GHG Reporting Program	Limestone and Dolomite Use	Mandatory	Consumption data	Annual reports using the Online System for Comprehensive Activity Reporting	QA/QC procedures developed by inventory re	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf (Section 5.2.3)

Summary of GHG Reporting Programs and Protocols for Glass Production and Other Uses of Carbonates

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Glass NESHAP	Glass Manufacturing	Arsenic	Glass Manufacture				Facilities are required to calculate theoretical arsenic production rates based on amount of arsenic-containing glass produced every 12-month period. This may not be useful for GHG purposes since they are not required to account for non-arsenic containing glass production. Therefore, a unit or facility total production rate may not be determined from the recordkeeping required by this regulation.
Glass NSPS	Glass Manufacturing	Particulate matter	Glass Manufacture				Facilties are required to meet PM limits based on g/kg glass produced basis. However, the rule does not specify that records must be kept of how much glass is produced, so the NSPS requirements may not be useful for GHG estimation purposes. Reports are required initially, and then if excess emissions are experienced at the facility
Glass Manufacturing Area Source NESHAP	Glass Manufacturing	Metal HAP	Glass Manufacture	Area source (<10 tpy single HAP or <25 tpy all HAP), operates continuous glass furnaces that use metal HAP as raw materials	Unit (glass furnace)	Feed rate (weight or weight percent) of each ingredient in the batch formulation (NOTE: The NESHAP requires other parameter monitoring devices to ensure PM control from the furnace, but these are not useful for GHG calculation.)	Specific monitoring method is not specified. However, throughput information records must be kept, these include throughput basis (feed to process or discharge from process unit) Production data must include amount (weight or weight percent) of each ingredient in the batch formulation.
European Bank for Reconstruction and Development	Limestone and Dolomite Use (including glass manufacturing)	CO2	Flue gas desulphurisation and glass manufacture		Facility	NA (activity data records)	CO2 (t) = Annual usage (t) * [(%CaCO3 * 12/100) + (%MgCO3 * 12/84)] *3.664
Canada, WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a,b]	Limestone and Dolomite Use	No protocol given					

[a] Industry trade groups for limestone and dolomite use include: Portland Cement Association, Iowa Limestone Producers Association, Illinois Association of Aggregate Producers, National Stone, Sand & Gravel Association, Kansas Ag
Minnesota, Aggregate Producers of Wisconsin, National Mining Association
[b] Industry trade groups for glass manufacturing include: National Glass association, Glass Association of North America, Institute of Materials, Minerals and Mining

Summary of GHG Reporting Programs and Protocols for Glass Production and Other Uses of Carbonates

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Glass NESHAP	Glass Manufacturing					40 CFR 61 Subpart N
Glass NSPS	Glass Manufacturing					40 CFR 60 Subpart CC
Glass Manufacturing Area Source NESHAP	Glass Manufacturing	Mandatory compliance	Consumption or production data	N/A, recordkeeping requirement only. Records must be kept for 5 years. Other than an initial notification, there are no reporting requirements.	Not specified.	40 CFR 63 Subpart SSSSSS
European Bank for Reconstruction and Development	Limestone and Dolomite Use (including glass manufacturing)	Mandated by this bank for proposed investment projects	Annual limestone usage, calcium carbonate content, magnesium carbonate content	CO2 estimates for lifetime of project, emission rate/hour, annual operating hours, input data for calculation	Verification of estimates by European Bank	http://www.ebrd.com/
Canada, WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a,b]	Limestone and Dolomite Use					

[a] Industry trade groups for limestone and dolomiggregate Producers Associatio
Minnesota, Aggregate Producers of Wisconsin,
[b]Industry trade groups for glass manufacturing ir

IPCC Emission Factors and Calculation Methods for Limestone/Dolomite Use - Glass Production

Tier 1. CO2 Emission Estimation Method - Glass Production

$$E_{CO2} = M_{glass} * EF * (1 - CR)$$

Tier 2. CO2 Emission Estimation Method - Glass Manufacturing Process

$$E_{CO2} = \sum (M_{glass\ type\ i} * EF_{glass\ type\ i} * [1 - CR_{glass\ type\ i}])$$

Glass types - flat, container, fiberglass, etc.

Tier 3. CO2 Emission Estimation Method - Carbonate Input

$$E_{CO2} = \sum (M_{carbonate\ type\ i} * EF_{carbonate\ type\ i} * \text{Calcination Fraction}_{carbonate\ type\ i})$$

Calcination fraction assumed to be 1.00 if not known.

Tier 1. CO2 Emission Factors - Glass Production

Glass Type	CO2 Emission Factor (ton/ton product)	Cullet Ratio
Generic	0.20	0.50

Tier 2. CO2 Emission Factors - Glass Manufacturing Process

Glass Type	CO2 Emission Factor (ton/ton product)	Cullet Ratio
Flat	0.21	0.10-0.25
Container - Flint	0.21	0.30-0.60
Container - Amber/Green	0.21	0.30-0.80
Fiberglass - E-glass	0.19	0.00-0.15
Fiberglass - Insulation	0.25	0.10-0.50
Specialty - TV Panel	0.18	0.20-0.75
Specialty - TV Funnel	0.13	0.20-0.70
Specialty - Tableware	0.10	0.20-0.60
Specialty - Lab/Pharma	0.03	0.30-0.75
Specialty - Lighting	0.20	0.40-0.70

Tier 3. CO2 Emission Factors - Carbonate Input

Mineral name - Carbonate	CO2 Emission Factor (ton/ton carbonate)
Calcite/aragonite (limestone) - CaCO3	0.43971
Magnesite - MgCO3	0.52197
Dolomite - CaMg(CO3)2	0.47732
Siderite - FeCO3	0.37987
Ankerite - Ca(Fe,Mg,Mn)(CO3)2	0.40822-0.47572
Rhodochrosite - MnCO3	0.38286
Sodium carbonate/soda ash - Na2CO3	0.41492

EU Emissions Trading Scheme Emission Factors and Calculation Methods for Limestone/Dolomite Use - Glass Production

Calculation method A. CO2 Emission Estimation Method - Carbonate Input

$$E_{CO2} = \sum (M_{carbonate\ type\ i} * EF_{carbonate\ type\ i})$$

Method also includes factor for carbon-containing additives (not shown above)

Calculation method B. CO2 Emission Estimation Method - Converted Alkali Earth/Oxides Quantities

$$E_{CO2} = \sum (M_{alkali\ earth/oxide\ type\ i\ (out)} - M_{alkali\ earth/oxide\ type\ I\ (in)}) * EFcarbonate\ type\ i$$

Method also includes factor for carbon-containing additives (not sh
Mass of alkali earth/oxides (CaO, MgO, Na2O, BaO, etc.) in produced glass minus mass of alkali earth/oxides entering as non-carbonates (i.e., recycled glass)
Glass types - flat, container, fiberglass, etc.

Calculation method A. CO2 Emission Factors - Carbonate Input

Carbonate Input	CO2 Emission Factor (ton/ton carbonate)
CaCO3	0.440
MgCO3	0.522
Na2CO3	0.415
BaCO3	0.223
Li2CO3	0.596
K2CO3	0.318
SrCO3	0.298
NaHCO3	0.524

Calculation method B. CO2 Emission Factors - Converted Alkali Earth/Oxides Quantities

Converted Alkali Earth/Oxide	CO2 Emission Factor (ton/ton earth/oxide)
CaO	0.785
MgO	1.092
Na2O	0.710
BaO	0.287

IPCC Emission Factors and Calculation Methods for Limestone/Dolomite Use - Other

Tier 1. CO2 Emission Estimation Method - Carbonate Consumption

$$E_{CO2} = M_{carbonate} * (0.85 * EF_{limestone} + 0.15 * EF_{dolomite})$$

$EF_{limestone}$ = 0.43971 ton CO2/ton carbonate; $EF_{dolomite}$ = 0.47732 ton CO2/ton carbonate
Carbonate quantities should be pure carbonates and not carbonate rock.
If only carbonate rock data are available, then a default purity of 95% can be assumed.
Assumes that limestone (85%) and dolomite (15%) are the only carbonates consumed.

Tier 2. CO2 Emission Estimation Method - Carbonate Consumption

$$E_{CO2} = (M_{limestone} * EF_{limestone}) + (M_{dolomite} * EF_{dolomite})$$

$EF_{limestone}$ = 0.43971 ton CO2/ton carbonate; $EF_{dolomite}$ = 0.47732 ton CO2/ton carbonate
Carbonate quantities should be pure carbonates and not carbonate rock.
If only carbonate rock data are available, then a default purity of 95% can be assumed.

Tier 3. CO2 Emission Estimation Method - Carbonate Input

$$E_{CO2} = \sum (M_{carbonate\ type\ i} * EF_{carbonate\ type\ i} * \text{Calcination Fraction}_{carbonate\ type\ i})$$

Calcination fraction assumed to be 1.00 if not known.

Tier 3. CO2 Emission Factors - Carbonate Input

Mineral name - Carbonate	CO2 Emission Factor (ton/ton carbonate)
Calcite/aragonite - CaCO3	0.43971
Magnesite - MgCO3	0.52197
Dolomite - CaMg(CO3)2	0.47732
Siderite - FeCO3	0.37987
Ankerite - Ca(Fe,Mg,Mn)(CO3)2	0.40822-0.47572
Rhodochrosite - MnCO3	0.38286
Sodium carbonate/soda ash - Na2CO3	0.41492

Australia Emission Factors and Calculation Methods for Limestone/Dolomite Use - Other (based on IPCC)

Default. CO2 Emission Estimation Method - Carbonate Consumption

$$E_{CO2} = (M_{carbonate} * EF_{carbonate})$$

Carbonate quantities are for carbonate material (not pure carbonate).

Higher Order. CO2 Emission Estimation Method - Carbonate Consumption

$$E_{CO2} = (M_{carbonate} * EF_{carbonate})$$

Carbonate quantities are for pure carbonate (not carbonate material).

Default. CO2 Emission Factors - Carbonate Material Input

Mineral name - Carbonate	CO2 Emission Factor (ton/ton carbonate)
Calcite/aragonite (limestone) - CaCO3	0.396
Magnesite (magnesium carbonate) - MgC(	0.522
Dolomite - CaMg(CO3)2	0.453

Default emission factors assume the following fractional purities: 0.90 for limestone; 0.95 for dolomite; and 1.00 for magnesium carbonate

Higher Order. CO2 Emission Factors - Pure Carbonate Input

Mineral name - Carbonate	CO2 Emission Factor (ton/ton carbonate)
Calcite/aragonite (limestone) - CaCO3	0.440
Magnesite (magnesium carbonate) - MgC(	0.522
Dolomite - CaMg(CO3)2	0.477

DOE 1605(b) Voluntary Reporting Program Emission Factors and Calculation Methods for Limestone/Dolomite Use - Other (based on

CO2 Emission Estimation Method

$$E_{CO2} = (M_{limestone} * FP_{limestone} * EF_{limestone}) + (M_{dolomite} * FP_{dolomite} * EF_{dolomite})$$

$EF_{limestone}$ = 0.440 ton CO2/ton carbonate; $EF_{dolomite}$ = 0.477 ton CO2/ton carbonate
If fractional purity (FP) of raw materials is not available, then a default FP of 100% can be assumed.

Review of Existing Programs Relevant to Source - HCFC-22 Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	HCFC-22 Production	HFC-23	industrial process - HCFC-22 production	Not specified	plant level (can be aggregate to national level)	gas stream and vent streams at the plant (the latter to measure HFC-23 captured for destruction and deduct accordingly)	**Tier 1: EHFC−23 = EFdefault • PHCFC−22** Where: E_{HFC-23} = by-product HFC-23 emissions from HCFC-22 production, kg $E_{Fdefault}$ = HFC-23 default emission factor, kg HFC-23/kg HCFC-22 $P_{HCFC-22}$ = total HCFC-22 production, kg Note: Suitable where plant-specific measurements are not available, default is all the estimated HFC-23 production is released into the atmosphere. **Tier 2: $E_{HFC-23} = EF_{calculated} \bullet P_{HCFC-22} \bullet F_{released}$** Where: E_{HFC-23} = by-product HFC-23 emissions from HCFC-22 production, kg $EF_{default}$ = HFC-23 calculated emission factor, kg HFC-23/kg HCFC-22 $P_{HCFC-22}$ = total HCFC-22 production, kg $F_{released}$ = Fraction of the year that this stream was released to atmosphere untreated, fraction **Tier 3A HFC-23 Emissions from Individual Process Streams (Direct Method):** $E_{HFC-23} = S_i, S_j \int_t C_{i\,j} \bullet f_{ij}$ Where: the sum over all i plants, over all j streams in each plant of the emitted mass flows f and concentrations C is integrated over time t. (See Notes for calculation of 'instantaneous' HFC-23 emissions in an individual process stream.) **Tier 3B Calculation of HFC-23 Emissions from Individual Process Streams (Proxy Method):** $E_{HFC-23} = S_i S_j \int t\, E_{i\,j}$ Where: Ei,j are the emissions from each plant and stream determined by the proxy methods. (See Notes for calculation of HFC-23 emissions in an individual process stream.) **Tier 3C Calculation of HFC-23 Emissions from Individual Process Streams (by monitoring reactor product)** $E_{HFC-23} = S_i \int t\, C_i \bullet P_i$ Where: Pi is the mass flow of HCFC-22 product from the plant reactor at the plant i, and Ci is the concentration of HFC-23 relative to the HCFC-22 product at the plant i. (See notes for calculation of HFC-23 emissions at an individual facility by in-process measurement.)	Meet the reporting requirements for Parties to the UNFCCC
Inventory of US Greenhouse Gas Emissions and Sinks	HCFC-22 Production	HFC-23	industrial process - HCFC-22 production	All US facilities	facility-level aggregated to national level	HFC-23 concentrations determined at the point the gas leaves the chemical reactor, for facilities that abate, monitor performance of oxidizers to verify destruction	Based on Tier 3, gas chromotography, measurements taken periodically	Meet the reporting requirements for Parties to the UNFCCC

Review of Existing Programs Relevant to Source - HCFC-22 Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	HCFC-22 Production	**Tier 1** - HFC-23 default EF factor; total HCFC-22 production. **Emission Factors:** Old plants: 0.04 kg HFC-23/kg HCFC-22 produced New Plants: 0.03 kg HFC-23/kg HCFC-22 produced Global average emissions (1978-1995): 0.02 kg HFC-23/kg HCFC-22 produced **Tier 2** - HFC-23 calculated EF Factor (based on average of carbon and fluorine efficiencies)--features of a well-managed HCFC-22 plant normally obtainable through accounting records; fraction of yr. stream was released untreated to atmosphere **Tier 3A**: concentration of HFC-23 in gas stream vented from process stream; mass flow of gas stream from process stream; length of time paramaters measured **Tier 3B:** standard mass emission of HFC-23 in vent stream per unit of proxy qty (e.g., process operating rate); dimenssionless factor; current process operating rate for vent stream; actual total duration of venting; qty of HFC-23 recovered; **Tier 3C:** concentration of HFC-23 in reactor product at facility; mass of HCFC-22 produced; fractional duration of HFC-23 venting; qty of HFC-23 recovered	US National GHG Inventory reports include: HFC emissions in TGCO2eq and Gg, HCFC-22 production (Gg)	In addition to other IPCC recommended QC checks: comparison of emission estimates using different approaches; direct emission measurement check	2006 IPCC Guidelines for National Greenhouse Gas Inventories Volume 3 Industrial Processes and Product Use http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
Inventory of US Greenhouse Gas Emissions and Sinks	HCFC-22 Production	information on quantities of critical feed components (e.g., HFC) and or products (HCFC-22) to feed into a material balance equation	US National GHG Inventory reports include: HFC emissions in TGCO2eq and Gg, HCFC-22 production (Gg)	Follows US QA/QC Plan	Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005

Review of Existing Programs Relevant to Source - HCFC-22 Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
World Resources Institute/World Business Council on Sustainable Development	HCFC-22 Production	HFC-23	industrial process - HCFC-22 production	Not specified	plant level (can aggreagate to corporate level)	gas stream and vent streams at the plant (98 to 99% of HFC-23 is discharged via the condenser vent)	**Approach 1: Continous emissions monitoring (CEMS)** practices (e.g., mass flow meters and totalizers), recommended approach. **Approach 2: Approach 2: HFC-23 Emissions = Σi(Flow Rate$_i$ x Concentration$_i$ x Flow Time$_i$) x (1 – Abatement Factor x Utilization Factor) x Conversion Factor** Where: i – a vapor stream in the facility Flow Rate – the flow of HFC-23 in the vapor stream (cubic meters/minute) Concentration – the concentration of HFC-23 in the vapor stream (grams/cubic meter) Flow Time – the amount of time that the HFC-23 flowed through the vapor stream (minutes) Fraction Abated (%) – percent of emissions abated by reduction technologies and practices (if applicable) Utilization Factor (%) – percent of time the abatement technology was in use (if applicable) Conversion Factor – the conversion factor from grams to metric tonnes (1 metric tonne/10^6 grams)	Voluntary

Review of Existing Programs Relevant to Source - HCFC-22 Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
World Resources Institute/World Business Council on Sustainable Development	HCFC-22 Production	**Approach 1** - most accurate, relies on CEM practices (e.g., mass flow meters, totalizers) **Approach 2:** equation based on integrating over time plant-specific mearusements of flow and concentration of HFC-23 in exhaust stream. Sampling & analysis needed.	N/A	1. Emission comparisons between data obtained and emissions data calculated in previous years in relation to changes in activity levels and technologies adopted. 2. Order of magnitude checks - when using approaches 1 and 2, approach 3 can be used to check if results are in the correct range.	Guidance and worksheet available for this sector at: http://www.ghgprotocol.org/calculation-tools/all-tools

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
World Resources Institute/World Business Council on Sustainable Development	HCFC-22 Production	HFC-23	industrial process - HCFC-22 production	Not specified	plant level (can aggreagate to corporate level)		**Approach 3: EHFC-23 = QHCFC-22 x EFapproach 3 x T x 11700** Where: EHFC-23 = Emissions of HFC-23 (metric tons) QHCFC-22 = Amount of HCFC-22 produced by plant (metric tons) EFapproach 3 = Emission factor for HFC-23 production (see below) T = Amount of time that the HFC-23 exhaust stream is released to the atmosphere, untreated 11700 = The Global Warming Value (GWP) of HFC-23. This value is a measure of the global warming potential of HFC-23 relative to CO2 over a 100 year timespan. Emission Factor calculation: [((100 – (CB/(100)) x Eloss x CC) + ((100 – (FB/100)) x Eloss x FC)] / 2 Where: CB = The carbon balance efficiency of the production process (Default value = 90%) CC = The carbon content factor (fraction) (Default value = 0.81) FB = The fluorine balance efficiency of the production process (Default value = 90%) FC = The fluorine content factor (fraction) (Default value = 0.54) Eloss = The loss in production efficiency of HCFC-22 that is attributable to the co-production of HFC-23 (fraction) (Default value = 1.0) **Approach 4: HFC-23 Emissions = (HCFC-22 Production x EF) x T x 11700** Where: HCFC-22 Production =Total amount of HCFC-22 produced by the facility in metric tons EF = HFC-23 Emission factor (metric tons of HFC-23/metric ton of HCFC-22 produced) (default is 0.04 kg HFC-23/kg HCFC-22 produced) T = The fraction of time in which the HFC-23 exhaust stream is vented to the atmosphere untreated. 11700 = The GWP for HFC-23 over a 100 year time horizon	
DOE 1605(b) Voluntary Reporting Program	HCFC-22 Production	HFC-23	industrial process - HCFC-22 production	Not specified	plant level	plants exhaust streams	Reporters can estimate HFC-23 emissions through either direct measurement or inference. CEMs practices (of all of a plant's exhaust streams usually the condenser vent). If CEMS not available, estimates based off periodic measurments of exhaust streams next best method. If direct measurements not available, production-based, emissions factor approach.	Voluntary
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	HCFC-22 Production	HFC-23	Industrial Process - HCFC-22 production	All (no deminimis) 3% of total emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries. For example semiconductor manufacturing emissions would include not only process emissions, but other direct emissions (including transportation, on-site energy, etc).	facility-level	Not specified	**Tier A** uses direct measurement, either continuous emissions monitoring or periodic direct measurements. **Tier B** is based on IPCC 2006, Tier 2 method (see equations above); a mass balance approach based on process efficiencies and plant-specific factors.	Voluntary

Review of Existing Programs Relevant to Source - HCFC-22 Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2004 HFC Guidelines World Resources Institute/World Business Council on Sustainable Development	HCFC-22 Production	**Approach 3:** equation based on flourine & carbon balance efficiencies, EF of HFC-23 produced (derived), duration of release. **Approach 4:** simplest, least accurate - input data includes HCFC-22 production data and duration of time HFC-23 exhaust stream vented untreated.	N/A	1. Emission comparisons between data obtained and emissions data calculated in previous years in relation to changes in activity levels and technologies adopted. 2. Order of magnitude checks - when using approaches 1 and 2, approach 3 can be used to check if results are in the correct range.	Guidance and worksheets available for this sector at http://www.ghgprotocol.org/calculation-tools/all-tools
DOE 1605(b) Voluntary Reporting Program	HCFC-22 Production	Non-direct measurement approach equation:HFC-23 emissions (metric tons) = 0.04 kg HFC-23/kg HCFC-22 produced * HCFC-22 produced (tons) * (1 – abatement factor (percent))	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	direct measurement should include quality control over monitoring operation	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf (page 139 of 318)
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	HCFC-22 Production	**Tier A** inputs regarding direct measurement (e.g., CEMs or periodic direct measurements) not further specified **Tier B** uses total HCFC-22 production and fraction of year the stream was released to the atmosphere untreated.	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	Page 39 (Reporting Requirements), Pages 110-111 (PFC Emissions from Aluminum Production) http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
							Tier C is based on calculation from *WRI/WBCSD, Calculating HFC-23 Emissions from the Production of HCFC-22, 2001* , using default emission factors for old and new plants as specified by IPCC 2006. Calculation is as follows: HFC-23 Emissions = (HCFC-22 Production x HFC-23 Emission Factor) x (1 -Fraction Abated x Utilization Factor) Where: HCFC-22 Production - total amount of HCFC-22 produced by the facility in metric tons HFC-23 Emission Factor – EF from HCFC-22 production (Mt of HFC-23/Mt of HCFC-22 produced) Fraction Abated (%) – percent of emissions abated by reduction technologies and practices (if applicable) Utilization Factor (%) – percent of time the abatement technology was in use (if applicable)	
HFC-23 Emission Reduction Partnership Program (per 1997 procedures)	HCFC-22 Production	HFC-23	US HCFC-22 manufacturers, 100% participation	**For companies using a material balance approach:** objective is an annual estimate of HFC-23 emissions that is within 1% of the true value with 95% confidence. **For companies using thermal oxidation to destroy HFC-23:** A destruction efficiency of 99 percent is recommended as a general performance standard. Any emissions of HFC-23 that is not captured and destroyed must be reported.	facility	**For companies using a material balance approach:** Sampling point is downstream of the reactor **For companies using thermal oxidation to destroy HFC-23:** monitoring should occur at thermal oxidizer, process vents, fugitive leak sources	EPA proposed approach permits each HCFC-22 production company to use existing methods to determine HFC-23 emissions so long as these methods meet certain performance standards. See notes tab. 3 of the 4 producers in 1997 determined emissions from a material balance approach - components include sampling frequency and determination of concentration of HFC-23 4th producer destroys HFC-23 - emissions approach based on performance standards already developed by EPA for thermal oxidizers (40 CFR Part 60 for control of VOC and 40 Part 63 for hazardous organic compounds) An initial performance test recommended along with continuous parametric monitoring to ensure the oxidizer operates properly (see notes tab)	Voluntary
HFC-23 Emission Reduction Partnership Program (per 2006 verification and procedures)	HCFC-22 Production	HFC-23	US HCFC-22 manufacturers, 100% participation	All (i.e. no deminimis)	facility-level per annum	Depends on facility (see notes tab for details) Includes HCFC-22 production, HFC-23 flow stream, Chloroform/HF utilization, HCFC-22 stocks	Depends on facility (see notes tab for details) Includes monitoring devices and estimation equations	voluntary (estimates used to report on this sector for the Inventory of US Greenhouse Gases and Sinks)

Review of Existing Programs Relevant to Source - HCFC-22 Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
		Tier C inputs includeHCFC-22 production, information on input data to determine fraction abated and utilization factor not further specified.			
HFC-23 Emission Reduction Partnership Program (per 1997 procedures)	HCFC-22 Production	**material balance approach:** information on quantities of critical feed components (e.g., HFC) and or products (HCFC-22) to feed into a material balance equation **approach for those using thermal oxidation:** based on either EPA reference methods or an emission estimate from the company Daily sampling is recommended however manufacturers may choose to demonstrate that their sampling plan provides information sufficient to meet stringent data quality objectives	**For companies using a material balance approach:** HCFC-22 production (lbs) and HFC-23 emissions (lbs) by month, performance standards met for the year, additional details on performance standards (e.g., those not met, corrective actions taken), changes in the way HFC-23 emissions were determined (relative to previous years) (e.g., why was the change made, comparison of accuracy of new and previous procedures) **For companies using thermal oxidation to destroy HFC-23:** Emission point (thermal oxidizer, process vents, fugitive leaks, startups, shutdowns, other), emissions (lb/hr), emissions determination (i.e., EPA reference methods, emission estimate, other), annual HCFC-22 production (lbs and kg), information on monitoring (continuous, temperature, percent of time the oxidizer was bypassed), changes in the way emissions were determined	QA/QC procedures in addition to those detailed in the performance standards procedures (see notes tab) not further specified. Not specified in 2007 source; however, annual reports provided by companies verified by recalculating results (see other row on 2006 verification procedures)	RTI and The Cadmus Group, 1998. Performance Standards for Determining Emissions of HFC-23 from the Production of HCFC-22. Draft Final Report. February 1998.
HFC-23 Emission Reduction Partnership Program (per 2006 verification and procedures)	HCFC-22 Production	Depends on facility (see notes tab for details) Includes HCFC-22 production, HFC-23/HCFC-22 stream ratio, HCl consumption, etc.	HFC emissions in TGCO2eq and Gg, HCFC-22 production	RTI (contractor) verified plant estimates in final report entitled, "Verification of Emission Estimates of HFC-23 from the Production of HCFC-23: Emissions from 1990 through 2006" Verification requirements not specified Comparison to 2006 IPCC Guidelines provided in report (see notes)	EPA (2008) "Verification of Emission Estimate of HFC-23 from the Production of HCFC-22: Emissions from 1990 through 2006." Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2005

IPCC Tier 3 additional equations

Tier 3a HFC-23 EMISSIONS FROM INDIVIDUAL PROCESS STREAMS (DIRECT METHOD)

$Eij = Cij \cdot fij \cdot t$

Eij = 'instantaneous' HFC-23 emissions from process stream *j* at plant *i* , kg
Cij = the concentration of HFC-23 in the gas stream actually vented from process stream *j* at plant *i* , kg HFC-23/kg gas
fij = the mass flow of the gas stream from process stream *j* at plant *i* (generally measured volumetrically and converted into mass flow using standard process engineering methods), kg gas/hour
t = the length of time over which these parameters are measured and remain constant, hours

TIER 3b CALCULATION OF HFC-23 EMISSIONS FROM INDIVIDUAL PROCESS STREAMS (PROXY METHOD)

$Eij = Sij \cdot Fij \cdot PORij \cdot t - Rij$

Eij = the mass emission of HFC-23 in vent stream *j* at plant *i* , kg
Sij = the standard mass emission of HFC-23 in vent stream *j* at plant *i* per 'unit' of proxy quantity
Fij = a dimensionless factor relating the measured standard mass emission rate to the emission rate at the actual plant operating rate.
PORij = the current process operating rate applicable to vent stream *j* at plant *i* averaged over *t* in 'unit/hour'.
t = the actual total duration *of venting* for the year, or the period if the process is not operated continuously in hours. Annual emissions become the sum of all the periods during the year
Rij = the quantity of HFC-23 recovered for vent stream *j* at plant *i* for use as chemical feedstock, and hence destroyed, kg.

$S_{T,ij} = C_{T,ij} \cdot f_{T,ij} / POR_{T,ij}$

S_{ij} = the standard mass emission of HFC-23 in vent stream *j* at plant *i,* kg/'unit'
$C_{T,ij}$ = the average mass fractional concentration of HFC-23 in vent stream *j* at plant *i* during the trial, kg/kg
$f_{T,ij}$= the average mass flowrate of vent stream *j* at plant *i* during the trial, kg/hour
$POR_{T,ij}$= the proxy quantity (such as process operating rate) at plant *i* during the trial, 'unit'/hour. The 'unit' depends on the proxy quantity adopted for plant *i* vent stream *j* (for example, kg/hour or m3/hour of feedstock)

TIER 3c CALCULATION OF HFC-23 EMISSIONS FROM INDIVIDUAL PROCESS STREAMS (BY MONITORING REACTOR PRODUCT)

$Ei = Ci \cdot Pj \cdot tF - Ri$

Ei = HFC-23 emissions from an individual facility *i* , kg
Ci = the concentration of HFC-23 in the reactor product at facility *i* , kg HFC-23/kg HCFC-22
Pi = the mass of HCFC-22 produced at facility *i* while this concentration applied, kg
tF = the fractional duration during which this HFC-23 is actually vented to the atmosphere, rather than destroyed, fraction
Ri = the quantity of HFC-23 recovered from facility *i* for use as chemical feedstock, and hence destroyed, kg

1605B Report summarizes reporting options in a table with a rating system:

Estimation Method Rating
Continuous emissions monitoring: Rating: A
Emission estimates based on representative, periodic direct measurement A Default, uncontrolled emissions factor, abatement/capture technology reduction value if applicable, that are publicly documented and have been widely reviewed and adopted by a public agency, a standards-setting organization or an industry group: Rating: B
Other default, uncontrolled emissions factor, abatement/capture technology reduction value if applicable: Rating: C

HFC-23 Emission Reduction Partnership Program (per 1997 procedures)
Procedures and performance standards for companies using a material balance approach (taken primarily from EPA Method 18, "Measurement of Gaseous Organic Compound Emissions by Gas Chromatography.")

(1) Develop and maintain a written Standard Operating Procedure (SOP) that will be followed by laboratory personnel for sample analysis. The SOP must incorporate the procedures and performance standards in this section.

(2) Analyze for HFC-23 by gas chromatography (GC) using a thermal conductivity detector or flame ionization detector.

(3) Purchase calibration standard(s) from an outside supplier who certifies the concentration(s). These standards are to be used for calibrating the GC.

(4) Initial calibration of the measurement system must use at least three calibration points that bracket the expected measurement range.

(5) Acceptance criteria for the calibration curves must be documented in a written SOP.

(6) A calibration check standard must be run after the calibration curve is established (prior to analysis of process samples) as an independent check of measurement system performance. Continuing calibration checks must be made on at least a monthly basis.

a. Check Standard Concentration: The check standard concentration and the typical process sample concentration must not differ by more than a factor of 10.
b. Check Frequency: Calibration checks are performed to detect significant problems with both bias and imprecision. At a minimum, one check must be performed each month.
c. Accuracy and Precision Acceptance Limits: A calibration check result must be within 10 percent of its certified value, and duplicate analyses must be within 5 percent of their mean value.6 If either of these limits is exceeded, then corrective actions must be taken. If the accuracy limit of 10 percent is exceeded, the measurement syste, must be recalibrated as part of the corrective action.

(7) Records of Accuracy and Precision: Calculate and maintain records of precision (as relative standard deviation) and accuracy (as percent bias). The continuing calibration check ensures that both precision and bias are within acceptable limits. Records must be kept for at least ten years.

(8) Flagging Data: When a monthly check fails to fall within the ± 10 percent acceptance limits, the data collected since the previous acceptable check are flagged to indicate that their quality is suspect.

HFC-23 Emission Reduction Partnership Program (per 1997 procedures)

Procedures and Performance Standards for plants using thermal oxidizers:

(1) Conduct a performance test by sampling the inlet to the oxidizer and the final vent for concentration of HFC-23 and the volumetric flow rate. EPA reference methods must be used to determine flow rate and HFC-23 concentration, and all quality control/quality assurance requirements in the methods must be met. Conduct at least 3 one-hour runs under normal or worst operating conditions. Also, conduct a one-time performance test under representative operating conditions for dioxins and furans using EPA Reference Method 23- "Determination of Polychlorinated Dibenzo-p-Dioxins and Polychlorinated Dibenzofurans from Stationary Sources."

(2) Report the destruction and removal efficiency based on the mass rate (kg/hr) of HFC-23 into the oxidizer and the mass rate out of the final vent. Also report the projected annual emissions of HFC-23 (kg/year) based on operation for 24 hours per day and 365 days per year. If HFC-23 is not detected in the final vent, report the detection limit and report emissions as "less than" the quantity calculated based on the detection limit. Because of the high destruction efficiency, expect low or non-detectable concentrations of HFC-23. Ensure that the detection limit is low enough to demonstrate the target destruction efficiency and document in the test report how the detection limit was determined.

(3) Perform continuous monitoring of the oxidizer to ensure it is operating properly. At a minimum, monitor the oxidizer temperature (must not be less than the temperature recorded during the performance test or 2,300_F, whichever is lower) and excess oxygen (must not be less than 2 percent).

a. Install, calibrate, and operate (according to the manufacturer's specifications) a temperature monitoring device equipped with a continuous recorder.

b. The monitoring device must have an accuracy of ±1 percent of the temperature being monitored or ±0.5_C, whichever is greater.

c. Report any 3-hour periods of operation in which the combustion temperature falls 50_F or more below the temperature recorded during the initial performance test or 2,300_F, whichever is lower.

(4) Maintain records of any events in which the HFC-23 bypasses the oxidizer and is emitted or when the oxidizer is not operating properly. Estimate the emissions of HFC-23 and include this estimate in the annual report of emissions.

(5) Measure emissions of HFC-23 from any process vents using EPA test methods (at least a one-time evaluation). Also determine fugitive emissions from leaks using EPA Method 21 and appropriate emission factors. Include these emissions in the annual report of emissions.

Review of Existing Programs Relevant to Source - HCFC-22 Production

HCFC-22 Production Facilities Data (HFC-23 Emission Reduction Partnership Program, per 2006 verification and procedures)

*please note that the listed plant methods are for plants currently in use and other plants were in use over the inventory time period (1990-2006)

Production Facility	Substance monitored	Method	Emissions Equations	Input Data	2006 IPCC Guidelines Comparison
"Plant 6" - procedure used for 1997-20061	HCFC-22 produced	measured based on changes in inventory and quantity shipped	$E_{23} = c_{23}/c_{22} * P_{22}$	E_{23} is HFC-23 emissions C_{23} is % HFC-23 in HCFC-22/HFC-23 stream C_{22} is % HCFC-22 in HCFC-22/HFC-23 stream P_{22} is HCFC-22 production	Conforms with Tier 3c approach
	Ratio of HFC-23 to HCFC-22 in process stream	measured at least twice per week			
"Plant 7" - procedure used for 1998-20062	HFC-23 generated	measured by a flow meter every 24 minutes and averaged over time	$Q_{23} = C_{23}/100 * F$	Q_{23} is mass of HFC-23 generated (lb/hr) C_{23} is percent HFC-23 in HFC-23/HCl stream F is mass flow rate of HFC-23/HCl stream (lb/hr)	Conforms with Tier 3c approach
	HFC-23 recovered	sum of change in inventory, amount shipped as product, and amount weighed to ship for thermal destruction	$E_{23} = Q_{23\text{-annual}} - R_{23}$	E_{23} is annual HFC-23 emissions R_{23} is annual amount of HFC-23 recovered (for sale or destruction) $Q_{23\text{-annual}}$ is annual amount of HFC-23 generated	
"Plant 8"	HCFC-22 produced	measured by meters and scales	N/A	N/A	Consistent with Tier 3 approach, but is a hybrid approach
	HFC-23 emissions	tested process vents, tested thermal oxidizer, analyzed fugitive leaks			

[1]Procedure used for 1990-1996 included monitoring chloroform consumption and the ratio of HFC-23 to HCFC-22 in the process stream, resulting in a positive bias for emission estimates

[2]Procedure used for 1990-1997 included monitoring the HF feed rate and the concentration of HFC-23

Source: EPA(2008) "Verification of Emissions Estimates of HFC-23 from the Production of HCFC-22: Emissions from 1990 through 2006." Prepared by RTI International March 2008.

Review of Existing Programs Relevant to Source - Hydrogen Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil - Refinery Processes	CH4, non-combustion CO2	Vented	None	Equipment-level	Vent stacks for equipment types	Tier III (IPCC) - process level emissions rates for: - Hydrogen Plants
California Mandatory GHG Reporting Program	Hydrogen production facilities	CO2, CH4, and N2O	Process, fugitive, and flaring emissions	Hydrogen production facilities that emit greater than or equal to 25,000 metric tonnes per year of CO2 from the combination of stationary combustion and process sources. If operation of the refinery results in emissions of less than 20,000 metric tonnes per year of CO2 for three consecutive years, the operator is exempt from reporting untill the emissions exceeds 25,000 metric tonnes per year of CO2	Facility and/or equipment emissions (e.g. storage tanks)	All activities resulting in CO2, CH4, and N2O emissions for hydrogen facilities	CO2 process emissions can be determined by continuous emissions monitoring systems (Attachment B to Resolution 07-54, Regulation for mandatory reporting of GHG emissions, Section 95113 (c)). Methods for calculating fugitive emissions, and emissions from flares and other control devices are obtained in sections 95114
Department of Energy 1605(b) Voluntary Reporting Program	Hydrogen Production	CO2	Industrial processes - Hydrogen Production ("only treat CO2 produced as a byproduct of hydrogen production as an industrial process emission if it is emitted into the atmosphere")	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	"A" rated estimate: Direct measurement at plant or mass balance calculation from inputs	Measure CO2 emissions directly at plant. Alternatively, use mass balance equations using composition of feedstock and products. Both are considered best practices, rated as "A."
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	Hydrogen Production	CO2	Industrial Process - from hydrogen production - CO2 process emissions	All (if deminimis [= <3%] can be calculated more simply	Facility	Dependent upon calculation method used.	May be calculated using 1) a continuous emissions monitoring system (CEMS), 2) fuel/feedstock mass balance method (see Note 1), or 3) feedstock process emissions method (see Note 2).

Review of Existing Programs Relevant to Source - Hydrogen Production

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil - Refinery Processes	Guideline	Process/equipment throughputs and feed compositions	Not applicable	Not applicable	Chapter 5.2
California Mandatory GHG Reporting Program	Hydrogen production facilities	Mandatory	Equipment count, operational information (e.g. days in operation, fuel consumed, vent rate)	Reports to be submitted no later than June 1 of every calender year. The report should contain the facility information, organizational and operational boundaries, direct and indirect emissions, name and contact information of the person preparing the report, and efficiency metrics when required (Section 95103). The operator shall separately identify and include in the emissions data report the emissions designated as de minimis (less than or equal to 3% of the facility's total CO2 equivalent emissions, not exceeding 20,000 metric tons of CO2).	Verification required by an accredited verficiation body	http://www.arb.ca.gov/regact/2007/ghg2007/ghg2007.htm
Department of Energy 1605(b) Voluntary Reporting Program	Hydrogen Production	Voluntary	In the "A" rated estimate, emissions are measured directly, or a measurement of feedstocks and composition is needed.	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Section 1.E.4.1.5 of of http://www.pi.energy.gov/enhancingGHGregistry/technicalguidelines.html. Also 10 CFR 300 (p 106 and 114), available at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	Hydrogen Production	Mandatory	Depends on the method used. See each method (notes 1 and 2) for a list of each variable used for each method. (source of data not specified)	Annual GHG emissions (process emissions CO2).	Verification by 3rd party (private firm or air district) annually or triennially depending on emission amount	http://www.arb.ca.gov/regact/2007/ghg2007/isor.pdf

Review of Existing Programs Relevant to Source - Hydrogen Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	CO2	Process and stationary combustion emissions	Simplified documentation for CO2 emissions <5% of facility GHG emissions (CO2 equivalent)	Facility, annual	Flue gas	Hourly CEMS (following 40CFR Part 60 or 40CFR Part 75 Appendix F)
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	CO2	Process and stationary combustion emissions	Simplified documentation for CO2 emissions <5% of facility GHG emissions (CO2 equivalent)	Facility, annual	Fuel and Feedstock Mass Balance	Calculate annual CO2 from daily data for fuel consumption, feedstock consumption, feedstock carbon content (see Note 3)
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	CO2	Process and stationary combustion emissions	Simplified documentation for CO2 emissions <5% of facility GHG emissions (CO2 equivalent)	Facility, annual	Fuel Stationary Combustion and Feedstock Process Emissions	Calculate annual CO2 based on Fuel consumption used for stationary combustion, and/or Daily feedstock consumption and feedstock carbon content (see Note 4)
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	CO2	Process and stationary combustion emissions	Simplified documentation for CO2 emissions <5% of facility GHG emissions (CO2 equivalent)	Facility, annual	Process Vents	Calculate CO2 emissions per venting event, by measuring vent rate, time duration, and CO2 concentration in vent (see Note 5)
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	CO2	Process and stationary combustion emissions	Simplified documentation for CO2 emissions <5% of facility GHG emissions (CO2 equivalent)	Facility, annual	Sulfur Recovery	Calculate annual CO2, based on annual volumetric flow of acid gas to sulfur recovery units and molecular fraction of CO2 (see Note 6)

Review of Existing Programs Relevant to Source - Hydrogen Production

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	Mandatory	Hourly CO2 concentration and flue gas flow measurements	Annual report includes Fuel consumption, Feedstock consumption, Hydrogen production, Flaring emissions, Transferred CO2 and CO, Process vent emissions, Sulfur recovery process emissions, Electric generating units, Cogeneration emissions, Indirect energy purchases, CO2 stationary combustion emissions, and CO2 process emissions	None mentioned	http://www.nmenv.state.nm.us/aqb/GHG/ghgrr_index.html
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	Mandatory	Monitor daily: fuel consumption, feedstock consumption, feedstock carbon content	Annual report includes Fuel consumption, Feedstock consumption, Hydrogen production, Flaring emissions, Transferred CO2 and CO, Process vent emissions, Sulfur recovery process emissions, Electric generating units, Cogeneration emissions, Indirect energy purchases, CO2 stationary combustion emissions, and CO2 process emissions	None mentioned	http://www.nmenv.state.nm.us/aqb/GHG/ghgrr_index.html
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	Mandatory	CO2 emissions based on fuel consumption used for stationary combustion, and/or Daily feedstock consumption and feedstock carbon content	Annual report includes Fuel consumption, Feedstock consumption, Hydrogen production, Flaring emissions, Transferred CO2 and CO, Process vent emissions, Sulfur recovery process emissions, Electric generating units, Cogeneration emissions, Indirect energy purchases, CO2 stationary combustion emissions, and CO2 process emissions	None mentioned	http://www.nmenv.state.nm.us/aqb/GHG/ghgrr_index.html
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	Mandatory	Per Venting event, measure vent rate, time duration, and CO2 concentration in vent	Annual report includes Fuel consumption, Feedstock consumption, Hydrogen production, Flaring emissions, Transferred CO2 and CO, Process vent emissions, Sulfur recovery process emissions, Electric generating units, Cogeneration emissions, Indirect energy purchases, CO2 stationary combustion emissions, and CO2 process emissions	None mentioned	http://www.nmenv.state.nm.us/aqb/GHG/ghgrr_index.html
New Mexico Green House Gas Mandatory Emissions Inventory (finalized 1/3/08)	Hydrogen Production	Mandatory	Per year, monitor volumetric flow of acid gas to sulfur recovery units, molecular fraction of CO2	Annual report includes Fuel consumption, Feedstock consumption, Hydrogen production, Flaring emissions, Transferred CO2 and CO, Process vent emissions, Sulfur recovery process emissions, Electric generating units, Cogeneration emissions, Indirect energy purchases, CO2 stationary combustion emissions, and CO2 process emissions	None mentioned	http://www.nmenv.state.nm.us/aqb/GHG/ghgrr_index.html

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines (Iron and Steel)	Iron and Steel	CO2, CH4	Process	N/A	National	N/A	**Tier 1: Production-Based Emission Factors** CO2 Emissions = [Blast Oxygen Furnace (BOF) Crude Steel Production (metric tons) x 1.46 tonne CO2/tonne steel] + [Electric Arc Furnace (EAF) Crude Steel Production (metric tons) x 0.08 metric ton CO2/metric ton steel] + [Open Hearth Furnace (OHF) Crude Steel Production (metric tons) x 1.72 tonne CO2/metric ton steel] CH4 Emissions (kg CH4) = Pig Iron Production x Pig Iron Production CH4 emission factor **Tier 2: National Statistic Approach** CO2 Emissons = [{Coke Consumed x Coke Carbon Content (CC)] +∑{Coke Oven Byproducts x Coke Oven Byproduct CC} + {Direct Injected Coal x Direct Injected Coal CC} + {Limestone x Limestone CC} + {Dolomite x Dolomite CC} + {EAF Carbon Electrodes x EAF Carbon Electrodes CC} + ∑{Other carbonaceous materials x Other carbonaceous materials CC} + {Coke Oven Gas x Coke Oven Gas CC} - {Steel Produced x Steel CC} - {Iron Produced not converted to steel x iron CC} - {Blast Furnace Gas x Blast Furnace Gas CC}] x 44/12 Carbon Contents are provided in Table 4.3 of IPCC Guidelines (See Notes) **Tier 3: Plant Specific Approach** CO2 Emissions = ∑CO2 Emissions from facility- or plant-specific emission estimates Tier 3 emissions can be measured or estimated at the facility or plant level using the Tier 2 methods provided for iron and steel production, direct reduced iron production, and sinter production. CH4 Emissions = ∑CH4 Emissions from facility- or plant-specific emission estimates IPCC 2006 GL also provide methodologies for estimating CO2 emissions from metallurgical coke production, however this production is considered an energy process; therefore, estimates are more closely associated with "combustion" processes.	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines (Iron and Steel)	Iron and Steel	**Tier 1:** Estimates based on production data and emission factors. Data inputs: Blast Oxygen Furnace, Electric Arc Furnace, and Open Hearth Furnace Steel Production data. **Tier 2:** CO2 only, Mass balance approach based on carbon inputs and outputs. Input data include consumption amounts and carbon contents for coke, coke oven byproducts, direct-injected coal, limestone, dolomite, electric arc furnace electrodes, other carbonaceous materials, and coke oven gas. Outputs include production amounts and carbon contents of steel produced, iron produced for non-steel purposes, and blast furnace gas. **Tier 3:** Aggregated facility- or plant-specific emission estimates. Data inputs: Facility or plant specific emission estimates likely realized using Tier 2 approach.	Base year and subsequent annual GHG emissions.	Compare emission factors and carbon contents to IPCC defaults. Check for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consult industry experts for third party reviews. Ensure that factors are consistent with those used for related Energy estimates.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Iron and Steel (Pig Iron Not Processed Into Steel)	CO2, CH4	Process	N/A	National	N/A	**Tier 1: Production-Based Emission Factors** CO2 Emissions = Pig Iron Production (Not Converted to Steel) x 1.35 metric ton CO2/metric ton pig iron produced	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.
2006 IPCC Guidelines	Iron and Steel (Direct Reduced Iron)	CO2, CH4	Process	N/A	National	N/A	**Tier 1: Production-Based Emission Factors** CO2 Emissions = Direct Reduced Iron Production x 0.7 metric ton CO2/metric ton direct reduced iron produced CH4 Emissions (kg CH4) = Natural Gas Consumed during DRI Production x 1kgCH4/TJ of Natural Gas Consumed **Tier 2: National Statistic Approach** CO2 Emissions = {(DRI Natural Gas Consumption x Natural Gas CC) + (DRI Coke Breeze Consumption x Coke Breeze CC) + (DRI Metallurgical Coke Consumption x Metallurgical Coke CC) x 44/12} Where: Natural Gas CC = 0.73 kgC/kg Coke Breeze CC = 0.83 kgC/kg (assumed gas coke) Metallurgical Coke CC = 0.83 kgC/kg	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.
2006 IPCC Guidelines	Iron and Steel (Sinter Production)	CO2, CH4	Process	N/A	National	N/A	**Tier 1: Production-Based Emission Factors** CO2 Emissions = Sinter Production x 0.2 metric ton CO2/metric ton sinter produced CH4 Emissions = Sinter Production x 0.07 kg CH4/metric ton of sinter produced **Tier 2: National Statistic Approach** CO2 Emissions = {(Purchased and Produced Coke Breeze Used for Sinter Production (CBR) x CC_{CBR}) + (Coke Oven Gas for Sinter x Coke Oven Gas CC) + (Blast Furnace Gas for Sinter x Blast Furnace Gas CC) + (∑[Process Materials (e.g., natural gas, fuel oil) x Process Material CC) - (Sinter Off-Gas Transferred Off-site x Sinter Off-Gas CC)} x 44/12 (Table 4.3 of IPCC 2006 Guidelines provides CCs. See Notes.)	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.
2006 IPCC Guidelines	Iron and Steel (Sinter Production)	CO2, CH4	Process	N/A	National	N/A	**Tier 1: Production-Based Emission Factors** CO2 Emissions = Pellet Production x 0.03 metric ton CO2/metric ton pellet produced	Mandatory reporting guidelines to meet the reporting requirements of the UNFCCC Secretariat.

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Iron and Steel (Pig Iron Not Processed Into Steel)	**Tier 1:** Pig Iron Produced for Purposes Other than Steel Production	Base year and subsequent annual GHG emissions.	Compare emission factors and carbon contents to IPCC defaults. Check for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consult industry experts for third party reviews. Ensure that factors are consistent with those used for related Energy estimates.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
2006 IPCC Guidelines	Iron and Steel (Direct Reduced Iron)	**Tier 1:** Direct Reduced Iron Production and Natural Gas consumed for direct reduced iron production **Tier 2:** Natural Gas, Coke Breeze, and Metallurgical Coke Consumed for DRI Production	Base year and subsequent annual GHG emissions.	Compare emission factors and carbon contents to IPCC defaults. Check for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consult industry experts for third party reviews. Ensure that factors are consistent with those used for related Energy estimates.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
2006 IPCC Guidelines	Iron and Steel (Sinter Production)	**Tier 1:** Sinter Production **Tier 2:** Coke Breeze Consumed for Sinter Production, Coke Oven Gas Consumed for Sinter Production, Blast Furnace Gas Consumed for Sinter Production, Other Process Materials (e.g., Natural Gas, Fuel Oil) Consumed for Sinter Production, and Sinter Off-Gas Produced. Country- or plant-specific sinter off-gas carbon contents are likely also needed. Defaults are not provided in IPCC GL.	Base year and subsequent annual GHG emissions.	Compare emission factors and carbon contents to IPCC defaults. Check for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consult industry experts for third party reviews. Ensure that factors are consistent with those used for related Energy estimates.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
2006 IPCC Guidelines	Iron and Steel (Sinter Production)	**Tier 1:** Pellet Production	Base year and subsequent annual GHG emissions.	Compare emission factors and carbon contents to IPCC defaults. Check for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consult industry experts for third party reviews. Ensure that factors are consistent with those used for related Energy estimates.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
WRI/WBCSD Protocol	Iron and Steel	CO2	Process	N/A	Corporate/Facility	N/A	**Approach 1:** Includes 4 Steps. The emission estimates for each step are summed to acheive the total emission estimate for Approach 1. Step 1) CO2 Emissions = Reducing Agents Consumed x CO2 Emission Factor. Sum emission for all Reducing Agents. Step 2) CO2 Emissions = Flux Consumed x CO2 Emission Factor x Fractional Purity of Flux. Sum emissions for all Flux. Step 3) CO2 Emissions = Blast Furnace Additives x CO2 Emission Factor. Sum emissions for all blast furnace additives. Step 4) CO2 Emissions = Iron and Scrap Metal Consumed x % Carbon in Metal / 100 x 44/12. Sum emissions for all metals. **Approach 2:** Use only if Approach 1 is not possible due to lack of reducing agent data. Includes 2 Steps. The emission estimates for each step are summed to acheive the total emission estimate for Approach 2. Step 1) CO2 Emissions = Iron and Steel Production x Emission Factor. Sum emissions for all iron and steel produced. Step 2) CO2 Emissions = Flux Consumed x CO2 Emission Factor x Fractional Purity of Flux. Sum emissions for all Flux. **Subtract CO2 contained in carbon-bearing byproduct (e.g., coke oven gas, blast furnace gas).** CO2 emissions in carbon-bearing byproduct are estimated according to the following steps: Step 1) CO2 Emissions = Carbon-bearing byproduct amount x net caloric value x emission factor. Sum for all carbon-bearing byproducts. Step 2) CO2 Emissions = Metal sold x Metal CC (plant-specific preferred) x 44/12. Sum for all sold metal. See Notes for CO2 emission factors and carbon contents.	Voluntary

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
WRI/WBCSD Protocol	Iron and Steel	Reducing Agents Consumed (e.g., coke) Flux Consumed (e.g., limestone, dolomite) Blast Furnace Additives Iron and Scrap Metal Consumed Iron and Steel Produced Carbon-bearing byproducts Produced (e.g., blast furnace gas) Metal Sold (Measured at Plant Level)	N/A	Check that emission factors are most accurate. Custom emission factors should seem reasonable relative to national or international defaults. Check to see that plant-specific data are used where possible (e.g., coke consumption). Check to see that company-wide data are not double counted. Checks should be made to make sure that purchased coke is not counted at both sites.	http://www.ghgprotocol.org/calculation-tools/sector-toolsets

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Climate Leaders	Iron and Steel	CO2	Energy and Process (Methods Include Metallurgical Coke Production, which IPCC Categorizes as Energy Emissions)	N/A	Corporate/Facility	N/A	Iron and steel facilities are encouraged to estimate their emissions from stationary combustion, purchased electricity, mobile sources, and/or HFC emissions from refrigerant/AC equipment use. Emission factors and production data should be based on plant-specific information. If plant-specific emission factors are unavailable, defaults are provided based on the IPCC 2006 GL (See Notes). In addition to these sources, process-specfic emission methodologies are provided. Estimates are broken out into the following: 1) Metallurgical Coke Production 2) Sinter Production 3) Limestone and Dolomite Production 4) Direct Reduced Iron Production 5) Primary Iron and Steel Production 6) EAF Steel Production In all following equations CC is used to abbreviate Carbon Content. 1) Metallurgical Coke Production Metallurgical Coke Production emissions are estimated according to the following equation: CO2 Emissions = [(Coking Coal Consumed x Coking Coal CC) + ∑(Process Material Amounts x Process Material CC) + ∑(Fuel not produced on-site Consumption x Fuel CC x Fuel Density) - (Coke Produced x Coke CC) - (Coke Oven Gas Transferred Offsite x Coke Oven Gas CC x Coke Oven Gas Density) - ∑(Coke Oven Byproducts x Coke Oven ByProduct CC)] x 44/12 2) Sinter Production Sinter production emissions are estimated according to the following equation: CO2 Emissions = [(Fuels Consumed x Fuel CC x Fuel Density) + ∑(Process Materials Consumed x Process Material CC) - (Sinter Off-Gas Transferred Off-site x Sinter Off-gas CC x Sinter Off-gas Density) - ∑(Process Materials Transferred Off-site x Process Material CC)] x 44/12 CH4 Emissions (kg) = Sinter Production x Sinter Production CH4 EF	Voluntary

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Climate Leaders	Iron and Steel	By-products sold off-site Iron and Steel sold off-site Flux (e.g., limestone) consumed Iron and Steel type-specific carbon factors Carbon electrode consumed Carbon electrode plant-specific carbon factor Process-related off-gas amounts produced	Baseline and subsequent annual CO2-eq GHG emissions, broken out by source type (core direct, core indirect, and optional) for domestic and international sources.	Check to make sure most accurate emission factors are being used. Are custom factors reasonable relative to national/international defaults? Data should be checked to make sure there is no double counting between plant process and plant energy data. Check to make sure only the coal being used for coking is used to determine the amount of reducing agent consumption emissions. Coke produced for the blast furnace should not be included in the calculation. External coke purchases should be included in the calcuation. Check to make sure no double counting of emissions for coke purchased from outside the facility.	http://www.epa.gov/stateply/documents/resources/ironsteel.pdf Current guidelines are in draft.

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Climate Leaders	Iron and Steel	CO2	Energy and Process (Methods Include Metallurgical Coke Production, which IPCC Categorizes as Energy Emissions)	N/A	Corporate/Facility	N/A	3) Limestone and Dolomite Production Limestone and Dolomite Production emissions are estimated according to the following equation: CO2 Emissions = ∑(Carbonate EF x Carbonate Consumed x Fraction of Calcination Achieved) - (Lime Kiln Dust Produced x Weigh Fraction of Original Carbonate in LKD x (1-LKD Fraction Calcination Acheived) x EF for Uncalcined Carbonate in LKD) If actual data is not available for the carbonate weight fraction, assume that 100% of calcination is acheived. 4) Primary Iron and Steel Production Primary Iron and Steel Production Emissions are estimated according to the following equation: CO2 Emissions = {[(Coke Consumed that was not generated on-site x Coke CC) + ∑(Fuels x Fuel CC x Fuel Density) + (Coal Directly Inject to Blast Furnace x Direct Injection Coal CC) + (Limestone Consumed x Limestone CC) + (Dolomite Consumed x Dolomite CC) + (Carbon Electrodes Consumed x Carbon Electrode CC) + ∑(Process Materials x Process Material CC) - (Steel Produced x Steel CC) - (Iron Produced x Iron CC) - (Blast Furnace Gas Transferred Off-site x Blast Furnace Gas CC x Blast Furnace Gas Density) - (Slag Transferred x Slag CC)]} x 44/12 CH4 Emissions = Pig Iron Produced in Blast Furnace x Pig Iron Produced in Blast Furnace EF 5) Direct Reduced Iron Production Direct Reduced Iron Emissions are calculated using the following equation. CO2 Emissions = [∑(Fuel Consumed x Fuel CC) + (Coke Breeze Consumed x Coke Breeze CC) + (Metallurgical Coke Consumed x Metallurgical Coke CC)] x 44/12 CH4 Emissions = Direct Reduced Iron Production x Direct Reduce Iron CH4 EF 6) Electric Arc Furnace (EAF) Steel Production CO2 Emissions = {(Carbon Electrode Consumed x Electrode CC) + ∑(Flux Consumed x Flux CC) + ∑(Carbon Additive (e.g., coke, coal) x Carbon Additive CC) + ∑(Alloying Additives x Alloying Additive CC) + (Pig Iron Charged x Pig Iron CC) + ∑(Fuels x Fuel CC) + (Scrap Steel Consumed x Scrap Steel CC)} x 44/12	Voluntary

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Climate Leaders	Iron and Steel	By-products sold off-site Iron and Steel sold off-site Flux (e.g., limestone) consumed Iron and Steel type-specific carbon factors Carbon electrode consumed Carbon electrode plant-specific carbon factor Process-related off-gas amounts produced	Baseline and subsequent annual CO2-eq GHG emissions, broken out by source type (core direct, core indirect, and optional) for domestic and international sources.	Check to make sure most accurate emission factors are being used. Are custom factors reasonable relative to national/international defaults? Data should be checked to make sure there is no double counting between plant process and plant energy data. Check to make sure only the coal being used for coking is used to determine the amount of reducing agent consumption emissions. Coke produced for the blast furnace should not be included in the calculation. External coke purchases should be included in the calcuation. Check to make sure no double counting of emissions for coke purchased from outside the facility.	http://www.epa.gov/stateply/documents/resources/ironsteel.pdf Current Guidelines are in draft.

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU ETS 1st Reporting Period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	Emissions may be calculated using a mass balance approach for the Tiers listed or separately for combustion (Annex II of EU ETS) and process (described below) emissions associated with production of pig iron and steel as individual activity of the integrated steelworks. **Mass balance approach:** Analyzes all carbon inputs, accumulations, inclusion in products and exports using the following equation: CO2 Emissions (tonnes CO2) = (∑ (activity $data_{input}$ x carbon $content_{input}$) - ∑ (activity $data_{products}$ x carbon $content_{products}$) - ∑ (activity $data_{export}$ x carbon $content_{export}$) - ∑ (activity $data_{stock\ changes}$ x carbon $content_{stock\ changes}$)) x 44 CO2/12 C Where: Input (metric tons C) = all carbon entering the boundaries of the installation, Products (metric tons C) = all carbon in prouducts and materials, including by-products, leaving the boundaries of the mass balance, Export (metric tons C) = carbon exported from the boundaries of the mass balance Stock changes (metric tons C) = stock increases of carbon within the boundaries of the installation	Mandatory
EU ETS 1st Reporting Period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	**Tier 1:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-7.5%; remaining mass flows are metered with max unc of +/-2.5%. **Tier 2:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-5.0%; remaining mass flows are metered with max unc of +/-2.5%. **Tier 3:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-2.5% **Tier 4:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-1.0% Carbon content: when calculating the mass balance the operator shall follow CEN, ISO or national standards in respect to representative sampling of fuels, products and by-products, the determination of their carbon contents and biomass fraction. Energy content: For the purpose of consistent reporting the energy content of each of the fuel and material streams (expressed as net-calorific value of the respective streams) shall be calculated.	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU ETS 1st Reporting Period	Coke ovens	Metered Fuel Data, including coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas, coke, tar, light oil, coke oven gas and alike.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU ETS 1st Reporting Period	Coke ovens	Metered Fuel Data, including coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas, coke, tar, light oil, coke oven gas and alike.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU ETS 1st Reporting Period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	**Process Emission Approach:** Process emissions are estimated according to the following equation, CO2 Emissions (tonne CO2) = $\sum$ (activity $data_{input}$ x emission $factor_{input}$) - $\sum$ (activity $data_{output}$ x emission $factor_{output}$) Activity dataINPUT can comprise coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas and alike. Activity dataOUTPUT can comprise: coke, tar, light oil, coke oven gas and alike. (permissible uncertainty varies depending on the tier) *Using Metered Fuel Data:* **Tier 1:** Mass flows of fuel into and out of the installation are metered to +/- 7.5% maximum permissible uncertainty **Tier 2:**Mass flows of fuel into and out of the installation are metered to +/- 5.0% maximum permissible uncertainty **Tier 3:** Mass flows of fuel into and out of the installation are metered to +/- 2.5% maximum permissible uncertainty **Tier 4:** Mass flows of fuel into and out of the installation are metered to +/- 1.0% maximum permissible uncertainty *or Using Net Caloric Value Data:* **Tier 1:** country-specific net calorific values for the respective fuel as listed in '1990 country specific net calorific values' of the 2000 IPCC 'G **Tier 2:** country-specific net calorific values for the respective fuel as re **Tier 3:** Measured using CEN, ISO or national standards *or Using Emission Factors* **Tier 1:** Inputs; Coke Oven Gas 47.7 tonne CO2/TJ, Blast Furnace Gas 241.8 tonne CO2/TJ **Tier 2:** Measured using CEN, ISO or national standards.	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU ETS 1st Reporting Period	Coke ovens	Metered Fuel Data, including coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas, coke, tar, light oil, coke oven gas and alike.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Coke ovens	CO2	Process and combustion	N/A	Facility Level	N/A	Emissions may be calculated using a mass balance approach for the Tiers listed or separately for combustion (Annex II of EU ETS) and process (described below) emissions. **Mass balance approach:** Analyzes all carbon inputs, accumulations, inclusion in products and exports using the following equation: CO2 Emissions (tonnes CO2) = (∑ (activity $data_{input}$ x carbon $content_{input}$) - ∑ (activity $data_{products}$ x carbon $content_{products}$) - ∑ (activity $data_{export}$ x carbon $content_{export}$) - ∑ (activity $data_{stock\ changes}$ x carbon $content_{stock\ changes}$)) x 44 CO2/12 C Where: Input (metric tons C) = all carbon entering the boundaries of the installation, Products (metric tons C) = all carbon in prouducts and materials, including by-products, leaving the boundaries of the mass balance, Export (metric tons C) = carbon exported from the boundaries of the mass balance Stock changes (metric tons C) = stock increases of carbon within the boundaries of the installation	Mandatory
EU Emissions Trading System 2nd reporting period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	**Tier 1:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-7.5%; remaining mass flows are metered with max unc of +/-2.5%. **Tier 2:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-5.0%; remaining mass flows are metered with max unc of +/-2.5%. **Tier 3:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-2.5% **Tier 4:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-1.0% Carbon content: when calculating the mass balance the operator shall follow CEN, ISO or national standards in respect to representative sampling of fuels, products and by-products, the determination of their carbon contents and biomass fraction. Energy content: For the purpose of consistent reporting the energy content of each of the fuel and material streams (expressed as net-calorific value of the respective streams) shall be calculated.	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Coke ovens	Metered Fuel Data, including coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas, coke, tar, light oil, coke oven gas and alike.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT
EU Emissions Trading System 2nd reporting period	Coke ovens	Metered Fuel Data, including coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas, coke, tar, light oil, coke oven gas and alike.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	**Process Emission Approach:** Process emissions are estimated according to the following equation, CO2 Emissions (tonne CO2) = $\sum$ (activity $data_{input}$ x emission $factor_{input}$) - $\sum$ (activity $data_{output}$ x emission $factor_{output}$) *Using Metered Fuel Data:* **Tier 1:** Mass flows of fuel into and out of the installation are metered to +/- 7.5% maximum permissible uncertainty **Tier 2:** Mass flows of fuel into and out of the installation are metered to +/- 5.0% maximum permissible uncertainty **Tier 3:** Mass flows of fuel into and out of the installation are metered to +/- 2.5% maximum permissible uncertainty **Tier 4:** Mass flows of fuel into and out of the installation are metered to +/- 1.0% maximum permissible uncertainty *or Using Net Caloric Value Data:* **Tier 1:** Reference Values provided in Section 11 of Annex I. (See Notes) **Tier 2:** country-specific net calorific values for the respective fuel as reported by the respective member state to the UNFCCC. **Tier 3:** Measured using CEN, ISO or national standards *or Using Emission Factors* **Tier 1:** Reference Factors. See Notes **Tier 2:** country-specific net calorific values for the respective fuel as reported by the respective member state to the UNFCCC. **Tier 3:** Measured using CEN, ISO or national standards	Mandatory
EU ETS 1st Reporting Period	Metal ore roasting and sintering installations	CO2	Process and combustion	N/A	Facility Level	N/A	Emissions may be calculated using a mass balance approach for the Tiers listed or separately for combustion (Annex II of EU ETS) and process (described below) emissions. **Mass balance approach:** Analyzes all carbon inputs, accumulations, inclusion in products and exports using the following equation: CO2 Emissions (tonnes CO2) = ($\sum$ (activity $data_{input}$ x carbon $content_{input}$) - $\sum$ (activity $data_{products}$ x carbon $content_{products}$) - $\sum$ (activity $data_{export}$ x carbon $content_{export}$) - $\sum$ (activity $data_{stock\ changes}$ x carbon $content_{stock\ changes}$)) x 44 CO2/12 C Where: Input (metric tons C) = all carbon entering the boundaries of the installation, Products (metric tons C) = all carbon in prouducts and materials, including by-products, leaving the boundaries of the mass balance, Export (metric tons C) = carbon exported from the boundaries of the mass balance Stock changes (metric tons C) = stock increases of carbon within the boundaries of the installation	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Coke ovens	Metered Fuel Data, including coal as raw material, coke slack, petrol coke, oil, blast furnace gas, coke oven gas, coke, tar, light oil, coke oven gas and alike.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT
EU ETS 1st Reporting Period	Metal ore roasting and sintering installations	tonnes of carbonate input material and process residues	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU ETS 1st Reporting Period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	**Mass Balance Tier 1:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-7.5%; remaining mass flows are metered with max unc of +/-2.5%. **Mass Balance Tier 2:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-5.0%; remaining mass flows are metered with max unc of +/-2.5%. **Mass Balance Tier 3:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-2.5% **Mass Balance Tier 4:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-1.0% Carbon content: when calculating the mass balance the operator shall follow CEN, ISO or national standards in respect to representative sampling of fuels, products and by-products, the determination of their carbon contents and biomass fraction. Energy content: For the purpose of consistent reporting the energy content of each of the fuel and material streams (expressed as net-calorific value of the respective streams) shall be calculated.	Mandatory
EU ETS 1st Reporting Period	Coke ovens	CO2	Process and combustion	N/A	Facility-level	N/A	**Process Emission Approach:** Process emissions are estimated according to the following equation, CO2 Emissions (metric ton CO2) = $\sum$ (activity data$_{\text{process input}}$ x emission factor $_{\text{x conversion factor}}$) **Tier 1:** Activity Data - tonnes of carbonate input material and process residues as weighed by operator or supplier with maximum permissible uncertainty of 5.0% Emission Factor - CaCO3, 0.440 metric ton CO2/metric ton CaCO3; MgCO3, 0.522 metric ton CO2/metric ton MgCO3 Conversion Factor - 1.0 **Tier 2:** Activity Data - metric tons of carbonate input material and process residues as weighed by operator or supplier with maximum permissible uncertainty of 2.5% Emission Factor - CaCO3, 0.440 metric ton CO2/metric ton CaCO3; MgCO3, 0.522 metric ton CO2/metric ton MgCO3 Activity-specific using ISO/CEN standards based on the amount of carbon in sinter produced and filtered dust.	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU ETS 1st Reporting Period	Coke ovens	tonnes of carbonate input material and process residues	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU ETS 1st Reporting Period	Coke ovens	tonnes of carbonate input material and process residues	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Metal ore roasting and sintering installations	CO2	Process and combustion	N/A	Facility-level	N/A	Emissions may be calculated using a mass balance approach for the Tiers listed or separately for combustion (Annex II of EU ETS) and process (described below) emissions. **Mass balance approach:** Analyzes all carbon inputs, accumulations, inclusion in products and exports using the following equation: CO2 Emissions (metric tons CO2) = (∑ (activity $data_{input}$ x carbon $content_{input}$) - ∑ (activity $data_{products}$ x carbon $content_{products}$) - ∑ (activity $data_{export}$ x carbon $content_{export}$) - ∑ (activity $data_{stock\ changes}$ x carbon $content_{stock\ changes}$)) x 44 CO2/12 C Where: Input (metric tons C) = all carbon entering the boundaries of the installation, Products (metric tons C) = all carbon in prouducts and materials, including by-products, leaving the boundaries of the mass balance, Export (metric tons C) = carbon exported from the boundaries of the mass balance Stock changes (metric tons C) = stock increases of carbon within the boundaries of the installation	Mandatory
EU Emissions Trading System 2nd reporting period	Metal ore roasting and sintering installations	CO2	Process and combustion	N/A	Facility Level	N/A	**Tier 1:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-7.5%; remaining mass flows are metered with max unc of +/-2.5%. Carbon content: Derived from standard emission factors for fuels or materails derived using the following equation: Carbon Content (tonne C/tonne) = Emission Factor (ton CO2/ton)/3.664 (ton CO2/ton C). Energy content: For the purpose of consistent reporting the energy content of each of the fuel and material streams (expressed as net-calorific value of the respective streams) shall be calculated. **Tier 2:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-5.0%; remaining mass flows are metered with max unc of +/-2.5%. Carbon Content: Country-specific carbon content by fuel-type as reported in latest national inventory submission to UNFCCC. **Tier 3:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-2.5% Carbon Content: Measured using CEN, ISO or national standards	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Metal ore roasting and sintering installations	tonnes of carbonate input material and process residues	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT
EU Emissions Trading System 2nd reporting period	Metal ore roasting and sintering installations	tonnes of carbonate input material and process residues	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Metal ore roasting and sintering installations	CO2	Process and combustion	N/A	Facility Level	N/A	**Tier 4:**Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-1.0% **Process Emission Approach:** Process emissions are estimated according to the following equation, CO2 Emissions (metric ton CO2) = $\sum$ (activity data$_{\text{process input}}$ x emission factor $_{\text{x conversion factor}}$) **Tier 1:** Activity Data - tonnes of carbonate input material and process residues as weighed by operator or supplier with maximum permissible uncertainty of 5.0% Emission Factor - CaCO3, 0.440 metric ton CO2/metric ton CaCO3; MgCO3, 0.522 metric ton CO2/metric ton MgCO3; FeCO3, 0.380 metric ton CO2/metric ton FeCO3 **Tier 2:** Activity Data - metric tons of carbonate input material and process residues as weighed by operator or supplier with maximum permissible uncertainty of 2.5% Emission Factor - CaCO3, 0.440 metric ton CO2/metric ton CaCO3; MgCO3, 0.522 metric ton CO2/metric ton MgCO3; FeCO3, 0.380 metric ton CO2/metric ton FeCO3 Activity-specific using ISO/CEN standards based on the amount of carbon in sinter produced and filtered dust.	Mandatory
EU ETS 1st Reporting Period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	Emissions may be calculated using a mass balance approach for the Tiers listed or separately for combustion (Annex II of EU ETS) and process (described below) emissions associated with production of pig iron and steel as individual activity of the integrated steelworks. **Mass balance approach:** Analyzes all carbon inputs, accumulations, inclusion in products and exports using the following equation: CO2 Emissions (metric tons CO2) = ($\sum$ (activity data$_{\text{input}}$ x carbon content$_{\text{input}}$) - $\sum$ (activity data$_{\text{products}}$ x carbon content$_{\text{products}}$) - $\sum$ (activity data$_{\text{export}}$ x carbon content$_{\text{export}}$) - $\sum$ (activity data$_{\text{stock changes}}$ x carbon content$_{\text{stock changes}}$)) x 44 CO2/12 C Where: Input (metric tons C) = all carbon entering the boundaries of the installation, Products (metric tons C) = all carbon in prouducts and materials, including by-products, leaving the boundaries of the mass balance, Export (tonnes C) = carbon exported from the boundaries of the mass balance Stock changes (tonnes C) = stock increases of carbon within the boundaries of the installation	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Metal ore roasting and sintering installations	tonnes of carbonate input material and process residues	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT
EU ETS 1st Reporting Period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, PET, PE, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	**Tier 1:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-7.5%; remaining mass flows are metered with max unc of +/-2.5%. **Tier 2:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-5.0%; remaining mass flows are metered with max unc of +/-2.5%. **Tier 3:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-2.5% **Tier 4:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-1.0% Carbon content: when calculating the mass balance the operator shall follow CEN, ISO or national standards in respect to representative sampling of fuels, products and by-products, the determination of their carbon contents and biomass fraction. Energy content: For the purpose of consistent reporting the energy content of each of the fuel and material streams (expressed as net-calorific value of the respective streams) shall be calculated.	Mandatory
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	**Process Emission Approach:** Process emissions are estimated according to the following equation, CO2 Emissions (tonne CO2) = $\sum$ (activity $data_{input}$ x emission $factor_{input}$) - $\sum$ (activity $data_{output}$ x emission $factor_{output}$) *Using Metered Fuel Data:* **Tier 1:** Mass flows of fuel into and out of the installation are metered to +/- 7.5% maximum permissible uncertainty **Tier 2:** Mass flows of fuel into and out of the installation are metered to +/- 5.0% maximum permissible uncertainty **Tier 3:** Mass flows of fuel into and out of the installation are metered to +/- 2.5% maximum permissible uncertainty **Tier 4:** Mass flows of fuel into and out of the installation are metered to +/- 1.0% maximum permissible uncertainty *or Using Net Caloric Value Data:* **Tier 1:** Country-specific net calorific values for the respective fuel as listed in '1990 country specific net calorific values' of the 2000 IPCC 'Good practice guidance and uncertainty management in national greenhouse gas inventories' (http://www.ipcc.ch/pub/guide.htm). **Tier 2:** Country-specific net calorific values for the respective fuel as re **Tier 3:** Measured using CEN, ISO or national standards	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, PET, PE, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, PET, PE, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	*or Using Emission Factors* **Tier 1:** **Inputs:** Coke Oven Gas 47.7 tonne CO2/TJ, Blast Furnace Gas 241.8 tonne CO2/TJ, Basic Oxygen Furnace Gas 186.6 tonne CO2/TJ, Graphite Electrodes 3.6 tonne CO2/tonne electrode, PET 2.24 tonne CO2/tonne PET, PE 2.85 tonne CO2/tonne PE, CaCO3 0.44 tonne CO2/tonne CaCO3, CaCO3-MgCO3 0.477 tonne CO2/tonne CaCO3-MgCO3 **Outputs:** Ore 0, Pig Iron, Pig Iron Scrap, and Iron Products 0.1467 tonne CO2/tonne, Steel Scrap and Steel Products 0.0147 tonne CO2/tonne **Tier 2:** Measured using CEN, ISO or national standards.	Mandatory
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	Emissions may be calculated using a mass balance approach for the Tiers listed or separately for combustion (Annex II of EU ETS) and process (described below) emissions associated with production of pig iron and steel as individual activity of the integrated steelworks. **Mass balance approach:** Analyzes all carbon inputs, accumulations, inclusion in products and exports using the following equation: CO2 Emissions (tonnes CO2) = (∑ (activity $data_{input}$ x carbon $content_{input}$) - ∑ (activity $data_{products}$ x carbon $content_{products}$) - ∑ (activity $data_{export}$ x carbon $content_{export}$) - ∑ (activity $data_{stock\ changes}$ x carbon $content_{stock\ changes}$)) x 44 CO2/12 C Where: Input (tonnes C) = all carbon entering the boundaries of the installation, Products (tonnes C) = all carbon in prouducts and materials, including by-products, leaving the boundaries of the mass balance, Export (tonnes C) = carbon exported from the boundaries of the mass balance Stock changes (tonnes C) = stock increases of carbon within the boundaries of the installation	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, PET, PE, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, Polyethylene terephthalate, Polyethylene, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	**Tier 1:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-7.5%; remaining mass flows are metered with max unc of +/-2.5%. Carbon content: Derived from standard emission factors for fuels or materails derived using the following equation: Carbon Content (tonne C/tonne) = Emission Factor (tonne CO2/tonne)/3.664 (tonne CO2/tonne C). Energy content: For the purpose of consistent reporting the energy content of each of the fuel and material streams (expressed as net-calorific value of the respective streams) shall be calculated. **Tier 2:** Activity Data : Subset of fuel and material mass flows are metered with maximum permissible uncertainty of less than +/-5.0%; remaining mass flows are metered with max unc of +/-2.5%. Carbon Content: Country-specific carbon content by fuel-type as reported in latest national inventory submission to UNFCCC. **Tier 3:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-2.5% Carbon Content: Measured using CEN, ISO or national standards	Mandatory
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	**Tier 4:** Activity Data: Mass flows are metered with maximum permissible uncertainty of less than +/-1.0% **Process Emission Approach:** Process emissions are estimated according to the following equation, CO2 Emissions (tonne CO2) = $\sum$ (activity $data_{input}$ x emission $factor_{input}$) - $\sum$ (activity $data_{output}$ x emission $factor_{output}$) *Using Metered Fuel Data:* **Tier 1:** Mass flows of fuel into and out of the installation are metered to +/- 7.5% maximum permissible uncertainty **Tier 2:** Mass flows of fuel into and out of the installation are metered to +/- 5.0% maximum permissible uncertainty **Tier 3:** Mass flows of fuel into and out of the installation are metered to +/- 2.5% maximum permissible uncertainty **Tier 4:** Mass flows of fuel into and out of the installation are metered to +/- 1.0% maximum permissible uncertainty *or Using Net Caloric Value Data:* **Tier 1:** Reference Values provided in Section 11 of Annex I. (See Notes) **Tier 2:** Country-specific net calorific values for the respective fuel as reported by the respective member state to the UNFCCC. **Tier 3:** Measured using CEN, ISO or national standards	Mandatory

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, Polyethylene terephthalate, Polyethylene, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, Polyethylene terephthalate, Polyethylene, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU Emissions Trading System 2nd reporting period	Pig iron and steel	CO2	Process and combustion	Primary (blast furnace (BF) and basic oxygen furnace (BOF)) and secondary (electric arc furnace (EAF)) steel production with a capacity exceeding 2,5 tonnes per hour	Facility Level	N/A	*or Using Emission Factors* **Tier 1: Reference Factors** Direct Reduced Iron 0.07 tonne CO2/tonne, EAF carbon electrodes 3.0 tonne CO2/tonne, EAF charge carbon 3.04 tonne CO2/tonne, Hot Briquetted Iron 0.07 tonne CO2/tonne, Oxygen Steel Furnace 1.28 tonne CO2/tonne, Petroleum Coke tonne CO2/tonne, Purchased Pig Iron 0.15 tonne CO2/tonne, Scrap Iron 0.15 tonne CO2/tonne, Steel 0.04 tonne CO2/tonne, CaCO3 0.44 tonne CO2/tonne CaCO3, CaCO3-MgCO3 0.477 tonne CO2/tonne CaCO3-MgCO3, FeCO3 0.380 tonne CO2/tonne. **Tier 2:** country-specific net calorific values for the respective fuel as reported by the respective country to the UNFCCC. **Tier 3:** Measured using CEN, ISO or national standards	Mandatory
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Iron and Steel Production	CO2	Process Emissions	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	N/A	**Carbon Dioxide Emissions from the Conversion of Iron to Steel** "A" rated method: Calculated from input data, measuring reducing agent consumed and carbon content CO2 emissions from conversion = (carbon in pig iron - carbon in steel products) x 44 CO2/12 C where the ratio cited is 44/12. **"B" rated method:** If plant-specific data are not available and default WRI-WBCSD based emission factors for the carbon content of the various metals (ore, Internationally traded crude (pig) iron, cast iron products or steel produced) can be used instead. See 1605(b) Note 3 for these factors. Carbon Dioxide Emissions from Furnace Additives "A" rated method: Calculated from input data, measuring the mass of the additive CO2 emissions from additives (recycled plastic compounts such as PVC, PET or PE) = mass of additive x its WRI-WBCSD based emission factor See 1605(b) Note 2.	Voluntary

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
EU Emissions Trading System 2nd reporting period	Pig iron and steel	Metered fuel and product materials including Coke Oven Gas, Blast Furnace Gas, Basic Oxygen Furnace Gas, Graphite Electrodes, Polyethylene terephthalate, Polyethylene, CaCO3, CaCO3-MgCO3, CaCO3-MgCO3, Iron Ore, Pig Iron, Pig Iron Scrap, and Iron Products, Steel Scrap and Steel Products.	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Iron and Steel Production	**Carbon Dioxide Emissions from Reducing Agent Consumption** **"A" rated method:** Mass (tons) and carbon content of reducing agent (ton CO2/ton of reducing agent) **"B" rated method:** Mass (tons) of reducing agent Carbon Dioxide Emissions from Furnace Additives "A" rated method: Mass (tons) of the furnace additive and the emission factor (ton CO2/ton of additive)	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Pages 2-32 (Reporting Guidelines), Pages 99-102 (Iron and Steel Production) http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf and 10 CFR 300 (p 106 and 114) at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Iron and Steel Production	CO2	Process Emissions	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	N/A	**Carbon Dioxide Emissions from Reducing Agent Consumption** "A" rated method: Calculated from input data, measuring reducing agent consumed and carbon content CO2 emissions = mass of the reducing agent consumed x percent carbon content x molecular ratio of CO2 to carbon where the reducing agent is coke from coal, coal, or petroleum coke, and known values for the carbon content of the reducing agent are used. The molecular ratio of CO2 to carbon is 44/12. "B" rated method: Calculated from input data, measuring mass of reducing agent consumed plant-specific data are not available and default IPCC (1997) emission factors for the carbon content of the reducing agents are used instead. **Carbon Dioxide Emissions from Graphite Electrodes in Electric Arc Furnaces** "A" rated method: Calculated from input data, which requires determining plant-specific emission factors for the electrodes and the mass of the electrodes CO2 emissions from the consumption of graphite electrodes = mass of the electrodes x electrode emission factor where the emission factor is tons of CO2 per tons of C in the electrode and must be determined for each plant "B" rated method: Calculated from input data, measuring quantities of steel If plant-specific data are not available emission estimates for electrode consumption by using a default value of 1.5 kg CO2 per ton of steel produced in EAF furnaces.	

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Iron and Steel Production	**Carbon Dioxide Emissions from Reducing Agent Consumption** "A" rated method: Mass (tons) and carbon content of reducing agent (ton CO2/ton of reducing agent) "B" rated method: Mass (tons) of reducing agent **Carbon Dioxide Emissions from Graphite Electrodes in EAF Furnaces** **"A" rated method:** Mass of the graphite electrode (tons) and emission factors (ton CO2/ton of electrode) **"B" rated method:** Mass of steel produced	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Pages 2-32 (Reporting Guidelines), Pages 99-102 (Iron and Steel Production) http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf and 10 CFR 300 (p 106 and 114) at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Iron and Steel Production	CO2	Direct Process	3% of total emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries.	Facility-level	N/A	**Default Method for Estimating Carbon Dioxide Emissions from Iron and Steel Production - All processes** **"C" rated method: Calculated from input data, measuring quantities of steel** If data required to estimate emissions from the various sources specified above are not available, then a default emissions factor of 1.75 MTCO2 per MT of steel, can be used. This would include emissions from all of these sources for integrated steel facilities. Tier A: Mass balance approach based on IPCC 2006 Tiers 2 and 3 (provided above) using plant-specific carbon contents. Tier B: Mass balance approach based on IPCC default carbon contents (IPCC 2006 GL Table 4.3, See Notes)	Voluntary

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Iron and Steel Production	**Default Method for Estimating Carbon Dioxide Emissions from Iron and Steel Production - All processes** **"C" rated method:** Mass of steel (tons) Consumption amounts and carbon contents for coke, coke oven byproducts, direct-injected coal, limestone, dolomite, electric arc furnace electrodes, other carbonaceous materials, coke oven gas. Production amounts and carbon contents of steel produced, iron produced for non-steel purposes, and blast furnace gas.	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	Page 39 (Reporting Requirements), Pages 112-114 (PFC Emissions from Aluminum Production) http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Inventory of U.S. Greenhouse Gas Emissions and Sinks	Iron and Steel Production	CO2, CH4	Process	N/A	National Level	N/A	The U.S. Inventory uses a mass balance approach to estimate CO2 emissions. In addition to process emissions from iron and steel production, the U.S. inventory includes emissions from U.S. metallurgical coke production. CO2 Emissions are estimated according to the following equation where carbon content is abbreviated as CC: CO2 Emissions = {[(Coking Coal x Coking Coal CC)-(Metallurgical Coke x Metallurgical Coke CC)] + [(Coke Consumed for Pig Iron Production x Metallurgical Coke CC) + (Scrap Steel Consumption x Scrap Steel CC) + (Steel Produced x CC EAF Anode) - (Steel Produced x Steel CC) - (Carbon in Coal Tar Produced x 75% Coal Tar Produced that is not used for Steel Production) - (Pig Iron Produced and Not Used for Steel Production x Pig Iron CC)] * 44/12} Where: Coking Coal CC = 25.56 Tg C/QBtu Metallurgical Coke CC = 31 TgC/Qbtu Scrap Steel CC = 0.5% EAF Anode CC = 0.0015 ton C/ton steel produced Pig Iron CC = 4% Crude Steel CC = 0.1% Activity data are provided by country-specific sources (e.g., AISI, USGS) CH4 emissions are estimated according to the following equation: CH4 emissions (kg) = [(sinter production x 0.5 gCH4/kg sinter produced) + (pig iron production x 0.9 g CH4/kg sinter production)]/1000 grams/kg	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat.

Review of Existing Programs Relevant to Source - Iron and Steel Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Inventory of U.S. Greenhouse Gas Emissions and Sinks	Iron and Steel Production	Activity Data (e.g., coking coal consumption, pig iron produciton, steel production) provided by industry groups and federal entities (e.g., American Iron and Steel Institute, US Geological Survey)	N/A	QAQC Procedures include completing a QAQC plan that follows the IPCC QAQC Approach which includes, comparing emission factors and carbon contents to IPCC defaults. Checking for inconsistencies in site-specific activity data if applicable (check measurment techniques, inaccurate reporting). Consulting industry experts for third party reviews. Ensuring that factors are consistent with those used for related Energy estimates.	http://www.epa.gov/climatechange/emissions/usinventoryreport.html

2006 IPCC Guidelines for National Greenhouse Gas Emission Inventories Table 4.3

Source: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf

TABLE 4.3
TIER 2 MATERIAL-SPECIFIC CARBON CONTENTS FOR IRON & STEEL AND COKE PRODUCTION (kg C/kg)

Process Materials	Carbon Content
Blast Furnace Gas	0.17
Charcoal*	0.91
Coal[1]	0.67
Coal Tar	0.62
Coke	0.83
Coke Oven Gas	0.47
Coking Coal	0.73
Direct Reduced Iron (DRI)	0.02
Dolomite	0.13
EAF Carbon Electrodes[2]	0.82
EAF Charge Carbon[3]	0.83
Fuel Oil[4]	0.86
Gas Coke	0.83
Hot Briquetted Iron	0.02
Limestone	0.12
Natural Gas	0.73
Oxygen Steel Furnace Gas	0.35
Petroleum Coke	0.87
Purchased Pig Iron	0.04
Scrap Iron	0.04
Steel	0.01

Source: Default values are consistent with the those provided in Vol 2 and have been calculated with the assumptions below. Complete references for carbon content data are included in Table 1.2 and 1.3 in Volume 2, Chapter 1.

Notes:

[1] Assumed other bituminous coal

[2] Assumed 80 percent petroleum coke and 20 percent coal tar

[3] Assumed coke oven coke

[4] Assumed gas/diesel fuel

* The amount of CO_2 emissions from charcoal can be calculated by using this carbon content value, but it should be reported as zero in national greenhouse gas inventories. (See Section 1.2 of Volume 1.)

WRI/WBCSD Iron and Steel Emission Factors

Default Emission factors for Reducing Agnets & Blast Furnaces Additives

Material	(t CO2 / t material)
Coal External Supply	2.80
Coke External Supply	3.10
Blast furnace Gas	3.60
BOF Gas	0.44
Prebaked anodes and coal electrodes	3.60
PVC	1.62
PET	2.24
PE	2.85

Note: Most of these values can be obtained from the stationary combustion guideline.

Default Emission factors for flux

Blast Furnace Gas Basic Oxygen Furnace Gas	Emission Factor (t CO2 / t flux)
EF limestone	0.44
EF dolomite	0.477

EF : emission factor

Source: 1996 IPCC Guidelines, Volume II - p 2.10.

Default Carbon contents

Metal	% of carbon
Ore	about 0%
Internationally traded crude (a.k.a. pig) iron	about 4%
Cast iron products	about 4%
Steel produced	0.40%

IPCC - NGGIP, 1999 - p.21/22

Bethlehem Steel Corporation and US Steel Group

Default Emission factors

Flux	Emission Factor (t CO2 / t flux)
Blast furnace Gas	0.44
BOF Gas	0.477

EF : emission factor

Source 1996 IPCC Guidelines, Volume II - p 2.10.

Review of Existing Programs Relevant to Source - Iron and Steel Production

Default Emission factors

	Emission factor
	tCO2/GJ
Coke Oven Gas	0.0436
Blast furnace Gas	0.2807
BOF Gas	0.1866
Residual Fuel Oil	0.077
Tar	0.09

IPCC - NGGIP, 1999 - p.21/22

Standard caracteristics of energy - private company onsite measurements 21/12/94 (Marie Marache, PwC, France)

Default Carbon contents

	% of carbon
Ore	about 0%
Internationally traded crude (a.k.a. pig) iron	about 4%
Cast iron products	about 4%
Steel produced	0.40%

IPCC - NGGIP, 1999 - p.21/22

Bethlehem Steel Corporation and US Steel Group

Notes for 1605b:

Note 1. **Table 1.E.10. Default CO2 Emissions Factors for Various Reducing Agents**

Reducing Agent	Emissions Factor (ton CO_2 / Ton reducing agent)
Coke from coal	3.1
Coal	2.5
Petroleum coke	3.6

Source: Intergovernmental Panel on Climate Change, Revised 1996 IPCC Guidelines for

Note 2. **Table 1.E.11. Default Emissions Factors for Furnace Additives**

Additive	Ton CO2 / Ton additive
PVC	1.62
PET	2.24
PE	2.85

Source: World Resources Institute / World Business Council for Sustainable Development,

Note 3. **Table 1.E.11. Default Emissions Factors for Furnace Additives**

Metal	Carbon Content (percent)
Ore	Approximately 0
Internationally traded crude (pig) iron	Approximately 4
Cast iron products	Approximately 4
Steel produced	0.40

Source: World Resources Institute / World Business Council for Sustainable Development,

Note 4.

Table 1.E.12. Default Carbon Content Values for Various Metals

Estimation Method	Rating
Carbon Dioxide Emissions From Reducing Agent	
Plant-specific data on reducing agent consumption and its carbon content	A
Default reducing agent emissions factors	B
Carbon Dioxide Emissions From Furnace Additives	
Mass balance using default furnace-additive emissions factor	A
Carbon Dioxide Emissions From the Conversion of Iron to Steel	
Mass balance based on plant-specific carbon content of pig iron minus plant-specific carbon content of steel	A
Mass balance based on default carbon content values	B
Carbon Dioxide Emissions From Graphite Electrodes in EAF Furnaces	
Mass Balance using plant-specific graphite electrode emissions factors	A
Mass Balance using default emissions factor of 1.5 kg CO2 per ton steel produced	B
Carbon Dioxide Emissions - All Processes	
Production times default emissions factor of 1.75 tons CO2 per ton of steel	C

EU ETS Specified Emission Factors Table 4

Source: http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT

Fuel type description	Emission factor (tCO_2/TJ)	Net calorific value (TJ/Gg)
	2006 IPCC guidelines (except biomass)	2006 IPCC guidelines
Crude oil	73,3	42,3
Orimulsion	76,9	27,5
Natural gas liquids	64,1	44,2
Motor gasoline	69,2	44,3
Kerosene	71,8	43,8
Shale oil	73,3	38,1
Gas/diesel oil	74,0	43,0
Residual fuel oil	77,3	40,4
Liquefied petroleum gases	63,0	47,3
Ethane	61,6	46,4
Naphtha	73,3	44,5
Bitumen	80,6	40,2
Lubricants	73,3	40,2
Petroleum coke	97,5	32,5
Refinery feedstocks	73,3	43,0
Refinery gas	51,3	49,5
Paraffin waxes	73,3	40,2
White spirit and SBP	73,3	40,2
Other petroleum products	73,3	40,2
Anthracite	98,2	26,7
Coking coal	94,5	28,2
Other bituminous coal	94,5	25,8
Sub-bituminous coal	96,0	18,9
Lignite	101,1	11,9
Oil shale and tar sands	106,6	8,9

Fuel type description	Emission factor (tCO_2/TJ)	Net calorific value (TJ/Gg)
	2006 IPCC guidelines (except biomass)	2006 IPCC guidelines
Patent fuel	97,5	20,7
Coke oven coke and lignite coke	107,0	28,2
Gas coke	107,0	28,2
Coal tar	80,6	28,0
Gas works gas	44,7	38,7
Coke oven gas	44,7	38,7
Blast furnace gas	259,4	2,5
Oxygen steel furnace gas	171,8	7,1
Natural gas	56,1	48,0
Industrial wastes	142,9	n.a.
Waste oils	73,3	40,2
Peat	105,9	9,8
Wood/wood waste	0	15,6
Other primary solid biomass	0	11,6
Charcoal	0	29,5
Biogasoline	0	27,0
Biodiesels	0	27,0
Other liquid biofuels	0	27,4
Landfill gas	0	50,4
Sludge gas	0	50,4
Other biogas	0	50,4
	Other sources	Other sources
Waste tyres	85,0	n.a.
Carbon monoxide	155,2	10,1
Methane	54,9	50,0

Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance for Direct Emissions form Iron and Steel Production Table 3, EPA February 2008: Do Not Cite or Quote

Process Materials	IPCC Carbon Content* (Metric ton C/Metric ton)
Blast Furnace Gas	0.17
Charcoal[a]	0.91
Coal	0.671
Coal tar	0.62
Coke	0.83
Coke Oven gas	0.47
Coking Coal	0.73
Direct reduced Iron (DRI)	0.02
Dolomite	0.13
EAF Carbon Electrodes	0.822
EAF Charge Carbon	0.833
Fuel Oil	0.864
Gas Coke	0.83
Hot Briquetted iron	0.02
Limestone	0.12
Natural Gas	0.73
Oxygen Steel Furnace Gas	0.35
Petroleum Coke	0.87
Purchased pig Iron	0.04
Scrap Iron	0.04
Steel	0.01

Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance for Direct Emissions form Iron and Steel Production Table 4, EPA February 2008: Do Not Cite or Quote

Carbonate	Mineral name(s)	Emission factor (metric tons CO2/metric ton carbonate)
CaCO3	Calcite or aragonite	0.44
MgCO3	Magnesite	0.52
CaMg(CO3)2	Dolomite	0.48
FeCO3	Siderite	0.38
Ca(Fe,Mg,Mn)(CO3)2	Ankerite	0.41-0.48
MnCO3	Rhodochrosaite	0.38
Na2CO3	Sodium carbonate or soda ash	0.41

EPA February 2008: Do Not Cite or Quote

Summary of GHG Reporting Programs and Protocols for Lead Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Lead production		No protocol given for lead production			
Canada Mandatory GHG Reporting	Lead production	CO2	Phase 1: Consistent with IPCC.	100,000 metric tons CO2e	Facility	NA (activity data records)
Australia National Mandatory GHG Reporting Program	Lead production	CO2	Process emissions from production of lead	Registration and reporting required for corporations if: they control facilities that emit at least 25,000 metric tons of CO2e, or produce or consume at least 100 terajoules of energy; or their corporate group emits at least 125,000 metric tons CO2e, or it produces or consumes at least 500 terajoules of energy.	Facility	NA (activity data records)

Summary of GHG Reporting Programs and Protocols for Lead Production

Reporting Program/Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]						[a] Industry trade groups include: International Lead and Zinc Study Group, International Zinc Association, American Foundry Society, Natural Resources Canada - Minerals and Metals, Non-Ferrous Founders' Society (NFFS), and Centre for Sustainable Resource Processing
Canada Mandatory GHG Reporting	Phase 1: No prescribed estimation methods, but should be consistent with IPCC (prioritize by Tier-method based on emissions levels).	Mandatory	Phase 1: Consistent with IPCC input data needed based on Tier-method selected.	Annual emissions data (in CO2e).	Phase 1: Information should be verifiable. No third party verification required.	C:\GHG Reporting Rule\Review of Existing Rules\Canada\page2.mht
Australia National Mandatory GHG Reporting Program	NGA default method: Based on carbon reductant usage (A), energy content of reductant (EC), and emission factor (EF) for reductant. $E = \sum A * EC * EF / 1000$ (See attached sheet for EC and EF default values.) Higher-order method: Facility-specific emission factors.	Mandatory	NGA default method: Quantity of carbon reductant consumed, and energy content of reductant. Higher-order method: Data needed to develop facility-specific emission factors.	NGA default method: Annual production and amount of carbon reductant consumed. Higher-order method: Annual production, amount of carbon reductant consumed, facility-specific emission factors, and emissions.	QA/QC procedures developed by inventory compiler. Rating system for emission estimation methods and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf

Summary of GHG Reporting Programs and Protocols for Lead Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
IPCC	Lead production (primary and secondary)	CO2	Sintering/ smelting and direct smelting, treatment of secondary raw materials	NA	Tier 1: Source category Tier 2: Source category or facility Tier 3: Facility	NA (activity data records)
US Inventory	Lead production (primary)	CO2	Process emissions from direct smelting	NA	Source category	NA (activity data records)
US Inventory	Lead production (secondary)	CO2	Process emissions from production from lead scrap, recycling lead acid batteries	NA	Source category	NA (activity data records)
NESHAP	Lead production (primary)	HAP	Process sources: sinter machines, blast furnaces, and dross furnaces. Fugitive sources: sinter machine charging and discharging, sinter crushing and sizing, blast furnace tapping, and dross furnace charging and tapping.	Major sources (>25 tons total HAP/yr or >10 tons of single HAP/yr)	Facility	Baghouses, sinter machine exhaust, smelting furnace flue, chimney, or ductworks

Summary of GHG Reporting Programs and Protocols for Lead Production

Reporting Program/Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
IPCC	Tier 1: Production-based emission factors. Tier 2: Production-based emission factors adjusted by material-specific carbon content. (See attached sheet for factors and equations.) Tier 3: Based on direct measurements or plant-specific data for reducing agents and other process materials (method does not contain any details on point and method of monitoring).		Tier 1: Production data. Tier 2: Production data and carbon contect of materials. Tier 3: Facility-specific measurements.	NA, not an industry reporting program	National inventory compiler responsible for QA/QC (Guidance on QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
US Inventory	Emission factor: [0.25 metric tons CO2/ton lead]		National production data. Source: USGS Minerals Yearbook	NA, not an industry reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf
US Inventory	Emission factor: [0.2 metric tons CO2/ton lead]		National production data. Source: USGS Minerals Yearbook	NA, not an industry reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf
NESHAP	Production data must be recorded. (Note that rule contains emission limits in terms of grams lead emitted per Mg lead metal produced. IInitial stack tests for lead emissions and control device (e.g., baghouse) operating parameter monitoring is required, but these are not useful for calculating GHG emissions)	Mandatory compliance	Production records of the weight and lead content of lead products, copper matte, and copper speiss. (Other collected data would not be useful for calculating GHG emissions)	NA, for production, recordkeeping requirement only. Retain production data for 5 years. (Note: semiannual reports are required, but they don't include production data.)		40 CFR Part 63 Subpart TTT

Summary of GHG Reporting Programs and Protocols for Lead Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
NESHAP	Lead production (secondary)	HAP	Smelting furnaces, refining kettles, agglomerating furnaces, dryers, and fugitive dust sources	All sources (major and area)	Facility (furnace or dryer)	Baghouses, afterburner or incinerator exhaust
NSPS	Lead production (primary)	PM, SOx	Sintering machine, sintering machine discharge end, blast furnace, dross reverberatory furnace, electric smelting furnace, and converter.		Facility	Opacity: Blast furnace, dross reverberatory furnace, and sintering machine discharge end. SOx: Sintering machine, electric furnace and converter.
NSPS	Lead production (secondary)	PM	Pot furnaces (refining kettles), blast furnaces, reverberatory furnaces		Facility	Furnace exhausts, baghouse outlets (stacks)

Summary of GHG Reporting Programs and Protocols for Lead Production

Reporting Program/Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
NESHAP	Note that rule contains lead emission concentration limits and total hydrocarbon emission limits for some furnace types. Control device operating parameters, afterburner or incinerator temperature must be monitored. However, these are not useful for GHG emissions calculation.	Mandatory compliance	N/A. Not useful for GHG emission calculation	NA. Required reports are not useful for GHG emission calculation		40 CFR Part 63 Subpart X
NSPS	Note that rule contains PM and SOx emissions concentration limits and requires: A continuous monitoring system to monitor and record opacity. A continuous monitoring system to monitor and record sulfur dioxide emissions. However, these are not useful for GHG calculation.	Mandatory compliance	N/A. Not useful for GHG emission calculation	NA. Required reports are not useful for GHG emission calculation		40 CFR Part 60 Subpart R
NSPS	N/A (Rule requires a PM emission test followed by opacity limits, but no monitoring)	Mandatory compliance	N/A. Not useful for GHG emission calculation	NA. Required reports are not useful for GHG emission calculation		40 CFR Part 60 Subpart L

IPCC Emission Factors and Calculation Methods for Lead

Tier 1. Generic CO2 Emission Factors (ton/ton product)

Imperial Smelt Furnace (ISF) Primary Lead Production	Direct Smelting (DS) Primary Lead Production	Default Primary Lead Emission Factor (80% ISF, 20% DS)	Treatment of Secondary Raw Materials (Secondary Lead Production)
0.59	0.25	0.52	0.2

Tier 2. Calculate CO2 emissions based on the carbon content of the metallurgical coke or other reductant consumed.

$$E_{CO2} = \sum [(M_{tons\ reductant\ consumed}) * (Ccontent_{reductant})] * 44/12$$

Tier 2. Material-Specific Default Carbon Content for Lead Production

Process Material	Carbon Content (kg carbon/kg)
Blast furnace gas	0.17
Charcoal	0.91
Coal	0.67
Coal tar	0.62
Coke	0.83
Coke oven gas	0.47
Coking coal	0.73
EAF carbon electrodes	0.82
EAF charge carbon	0.83
Fuel oil	0.86
Gas coke	0.83
Natural gas	0.73
Petroleum coke	0.87

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
2006 IPCC Guidelines	Lime Production	CO_2	Industrial Processes - process emissions from lime production	N/A	National	N/A	**Tier 1: Product of lime production and emission factor** Emissions = PRODlime x EFlime **Where:** PRODlime = lime production, tons EFlime = lime emission factor, tons CO_2/ton lime Note: can sum emissions across lime type, if data is available (default values provided below). **Default Values:** EFlime: 0.75 tons CO_2/ton lime **Tier 2: Uses production data by lime type and a correction factor for lime kiln dust (LKD) and hydrated lime** Emissions = Σ (PRODlime x EFlime x CFlkd x CFhydr) for each lime type **Where:** PRODlime = lime production, tons EFlime = lime emission factor, tons CO_2/ton lime CFlkd = correction factor for LKD, dimensionless CFhydr = correction factor for hydrated lime, dimensionless **Default Values:** EF: 0.75 (High Calcium Lime), 0.86 (Dolomitic Lime), 0.59 (Hydraulic Lime), tons CO_2/ton lime CFlkd: 1.02, dimensionless CFhydr: 0.97, dimensionless
2006 IPCC Guidelines	Lime Production	CO_2	Industrial Processes - process emissions from lime production	N/A	National	N/A	**Tier 3: Uses plant-specific data for types and quantities of carbonates consumed** Emissions = Σ [(EFcarb x CONScarb x FRcarb) - PRODlkd x C x (1 - FRcalc) x EFuncalc] for each carbonate type **Where:** EFcarb = emission factor for the carbonate type, tons CO_2/ton carbonate CONScarb = consumption of the carbonate type, tons FRcarb = fraction calcination achieved for the carbonate type, fraction PRODlkd = lime kiln dust, tons C = weight fraction of the original carbonate in the LKD, fraction FRcalc = fraction of LKD calcinated EFuncalc = emission factor for the uncalcined carbonate in LKD, tons CO_2/tons carbonate **Default Values:** EFcarb: 0.43971 (calcite/aragonite), 0.52917 (MgCO3), 0.47732 (dolomite), 0.37987 (siderite), 0.40822 - 0.47572 (ankenite), 0.38286 (rhodochrosite), 0.41492 (sodium carbonate/soda ash) tons CO_2/ton carbonate FRcarb: 1.0, fraction FRcalc: 1.0, fraction

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat.	**Tier 1:** National lime production **Tier 2:** National lime production, disaggregated by lime type.	Base year and subsequent annual GHG emissions. A National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers, especially between Tiers 1/2 (a national, top-down approach) and Tiers 3 (a bottom-up approach). Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf
2006 IPCC Guidelines	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat.	**Tier 3:** Plant-level data on carbonate consumption Fraction of calcination achieved LKD production	Base year and subsequent annual GHG emissions. A National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers, especially between Tiers 1/2 (a national, top-down approach) and Tiers 3 (a bottom-up approach). Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
U.S. Inventory of Greenhouse Gas Emissions and Sinks	Lime Production	CO_2	Industrial Processes - process emissions from lime production	N/A	National	N/A	**IPCC Tier 2:** Emissions = Σ (PRODlime x EFlime x CFlkd x CFhydr) for each lime type **Where:** PRODlime = lime production, tons EFlime = lime emission factor, tons CO_2/tons lime CFlkd = correction factor for LKD, dimensionless CFhydr = correction factor for hydrated lime, dimensionless **Default Values:** EF: 0.75 (High Calcium Lime), 0.86 (Dolomitic Lime), 0.59 (Hydraulic Lime) tons CO_2/ton lime CFlkd: 1.02, dimensionless CFhydr: 0.97, dimensionless
WRI/WBCSD Protocol	Lime Production	CO_2	Process	N/A	Corporate/Facility	N/A	**Approach 1: Emissions based on production data** Emissions = Σ {(PRODlime x SR x CaO Content) x [1-(FRhydr x WChydr)] x CFlkd} for each lime type **Where:** PRODlime = lime production of each lime type, in tons SR = Stoichiometric ratio of each lime type, fraction CaO Content = CaO or CaO · Mg) content of each lime type, fraction FRhydr = fraction of hydrated lime in each lime type, fraction WChydr = water content of the hydrated lime in each lime type, fraction CDlkd = correction factor for LKD, dimensionless **Default Values**: FRhydr: 0.1, dimensionless WChydr: 0.28, fraction CFlkd: 1.02, dimensionless SR: 0.785 (High Ca & Hydraulic Lime), 0.913 (Dolomitic Lime), fraction CaO Content: 0.95 (High Ca Lime), 0.95 (Dolomitic Lime), 0.75 (Hydraulic Lime), fraction
WRI/WBCSD Protocol	Lime Production	CO_2	Process	N/A	Corporate/Facility	N/A	**Approach 2: Emissions based on carbonate consumption** Emissions = Σ [(EFcarb x CONScarb x FRcarb) - PRODlkd x C x (1 - FRcalc) x EFuncalc] for each carbonate type **Where:** EFcarb = emission factor for the carbonate type, tons CO2/ton carbonate CONScarb = consumption of the carbonate type, tons FRcarb = fraction calcination achieved for the carbonate type, fraction PRODlkd = lime kiln dust, tons C = weight fraction of the original carbonate in the LKD, fraction FRcalc = fraction of LKD calcinated, fraction EFuncalc = emission factor for the uncalcined carbonate in LKD, tons CO2/tons carbonate **Default Values:** EFcarb: 0.44 (calcite/aragonite), 0.52 (MgCO3), 0.48 (dolomite), 0.38 (siderite), 0.40 - 0.48 (ankenite), 0.38 (rhodochrosite), 0.41 (sodium carbonate/soda ash), tons CO_2/ton carbonate FRcarb = 1.0, fraction FRcalc = 1.0, fraction

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
U.S. Inventory of Greenhouse Gas Emissions and Sinks	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat.	National lime production, disaggregated by lime type	Base year and subsequent annual GHG emissions, as well as activity data.	Comparisons could be made between emissions estimated using different tiers, especially between Tiers 1/2 (a national, top-down approach) and Tiers 3 (a bottom-up approach). Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	U.S. EPA (2008) U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2006. Available online at http://www.epa.gov/climatechange/emissions/usinventoryreport.html
WRI/WBCSD Protocol	Voluntary Reporting	**Approach 1:** Lime production, disaggregated by lime type CaO or CaO · MgO content, disaggregated by lime type, if available Proportion of hydrated lime in each lime type, if available Water content of the hydrated lime in each lime type, if available	N/A	Comparisons could be made between emissions estimated using the two different approaches. Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	http://www.ghgprotocol.org/calculation-tools/lime-sector
WRI/WBCSD Protocol	Voluntary Reporting	**Approach 2:** Plant-level data on carbonate consumption Fraction of calcination achieved LKD production	N/A	Comparisons could be made between emissions estimated using the two different approaches. Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	http://www.ghgprotocol.org/calculation-tools/lime-sector

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
EU ETS 1st Reporting Period	Lime Production	CO_2	Process and combustion	> 50 tons/day of lime production	Facility	N/A	**Calculation Method A: Carbonates** Emissions = Σ [(INPUTcarb - OUTPUTcarb) x EF x CF] for each carbonate type **Where:** INPUTcarb and OUTPUTcarb = the amount of $CaCO_3$, $MgCO_3$, or other alkali earth or alkali carbonates used, tons EF: emission factor, tons CO2/ton carbonate CF: conversion factor to account for C not converted into CO_2, dimensionless **Carbonate Method Tier 1:** Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-5% uncertainty **Carbonate Method Tier 2:** Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-2.5% uncertainty **Default Values:** EF: 0.44 ($CaCO_3$), 0.522 ($MgCO_3$) tons CO_2/ton carbonate CF: 1.0, dimensionless A calculation for other EFs is provided in the notes section A methodology for calculating combustion emissions is provided in Annex II of the EU ETS.
EU ETS 1st Reporting Period	Lime Production	CO_2	Process and combustion	> 50 tons/day of lime production	Facility	N/A	**Calculation Method B: Alkali Earth/Oxides** Emissions = Σ [(OUTPUTalkali - INPUTalkali) x EF x CF] **Where:** OUTPUTalkali and INPUTalkali = the amount of CaO, MgO, or other alkali earth/oxides converted from their respective carbonates, tons EF = emission factor, ton CO_2/ton alkali CF: conversion factor to account for C not converted into CO_2, dimensionless **Alkali Earth/Oxides Method Tier 1:** Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-5% uncertainty **Alkali Earth/Oxides Method Tier 2:** Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-2.5% uncertainty **Default Values:** EF: 0.785 (CaO), 1.092 (MgO) CF: 1.0 A calculation for other EFs is provided in the notes section. A methodology for calculating combustion emissions is provided in Annex II of the EU ETS.

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU ETS 1st Reporting Period	Mandatory Reporting	**Calculation Method A:** Consumption of alkali earth or alkali carbonates	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU ETS 1st Reporting Period	Mandatory Reporting	**Calculation Method B:** Consumption of alkali earth/oxides converted from their respective carbonates	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
EU ETS 2nd Reporting Period	Lime Production	CO_2	Process and combustion	> 50 tons/day of lime production	Facility		**Calculation Method A: Carbonates** Emissions = Σ (INPUTcarb x EF x CF) for each carbonate type **Where:** INPUTcarb = the amount of relevant carbon-bearing kiln inputs (other than fuels), tons EF: emission factor, tons CO2/ton carbonate CF: conversion factor to account for C not converted into CO_2, dimensionless Carbonate Method Tier 1: Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-7.5% uncertainty **Carbonate Method Tier 2:** Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-5% uncertainty **Carbonate Method Tier 1:** Activity data: Amount of pure carbonates in process input and output are metered with maximum permissible uncertainty of less than +-2.5% uncertainty **Default Values:** EF: 0.440 (CaCO3), 0.522 (MgCO3), tons CO_2/ton carbonate CF: 1.0 (Tier 1), 0 ≤ CF ≤ 1 (Tier 2), dimensionless A methodology for calculating combustion emissions is provided in Annex II of the EU ETS.
EU ETS 2nd Reporting Period	Lime Production	CO_2	Process and combustion	> 50 tons/day of lime production	Facility		**Calculation Method B: Alkali Earth/Oxides** Emissions = Σ (OUTPUTalkali x EF x CF) for each alkali type **Where:** OUTPUTalkali = the amount of CaO, MgO, or other alkali earth/oxides produced, tons EF = emission factor, tons CO2/ton alkali CF: conversion factor to account for C not converted into CO_2, dimensionless **Alkali Earth/Oxides Method Tier 1:** Activity data: Amount of alkali earth/oxidess in process output are metered with maximum permissible uncertainty of less than +-5% uncertainty **Alkali Earth/Oxides Method Tier 2:** Activity data: Amount of alkali earth/oxides in process output are metered with maximum permissible uncertainty of less than +-2.5% uncertainty **Default Values:** EF: 0.785 (CaO), 1.092 (MgO) tons CO_2/ton alkali CF: 1.0 (Tier 1), 0 ≤ CF ≤ 1 (Tier 2), dimensionless A methodology for calculating combustion emissions is provided in Annex II of the EU ETS.

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU ETS 2nd Reporting Period	Mandatory Reporting	**Calculation Method A:** Consumption of carbon-bearing kiln inputs (e.g., chalk or limestone)	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	Third party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF
EU ETS 2nd Reporting Period	Mandatory Reporting	**Calculation Method B:** Consumption of alkali earth/oxides (i.e., lime)	Emissions Chosen tiers and methods Activity data Emission factor(s) Conversion factor(s)	Third party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Lime Production	CO_2	Direct Process	3% of a facility's total CO_2-equivalent emissions can be considered deminimis	Facility		**Approach 1: Mass Balance Based on Carbonate Inputs:** Emissions = SUM [(EFcarb x CONScarb x FRcarb) - PRODlkd x C x (1 - FRcalc) x EFuncalc] for each carbonate type **Where:** EFcarb = emission factor for the carbonate type, tons CO2/ton carbonate CONScarb = consumption of the carbonate type, tons FRcarb = fraction calcination achieved for the carbonate type, fraction PRODlkd = lime kiln dust, tons C = weight fraction of the original carbonate in the lime kiln dust (LKD), fraction FRcalc = fraction of LKD calcinated, fraction EFuncalc = emission factor for the uncalcined carbonate in LKD, tons CO2/ton carbonate **Default Values:** EFcarbs: 0.43971 (calcite/aragonite), 0.52917 (MgCO3), 0.47732 (dolomite), 0.37987 (siderite), 0.40822 - 0.47572 (ankenite), 0.38286 (rhodochrosite), 0.41492 (sodium carbonate/soda ash), tons CO_2/ton carbonate FRcarb = 1.0, fraction FRcalc = 1.0, fraction **Approach 2: Mass Balance Based on Production:** Emissions = SUM [PRODlime x EFlime x CFlkd x CFhydr] for each lime type **Where:** PRODlime = lime production, tons EFlime = lime emission factor, tons CO2/ton lime CFlkd = correction factor for LKD, dimensionless CFhydr = correction factor for hydrated lime, dimensionless **Default Values:** CFlkd: 1.02, dimensionless CFhydr: 0.97, dimensionless EF: 0.75 (High Calcium Lime), 0.86 (Dolomitic Lime), 0.59 (Hydraulic Lime), tons CO_2/ton lime

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Voluntary	**Approach 1:** Plant-level data on carbonate consumption Fraction of calcination achieved LKD production **Approach 2:** National lime production data by type	Annual GHG emissions (CO_2 equivalents), including the base year Activity and throughput data for each facility. Whether or not the entity is participating as a transitional reporter The consolidation approach(es) employed (i.e., operational control, financial control, equity share) Estimation methodology Recalculations discussion Detailed description of each facility and its emission sources	Independent third-party verification system	http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Lime Production	CO_2	Industrial Process - process emissions from lime production	All (no deminimis)	Corporate/Facility	N/A	**"A" Rated Estimate: Uses measured, site-specific values** Emissions = Σ { PRODlime x [(CONTcao x SRcao) + (CONTmg x SRmg)] } for each lime type **Where:** PRODlime = lime production for each lime type, tons CONTcao = CaO content of lime for each lime type, % by mass SRcao = stoichiometric weight ratio of CO_2 to CaO, dimensionless CONTmg = MgO content of lime for each lime type, % by mass SRmg = stoichiometric weigh ratio of CO_2 to MgO, dimensionless **Default Values:** SRcao: 0.7848 SRmg: 1.0918 **"B" Rated Estimate: Mass balance equation** Emissions = Σ (PRODlime x EF) for each lime type **Where:** PRODlime = lime production for each lime type, tons EF = lime emission factor for each lime type, tons CO_2/ton lime **Default Values:** EF: 0.75 (High Ca), 0.86 (Dolomitic), 0.59 (Hydraulic) EF: Emission Factor EX: Exports PROD: Production FR: Fraction CF: Consumption Factor CONS: Consumption IM: Imports SR: Stoichiometric Ratio

Review of Existing Programs Relevant to Source - Lime Manufacturing

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Voluntary	**"A" Rated Estimate:** CaO content of lime (as a percent by mass in tons), disaggregated by lime type MgO content of lime (as a percent by mass in tons), disaggregated by lime type Lime production, , disaggregated by lime type **"B" Rated Estimate:** Lime production, disaggregated by lime type	Annual direct and indirect emissions, minus any sequestration of GHGs Average emissions rating reflecting the methodology used, with "A" being the most certain and "B" being the least certain Organization boundaries Methodology	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Pages 2-32 (Reporting Guidelines), Pages 102-104 (Lime production) http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf and 10 CFR 300 (p 106 and 114) at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf

Notes on GHG Calculation Methods and Procedures for Lime

Note 1. EU ETS 1st Reporting Period, Calculation Method A. Used to calcluate EF from other carbon-bearing non-fuels.

In General:	Emission Factor (EF) =	Where:
$X_y(CO_3)_z$	$[M_{CO2}] / \{Y * [M_x] + Z * [M_{CO3\ 2-}]\}$	X = alkali earth or alkali metal M_x = molecular weight of X in [g/mol] M_{CO2} = molecular weight of CO2 = 44 [g/mol} M_{CO3-} = molecular weight of CO_3^{2-} = 60 [g/mol] Y = stoichiometric number of X = 1 (for alkali earth metals) = 2 (for alkali metals) Z = stoichiometric number of CO_3^{2-} = 1

Source: Official Journal of the European Union, Commission Decision of 29 January 2004, available online at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Note 2. EU ETS 1st Reporting Period, Calculation Method B. Used to calcluate EF from other carbon-bearing non-fuels.

In General:	Emission Factor (EF) =	Where:
$X_y(CO_3)_z$	$[M_{CO2}] / \{Y * [M_x] + Z * [M_{CO3\ 2-}]\}$	X = alkali earth or alkali metal M_x = molecular weight of X in [g/mol] M_{CO2} = molecular weight of CO2 = 44 [g/mol} M_{CO3-} = molecular weight of CO_3^{2-} = 60 [g/mol] Y = stoichiometric number of X = 1 (for alkali earth metals) = 2 (for alkali metals) Z = stoichiometric number of CO_3^{2-} = 1

Source: Official Journal of the European Union, Commission Decision of 29 January 2004, available online at http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF

Review of Existing Programs Relevant to Source - Magnesium Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Magnesium Production	SF6, CO2, HFC-134a, fluoronated ketone (FK), byproducts	Magnesium production processes	NA	National	
Department of Energy 1605(b) Voluntary Reporting Program	Magnesium Production	SF6	Magnesium production processes	All (no deminimis)	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company")	
Magnesium Partnership	Magnesium Production	SF6	Magnesium production processes	All (no deminimis)	Entity level	

Review of Existing Programs Relevant to Source - Magnesium Production

Reporting Program/Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)		
2006 IPCC Guidelines	CO2 Emissions are estimated as follows: **Tier 1:** Product of emission factor and production (dolomite & magnesite) EC2O = (Pd*EFd + Pmg*EFmg)*10^-3 Where: EC2O = C2O emissions, Gg EFd,mg = C2O emission factor (default), 5.13d & 2.83mg ton C2O/ton magnesium produced Pd,mg = magnesium production, ton **Tier 2:** Product of emission factor and production EC2O = Sum(Pi*EFi)*10^-3 Where: EC2O = C2O emissions, Gg EFi = plant specific C2O emission factor (default), ton C2O/ton magnesium produced Pi = plant specific magnesium production, ton **Tier 3:** Monitored plant level CO2 emissions from primary magnesium facilities that are then aggregated.	SF6 Emissions are estimated as follows: **Tier 1:** Product of emission factor and production (dolomite + magnesite) ESF6 = MGc*EFsf6*10^-3 Where: Esf6 = SF6 emissions, ton EFsf6 = SF6 emission factor (default), 1 kg SF6/ton magnesium produced MGc = magnesium casting or handling in the country, tons **Tier 2: Consumption** Esf6 = Csf6 Where: Esf6 = SF6 emissions, tons Csf6 = consumption of SF6, tons **Tier 3:** Monitored plant level SF6 emissions from primary magnesium facilities that are then aggregated.	HFC-134a, FK, byproduct emissions are estimated as follows: **Tier 3:** Monitored plant level HFC-134a, FK, and byproduct emissions from primary magnesium facilities that are then aggregated.
Department of Energy 1605(b) Voluntary Reporting Program	**"A" rated approach:** Use purchase data at corporate level to determine consumption, which equals emissions. **"B" rated approach:** Use activity data of magnesium production with a default emissions factor. Default emission factors are provided in (kg SF6/ MT Mg) and are in Magnesium Note 1.		
Magnesium Partnership	Entity magnesium production and SF6 consumption data		

Review of Existing Programs Relevant to Source - Magnesium Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)		
2006 IPCC Guidelines	Mandatory	CO2 Emissions: **Tier 1:** national production of magnesium. **Tier 2:** Plant-level magnesium production and CO2 emission rate **Tier 3:** Measured CO2 emissions	SF6 Emissions: **Tier 1:** National production of magnesium. **Tier 2:** Plant-level SF6 consumption data **Tier 3:** Measured SF6 emissions	HFC-134a, FK, byproduct emissions are estimated as follows: **Tier 3:** Measured plant level HFC-134a, FK, and byproduct emissions
Department of Energy 1605(b) Voluntary Reporting Program	Voluntary	**"A" rated approach:** Purchase data on SF6. **"B" rated approach:** Production data on magnesium (as ton per time period) and default emission factors from the US Inventory		
Magnesium Partnership	Voluntary	Entity magnesium production and SF6 consumption data		

Review of Existing Programs Relevant to Source - Magnesium Production

Reporting Program/Guidance	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements. To improve transparency, it is good practice to report emissions estimates from the magnesium source category separately by industry segments such as primary production, secondary production and casting. Additional information can be provided based on the direct reporting or national cover gas sales-based estimate of potential emissions.	It is good practice to conduct quality control checks as outlined in Volume 1, Chapter 6 of the IPCC Guidelines and an expert review of the emissions estimates. Additional quality control checks, as outlined in Volume 1, Chapter 6, and quality assurance procedures may also be applicable, particularly for higher tier methods. Inventory compilers are encouraged to use higher tier QA/QC for key categories as identified in Volume 1, Chapter 4 of the IPCC Guidelines. Additional procedures specific to magnesium production are: Comparison of emissions estimates using different approaches Review of plant-level data Review of national activity data Assessment of emission factors Peer review Verification of SF6 emissions data	Section 4.5 of http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf
Department of Energy 1605(b) Voluntary Reporting Program	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Section 1.E.4.4.5 of http://www.pi.energy.gov/enhancingGHGregistry/technicalguidelines.html, and 10 CFR 300 (p 106 and 114) at http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf
Magnesium Partnership	Annual report is filed with the Program that reports magnesium production and SF6 consumption data. In some instances the Partner also reports cylinder tracking data to verify SF6 consumption (not required)	Partner data is recorded and examined for accuracy as part of the annual reporting process. This effort includes a comparison with historical data, SF6 emission rate, and comparison with other entities in the same production category (e.g., die casting).	Partnership MOU: http://www.epa.gov/magnesium-sf6/join/index.html

Note 1. Emission factors for magnesium production, used in a "B" rated estimate are as follows. The units are kg SF6 per metric ton Mg produced.
Secondary Production 1.0
Die Casting 0.74
Die Casting (small parts) 5.2
Gravity Casting 2
Wrought Products 1
Anodes 1

2006 IPCC Guidelines

Tier 1 CO2 tonnes of CO2 emissions per tonne of primary Mg produced
Dolomite Produciton 5.13
Magnesitie Production 2.83

Tier 1 SF6 kg SF6 per tonne Mg casting
All casting processes 1.0

Nitric Acid Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006	Nitric Acid Production	N2O	Industrial Process - process emissions from nitric acid production	N/A	National		**IPCC 2006 Tier 1 Methodology:** The emission factor was determined as a weighted average of 2 kg N2O / metric ton HNO3 for plants 28 using non-selective catalytic reduction (NSCR) systems and 9 kg N2O/metric ton HNO3 for plants not equipped with NSCR (IPCC 2006). In the process of destroying NOx, NSCR systems destroy 80 to 90 percent of the N2O, which is accounted for in the emission factor of 2 kg N2O/metric ton HNO3. An estimated 20 percent of HNO3 plants in the United States are equipped with NSCR (Choe et al. 1993). Hence, the emission factor is equal to (9 × 0.80) + (2 × 0.20) = 7.6 kg N2O per metric ton HNO3. Emissions are calculated by multiplying this emission factory by national production of nitric acid.	Meet the reporting requirements for Parties to the UNFCCC
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Nitric Acid Production	N2O	Industrial Process - process emissions from nitric acid production	N/A	Entity-level. (for lower levels of aggregation than an entire corporation, the reporting entity must "have a legal basis and must be defined in a way that is consistent with the management structure of the parent company") (Page 18, Federal Register document)	"A" rated method: continuous emissions monitoring at plant-level. Details on CEM at nitric plants are not provided; see note 1 in the notes sheet for general guidance on direct measurement.	**"A" rated approach - Continuous emission monitoring (CEM):** CEM accounting for emissions from confined and uncontrolled streams. If pollutant information is not available for uncontrolled streams, monitoring of confined streams only is acceptable. If CEM is not possible, emissions can be estimated using an emission factor based on direct, periodic measurements of plant emissions. Emission factors must account for emission rates and abatement system efficacy and frequency of use of abatement technologies. Details on CEM at nitric plants are not provided; see note 1 in the notes sheet for general guidance on direct measurement. **"B" rated approach - product of IPCC default emission factors and production:** If plant-level emission information is not available, IPCC 2000 default emission factors are used. **"C" rated approach - product of other emission factors and production:** Estimates based on, "...other published default values."	Voluntary reporting.

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2006	Nitric Acid Production	National nitric acid production. Nitric acid production data for 1990 through 2004 was obtained from the U.S. Census Bureau, Current Industrial Reports (2006) and for 2005 through 2006, from the U.S. Census Bureau, Current Industrial Reports (2007).	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	The overall uncertainty associated with the 2006 N2O emissions estimate from nitric acid production was calculated using the IPCC 2006 Tier 2 methodology.	http://epa.gov/climatechange/emissions/downloads/08_Industrial.pdf
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Nitric Acid Production	**"A" rated approach:** Continuous emission monitoring data, or Direct, periodic measurement data to establish emission rate; abatement system utilization factor; abatement system efficacy factor. **"B" rated approach:** IPCC 2000 default emission factors; nitric acid production. **"C" rated approach:** Undefined.	Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and sub entity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf; Federal Register Document http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf (Pages 18, 106, 107)

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Nitric Acid Production	N2O	Industrial Process - process emissions from nitric acid production	N/A	National		Emissions are estimated as follows: **Tier 1: Product of emission factor and production** EN2O = EF * NAP Where: EN2O = N2O emissions, kg EF = N2O emission factor (default), kg N2O/tonne nitric acid produced NAP = nitric acid production, tonnes Notes: When applying the Tier 1 method, assume no abatement of N2O emissions and use the highest default emission factor based on technology type (default emission factors presented below).	Meet the reporting requirements for Parties to the UNFCCC
2006 IPCC Guidelines	Nitric Acid Production	N2O	Industrial Process - process emissions from nitric acid production	N/A	National		**Tier 2: Uses plant-level production data disaggregated by technology type and default emission factors classified by technology type. Emissions are calculated as follows:** EN2O = SUM[(EFi * NAPi *(1-DFj * ASUFj)] Where: EN2O = emissions of N2O, kg EFi = N2O emission factor for technology type i, kg N2O/tonne nitric acid produced NAPi = nitric acid production from technology type i, tonnes DFj = destruction factor for abatement technology type j, fraction ASUFj = abatement system utilization factor for abatement technology type j, fraction Default emission factors presented below.	

Nitric Acid Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Nitric Acid Production	**Tier 1:** national production of nitric acid.	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	See Note 3.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf
2006 IPCC Guidelines	Nitric Acid Production	**Tier 2**: plant-level production data disaggregated by technology type and abatement system type.	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	See Note 3.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Nitric Acid Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Nitric Acid Production	N2O	Industrial Process - process emissions from nitric acid production	N/A	National		**Tier 3: Plant-level production data is disaggregated by technology type and plant level emission factors that are obtained from direct measurement of emissions. These may be derived from irregular sampling of emissions of N2O or periodic emissions monitoring of N2O undertaken over a period(s) that reflects the usual pattern of operation of the plant**. **IPCC 2006 default emission factors by production process (for Tier 1/2 methods):** (1) Plants with Non-Selective Catalytic Reduction (NSCR): 2 kg N2O/tonne nitric acid ±10% (2) Plants with process-integrated or tailgas N2O destruction: 2.5 kg N2O/tonne nitric acid ±10% (3) Atmospheric pressure plants (low pressure): 5 kg N2O/tonne nitric acid ±10% (4) Medium pressure combustion plants: 7 kg N2O/tonne nitric acid ±20% (5) High pressure plants: 9 kg N2O/tonne nitric acid ±40%	

Nitric Acid Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Nitric Acid Production	**Tier 3**: plant-level production data disaggregated by technology and abatement system; however, production data are not used to estimate emissions where continuous emissions monitoring (CEM) data are available.	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	See Note 3.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
WRI/WBCSD Protocol	Nitric Acid Production	N2O	Industrial process emissions from nitric acid production	N/A	Corporate/Facility		**Approach 1: Direct monitoring of N2O emissions.** Precise direct monitoring of N2O emissions requires measurement of both the exit stream and the uncontrolled stream. However, data quality is satisfactory even where measurement data are available only for the exit stream. **Approach 2: Using N2O site-specific emissions factors.** N2O Emissions = nitric acid production x N2O emissions factor x (1 – (N2O destruction factor x abatement technology use factor)) **Approach 3: Using N2O default emissions factors.** N2O Emissions = nitric acid production x N2O emissions factor x (1 – (N2O destruction factor x abatement technology use factor)) Default emission factors by production process are from IPCC 2006 (Volume 3, Chapter 3.3)	Voluntary reporting.
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Nitric Acid Production	N2O	Direct Process	3% of total emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries.	Facility-level		**Tier A1:** Direct measurement. **Tier A2:** Mass balance approach based on plant-specific factors for destruction and utilization factors for an abatement technology and N2O emission factor based on direct measurements. **Tier B:** **Mass balance based on default N2O Emission factor by technology type.** Mass balance based on WRI/WBCSD, Calculating N2O Emissions from the Production of Nitric Acid, 2001, (Consistent with IPCC 2006 Equation 3.6: N2O Emissions from Nitric Acid Production, Tier 2) Default Emission Factors from IPCC 2006, Table 3.3	Voluntary reporting.

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
WRI/WBCSD Protocol	Nitric Acid Production	**Approach 2/3:** (1) Quantity of nitric acid produced (metric tonnes) (2) If default emission factor is not used, need data on the destruction efficiency of any abatement system used as well as abatement system utilization factor.	N/A	See Note 2.	http://www.ghgprotocol.org/calculation-tools/sector-toolsets
The Climate Registry (General Reporting Protocol For the Voluntary Reporting Program, Draft of October 29, 2007)	Nitric Acid Production	Quantity of nitric acid produced (metric tonnes) and data on the destruction efficiency of any abatement system used as well as abatement system utilization factor.	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	Page 39 (Reporting Requirements), Page 118 (PFC Emissions from Aluminum Production) http://www.theclimateregistry.org/downloads/Draft_GRP.pdf

Nitric Acid Manufacturing

Note 1. Direct measurement methods

Continuous emission monitoring (CEM) is one method of direct measurement. CEM requires inserting a probe into the exhaust stack of an industrial process system, and continuously measuring and recording concentrations of gases that flow through the exhaust pipe.

Emissions can also be estimated through periodic direct measurements. Like CEM, periodic measurements directly measure emissions passing through exhaust streams. As the name implies, though, periodic measurements only provide samples of the exhaust stream at particular points in time. The data gathered from these measurements are used in conjunction with estimates of exhaust flow rates and other activity data to extrapolate to total emissions over a given period of time. Since periodic measurements yield a sample of total emissions, any difference in the quality of data with the CEM approach will depend upon the information available about the emissions profile. If exhaust flow rates are well known, as might be the case for a plant that operates at the same level continuously, there may be very little difference in emissions estimates from the two methods. For a plant whose output varies over time, producing a data set from periodic measures whose accuracy compares with that from CEM measurements can be challenging.

To ensure consistency and reliability, reporters using any direct measurement data should ensure that their measurement systems are subject to periodic calibration practices.

Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems.

In the absence of industry-specific standard methods, reporters should follow internationally accepted, generalized standard methods for managing and calibrating measurement systems.

Reporters seeking general guidance on methods for managing and calibrating measurement systems should consult the ISO's guidance document, ISO 10012 - Measurement Management Systems - Requirements for Measurement Processes and Measuring Equipment. Available at website: http://www.iso.ch.

Note 2: WRI/SBCSD QA/QC Procedures

1. Emissions comparisons:

Compare the emissions data obtained with emissions data calculated for the same facility in previous years. A calculation error is probable if differences between current data and data from previous years cannot be explained by changes in activity levels or changes in production technologies employed.

2. Order of magnitude checks:

If you have used Approaches 1 or 2 to calculate your emissions, you can employ the method proposed in Approach 3 to check whether your results are in the correct range.

Note 3: 2006 IPCC Guidelines QA/QC

If emissions are calculated using data from individual nitric acid plants (Tier 2/3 bottom-up approach), estimates are compared to emissions calculated using national production data (top-down approach). Results should be recorded and unexplained discrepancies investigated.

Where plant-level data is used, an independent review of the time series of emissions beginning in the base year, and an explanation of trends in emissions when making historical comparisons is necessary. Also, confirm that internationally recognized, standard methods were used. compare plant-based factors to the IPCC defaults to ensure that the plant-specific factors are reasonable. Explain and document any differences between plant-specific factors and default factors, particularly any differences in plant characteristics that might lead to these differences.

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
New Mexico GHG Mandatory Emissions Inventory	Petroleum refineries	CO_2 reporting starts 2008, CH_4 reporting starts 2010, future climate change reporting procedures are currently being written	Fugitive Emissions	25,000 metric tons	Facility (e.g. gas processing facilities) and/or equipment level (e.g. dehydrator vents)	Equipment discharges (e.g. valves, pump seals, connectors, and flanges)	2009 reporting procedures will be made available in 10/2008	Mandatory
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Gas - Processing	CH_4, non-combustion CO_2	Vented	None	Equipment-level	Equipment discharges (e.g. valves, open-ended lines, vent stacks)	Tier III (IPCC) - equipment emissions rates for intentional fugitives: - Glycol Dehydrator - Glycol Pumps - Acid Gas Removal - Sour Gas Processing	Guideline
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil - Refinery Processes	CH_4, non-combustion CO_2	Vented	None	Equipment-level	Vent stacks for equipment types	Tier III (IPCC) - process level emissions rates for: - FCC Regeneration - Cokers - Other catalyst regeneration - Asphalt blowing - Other refinery process vents	Guideline
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Storage	CH_4	Vented	None	Equipment-level	Tank PRV/vents	Tier III (IPCC) - tank level emissions rates for: - Flashing Losses - Tanks working/standing losses - Produced water tanks - Natural gas blanketed tanks	Guideline
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Petroleum Products - Loading, ballasting, and transit	CH_4	Vented	None	Process-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier III (IPCC) - process level emissions rates for: - Loading losses - Ballasting - Transit	Guideline
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas	CH_4	Vented	None	Process/Equipment-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier III (IPCC) - process/equipment level emissions rates for: - Gas driven pneumatic devices - Gas driven chemical injection pumps - Exploratory drilling and well testing - Casing Gas	Guideline
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Non-routine	CH_4	Vented	None	Process/Equipment-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier III (IPCC) - process/equipment level (BY SECTOR) emissions rates for: - Vessel blowdowns - Compressors starts, blowdowns - well workovers, cleanups - pipeline blowdowns - pressure relief valves - pipeline mishaps - well blowouts - ESD - Station blowdowns Tier II (IPCC) - facility level emissions rates for: - Gas processing plants non-routine discharges	Guideline

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
New Mexico GHG Mandatory Emissions Inventory	Petroleum refineries	Not available	Not available	Not available	http://www.nmenv.state.nm.us/aqb/ghg/ghgrr_index.html; http://www.nmenv.state.nm.us/aqb/ghg/documents/Title_V_Notice_of_ghg_reqmts.pdf; http://www.nmenv.state.nm.us/aqb/ghg/documents/NM_GHGEI_quantif_proced2008.pdf
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Gas - Processing	Process/equipment throughputs	Not applicable	Not applicable	Chapter 5.1
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil - Refinery Processes	Process/equipment throughputs and feed compositions	Not applicable	Not applicable	Chapter 5.2
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Storage	Process/equipment throughputs and feed compositions, temperatures, and pressures	Not applicable	Not applicable	Chapter 5.4
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Petroleum Products - Loading, ballasting, and transit	Process/equipment throughputs and feed compositions	Not applicable	Not applicable	Chapter 5.5
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas	Equipment counts/activity frequency	Not applicable	Not applicable	Chapter 5.6
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Non-routine	Equipment counts, facility counts	Not applicable	Not applicable	Chapter 5.7

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Equipment Leaks	CH_4, non-combustion CO_2	Fugitives	None	Facility-level	Facility input	Tier II (IPCC) - facility level emissions rates for: - Onshore gas production - Offshore gas production - Onshore oil production - Offshore oil production - Gas processing plants - Gas storage stations - Gas transmission pipelines - Crude transportation pipelines - Gas distribution pipelines - Refineries	Guideline
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Equipment Leaks	CH_4, non-combustion CO_2	Fugitives	None	Equipment-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier III (IPCC) - equipment emissions rates for leaks from: - Wellheads - Separators - Heater Treaters - Tanks - Compressors - Heaters - Dehydrators - Pipelines - Meters - Anaerobic water treating - Biotreaters	Guideline
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	CH_4	Vented	None	Sector-level	Sector-level counts	Tier I (IPCC)- sector level emissions rates from intentional releases for: - Transmission - Storage	Guideline
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	CH_4	Vented	None	Equipment-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier II or III (IPCC)- equipment level emissions rates for intentional releases from: - Glycol dehydrators - Pneumatic devices - Other control devices - Gas-powered pumps - Blowdown/Maintenance Engineering calculation methodologies for: - Pig traps - Overhauls - Flaring	Guideline
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	CH_4, non-combustion CO_2	Fugitives	None	Sector-level	Sector capacities	Tier 1 (IPCC)- sector level emissions rates for unintentional leaks for: - Transmission - Storage	Guideline

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Equipment Leaks	Facility throughput, facility count, and pipeline mile	Not applicable	Not applicable	Chapter 6.1
API - Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry	Oil and Gas - Equipment Leaks	Equipment counts	Not applicable	Not applicable	Chapter 6.2, 6.3
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	Asset miles and storage station counts	Not applicable	Not applicable	Chapter 3.1, Table 3-1, page 39
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	Equipment counts or throughputs	Not applicable	Not applicable	Chapters 3.2 - 3.5
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	Asset miles and storage station counts	Not applicable	Not applicable	Chapter 4.3.1, Table 4-2, page 58

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	CH_4, non-combustion CO_2	Fugitives	None	Facility-level	Facility counts and capacities	Tier II (IPCC) - facility level emissions rates for unintentional leaks from: - Transmission compressor stations - Transmission M&R stations - Transmission pipeline - Storage reciprocating compressors - Storage centrifugal compressors - Storage stations	Guideline
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	CH_4, non-combustion CO_2	Fugitives	None	Equipment-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier III (IPCC) - equipment level emissions rates for unintentional leaks from: - Transmission compressor stations - Reciprocating compressors - Centrifugal compressors - Transmission M&R stations - Transmission interconnects - 4 types of pipeline - Storage stations - Storage well counts - Gathering pipeline	Guideline
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	CH_4, non-combustion CO_2	Fugitives	None	Equipment-level	Equipment discharges (i.e. valves, open-ended lines, vent stacks)	Tier III+ (IPCC)- equipment level emissions rates for unintentional leaks from: - Connectors - Valves - Regulators - Meters - Blowdown systems - Open-ended lines - Controllers - Compressor seals	Guideline

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	Pipeline miles, and station counts	Not applicable	Not applicable	Chapter 4.3.2, Table 4-3, page 59
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	Pipeline miles, and station counts, equipment cour	Not applicable	Not applicable	Chapter 4.3.3, Table 4-4, pages 61-62
INGAA - Greenhouse Gas Emissions Estimation Guidelines for Natural Gas Transmission and Storage, Volume 1	Gas - Transmission/Storage	Equipment counts	Not applicable	Not applicable	Chapter 4.4

Fugitives Natural Gas and Oil Systems

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
World Resources Institute/ World Business Council for Sustainable Development GHG Protocol Corporate Standard, Revised Edition 2003	Organizations with operations that result in greenhouse gas (GHG) emissions e.g. corporations (primarily) , universities, NGOs, and governement agencies. This includes the oil and gas industry	CH_4, CO_2 and other GHG gases	**Scope 1** emissions which includes direct emissions i.e. fugitive emissions (e.g. leaks from pressurized equipment, CH_4 leaks from transmission and storage facilities) and process emissions (e.g. process vents, maintenance), and **Scope 3** emissions which includes indirect emissions i.e. process emissions (product used as feedstock or emissions from the production of purchased materials) and fugitive emissions (CH4 and CO2 from waste landfills or from the production of purchased materials), as defined by the protocol. (Scope 2 covers emissions from stationary combustion (consumption of purchased electricity, heat, or steam))	No de minimis	Facility and/or equipment/ process unit emissions	All activities resulting in direct and indirect emission of GHG gases for the corporation or organisation	Companies need to choose a base year for which verifiable emissions data are available and specify their reasons for choosing the year. "The base year emissions is used as an historic datum against which the company's emissions are tracked over time. Emissions in the base year should be recalculated to reflect a change in the structure of the company, or to reflect a change in the accounting methodology used. This ensures data consistency over time." Direct measurement of GHG emissions by monitoring concentration and flow rate can be conducted. Calculation-based methodologies for estimating emissions involve the calculation of emissions based on activity data and emission factors	Guideline
California Climate Action Registry General Reporting Protocol, March 2007	All legal entities (e.g. corporations, institutions, and organisations) registered in California, including oil and gas systems	CH_4, CO_2 and other GHG gases	All direct and indirect fugitive greenhouse gas (GHG) emissions from all facilities in California (U.S. optional)	No de minimis	Facility and/or equipment/ process unit emissions	All activities resulting in indirect and direct emission of GHG gases for the entity	The CCAR does not specify methodology to calculate fugitive emissions however it provides the following references for use in making fugitive calculations: WRI/WBCSD Corporate GHG Accounting Tools (2004); Guidelines for Measurement and Reporting of Emissions in the UK by DEFRA (2001); U.S. EPA Climate Leaders Inventory Protocol, U.S. (2002); Guidance to the CCAR, General Reporting Protocol, Appendix B and C (includes guidance on direct fugitive emission calculations from the coal, oil, and gas industry, 2002); API Compendium of GHG Estimations Methodologies for the Oil and Gas Industry (2001); Inventory of California GHG Emissions and Sinks: 1990-2000 (2002); and Inventory of U.S. GHG Emissions and Sinks: 1990-2000 (2002), U.S. EPA	Voluntary
2006 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 2, Chapter 4	Oil and Gas Industry Systems	CH_4, CO_2 and other GHG gases	Report fugitive emissions from oil and gas sectors (e.g. production, processing)	No de minimis	Oil and gas industry segment emissions (e.g. sweet gas plants, sour gas plants)	All activities resulting in CH_4 and CO_2 fugitive emissions for oil and gas systems (e.g. venting, flaring)	Companies need to choose a base year for which verifiable emissions data are available. The base year emissions is used as an historic control against which the company's emissions are tracked over time. This ensures data consistency over time. Direct measurement of GHG emissions by monitoring concentration and flow rate can also be conducted. "**Tier 1** calculation-based methodologies for estimating emissions involve the calculation of emissions based on activity data and default industry segment emission factors"	Guideline

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
World Resources Institute/ World Business Council for Sustainable Development GHG Protocol Corporate Standard, Revised Edition 2003	Organizations with operations that result in greenhouse gas (GHG) emissions e.g. corporations (primarily) , universities, NGOs, and governement agencies. This includes the oil and gas industry	Emission factors used for the calculations may be published or default factors, based on company specific data, site-specific data, or direct emission or other measurements. Activity data (e.g. fuel consumption, input material flow, or product output). To ensure the collection of high quality activity data, chapter 7 provides measures for the establishment of a robust data collection system	Records of methods, data (e.g. activity factors), processes, systems, assumptions, and estimates should be documented. The report should include an outline of the operational and organizational boundaries chosen, and if scope 3 is included, a list specifying which types of activities are covered; reporting for each scope and GHG gas separately; reporting period; chosen base year and emissions profile over a time period to clarify the chosen policy for making base year emissions recalculations; and any chosen exclusions of sources or facilities	Rigorous quality checks on data handling, documentation and calculations based upon IPCC QAQC guidelines which includes uncertainty analysis Third party verification required	http://www.ghgprotocol.org/standards
California Climate Action Registry General Reporting Protocol, March 2007	All legal entities (e.g. corporations, institutions, and organisations) registered in California, including oil and gas systems	Depends on the calculation method utilised from the references provided	The report should **at least** include: an outline of the operational and organizational boundaries chosen; reporting period; chosen base year and emissions profile over a time period (if participant chooses to define a baseline); and total significant direct and indirect (from electricity usage, co-generation, steam imports, district heating, and cooling) GHG emissions. Emissions represented by sources and gases which are less than 5% of the entity's total annual GHG emissions (de minimis sources) can be excluded from the inventory	Certified/verified by an independent third -party organisation that has been approved by the state of California and the Registry	http://www.climateregistry.org/PROTOCOLS/
2006 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 2, Chapter 4	Oil and Gas Industry Systems	Emission factors used for the **Tier 1** calculations are appropriate default emission factors for each "applicable segment or subcategory of a country's oil and gas industry and are only used for non-key sources" (2006 IPCC Guidelines for National GHG Inventories, Section 4.2.2.2). Activity data (e.g. fuel consumption, input material flow, or product output). To ensure the collection of high quality activity data, chapter 7 provides measures for the establishment of a robust data collection system	Base year and annual GHG emissions estimates. Summaries of the methods used, references to all source data should be included for transparency, reported analysis should show trend analysis, activity data and emission intensities (i.e. average emissions per unit of activity indicator) over time, expected accuracy of the results and areas of greatest uncertainty should be noted	QAQC conducted according to Volume 1, Chapter 6 of the IPCC Guidelines which requires the calculations of uncertainty at the source category level that are then combined to summary levels for the entire inventory	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm

Fugitives Natural Gas and Oil Systems

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 2, Chapter 4	Oil and Gas Industry Systems	CH_4, CO_2 and other GHG gases	Report fugitive emissions from oil and gas sectors (e.g. production, processing)	No de minimis	Oil and gas industry segment emissions (e.g. sweet gas plants, sour gas plants)	All activities resulting in CH_4 and CO_2 fugitive emissions for oil and gas systems (e.g. venting, flaring)	Companies need to choose a base year for which verifiable emissions data are available. The base year emissions is used as an historic control against which the company's emissions are tracked over time. This ensures data consistency over time. Direct measurement of GHG emissions by monitoring concentration and flow rate can also be conducted. **Tier 2** calculation-based methodologies for estimating emissions involve the calculation of emissions based on activity data and country-specific industry segment emission factors or by performing a mass balance using country-specific oil and/or gas production information	Guideline
2006 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 2, Chapter 4	Oil and Gas Industry Systems	CH_4, CO_2 and other GHG gases	Report fugitive emissions from oil and gas system equipment leaks, flaring, venting, incineration, evaportion and flashing losses, and activities(e.g. pipeline dig-ins)	No de minimis	Facility and/or equipment emissions (e.g. dehydrator vents, AGR units)	All activities resulting in CH_4 and CO_2 fugitive emissions for oil and gas systems	Companies need to choose a base year for which verifiable emissions data are available and specify their reasons for choosing the year. The base year emissions is used as an historic datum against which the company's emissions are tracked over time. This ensures data consistency over time. Direct measurement of GHG emissions by monitoring concentration and flow rate can also be conducted. **Tier 3** calculation-based methodologies for estimating emissions involve "rigorous bottom-up assessment by primary type of source (e.g. evaporation losses, equipment leaks) at the individual facility level with appropriate accounting of contributions from temporary and minor field or well-site installations." The calculation of emissions is based on activity data and facility-specific emission factors	Guideline
New England Governers/ Eastern Canadian Premiers	No protocol given		No protocol given					
California Mandatory GHG Reporting Program	Refineries	CO_2, CH_4, and N_2O	Process, fugitive, and flaring emissions	Refineries that emit greater than or equal to 25,000 metric tons per year of CO_2 from the combination of stationary combustion and process sources. If operation of the refinery results in emissions of less than 20,000 metric tons per year of CO2 for three consecutive years, the operator is exempt from reporting untill the emissions exceeds 25,000 metric tons per year of CO2.	Facility and/or equipment emissions (e.g. storage tanks)	All activities resulting in CO_2, CH_4, and N_2O emissions for refineries	CO_2 process emissions can be determined by continuous emissions monitoring systems (Attachment B to Resolution 07-54, Regulation for mandatory reporting of GHG emissions, Section 95113 (c)). Methods for calculating fugitive emissions, and emissions from flares and other control devices are obtained in sections 95113 (d) and 95113 (e) respectively	Mandatory

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 2, Chapter 4	Oil and Gas Industry Systems	Emission factors used for the **Tier 2** calculations are "country-specific emission factors for each applicable segment or subcategory of a country's oil and gas industry" (2006 IPCC Guidelines for National GHG Inventories, Section 4.2.2.2). Tier 2 emission factors are extensive and therefore not listed in IPCC Guideline document. Activity data (e.g. fuel consumption, input material flow, or product output). To ensure the collection of high quality activity data, chapter 7 provides measures for the establishment of a robust data collection system. For mass balance calculations (4.2.2.2) country-specific production volumes, gas-to-oil ratios, gas compositions, and information regarding the level of gas conservation is required	Base year and annual GHG emissions estimates. Summaries of the methods used, references to all source data should be included for transparency, reported analysis should show trend analysis, activity data and emission intensities (i.e. average emissions per unit of activity indicator) over time, expected accuracy of the results and areas of greatest uncertainty should be noted	QAQC conducted according to Volume 1, Chapter 6 of the IPCC Guidelines which requires the calculations of uncertainty at the source category level that are then combined to summary levels for the entire inventory	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
2006 IPCC Guidelines for National Greenhouse Gas Inventory, Volume 2, Chapter 4	Oil and Gas Industry Systems	Emission factors used for the **Tier 3** calculations are "facility and country-specific emission factors for each facility in the oil and gas industry" (2006 IPCC Guidelines for National GHG Inventories, Section 4.2.2.2). Tier 3 emission factors are extensive and therefore not listed in IPCC Guideline document. Activity data (e.g. fuel consumption, input material flow, or product output). To ensure the collection of high quality activity data, chapter 7 provides measures for the establishment of a robust data collection system	Base year and annual GHG emissions estimates. Summaries of the methods used, references to all source data should be included for transparency, reported analysis should show trend analysis, activity data and emission intensities (i.e. average emissions per unit of activity indicator) over time, expected accuracy of the results and areas of greatest uncertainty should be noted	QAQC conducted according to Volume 1, Chapter 6 of the IPCC Guidelines which requires the calculations of uncertainty at the source category level that are then combined to summary levels for the entire inventory	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
New England Governers/ Eastern Canadian Premiers	No protocol given	No protocol given			
California Mandatory GHG Reporting Program	Refineries	Equipment count, operational information (e.g. days in operation, fuel consumed, vent rate)	Reports to be submitted no later than June 1 of every calender year. The report should contain the facility information, organizational and operational boundaries, direct and indirect emissions, name and contact information of the person preparing the report, and efficiency metrics when required (Section 95103). The operator shall separately identify and include in the emissions data report the emissions designated as de minimis (less than or equal to 3% of the facility's total CO_2 equivalent emissions, not exceeding 20,000 metric tons of CO_2).	Verification required by an accredited verficiation body	http://www.arb.ca.gov/regact/2007/ghg2007/ghg2007.htm

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
IPIECA - Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions	Oil and Gas	CH_4, non-combustion CO_2	Fugitives	None	All levels	All types	Tiers I, II, and III (IPCC)definitions and reporting methods for all fugitive greenhouse gas emissions in the oil and gas industry	Voluntary
Western Regional Air Partnership (WRAP)	Oil and Gas Production Industry	VOC	Fugitive emissions: oil well tanks, oil and gas well pneumatic devices; gas well dehydrators, well head compressor, flaring and venting from completions; and controlled and uncontrolled condensate tank emissions	No de minimis	Colorado, Montana, New Mexico, North Dakota, Utah and Wyoming gas and oil wells	Gas and oil wells	Emissions are quantified by calculation based method using emission factors and activity factors. Methods used are specificed in chapter 2.	Voluntary
Western Climate Initiative	No protocol given (Currently WCI has some GHG Reporting Design Options that are under review January 10, 2008. They expect to employ The Climate Registry's quantification protocols and reporting systems)							
The Climate Registry (General Reporting Protocol for the Voluntary Reporting Program), 2007	All legal entities (e.g. corporations, institutions, and organisations) including the oil and gas industry	CH_4, CO_2 and other GHG gases	All greenhouse gas (GHG) emissions from all facilities in Canada, Mexico, and the U.S. (reporting emissions from worldwide facilities is optional)	No de minimis	Report direct and indirect emissions for each type of process source and biomass. Emissions are classifed under scope 1 ,2, 3, (WRI) and biogenic emissions.	All activities resulting in emission of GHG gases for the entity	Emissions are quantified by measurement-based or calculation-based methodology. Measurement-based methodology monitor gas flow (continuous, flow meter) and test methane concentration in the flue gas. Calculation-based methodologies involve the calculation of emissions based on activity data and emission factors. Additional guidelines for quantifying emissions from sector-specific sources, that is, sources that apply only to particular industry sectors are also provided	Voluntary

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
IPIECA - Petroleum Industry Guidelines for Reporting Greenhouse Gas Emissions	Oil and Gas	All types	Voluntary application for any reporting	Provides guidelines for assurance detailing: - Implementing an inventory quality management system - Verification through: a. Objectives b. Concept of materiality c. Establishing verification parameters e. Selecting verifier f. Preparing for a verification g. Using verification findings	Chapter 6 defines the Tiers of evaluating emissions Chapter 8 defines and provides details for QA/QC Appendix B provides linkages between tiers for each sector
Western Regional Air Partnership (WRAP)	Oil and Gas Production Industry	Well-specific production and emission factors provided by the Wyoming Department of Environmental Quality and the Colorado Department of Public Health and Environment are used, however EF were adjusted for specific formations, well depths, and controls (not specified) for some some states. Activity factor or well-specific data obtained from the oil and gas commissions of the respective states (wells categorized as CBM,oil, and gas wells)	Methods, base year emissions, future projection for 2020, geographical area covered	Not specified	http://www.wrapair.org/forums/ssjf/documents/eictts/OilGas/WRAP_Oil&Gas_Final_Report.122805.pdf
Western Climate Initiative	No protocol given (Currently WCI has some GHG Reporting Design Options that are under review January 10, 2008. They expect to employ The Climate Registry's quantification protocols and reporting systems)	No protocol given			http://www.westernclimateinitiative.org/WCI_Meetings_Events.cfm
The Climate Registry (General Reporting Protocol for the Voluntary Reporting Program), 2007	All legal entities (e.g. corporations, institutions, and organisations) including the oil and gas industry	Activity data (e.g. fuel consumption, input material flow, or product output). Emission factors may be determined by means of direct measurement and laboratory analyses or generalized default factors may be used	Base year and total annual emissionsin CO_2e (total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries. For example semiconductor manufacturing emissions would include not only process emissions, but other direct emissions (including transportation, on-site energy, etc)) disaggregated on the basis of geographic area, scope, direct emissions by source type, GHG gas, and facility. Annual report should also contain GHG estimation approaches, factors, list of de minimis sources, company/entity infomation, and thrid-party verification status. Emissions represented by sources and/or gases (on a CO_2 equivalency basis) which are less than or equal to 3% of the entity's total annual emissions can be excluded from the inventory (de minimis sources)	Rigorous third-party verification system, based on the California Climate Action Registry's verfication approach	http://www.theclimateregistry.org/

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU ETS 1st Reporting Period	Mineral Oil Refining	CO_2	Process and combustion	No threshold	Facility	Operators may calculate emissions using a mass-balance approach, or for every fuel type and process of the installation (the activity data for each process leading to CO2 emissions is detailed below). **Catalytic cracker regenaration and other catalyst regeneration**: Activity data is the amount of coke [t] burned from catalyst, determined based on industry best practices guidelines (tier 1) or calculated from the heat and material balance over the catalytic cracker (tier 2). **Cokers**:Activity data is the amount of coke [t] produced, derived by weighing (maximum permissible uncertainty varies depending on the tier). **Refinery hydrogen production**: Activity data is the amount of hydrocarbon feed [t feed] processed, derived by volume metering (maximum permissible uncertainty varies depending on the tier).	Operators may calculate emissions using a mass-balance approach, or for every fuel type and process of the installation (the EF, and CF -if applicable- for each process is detailed below). **Catalytic cracker regeneration and other catalyst regeneration**: EF [t CO2/t coke] is based on the carbon content of the coke derived according to CEN, ISO or national standards. CF is assumed to be 1. **Cokers**: Specific EF [t CO2/ t coke] based on industry best practice guidelines (tier 1) or derived based on the measured CO2 content in off-gases according to CEN, ISO or national standards. **Refinery hydrogen production**: EF is either based on a reference value of 2.9 tCO2/t feed processed conservatively based on ethane (tier 1) or calculated from the carbon content of the feed gas determined according to CEN, ISO or national standards (tier 2).	Mandatory Reporting
EU ETS 2nd Reporting Period	Mineral Oil Refining	CO_2	Process and combustion	No threshold	Facility	**Catalytic cracker regeneration, other catalyst regeneration and flexi-cokers**: the emissions are calculated by a material balance, taking into account the state of the input air and the flue gas. All CO in the flue gas should be accounted for as CO2.The analysis of input air and flue gases will be done according to the CEN, ISO or national standards. **Refinery Hydrogen Production**: Activity data is the amount of hydrocarbon feed [t feed] processed (maximum permissible uncertainty varies depending on the tier).	**Catalytic cracker regeneration, other catalyst regenerationand flexi-cokers**:See activity data. **Refinery hydrogen production**: EF is either based on a reference value of 2.9 tCO2/t feed processed conservatively based on ethane (tier 1) or calculated from the carbon content of the feed gas determined according to CEN, ISO or national standards (tier 2).	Mandatory Reporting

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU ETS 1st Reporting Period	Mineral Oil Refining	Reporting requirements for all sources (in addition to emissions): - Chosen tiers and methods - Activity data - Emission factor - Conversion factor		3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF
EU ETS 2nd Reporting Period	Mineral Oil Refining	Reporting requirements for all sources (in addition to emissions): - Chosen tiers and methods - Activity data - Emission factor - Conversion factor		3rd party verification	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:32007D0589:EN:NOT

Review of Existing Programs Relevant to Source - Petrochemical Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
2006 IPCC Guidelines	Petrochemical Production	CO_2, CH_4	Industrial Processes - process emissions from petrochemical production	N/A	National	N/A	**Tier 1: Product-based emission factor method** CO_2 Emissions = Σ (PRODpetro x EF x GAF/100) for each petrochemical CH_4 Emissions = Σ [(PRODpetro x EFfug) + (PRODpetro x EFvent)] for each petrochemical **Where:** PRODpetro: annual production for each petrochemical, tons EF: emission factor for each petrochemical, tons CO_2/tons petrochmeical EFfug: fugitive emission factor for each petrochmeical, kg CH_4/ton petrochemical EFvent: vent emission factor for each petrochemical, kg CH_4/ton petrochemical GAF: Geographic Adjustment Factor Note: petrochemical production may be estimated using the following equation: PRODpetro = [CONSfs x SPFprimary] for each petrochemical **Where:** CONSfs = feedstock consumption for each feedstock, tons SPFprimary = specific production factor for each primary product from each petrochemical and each feedstock, tons primary production/ton feedstock Default values provided in the Notes tab
2006 IPCC Guidelines	Petrochemical Production	CO_2, CH_4	Industrial Processes - process emissions from petrochemical production	N/A	National	N/A	**Tier 2: Total feedstock carbon balance method** CO_2 Emissions = { Σ (FS x FCC) - [PRODprimary x PCCprimary + Σ (PRODsecondary x PCCsecondary)]} x 44/12 for each petrochemical and feedstock There is no Tier 2 estimation of CH4 emissions **Where:** FS = feedstock consumption of each feedstock for each petrochemical, tons FCC = feedstock carbon content of each feedstock, tons C/tons feedstock PRODprimary = annual production of each primary petrochemical, tons PCCprimary = carbon content of each primary petrochemical, tons C/tons petrochemical PRODsecondary = annual production of each secondary petrochemical, tons PCCsecondary = carbon content of each secondary petrochemical, tons C/tons petrochmical **Note:** only ethylene and acrylonitrile result in secondary production; for these petrochemicals Ethylene PRODsecondary = (CONSfs x SPFsecondary) Acrylonitrile PRODsecondary = (PRODacry x SPFsecondary) **Where:** CONSfs = feedstock consumption for each feedstock, tons SPFsecondary = specific production factor for each secondary product from each petrochemical and each feedstock, tons secondary production/tons feedstock PRODacry = acrylonitrile production from each feedstock, tons Default values provided in the notes tab

Review of Existing Programs Relevant to Source - Petrochemical Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat	**Tier 1:** Petrochemical Production (and/or Feedstock Consumption)	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers. Comparisons between default and calculated emission factors. Site-specific activity data check.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf
2006 IPCC Guidelines	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat	**Tier 2:** Feedstock Consumption Primary Petrochemical Production Secondary Production (and/or Secondary Feedstock Consumption)	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers. Comparisons between default and calculated emission factors. Site-specific activity data check.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Review of Existing Programs Relevant to Source - Petrochemical Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
2006 IPCC Guidelines	Petrochemical Production	CO_2, CH_4	Industrial Processes - process emissions from petrochemical production	N/A	National	N/A	**Tier 3:** CO_2 Emissions = Ecombust + Event + Eflared, where Ecombust = CONSfuel x NCV x EF_{CO2}, and Eflare = Gas Flared x NCV x EF_{CO2}, for each fuel. CH_4 Emissions = Ecombust + Event + Eflared, where Ecombust = CONSfuel x NCV x EF_{CH4}, and Eflare = Gas Flared x NCV x EF_{CH4}, for each fuel. OR CH_4 Emissions = Σ [(CONCvoc x FR_{CH4} - CONCch4 x WS x PA] over time **Where:** CONSfuel = fuel consumption for each fuel used to produce each petrochemical, tons NCV = net calorific value of each fuel, TJ/ton EF_{CO2} = CO_2 emission factor for each fuel, tons CO_2/TJ EF_{CH4} = CH_4 emission factor for each fuel, kg CH_4/TJ CONCvoc = VOC concentration at the plant, µg/m^3 FR_{CH4} = fraction of total CONCvoc that is CH_4, fraction CONCch4 = ambient CH_4 concentration at background location, µg/m3 WS = wind speed at the plant, m/s PA = plume area, m^3 Default values provided in the Notes tab
U.S. Inventory of Greenhouse Gas Emissions and Sinks	Petrochemical Production	CO_2, CH_4	Industrial Processes - process emissions from petrochemical production	N/A	National		**Modified Tier 1/Tier 2 approach** Non-carbon black CO_2 and CH_4 emissions = Σ (PRODpetro x EF) for each petrochemical (excluding carbon black) Carbon black CO_2 emissions = C content in carbon black CH_4 emissions - Σ [(FS x FCC) - (PRODcblack x PCCcblack)] for each feedstock **Where:** PRODpetro: annual production for each petrochemical, tons EF: emission factor for each petrochemical, tons CO_2/tons petrochemical for CO_2 and kg CH_4/ton petrochemical for CH_4 FS = feedstock consumption of each feedstock, tons FCC = feedstock carbon content of each feedstock, tons C/tons feedstock PRODcblack = annual primary production of carbon black, tons PCCcblack = carbon content of carbon black, tons C/tons petrochemical PRODsecondary = annual production of each secondary petrochemical, tons PCCsecondary = carbon content of each secondary petrochemical, tons C/tons petrochemical Default values provided in the Notes tab

Review of Existing Programs Relevant to Source - Petrochemical Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines		**Tier 3:** Fuel Consumed for Production Gas Flared During Production CO_2 Emitted from Process Vents	Base year and subsequent annual GHG emissions. National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers. Comparisons between default and calculated emission factors. Site-specific activity data check.	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf
U.S. Inventory of Greenhouse Gas Emissions and Sinks	Mandatory reporting to meet the reporting requirements of the UNFCCC Secretariat	National petrochemical production data, disaggregated by petrochemical type	Base year and subsequent annual GHG emissions, as well as activity data. A National Inventory Report documenting background, methodology, uncertainty, recalculations, and planned improvements.	Comparisons could be made between emissions estimated using different tiers. Comparisons between default and calculated emission factors. Site-specific activity data check, especially across the time series.	U.S. EPA (2008) U.S. Inventory of Greenhouse Gas Emissions and Sinks: 1990 - 2006. Available online at http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Review of Existing Programs Relevant to Source - Petrochemical Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Petrochemical Production	CH_4	Industrial Process - petrochemical production	All (no deminimis)	Corporate/Facility	N/A	**"A" Rating Approach:** Direct emissions monitoring or CEM **"B" Rating Approach:** Emissions = Σ (PRODpetro x EF) for each petrochemical **Where:** PRODpetro = annual petrochemical production, tons EF = emission factor for each petrochemical, kg CH_4/ton petrochemical **Default Values:** Use facility-specific emission factors if applicable. Other default values provided in Notes page.

Review of Existing Programs Relevant to Source - Petrochemical Production

Reporting Program/Guidance	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Technical Guidelines Voluntary Reporting of Greenhouse Gases (1605(b)) Program	Voluntary	**"A" Rating Approach:** Direct emissions monitoring **"B" Rating Approach:** Petrochemical production Facility-specific emission factor, if applicable	Annual direct and indirect emissions Average emissions rating reflecting the methodology used, with "A" being the most certain and "B" being the least certain Organization boundaries Methodology	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	Pages 2-32 (Reporting Guidelines), Page 106 http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf Federal Register Document http://www.pi.energy.gov/enhancingGHGregistry/documents/FinalGenGuidelines041306.pdf (Pages 18, 106, 114)

General Abbreviations Used

EF: Emission Factor	EX: Exports
PROD: Production	FR: Fraction
CF: Consumption Factor	CONS: Consumption
IM: Imports	SR: Stoichiometric Ratio

Notes on GHG Calculation Methods and Procedures for Petrochemical Production

Note 1. All tables are from the Intergovernmental Panel on Climate Changed, Revised IPCC Guidelines for National Greenhouse Gas Inventories (2006). Available online at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Table 1.E.22. Rating of Estimation Methods for Methane Emissions from Petrochemical Production

Estimation Method	Rating
Continuous emissions monitoring or other Direct measurement	A
Use of IPCC provided default factors	B

Table 1.E.21. Default Emissions Factors for Methane Emissions from Petrochemical Production

Petrochemical	Methane Emissions (Grams per Kilogram of Production)
Carbon Black	11
Ethylene	1
Ethylene Dichloride	0.4
Styrene	4

Petrochemical Production Tier 1 Default Feedstocks and Processes

Petrochemical Process	Default Feedstock	Default Process
Methanol	Natural Gas	Conventional steam reforming without primary reformer
Ethylene	North America, South America, Australia - Ethane Other Continents - Naphtha	Steam cracking
Ethylene Dichloride (EDC) / Vinyl Chloride Monomer (VCM)	Ethylene	Balanced Process for EDC production with integrated VCM production plant
Ethylene Oxide	Ethylene	Catalytic Oxidation, Air Process, with thermal treatment
Acrylonitrile	Propylene	Direct Ammoxidation with secondary products burned for energy recovery or flared
Carbon Black	Carbon black feedstock and natural gas	Furnace black process with thermal treatment

Methanol Production CO_2 EFs (tons CO_2/ton methanol produced)

	Feedstock				
Process Configuration	Natural gas	Natural gas + CO_2	Oil	Coal	Lignite
Conventional Steam Reforming, without primary reformer (Default Process and Natural Gas Default Feedstock)	0.67				
Conventional Steam Reforming, with primary reformer	0.497				
Conventional Steam Reforming, Lurgi Conventional process	0.385	0.267			
Conventional Steam Reforming, Lurgi Low Pressure Process	0.267				
Combined Steam Reforming, Lurgi Combined Process	0.396				
Conventional Steam Reforming, Lurgi Mega Methanol Process	0.31				
Partial oxidation process			1.376	5.285	5.02
Conventional Steam Reforming with integrated ammonia production	1.02				

Methanol Production Feedstock Consumption Factors (GJ feedstock input/ton methanol produced)					
	Feedstock				
Process Configuration	Natural gas	Natural gas + CO_2	Oil	Coal	Lignite
Conventional Steam Reforming, without primary reformer (Default Process and Natural Gas Default Feedstock)	36.5				
Conventional Steam Reforming, with primary reformer	33.4	29.3			
Conventional Steam Reforming, Lurgi Conventional process	31.4				
Conventional Steam Reforming, Lurgi Low Pressure Process	29.3				
Combined Steam Reforming, Lurgi Combined Process	31.6				
Conventional Steam Reforming, Lurgi Mega Methanol Process	30.1				
Partial Oxidation Process			37.15	71.6	57.6

Steam Cracking Ethylene Production Tier 1 CO_2 EFs (tons CO_2/ton ethylene produced)						
Process Configuration	Feedstock					
	Naphtha	Gas Oil	Ethane	Propane	Butane	Other
Ethylene (Total Process and Energy Feedstock Use)	**1.73**	**2.29**	**0.95**	**1.04**	**1.07**	**1.73**
Process Feedstock Use	1.73	2.17	0.76	1.04	1.07	1.73
Supplemental Fuel (Energy Feedstock) Use	0	0.12	0.19	0	0	0

Default Geographic Adjustment Factor (GAF) for Tier 1 CO_2 EFs for Steam Cracker	
Geographic Region	Adjustment Factor
Western Europe	100%
Eastern Europe	110%
Japan and Korea	90%
Asia, Africa, Russia	130%
North American and south America and Australia	110%

Default Methane EFs for Ethylene Production	
Feedstock	kg CH_4/ton ethylene produced
Ethane	6
Naphtha	3
All Other Feedstocks	3

Ethylene Dichloride (EDC)/Vinyl-chloride (VCM) Production Process Tier 1 CO_2 EFs		
Process Configuration	**ton CO_2/ton EDC produced**	**ton CO_2/ton VCM produced**
Direct Chlorination Process		
Noncombustion Process Vent	negligible emissions	negligible emissions
Combustion Emissions	0.191	0.286
Total CO2 Emission Factor	**0.191**	**286**
Oxychlorination Process		
Noncombustion Process Vent	0.0113	0.0166
Combustion Emissions	0.191	0.286
Total CO2 Emission Factor	**0.202**	**0.302**
Balanced Process [default process]		
Noncombustion Process Vent	0.0057	0.0083
Combustion Emissions	0.191	0.286
Total CO2 Emission Factor	**0.196**	**0.294**

Ethylene Dichloride (EDC)/Vinyl-chloride Monomer (VCM) Process Tier 1 Feedstock Consumption Factors		
Process Configuration	**on ethylene/ton EDC produce**	**ton ethylene/ton VCM produced**
Direct Chlorination Process	0.29	--
Oxychlorination Process	0.302	--
Balanced Process	0.296	0.47

Ethylene Dichloride (EDC)/Vinyl-chloride Monomer (VCM) Process Tier 1 Default CH_4 EFs	
Process Configuration	CH_4/ton VCM product produced
Integrated EDC/VCM Production Plant	0.0226

Ethylene Oxide Production, Feedstock Consumption, and CO_2 EFs			
Process Configuration	Catalyst Selectivity	Feedstock Consumption (ton ethylene/ton ethylene oxide)	EF (tons CO_2/ton ethylene oxide)
Air Process (default process)	Default (70)	0.90	0.863
	75	0.85	0.663
	80	0.80	0.5
Oxygen Process	Default (75)	0.85	0.663
	80	0.80	0.5
	85	0.75	0.35

Ethylene Oxide Production Tier 1 CH_4 EFs	
Process Configuration	kg CH_4/ton ethylene oxide produced
No Thermal Treatment (default factor)	1.79
Thermal Treatment	0.79

Acrylonitrile Production CO_2 EFs	
Process Configuration	tons CO_2/ton acrylonitrile produced
Secondary Products Burned for Energy Recovery/Flared (default)	1.00
Acetonitrile Burned for Energy Recovery/Flared	0.83
Acetonitrile and Hydrogen Cyanide Recovered as Product	0.79

Carbon Black Production Tier 1 CO_2 EF (tons CO_2/ton carbon black produced)			
Process Configuration	Primary Feedstock	Secondary Feedstock	Total Feedstock
Furnace Black Process (default process)	1.96	0.66	2.62
Thermal Black Process	4.59	0.66	5.25
Acetylene Black Process	0.12	0.66	0.78

Carbon Black production Tier 1 CH_4 EFs	
Process Configuration	CH_4/ton carbon black produced
No Thermal Treatment	28.7
Thermal Treatment	0.06

Ethylene Steam Cracking Feedstock-Product Matrix (kg product/ton feedstock)						
Product	**Naphtha**	**Gas Oil**	**Ethane**	**Propane**	**Butane**	**Others**
High Value Chemicals	**645**	**569**	**842**	**638**	**635**	**645**
Ethylene	324	250	803	465	441	324
Propylene	168	144	16	125	151	168
Butadiene	50	50	23	48	44	50
Aromatics	104	124	0	0	0	104
Fuel grade products and backflows	**355**	**431**	**157**	**362**	**365**	**355**
Hydrogen	11	8	60	15	14	11
Methane	139	114	61	267	204	139
Ethane and propane after recycle	0	0	0	0	0	0
Other C4	62	40	6	12	33	62
C5/C6	40	21	26	63	108	40
C7+ non-aromatics	12	21	0	0	0	12
<430C	52	26	0	0	0	52
>430C	34	196	0	0	0	34
Losses	5	5	5	5	5	5
Total (High Value Chemicals + Fuel Grade Products and Backflows)	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**	**1,000**

Secondary Product Production Factors for Acrylonitrile Production Process	
Secondary Product	**kg secondary product/ton acrylonitrile produced**
Acetonitrile	18.5
Hydrogen Cyanide	105

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
EU Emission Trading Scheme	CO2 from natural gas combustion	CO2	All "Mineral" Oil Refineries Minimum uncertainty tiers are based on facility emissions: ● Category A: Emissions ≤ 50 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category B: Emissions > 50 ktonnes and ≤ 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category C: Emissions > 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Low Emissions Category, Emissions < 25 ktonnes of fossil CO2 before subtraction of transferred CO2	Group of minor sources selected by operator that emit 1 ktonne or less per year, or that contribute less than 2% of total annual emissions (up to no more than 20 ktonnes) before subtraction of transferred fossil CO_2, whichever is the highest in terms of absolute emissions.	Facility	**Fall Back Approach** In cases where it is not technically feasible or would lead to unreasonable costs to apply at least Tier 1 requirements for all (except de minimis) source streams, operator may apply alternative monitoring technology provided the following overall uncertainty thresholds are met: Category A: 7.5%, Category B: 5.0%, and Category C: 2.5%. **Low Emissions Category Exemptions** Member states may permit use of lower tier approaches (Tier 1 a minimum level), member states may allow simplified monitoring plans, member states may waive lab accreditation, and member states may waive proof of calibration requirement addressing uncertainty. **De Minimis Sources** Facility may use its own non-tier methods.

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
EU Emission Trading Scheme	CO2 from natural gas combustion	Calculation Method CO2 = FF x NCF x EF x OF where: CO2 = tonnes (t) of CO2 emitted FF = fuel flow (t or Nm3) NCF = net calorific value (Tj/t or Tj/ Nm3 EF = emission factor (tCO2/t or tCO2/Tj) OF = oxidation factor (fraction)	Mandatory	Fuel consumption, net calorific value (see notes), country-specific emission factor or default (see notes), oxidation factor (1).

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
EU Emission Trading Scheme	CO2 from natural gas combustion	Emissions, chosen approach (measurement or calculation), chosen tiers and method (if applicable), activity data , net calorific value, emission factors, oxidation/ conversion factors, mass flow, carbon, and energy content for each fuel or material (material balance approach), for a CEMS, annual CO_2 emission and supplementary calculation or material balance approach data, changes in tiers and any other installation changes.	Annual	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data as follows: Concentration: Csub = Cavg + SD Where: Csub = substitute value for hour Cavg = concentration arithmetic mean of annual data set SD = standard deviation best estimate of annual data set If one year is not applicable because of facility changes use a period approved by competent authority. Other Parameters: Substitute values through a mass balance model or energy balance approach for process. Remaining measurement elements will be used to validate.	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data. Equipment: Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Documentation: Establish an effective data control system and document data flow activities. Corrective Action: Promptly take appropriate corrective action and correct data when data flow or control activities are found to not function effectively or to function outside of set boundaries. Third Party Verification: Required. Verification process and report submitted with annual report.	MRG 2007 - Commission Decision C(2007)3416 of 18 July 2007 (Annex I, Directive 2003/87/EC) (MRG 2007, Annexes I, II, III, and XII)

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Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
EU Emission Trading Scheme	Refinery fuel gas combustion	CO2	All "Mineral" Oil Refineries Minimum uncertainty tiers are based on facility emissions: ● Category A: Emissions ≤ 50 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category B: Emissions > 50 ktonnes and ≤ 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category C: Emissions > 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Low Emissions Category, Emissions < 25 ktonnes of fossil CO2 before subtraction of transferred CO2	Group of minor sources selected by operator that emit 1 ktonne or less per year, or that contribute less than 2% of total annual emissions (up to no more than 20 ktonnes) before subtraction of transferred fossil CO_2, whichever is the highest in terms of absolute emissions.	Facility	**Fall Back Approach** In cases where it is not technically feasible or would lead to unreasonable costs to apply at least Tier 1 requirements for all (except de minimis) source streams, operator may apply alternative monitoring technology provided the following overall uncertainty thresholds are met: Category A: 7.5%, Category B: 5.0%, and Category C: 2.5%. **Low Emissions Category Exemptions** Member states may permit use of lower tier approaches (Tier 1 a minimum level), member states may allow simplified monitoring plans, member states may waive lab accreditation, and member states may waive proof of calibration requirement addressing uncertainty. **De Minimis Sources** Facility may use its own non-tier methods.

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
EU Emission Trading Scheme	Refinery fuel gas combustion	Calculation Method CO2 = FF x NCF x EF x OF where: CO2 = tonnes (t) of CO2 emitted FF = fuel flow (t or Nm3) NCF = net calorific value (Tj/t or Tj/ Nm3 EF = emission factor (tCO2/t or tCO2/Tj) OF = oxidation factor (fraction)	Mandatory	Fuel consumption, country-specific, measured, or default net calorific value (see notes), country-specific, facility-specific, or default emission factor (51.3 Tj/Gg), oxidation factor (1).

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
EU Emission Trading Scheme	Refinery fuel gas combustion	Emissions, chosen approach (measurement or calculation), chosen tiers and method (if applicable), activity data , net calorific value, emission factors, oxidation/ conversion factors, mass flow, carbon, and energy content for each fuel or material (material balance approach), for a CEMS, annual CO_2 emission and supplementary calculation or material balance approach data, changes in tiers and any other installation changes.	Annual	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data as follows: Concentration: Csub = Cavg + SD Where: Csub = substitute value for hour Cavg = concentration arithmetic mean of annual data set SD = standard deviation best estimate of annual data set If one year is not applicable because of facility changes use a period approved by competent authority. Other Parameters: Substitute values through a mass balance model or energy balance approach for process. Remaining measurement elements will be used to validate.	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data.. Equipment: Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Documentation: Establish an effective data control system and document data flow activities. Corrective Action: Promptly take appropriate corrective action and correct data when data flow or control activities are found to not function effectively or to function outside of set boundaries. Third Party Verification: Required. Verification process and report submitted with annual report.	MRG 2007 - Commission Decision C(2007)3416 of 18 July 2007 (Annex I, Directive 2003/87/EC) (MRG 2007, Annexes I, II, III, and XII)

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Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
EU Emission Trading Scheme	Fuel Oils	CO2	All "Mineral" Oil Refineries Minimum uncertainty tiers are based on facility emissions: ● Category A: Emissions ≤ 50 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category B: Emissions > 50 ktonnes and ≤ 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category C: Emissions > 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Low Emissions Category, Emissions < 25 ktonnes of fossil CO2 before subtraction of transferred CO2	Group of minor sources selected by operator that emit 1 ktonne or less per year, or that contribute less than 2% of total annual emissions (up to no more than 20 ktonnes) before subtraction of transferred fossil CO_2, whichever is the highest in terms of absolute emissions.	Facility	**Fall Back Approach** In cases where it is not technically feasible or would lead to unreasonable costs to apply at least Tier 1 requirements for all (except de minimis) source streams, operator may apply alternative monitoring technology provided the following overall uncertainty thresholds are met: Category A: 7.5%, Category B: 5.0%, and Category C: 2.5%. **Low Emissions Category Exemptions** Member states may permit use of lower tier approaches (Tier 1 a minimum level), member states may allow simplified monitoring plans, member states may waive lab accreditation, and member states may waive proof of calibration requirement addressing uncertainty. **De Minimis Sources** Facility may use its own non-tier methods.

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
EU Emission Trading Scheme	Fuel Oils	Calculation Method CO2 = FF x NCF x EF x OF where: CO2 = tonnes (t) of CO2 emitted FF = fuel flow (t or Nm3) NCF = net calorific value (Tj/t or Tj/ Nm3 EF = emission factor (tCO2/t or tCO2/Tj) OF = oxidation factor (fraction)	Mandatory	Fuel consumption, country-specific, measured, facility-specific, or default (see notes) net calorific value, country-specific, measured, facility-specific, or default emission factor (see notes), oxidation factor (1).

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
EU Emission Trading Scheme	Fuel Oils	Emissions, chosen approach (measurement or calculation), chosen tiers and method (if applicable), activity data , net calorific value, emission factors, oxidation/ conversion factors, mass flow, carbon, and energy content for each fuel or material (material balance approach), for a CEMS, annual CO_2 emission and supplementary calculation or material balance approach data, changes in tiers and any other installation changes.	Annual	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data as follows: Concentration: Csub = Cavg + SD Where: Csub = substitute value for hour Cavg = concentration arithmetic mean of annual data set SD = standard deviation best estimate of annual data set If one year is not applicable because of facility changes use a period approved by competent authority. Other Parameters: Substitute values through a mass balance model or energy balance approach for process. Remaining measurement elements will be used to validate.	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data. Equipment: Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Documentation: Establish an effective data control system and document data flow activities. Corrective Action: Promptly take appropriate corrective action and correct data when data flow or control activities are found to not function effectively or to function outside of set boundaries. Third Party Verification: Required. Verification process and report submitted with annual report.	MRG 2007 - Commission Decision C(2007)3416 of 18 July 2007 (Annex I, Directive 2003/87/EC) (MRG 2007, Annexes I, II, III, and XII)

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Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
EU Emission Trading Scheme	Refinery Hydrogen Production	CO2	All "Mineral" Oil Refineries Minimum uncertainty tiers are based on facility emissions: ● Category A: Emissions ≤ 50 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category B: Emissions > 50 ktonnes and ≤ 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category C: Emissions > 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Low Emissions Category, Emissions < 25 ktonnes of fossil CO2 before subtraction of transferred CO2	Group of minor sources selected by operator that emit 1 ktonne or less per year, or that contribute less than 2% of total annual emissions (up to no more than 20 ktonnes) before subtraction of transferred fossil CO_2, whichever is the highest in terms of absolute emissions.	Facility	**Fall Back Approach** In cases where it is not technically feasible or would lead to unreasonable costs to apply at least Tier 1 requirements for all (except de minimis) source streams, operator may apply alternative monitoring technology provided the following overall uncertainty thresholds are met: Category A: 7.5%, Category B: 5.0%, and Category C: 2.5%. **Low Emissions Category Exemptions** Member states may permit use of lower tier approaches (Tier 1 a minimum level), member states may allow simplified monitoring plans, member states may waive lab accreditation, and member states may waive proof of calibration requirement addressing uncertainty. **De Minimis Sources** Facility may use its own non-tier methods.

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
EU Emission Trading Scheme	Refinery Hydrogen Production	Measurement Method (CEMS) or Combined Measurement/Calculation Method Measurement Method: CO2 = CO2 concentration x flue gas flow CO2 concentration = continuous measurement at representative point. Flue gas flow: method A: Mass balance approach, or Flue gas flow: method B: Continuous flow monitor at representative point. CO2 Concentration: Continuous measurement at representative point by standardized methods that limits sampling and measurement bias and has a known measurement uncertainty. CEN standards shall be used if available, otherwise ISO or national standards shall be used. Flue Gas Flow: Method A: Mass balance approach taking into account all significant parameters input parameters (air flow, process efficiency, etc.) and output parameters (product output, O2 concentration, SO2 and NOx concentration, etc.). Specific approach must be approved by competent authority Method B: Continuous flow monitor at representative point. Use standardized methods that limit sampling and measurement bias and has a known measurement uncertainty. CEN standards shall be used if available, otherwise ISO or national standards shall be used. Calculation Method: CO2 = Feed x EF where: CO2 = tonnes (t) of CO2 emitted Feed = hydrocarbon feed (t) EF = emission factor (tCO2/t feed) Tier 1 emission factor: 2.9 Tier 2 emission factor: calculated from carbon content	Mandatory	Hydrocarbon feed, emission factor,

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Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
EU Emission Trading Scheme	Refinery Hydrogen Production	Emissions, chosen approach (measurement or calculation), chosen tiers and method (if applicable), activity data , net calorific value, emission factors, oxidation/ conversion factors, mass flow, carbon, and energy content for each fuel or material (material balance approach), for a CEMS, annual CO_2 emission and supplementary calculation or material balance approach data, changes in tiers and any other installation changes.	Annual	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data as follows: Concentration: Csub = Cavg + SD Where: Csub = substitute value for hour Cavg = concentration arithmetic mean of annual data set SD = standard deviation best estimate of annual data set If one year is not applicable because of facility changes use a period approved by competent authority. Other Parameters: Substitute values through a mass balance model or energy balance approach for process. Remaining measurement elements will be used to validate.	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data. Equipment: Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Documentation: Establish an effective data control system and document data flow activities. Corrective Action: Promptly take appropriate corrective action and correct data when data flow or control activities are found to not function effectively or to function outside of set boundaries. Third Party Verification: Required. Verification process and report submitted with annual report.	MRG 2007 - Commission Decision C(2007)3416 of 18 July 2007 (Annex I, Directive 2003/87/EC) (MRG 2007, Annexes I, II, III, and XII)

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Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
EU Emission Trading Scheme	Catalytic cracker regeneration and other catalyst regeneration, flexi-cokers	CO2	All "Mineral" Oil Refineries Minimum uncertainty tiers are based on facility emissions: ● Category A: Emissions ≤ 50 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category B: Emissions > 50 ktonnes and ≤ 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Category C: Emissions > 500 ktonnes of fossil CO2 before subtraction of transferred CO2 ● Low Emissions Category, Emissions < 25 ktonnes of fossil CO2 before subtraction of transferred CO2	Group of minor sources selected by operator that emit 1 ktonne or less per year, or that contribute less than 2% of total annual emissions (up to no more than 20 ktonnes) before subtraction of transferred fossil CO_2, whichever is the highest in terms of absolute emissions.	Facility	**Fall Back Approach** In cases where it is not technically feasible or would lead to unreasonable costs to apply at least Tier 1 requirements for all (except de minimis) source streams, operator may apply alternative monitoring technology provided the following overall uncertainty thresholds are met: Category A: 7.5%, Category B: 5.0%, and Category C: 2.5%. **Low Emissions Category Exemptions** Member states may permit use of lower tier approaches (Tier 1 a minimum level), member states may allow simplified monitoring plans, member states may waive lab accreditation, and member states may waive proof of calibration requirement addressing uncertainty. **De Minimis Sources** Facility may use its own non-tier methods.

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EU Emission Trading Scheme	Catalytic cracker regeneration and other catalyst regeneration, flexi-cokers	Material Balance Material balance taking into account input air and flue gas. All CO in flue gas shall be accounted for as CO2: tCO2 = tCO x 1571 Where: t = tonnes	Mandatory	Analysis of input air and flue gases and choice of tiers.

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Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
EU Emission Trading Scheme	Catalytic cracker regeneration and other catalyst regeneration, flexi-cokers	Emissions, chosen approach (measurement or calculation), chosen tiers and method (if applicable), activity data , net calorific value, emission factors, oxidation/ conversion factors, mass flow, carbon, and energy content for each fuel or material (material balance approach), for a CEMS, annual CO_2 emission and supplementary calculation or material balance approach data, changes in tiers and any other installation changes.	Annual	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data as follows: Concentration: Csub = Cavg + SD Where: Csub = substitute value for hour Cavg = concentration arithmetic mean of annual data set SD = standard deviation best estimate of annual data set If one year is not applicable because of facility changes use a period approved by competent authority. Other Parameters: Substitute values through a mass balance model or energy balance approach for process. Remaining measurement elements will be used to validate.	Calculation or Material Balance: General requirement to correct data when outside of control boundaries. CEMS: When an hour is out of control calculate substitute data. Equipment: Relevant measurement equipment shall be calibrated, adjusted, and checked at regular intervals and prior to use. Documentation: Establish an effective data control system and document data flow activities. Corrective Action: Promptly take appropriate corrective action and correct data when data flow or control activities are found to not function effectively or to function outside of set boundaries. Third Party Verification: Required. Verification process and report submitted with annual report.	MRG 2007 - Commission Decision C(2007)3416 of 18 July 2007 (Annex I, Directive 2003/87/EC) (MRG 2007, Annexes I, II, III, and XII)

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Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
CARB GHG Reporting Program	CO2 from Natural Gas Combustion	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	CO2 from Natural Gas Combustion	Calculation Method 1. Calculate CO2 Emissions Using Measured Heat Content: CO2 = Σ $Fuel_p$ x HHV_p x EF x 0.001 CO2 = metric tonnes of CO2 emitted n = period/frequency of heat content measurements over the year FuelP = Mass or volume of fuel combusted for the measurement period specified by fuel type, units of mass or volume per unit time HHVP = high heat value measured for the measurement period specified by fuel type, MMBtu per unit mass or volume EF = Default CO2 emission factor, kg CO2/MMBtu 0.001 = factor to covert kg to metric tonnes 2. Calculate CO2 Emissions Using Measured Carbon Content: CO2 = Σ $Fuel_n$ x CC x 1/MVC x 3.664 x 0.001 CO2 = tonnes of CO2 emitted Fueln = volume of gaseous fuel combusted in month "n", scf CCn = carbon content from fuel analysis for month "n", kg C/kg-mole fuel, determined using ASTM D1945-03 or ASTM D1946-90. MVC = molar volume conversion factor (849.5 scf/kg-mol for STP of 20°C and 1 atm or 836 scf/kg-mol for STP of 60°F and 1 atm. 3.664 = conversion factor for C to CO2 0.001 = factor to covert kg to metric tonnes	Mandatory	Fuel consumption, calorific value (high heat value or default (see notes)), default emission factor (see notes) or measured monthly carbon content, oxidation factor (1).

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
CARB GHG Reporting Program	CO2 from Natural Gas Combustion	Direct GHG emissions, electricity transactions information, and other emissions data; fuel consumption by fuel type and indirect electric and thermal energy consumption; efficiency metrics when required; and a signed and dated certification statement.	Annual	Calculation or Material Balance: Fuel Activity Data The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. If the operator is unable to obtain fuel analytical data such that more than 20% of emissions cannot be directly accounted for, and the source for which data are missing is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the emissions from that source shall be considered unverifiable for the report year. If the fuel analytical data capture rate is at least 80% but less than 100% for any emissions source, and that source is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the operator shall use the mean of the fuel analytical data results captured to substitute for the missing values for the period of missing data. CEMS: Not specified	Fuel Activity Data: The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. CEMS: Not specified. Equipment: All fuel activity measurement devices (mass or volume flow) shall be maintained and calibrated to maintain a measurement uncertainty of not more than 5%. Documentation: Establish, document, implement, and maintain a system that provides clarity, transparency, and completeness of data. Corrective Action: No specific requirements. Third Party Verification: Required annually for all petroleum refinery emission reports.	Proposed Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (Title 17, California Code of Regulations, Subchapter 10, Article 1, Sections 95100 to 95133)

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CARB GHG Reporting Program	Refinery Fuel Gas Combustion	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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CARB GHG Reporting Program	Refinery Fuel Gas Combustion	Calculation Method: for fuel mixture, one of the following methods are used: 1. Measure the flow rate of each fuel stream prior to mixing, apply the fuel specific sampling scheme specified for each fuel, calculate CO2 emissions for each fuel in the mixture, and sum to calculate total combustion emissions. 2. Measure the flow rate of the fuel mixture and apply the method for calculating CO2 emissions using measured heat and carbon content. Equation: 1. Calculate CO2 emissions using measured carbon content: $CO2 = \sum Fuel_n * CC_n * 1/MVC * 3.664 * 0.001$ Where: CO2 = tonnes of CO2 emitted Fueln = volume of gaseous fuel combusted in month "n", scf CCn = carbon content from fuel analysis for month "n", kg C/kg-mole fuel MVC = molar volume conversion factor (849.5 scf/kg-mol for STP of 20°C and 1 atm or 836 scf/kg-mol for STP of 60°F and 1 atm. 3.664 = conversion factor for C to CO2 0.001 = factor to covert kg to metric tones	Mandatory	Fuel consumption, calorific value (high heat value), emission factor, oxidation factor (1).

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
CARB GHG Reporting Program	Refinery Fuel Gas Combustion	Direct GHG emissions, electricity transactions information, and other emissions data; fuel consumption by fuel type and indirect electric and thermal energy consumption; efficiency metrics when required; and a signed and dated certification statement.	Annual	Calculation or Material Balance: Fuel Activity Data The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. If the operator is unable to obtain fuel analytical data such that more than 20% of emissions cannot be directly accounted for, and the source for which data are missing is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the emissions from that source shall be considered unverifiable for the report year. If the fuel analytical data capture rate is at least 80% but less than 100% for any emissions source, and that source is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the operator shall use the mean of the fuel analytical data results captured to substitute for the missing values for the period of missing data. CEMS: Not specified	Fuel Activity Data: The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. CEMS: Not specified. Equipment: All fuel activity measurement devices (mass or volume flow) shall be maintained and calibrated to maintain a measurement uncertainty of not more than 5%. Documentation: Establish, document, implement, and maintain a system that provides clarity, transparency, and completeness of data. Corrective Action: No specific requirements. Third Party Verification: Required annually for all petroleum refinery emission reports.	Proposed Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (Title 17, California Code of Regulations, Subchapter 10, Article 1, Sections 95100 to 95133)

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
CARB GHG Reporting Program	Refinery Fuel Gas Combustion	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	Refinery Fuel Gas Combustion	2. Calculate CO2 Emissions Using Measured Heat and Carbon Content. For each separate fuel gas system, the operator shall calculate a daily fuel specific emission factor using the following equation. Small refiners calculate a weekly emission factor for each refinery fuel gas system. EFCO2-A = CCA/HHVA * MWA/MVC * 0.664 * 1000 Where: EFCO2-A = daily CO2 emission factor for fuel gas system A (tonnes CO2/MMBtu) CCA = fuel gas carbon content for fuel gas system A (kg C/kg fuel) HHVA = high heating value for fuel gas system A (MMBtu/scf) MWA = molecular weight of refinery fuel A (kg/kg-mol) MVC = same as method 1 above. System-specific weekly or daily emission factors are used to calculate daily CO2 emissions from combustion devices: $CO2\text{-}A = \sum HHV_{DA} * FR_A * EF_{CO2\text{-}A}$ Where: CO2-A = CO2 emissions resulting from combustion of fuel gas from system A (tonnes/yr) HHVDA = daily average high heating value for system A (Btu/scf). Small refiners can use weekly HHV. FRA = daily fuel consumption for fuel gas system A (scf/d) EFCO2-A = same as above The following equation calculates total CO2 emissions from the combustion of fuel gas (metric tonnes/yr): Total CO2 = CO2-A + CO2-B + CO2-C +…CO2-X CO2-A,B,C…X = CO2 emissions from combustion sources in fuel gas system A, B, C,…X. (metric tonnes/yr)	Mandatory	Fuel consumption, calorific value (high heat value), emission factor, oxidation factor (1).

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CARB GHG Reporting Program	Fuel Oils	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	Fuel Oils	Calculation Using Default Emission Factors and Default Heat Contents $CO2 = Fuel \times HHV_D \times EF_{CO2} \times 0.001$ Where: CO2 = CO2 emissions from a specific fuel type, metric tonnes CO2/year Fuel = mass or volume of fuel combusted specified by fuel type, unit of mass or volume per year HHV_D = default high heat value specified by fuel type supplied by ARB, MMBtu per unit of mass or volume EF_{CO2} = default CO2 emission factor, kg CO2/MMBtu 0.001 = factor to convert kg to metric tones	Mandatory	Fuel consumption (for each shipment or monthly), default heat content (see notes), default emission factor (see notes), oxidation factor (1).

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Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
CARB GHG Reporting Program	Fluid catalytic cracking and fluid coker continuous catalyst regeneration, and other catalyst regeneration	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	Fluid catalytic cracking and fluid coker continuous catalyst regeneration, and other catalyst regeneration	Material Balance 1. FCCU or Fluid Coker Continuous Regeneration Material balance to calculate a daily coke burn rate taking into account hourly regenerator input and output. Daily average coke burn rate kg/day is multiplied by operating days and coke carbon fraction. Default carbon fraction is one. Coke Burn Rate (CR) = K1Qr(%CO2 + %CO) + K2Qa - K3Qr[%CO/2 + %CO2 + %O2] + K3Qoxy(%Oxy) Where: CR = coke burn rate (kg/hr or lb/hr) K1, K2, K3 = material balance and conversion factors (40 CFR 63.1564) Qr = volumetric flow rate of exhaust gas upstream of the emission control system (dscm/min or dscf/min) Qa = volumetric flow rate of air to regenerator as determined from control room instrumentation (dscm/min or dscf/min) %CO2 = percent CO2 concentration in regenerator exhaust, % by volume dry basis %CO = percent CO concentration in regenerator exhaust, percent by volume - dry basis %O2 = percent oxygen concentration in regenerator exhaust, percent by volume - dry basis Qoxy = volumetric flow rate of O2 enriched air to regenerator as determined from control room instrumentation (dscm/min or dscf/min) %Oxy = O2 concentration in O2 enriched air stream inlet to regenerator, percent by volume - dry basis Exhaust Flow (Qr) = (79 * Qa + (100 - %Qoxy) x Qoxy)/(100 - %CO2 - %CO - %O2) CO2 = Sum of daily avg CR * CF * 3.664 Where: CO2 = annual CO2 emissions (kg) CR = avg coke burn rate (kg/day) CF = carbon fraction in coke (default = 1) 3.644 = C to CO2 conversion factor	Mandatory	Input air flow and O2 as determined by control room instruments, and regenerator outlet air flow before control device, as well as measured % CO, O2, and CO2 in regenerator exhaust.

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CARB GHG Reporting Program	Fluid catalytic cracking and fluid coker continuous catalyst regeneration, and other catalyst regeneration	Direct GHG emissions, electricity transactions information, and other emissions data; fuel consumption by fuel type and indirect electric and thermal energy consumption; efficiency metrics when required; and a signed and dated certification statement.	Annual	Calculation or Material Balance: Fuel Activity Data The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. If the operator is unable to obtain fuel analytical data such that more than 20% of emissions cannot be directly accounted for, and the source for which data are missing is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the emissions from that source shall be considered unverifiable for the report year. If the fuel analytical data capture rate is at least 80% but less than 100% for any emissions source, and that source is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the operator shall use the mean of the fuel analytical data results captured to substitute for the missing values for the period of missing data. CEMS: Not specified	Fuel Activity Data: The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. CEMS: Not specified. Equipment: All fuel activity measurement devices (mass or volume flow) shall be maintained and calibrated to maintain a measurement uncertainty of not more than 5%. Documentation: Establish, document, implement, and maintain a system that provides clarity, transparency, and completeness of data. Corrective Action: No specific requirements. Third Party Verification: Required annually for all petroleum refinery emission reports.	Proposed Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (Title 17, California Code of Regulations, Subchapter 10, Article 1, Sections 95100 to 95133)

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CARB GHG Reporting Program	Fluid catalytic cracking and fluid coker continuous catalyst regeneration, and other catalyst regeneration	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	Fluid catalytic cracking and fluid coker continuous catalyst regeneration, and other catalyst regeneration	2. Other Continuous Catalyst Regeneration CO2 = Ccirc x (CFspent - CFregen) x H x 3.664 Where: CO2 = annual CO2 emissions (tonnes) Ccirc = avg catalyst regeneration rate (tonnes/hr) CFspent = carbon fraction on spent catalyst CFregen = carbon fraction on regenerated catalyst (default = 0) H = hours regenerator was operational (hr/yr) 3. Periodic Catalyst Regeneration CO2 = ∑CRR x (CFspent x CFregen) x 3.664 Where: O2 = annual CO2 emissions (kg) CRR = mass of catalyst regenerated per cycle (mass/regeneration cycle) CFspent = weight fraction carbon on spent catalyst CFregen = weight fraction carbon on regenerated catalyst (default = 0) (mass/regeneration cycle) n = number of regeneration cycles	Mandatory	Input air flow and O2 as determined by control room instruments, and regenerator outlet air flow before control device, as well as measured % CO, O2, and CO2 in regenerator exhaust.

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CARB GHG Reporting Program	Refinery Hydrogen Production	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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CARB GHG Reporting Program	Refinery Hydrogen Production	Operators of facilities that combust fossil fuels, biomass, or municipal solid waste, and operate CEMS, may use CO2 or O2 concentrations and flue gas flow measurements to determine hourly CO2 mass emissions using methodologies provided in 40 CFR Part 75, Appendix F. Hourly CO2 mass emissions over a year are summed. 1. CO2 Measurement Method (CEMS): CO2 = CO2 concentration x flue gas flow CO2 Concentration: If the operator of a facility that combusts biomass uses O2 concentrations to calculate CO2 concentrations, annual source testing must demonstrate that calculated CO2 concentrations are within 5% of measured CO2 concentrations. For facilities that combust municipal solid waste, CO2 emission calculations shall not be based on O2 concentrations. If a facility does not have CEMS and the operator adds one to measure CO2 concentrations, the CEMS must meet the requirements of 40 CFR Part 75. Flue Gas Flow: If a facility is subject to requirements in 40 CFR Part 60 or 40 CFR Part 75 and the operator chooses to add devices to an existing CEMS for the purpose of measuring CO2 concentrations or flue gas flow, the operator shall select and operate the added devices pursuant to the requirements in 40 CFR Part 60 or Part 75 that apply to the facility.	Mandatory	For Mass Balance and Process Emissions Methods, determine carbon content of feedstock mixtures daily. Determine carbon content of natural gas that is not mixed with another fuel or feedstock prior to consumption once a month.

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CARB GHG Reporting Program	Refinery Hydrogen Production	2. Mass Balance Calculations: Fuel and Feedstock Mass Balance $CO2 = \Sigma [(F * CF_F) + (FS + CF_{FS}) - S] * 3.664 \times 0.001$ Where: CO2 = carbon dioxide process and stationary combustion emissions (metric tonnes/yr) n = number of operation per reporting period F = fuel consumption rate (scf/day) CF_F = carbon content of fuel (kg C/scf fuel) FS = feedstock consumption rate (scf/day) CF_{FS} = carbon content of feedstock (kg C/scf fuel) S = carbon accounted for elsewhere (kg C/day) 3.664 = factor to convert C to CO2 0.001 = factor to convert kg to metric tonnes 3. Mass Balance Calculations: Feedstock Process Emissions $CO2 = \Sigma_{((}FSR \times CF) - S] \times 3.664 \times 0.001$ Where: CO2 = carbon dioxide emissions (metric tonnes/yr) n = number of operational days FSR = feedstock supply rate (scf/day) CF = carbon content of feedstock (kg C/scf fuel) S = carbon accounted for elsewhere (kg C/day) 3.664 = factor to convert C to CO2 0.001 = factor to convert kg to metric tonnes	Mandatory	For Mass Balance and Process Emissions Methods, determine carbon content of feedstock mixtures daily. Determine carbon content of natural gas that is not mixed with another fuel or feedstock prior to consumption once a month.

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CARB GHG Reporting Program	CH_4 and N_2O Combustion Emissions	CH_4 and N_2O	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	CH_4 and N_2O Combustion Emissions	Calculation Method: 1. If heat content is measured, CH4 and N2O emissions are calculated using the following equation: CH4 or N2O = Σ Fuelp x HHVp x EF x 0.001 Where: CH4 or N2O = combustion emissions from specific fuel type, metric tonnes per year n = period/frequency of heat content measurements over the year FuelP = mass or volume of fuel combusted for the measurement period specified by fuel type, units of mass or volume per unit time HHVP = high heat value measured for the measurement period specified by fuel type, MMBtu per unit mass or volume EF = default emission factor, kg CH4 or N2O per MMBtu 0.001 = factor to convert kg to metric tonnes 2. If heat content is not measured, CH4 and N2O emissions are calculated using the following equation: CH4 or N2O = Fuel * HHVD * EF * 0.001 Where: CH4 or N2O = combustion emissions from specific fuel type, metric tonnes per year Fuel = mass or volume of fuel combusted specified by fuel type, unit of mass or volume per year HHVD = default high heat value specified by fuel type supplied by ARB, MMBtu per unit of mass or volume EF = default emission factor, kg CH4 or N2O per MMBtu 0.001 = factor to convert kg to metric tonnes 3. CH4 and N2O emissions can be calculated using source specific emission factors derived from source tests conducted at least annually.	Mandatory	Fuel consumption (see other fuel tables), calorific values (see other fuel tables), default emission factors (see notes)

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Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
CARB GHG Reporting Program	CH_4 and N_2O Combustion Emissions	Direct GHG emissions, electricity transactions information, and other emissions data; fuel consumption by fuel type and indirect electric and thermal energy consumption; efficiency metrics when required; and a signed and dated certification statement.	Annual	Calculation or Material Balance: Fuel Activity Data The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. If the operator is unable to obtain fuel analytical data such that more than 20% of emissions cannot be directly accounted for, and the source for which data are missing is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the emissions from that source shall be considered unverifiable for the report year. If the fuel analytical data capture rate is at least 80% but less than 100% for any emissions source, and that source is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the operator shall use the mean of the fuel analytical data results captured to substitute for the missing values for the period of missing data. CEMS: Not specified	Fuel Activity Data: The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. CEMS: Not specified. Equipment: All fuel activity measurement devices (mass or volume flow) shall be maintained and calibrated to maintain a measurement uncertainty of not more than 5%. Documentation: Establish, document, implement, and maintain a system that provides clarity, transparency, and completeness of data. Corrective Action: No specific requirements. Third Party Verification: Required annually for all petroleum refinery emission reports.	Proposed Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (Title 17, California Code of Regulations, Subchapter 10, Article 1, Sections 95100 to 95133)

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CARB GHG Reporting Program	Flares and Other Control Devices	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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CARB GHG Reporting Program	Flares and Other Control Devices	**CO2 from combustion of hydrocarbons routed to flares:** 1. Operators reporting CH4 and NMHC emissions to their local Air Quality Management District shall calculate CO2 emissions as follows: $CO2 = \sum_i [CF_{NMHC} \times NMHC \times FE/(100 - FE) \times 3.664 + CH4 \times FE/(100 - FE) \times 2.746] \times 0.001$ Where: CO2 = emissions of CO2 (metric tonnes/yr) CF_{NMHC} = carbon fraction in NMHC = 0.6 NMHC = flare non-methane hydrocarbon emissions (kg/day) CH4 = flare methane emissions (kg/day) FE = flare destruction efficiency (%) = 98% if gas combusted HHV > 200 Btu/scf or 93% if gas combusted HHV < 200 Btu/scf 2.746 = conversion factor – methane to carbon dioxide 0.001 = conversion factor – carbon to carbon dioxide Operators shall also report the sum of all flare CH4 emissions (metric tonnes/yr) 2. Operators subject to Rule 1118 – Control of Emissions from Refinery Flares (South Coast Air Quality Management District) shall calculate ROG as specified in Attachment B of Rule 1118, and report flare CO2 emissions as follows: $CO2 = \sum (CF_{ROF} * [ROG * FE (100-FE)] * 3.664) * 0.001$ Where: CO2 = emissions of CO2 (metric tonnes/yr) CFROG = carbon fraction in ROG = 0.6 ROG = reactive organic gas flare emissions (kg/day) FE = flare destruction efficiency (%) = 98% if gas combusted HHV > 200 Btu/scf, or 93% if gas combusted HHV < 200 Btu/scf 3.664 = conversion factor – carbon to carbon dioxide 0.001 = conversion factor – kg to metric tonnes	Mandatory	For low Btu gases, CCA and MWA must be measured quarterly using on-line instrumentation of by lab analysis of a representative sample drawn from the system, using ASTM D1945-03 or ASTM D1946-90, and computing an annual average value.

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Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
CARB GHG Reporting Program	Flares and Other Control Devices	Direct GHG emissions, electricity transactions information, and other emissions data; fuel consumption by fuel type and indirect electric and thermal energy consumption; efficiency metrics when required; and a signed and dated certification statement.	Annual	Calculation or Material Balance: Fuel Activity Data The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. If the operator is unable to obtain fuel analytical data such that more than 20% of emissions cannot be directly accounted for, and the source for which data are missing is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the emissions from that source shall be considered unverifiable for the report year. If the fuel analytical data capture rate is at least 80% but less than 100% for any emissions source, and that source is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the operator shall use the mean of the fuel analytical data results captured to substitute for the missing values for the period of missing data. CEMS: Not specified	Fuel Activity Data: The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. CEMS: Not specified. Equipment: All fuel activity measurement devices (mass or volume flow) shall be maintained and calibrated to maintain a measurement uncertainty of not more than 5%. Documentation: Establish, document, implement, and maintain a system that provides clarity, transparency, and completeness of data. Corrective Action: No specific requirements. Third Party Verification: Required annually for all petroleum refinery emission reports.	Proposed Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (Title 17, California Code of Regulations, Subchapter 10, Article 1, Sections 95100 to 95133)

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CARB GHG Reporting Program	Flares and Other Control Devices	CO_2	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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CARB GHG Reporting Program	Flares and Other Control Devices	3. Operators not reporting flare emissions their local AQMD/APCD calculate CO2 emissions as shown below: CO2 = RFT * EFNMHC * CFNMHC * 3.664 * 0.001 Where: CO2 = CO2 emissions (metric tonnes/year) RFT = refinery feed throughput (m3/yr) EFNMHC = NMHC emission factor = 0.002 kg/m3 CFNMHC = factor to convert NMHC to carbon = 0.6 3.664 = conversion factor – carbon to carbon dioxide 0.001 = conversion factor – kg to metric tonnes For the destruction of low Btu gases using other methods like incineration or combustion as a supplemental fuel: CO2 = GVA * CCA * MWA * 1/MVC * 3.664 * 0.001 Where: CO2 = CO2 emissions (metric tonnes/year) GVA = volume of gas A destroyed annually (scf/yr) CCA = carbon content of gas A (kg F/kg fuel) MWA = molecular weight of gas A MVC = molar volume conversion factor (849.5 scf/kg-mol for STP of 20°C and 1 atm or 836 scf/kg-mol for STP of 60°F and 1 atm. 3.664 = conversion factor for C to CO2 0.001 = factor to covert kg to metric tonnes	Mandatory	For low Btu gases, CCA and MWA must be measured quarterly using on-line instrumentation of by lab analysis of a representative sample drawn from the system, using ASTM D1945-03 or ASTM D1946-90, and computing an annual average value.

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CARB GHG Reporting Program	Fugitive Emissions	CO_2, CH_4, and N_2O	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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CARB GHG Reporting Program	Fugitive Emissions	Calculation Methods, EPA TANKS model (for storage tanks) 1. Wastewater treatment CH4 & N2O CH4 = [(Q x COD) – S] x B x MCF x 0.001 CH4 = methane emissions (tonnes/yr) Q = volume of wastewater treated (m3/yr) COD = average of quarterly determinations of chemical oxygen demand of wastewater (kg/m3) S = organic component removed as sludge (kg COD/yr) B = methane generation capacity = 0.25 kg CH4/kg COD MCF = methane conversion factor for anaerobic decay = 0.8 0.001 = factor to convert kg to metric tonnes N2O = Q x Nqave x EFN2O x 3.142 x 0.001 N2O = N2O emissions (metric tonnes/yr) Q = volume of wastewater treated (m3/yr) Nqave = average of quarterly determinations of N in effluent (kg N/m3) EFN2O = emission factor for N2O from discharged wastewater = 0.005 kg N2O-N/kg N 3.142 = factor to convert kg N2O-N to kg N2O 0.001 = factor to convert kg to metric tonnes	Mandatory	Volume of wastewater treated, COD, emission factors

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CARB GHG Reporting Program	Fugitive Emissions	2. Oil-Water Separators CH4 = Fsep * Vwater * CFNMHC * 0.001 CH4 = methane emissions (metric tonnes/yr) Fsep = NMHC emission factor (kg/m3) Vwater = volume of wastewater treated by the separator (m3/yr) CFNMHC = NMHC to CH4 conversion factor = 0.6 0.001 = factor to convert kg to metric tonnes 3. Equipment Fugitive Emissions CH4 = EVOC * t * CFVOC * 0.001 CH4 = methane emissions (metric tonnes/yr) EVOC = total VOC leak emissions determined using CAPCOA Method 3: Correlation Equation Method (kg/hr) t = hours components were pressurized (default = 8,760 hrs/yr) CFVOC = 0.6 (default VOC to CH4 conversion factor)	Mandatory	Volume of wastewater treated, COD, emission factors

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CARB GHG Reporting Program	Refinery Process Emissions (process vents, asphalt production, and sulfur recovery)	CO_2, CH_4, and N_2O	Petroleum refineries that emit greater than or equal to 25,000 metric tonnes of CO_2 in any calendar year after 2007 from the combination of stationary combustion and process sources. If subject refinery's emissions drop to less than 20,000 metric tons of CO_2 from combustion for three consecutive report years, the operator is exempt from reporting until CO_2 emissions exceed 25,000 tonnes in any future calendar year	The operator may elect to designate one or more sources as *de minimis* that collectively produce no more than 3% of the facility's total CO_2e emissions, but in no case exceeding 20,000 metric tonnes CO_2e. The operator may estimate emissions for these *de minimis* sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team. The operator shall separately identify and include in the emissions data report the emissions designated as *de minimis* . The operator shall determine CO_2 equivalence according to 100-year global warming potentials.	Facility	**De Minimis Sources** The operator may estimate emissions for de minimis sources using alternative methods of the operator's choosing, subject to the concurrence of the verification team

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CARB GHG Reporting Program	Refinery Process Emissions (process vents, asphalt production, and sulfur recovery)	1. Process Vents: Ex = Σ VR x Fx x MWx / MVC x VT x 0.001 Ex = emissions of x (metric tonnes/yr) (x = CO2, CH4, N2O) VR = vent rate (scf/unit time) Fx = molar fraction of x in vent gas stream MWx = molecular weight of X (kg/kg-mol) MVC = molar volume conversion (849 scf/kg-mole, for STP of 20°C and 1 atm, and 836 scf/kg-mole, for STP of 60°F and 1 atm) VT = time duration of venting n = number of venting events 0.001 = factor to convert kg to metric tonnes 2. Asphalt Production CO2 and CH4 emissions CH4 = (MA * EF * MWCH4/MVC)(1 – DE) * 2.743 * 0.001 Where: CH4 = CH4 emissions (metric tonnes/yr) MA = mass of asphalt blown (103 bbl/yr) EF = default emission factor (2,555 scf CH4/103 bbl) MWCH4 = CH4 molecular weight (16 kg/kg-mole) MVC = molar volume conversion (849.5 scf/kg-mole, for STP of 20°C and 1 atm, or 836 scf/kg-mole, for STP of 60°F and 1 atm) DE = control measure destruction efficiency (default = 0.98) 2.743 = CH4 to CO2 conversion factor 0.001 = conversion factor – kg to metric tonnes	Mandatory	Process vent information, mass of asphalt blown, emission factors, volumetric flow rate of acid gas to SRU

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Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
CARB GHG Reporting Program	Refinery Process Emissions (process vents, asphalt production, and sulfur recovery)	3. Sulfur Recovery $CO_2 = (MA * EF * MWCH_4/MVC) * DE * 2.743 * 0.001$ Where: CO_2 = CO_2 emissions (metric tonnes/yr) MA = mass of asphalt blown (103 bbl/yr) EF = default emission factor (2,555 scf CH_4/103 bbl) $MWCH_4$ = CH_4 molecular weight (16 kg/kg-mole) MVC = molar volume conversion (849.5 scf/kg-mole, for STP of 20°C and 1 atm, or 836 scf/kg-mole, for STP of 60°F and 1 atm) DE = control measure destruction efficiency (default = 0.98) 2.743 = CH_4 to CO_2 conversion factor 0.001 = conversion factor – kg to metric tonnes	Mandatory	Process vent information, mass of asphalt blown, emission factors, volumetric flow rate of acid gas to SRU

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
CARB GHG Reporting Program	Refinery Process Emissions (process vents, asphalt production, and sulfur recovery)	Direct GHG emissions, electricity transactions information, and other emissions data; fuel consumption by fuel type and indirect electric and thermal energy consumption; efficiency metrics when required; and a signed and dated certification statement.	Annual	Calculation or Material Balance: Fuel Activity Data The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. If the operator is unable to obtain fuel analytical data such that more than 20% of emissions cannot be directly accounted for, and the source for which data are missing is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the emissions from that source shall be considered unverifiable for the report year. If the fuel analytical data capture rate is at least 80% but less than 100% for any emissions source, and that source is not subject to separate fuel analytical data capture requirements specified in 40 CFR Part 75 or Part 60, the operator shall use the mean of the fuel analytical data results captured to substitute for the missing values for the period of missing data. CEMS: Not specified	Fuel Activity Data: The operator shall demonstrate every reasonable effort to obtain a fuel analytical data capture rate of 100% for each report year. CEMS: Not specified. Equipment: All fuel activity measurement devices (mass or volume flow) shall be maintained and calibrated to maintain a measurement uncertainty of not more than 5%. Documentation: Establish, document, implement, and maintain a system that provides clarity, transparency, and completeness of data. Corrective Action: No specific requirements. Third Party Verification: Required annually for all petroleum refinery emission reports.	Proposed Regulation for the Mandatory Reporting of Greenhouse Gas Emissions (Title 17, California Code of Regulations, Subchapter 10, Article 1, Sections 95100 to 95133)

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
DOE 1605(b) Program	CO2 from Natural Gas Combustion	CO_2	Voluntary Program with different reporting requirements for entities with greater than or less than 10,000 metric tonnes of CO_2 equivalent GHG emissions per year. Large entities with 10,000 metric tonnes of CO2 equivalent GHG emissions/yr or more must report emissions for the entity as a whole. Small entities with less than 10,000 metric tonnes of CO2 equivalent GHG emissions/yr may elect to report emissions for a single chosen activity rather than for the entity as a whole.	De minimis emissions means emissions from one or more sources and of one or more greenhouse gases that, in aggregate, are less than or equal to 3 percent of the total annual CO_2 equivalent emissions of a reporting entity.	Entity-wide (based on financial control or other DOE approved definition) for large entities (>10,000 metric tonnes emissions of CO_2 equivalents/yr)	**De Minimis Sources** Emissions from de minimis sources may be excluded from the total emissions, but source must identify the types of emissions and provide an emission estimate using methods in the Technical Guidelines.
DOE 1605(b) Program	Refinery Fuel Gas Combustion	CO_2	Voluntary Program with different reporting requirements for entities with greater than or less than 10,000 metric tonnes of CO_2 equivalent GHG emissions per year. Large entities with 10,000 metric tonnes of CO2 equivalent GHG emissions/yr or more must report emissions for the entity as a whole. Small entities with less than 10,000 metric tonnes of CO2 equivalent GHG emissions/yr may elect to report emissions for a single chosen activity rather than for the entity as a whole.	De minimis emissions means emissions from one or more sources and of one or more greenhouse gases that, in aggregate, are less than or equal to 3 percent of the total annual CO_2 equivalent emissions of a reporting entity.	Entity-wide (based on financial control or other DOE approved definition) for large entities (>10,000 metric tonnes emissions of CO_2 equivalents/yr)	**De Minimis Sources** Emissions from de minimis sources may be excluded from the total emissions, but source must identify the types of emissions and provide an emission estimate using methods in the Technical Guidelines.

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
DOE 1605(b) Program	CO2 from Natural Gas Combustion	Three methods are available: direct measurement (CEMS), mass balance, and inferring emissions from activity data and sample emissions measurement. Quality ratings of method vary based on input data used in the calculations. For CEMS- Methods and data quality should be comparable to data reported under Climate Leaders. Equation: CE = QF * CC * FC Where: CE = CO2 emissions (metric tonnes) QF = quantity of fuel (measured in weight, volume, or heating value) CC = carbon coefficient (a ratio, metric tonnes C as CO2 per "unit" of fuel, as above) FC = fraction combusted The carbon coefficient for the fuel is the theoretical maximum CO2 emission rate expressed in terms of units of carbon dioxide per unit of fuel. A default emission factor may be calculated by multiplying the carbon coefficient (CC) by the assumed fraction combusted (FC).	Voluntary	Fuel consumption based on measured purchases or consumption; measured, contractual, or default calorific values (see notes); emission factor based on gas analysis or default (see notes); oxidation factor (0.995)
DOE 1605(b) Program	Refinery Fuel Gas Combustion	Three methods are available: direct measurement (CEMS), mass balance, and inferring emissions from activity data and sample emissions measurement. Quality ratings of method vary based on input data used in the calculations. For CEMS- Methods and data quality should be comparable to data reported under Climate Leaders. Equation: CE = QF * CC * FC Where: CE = CO2 emissions (metric tonnes) QF = quantity of fuel (measured in weight, volume, or heating value) CC = carbon coefficient (a ratio, metric tonnes C as CO2 per "unit" of fuel, as above) FC = fraction combusted The carbon coefficient for the fuel is the theoretical maximum CO2 emission rate expressed in terms of units of carbon dioxide per unit of fuel. A default emission factor may be calculated by multiplying the carbon coefficient (CC) by the assumed fraction combusted (FC).	Voluntary	Fuel consumption based on measured purchases or consumption, EIA default emission factor (17.42 tonnes carbon/billion Btu); oxidation factor (0.98 for flaring, 0.99 for boilers)

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
DOE 1605(b) Program	CO2 from Natural Gas Combustion	Entity reporting boundaries; potential sources of GHG emissions and sequestration; emissions estimation methods and information sources; and emissions inventory including direct and indirect GHG emissions, minus sequestration, expressed as metric tonnes of CO2 equivalent emissions in a specified year. Reporters not intending to register emission reductions may choose to report their emissions and/or their emission reductions on an entity-wide basis or for selected elements of their entities, selected gases or selected sources.	Annual	Not specified	Calculation or Material Balance: Not specified. CEMS: Not specified. Equipment: No specific requirements. Documentation: Implies documentation and preservation of data for potential third party verification. Corrective Action: No specific requirements. Third Party Verification: Encourages, but does not require, independent verification of annual reports by third party professional verifiers.	10 CFR Part 300, Guidelines for Voluntary Greenhouse Gas Reporting - as called for under Section 1605 (b) of the Energy Policy Act of 1992. (Technical Guidelines, Chapter 1, Parts A and C: Stationary Source Combustion)
DOE 1605(b) Program	Refinery Fuel Gas Combustion	Entity reporting boundaries; potential sources of GHG emissions and sequestration; emissions estimation methods and information sources; and emissions inventory including direct and indirect GHG emissions, minus sequestration, expressed as metric tonnes of CO2 equivalent emissions in a specified year. Reporters not intending to register emission reductions may choose to report their emissions and/or their emission reductions on an entity-wide basis or for selected elements of their entities, selected gases or selected sources.	Annual	Not specified	Calculation or Material Balance: Not specified. CEMS: Not specified. Equipment: No specific requirements. Documentation: Implies documentation and preservation of data for potential third party verification. Corrective Action: No specific requirements. Third Party Verification: Encourages, but does not require, independent verification of annual reports by third party professional verifiers.	10 CFR Part 300, Guidelines for Voluntary Greenhouse Gas Reporting - as called for under Section 1605 (b) of the Energy Policy Act of 1992. (Technical Guidelines, Chapter 1, Parts A and C: Stationary Source Combustion)

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Applicability Threshold	De Minimis Levels	Level of Reporting (e.g., facility, unit)	Exemptions
DOE 1605(b) Program	Fuel Oils	CO_2	Voluntary Program with different reporting requirements for entities with greater than or less than 10,000 metric tonnes of CO_2 equivalent GHG emissions per year. Large entities with 10,000 metric tonnes of CO2 equivalent GHG emissions/yr or more must report emissions for the entity as a whole. Small entities with less than 10,000 metric tonnes of CO2 equivalent GHG emissions/yr may elect to report emissions for a single chosen activity rather than for the entity as a whole.	De minimis emissions means emissions from one or more sources and of one or more greenhouse gases that, in aggregate, are less than or equal to 3 percent of the total annual CO_2 equivalent emissions of a reporting entity.	Entity-wide (based on financial control or other DOE approved definition) for large entities (>10,000 metric tonnes emissions of CO_2 equivalents/yr)	**De Minimis Sources** Emissions from de minimis sources may be excluded from the total emissions, but source must identify the types of emissions and provide an emission estimate using methods in the Technical Guidelines.
DOE 1605(b) Program	CH_4 and N_2O Combustion Emissions	CH_4 and N_2O	Voluntary Program with different reporting requirements for entities with greater than or less than 10,000 metric tonnes of CO_2 equivalent GHG emissions per year. Large entities with 10,000 metric tonnes of CO2 equivalent GHG emissions/yr or more must report emissions for the entity as a whole. Small entities with less than 10,000 metric tonnes of CO2 equivalent GHG emissions/yr may elect to report emissions for a single chosen activity rather than for the entity as a whole.	De minimis emissions means emissions from one or more sources and of one or more greenhouse gases that, in aggregate, are less than or equal to 3 percent of the total annual CO_2 equivalent emissions of a reporting entity.	Entity-wide (based on financial control or other DOE approved definition) for large entities (>10,000 metric tonnes emissions of CO_2 equivalents/yr)	**De Minimis Sources** Emissions from de minimis sources may be excluded from the total emissions, but source must identify the types of emissions and provide an emission estimate using methods in the Technical Guidelines.

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place)
DOE 1605(b) Program	Fuel Oils	Three methods are ionary source combustion: direct measurement (CEMS), mass balance, and inferring emissions from activity data and sample emissions measurement. Quality ratings of method vary based on input data used in the calculations. CEMS - Methods and data quality should be comparable to data reported under Climate Leaders. Equation: CE = QF * CC * FC Where: CE = CO2 emissions (metric tonnes) QF = quantity of fuel (measured in weight, volume, or heating value) CC = carbon coefficient (a ratio, metric tonnes C as CO2 per "unit" of fuel, as above) FC = fraction combusted A default emission factor may be calculated by multiplying the carbon coefficient (CC) by the assumed fraction combusted (FC) The carbon coefficient for the fuel is the theoretical maximum CO2 emission rate expressed in terms of units of carbon dioxide per unit of fuel.	Voluntary	Fuel consumption based on measured purchases or consumption, standard calorific values or default (see notes), default emission factor based on Btu content or carbon content (see notes), oxidation factor (0.99)
DOE 1605(b) Program	CH_4 and N_2O Combustion Emissions	Possible emissions estimation methods are CEMS and calculation method. 1. Use of emission factors: CE = QF x EF Where: CE = GHG emissions (metric tonnes) QF = quantity of fuel (measured in weight, volume, or heating value) EF = emission factor (mass GHG per "unit" of fuel)	Voluntary	Fuel consumption based on measured purchases or consumption; measured, contractual, or default calorific values (see notes); default emission factor (see notes)

Summary of GHG Reporting Programs and Protocols for Petroleum Refineries

Reporting Program/ Guidance	Source Category (or Fuel)	Reports to Program	Reporting Frequency	Missing Data Requirements	Quality Assurance/ Quality Control Procedures	Source
DOE 1605(b) Program	Fuel Oils	Entity reporting boundaries; potential sources of GHG emissions and sequestration; emissions estimation methods and information sources; and emissions inventory including direct and indirect GHG emissions, minus sequestration, expressed as metric tonnes of CO2 equivalent emissions in a specified year. Reporters not intending to register emission reductions may choose to report their emissions and/or their emission reductions on an entity-wide basis or for selected elements of their entities, selected gases or selected sources.	Annual	Not specified	Calculation or Material Balance: Not specified. CEMS: Not specified. Equipment: No specific requirements. Documentation: Implies documentation and preservation of data for potential third party verification. Corrective Action: No specific requirements. Third Party Verification: Encourages, but does not require, independent verification of annual reports by third party professional verifiers.	10 CFR Part 300, Guidelines for Voluntary Greenhouse Gas Reporting - as called for under Section 1605 (b) of the Energy Policy Act of 1992. (Technical Guidelines, Chapter 1, Parts A and C: Stationary Source Combustion)
DOE 1605(b) Program	CH_4 and N_2O Combustion Emissions	Entity reporting boundaries; potential sources of GHG emissions and sequestration; emissions estimation methods and information sources; and emissions inventory including direct and indirect GHG emissions, minus sequestration, expressed as metric tonnes of CO2 equivalent emissions in a specified year. Reporters not intending to register emission reductions may choose to report their emissions and/or their emission reductions on an entity-wide basis or for selected elements of their entities, selected gases or selected sources.	Annual	Not specified	Calculation or Material Balance: Not specified. CEMS: Not specified. Equipment: No specific requirements. Documentation: Implies documentation and preservation of data for potential third party verification. Corrective Action: No specific requirements. Third Party Verification: Encourages, but does not require, independent verification of annual reports by third party professional verifiers.	10 CFR Part 300, Guidelines for Voluntary Greenhouse Gas Reporting - as called for under Section 1605 (b) of the Energy Policy Act of 1992. (Technical Guidelines, Chapter 1, Parts A and C: Stationary Source Combustion)

Petroleum Refineries Notes: Default Emission Factors

Fuel CO2 - CARB

Fuel Type	CARB Fraction Oxidized	CARB Default Carbon Content (HHV)	CARB Default Heat Content (HHV)	CARB Default CO_2 Emission Factor (HHV)	CARB Default CO_2 Emission Factor (HHV)
Natural Gas (By Heat Content)		**kg C/ MMBtu**	**Btu / Standard cubic foot**	**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
975 to 1,000 Btu / Std cubic foot	1	14.73	n/a	53.97	n/a
1,000 to 1,025 Btu / Std cubic foot	1	14.43	n/a	52.87	n/a
1,025 to 1,050 Btu / Std cubic foot	1	14.47	n/a	53.02	n/a
1,050 to 1,075 Btu / Std cubic foot	1	14.58	n/a	53.42	n/a
1,075 to 1,100 Btu / Std cubic foot	1	14.65	n/a	53.68	n/a
Greater than 1,100 Btu / Std cubic foot	1	14.92	n/a	54.67	n/a
Unspecified (weighted U.S. average)	1	14.47	1,027	53.02	0.0544
Unspecified (IPCC)	--	--	--	--	--
Other Gas		**kg C/ MMBtu**	**Btu / Standard cubic foot**	**kg CO_2 / MMBtu**	**kg CO_2 / Standard cub. ft.**
Refinery Fuel Gas	--	--	--	--	--
Low Btu Gas	--	--	--	--	--
Petroleum Products		**kg C/ MMBtu**	**MMBtu / Barrel**	**kg CO_2 / MMBtu**	**kg CO_2 / gallon**
Diesel Fuel / Distillate Fuel Oil (#1, 2, & 4)	1	19.95	5.825	73.1	10.15
Jet Fuel	1	19.33	5.67	70.83	9.57
Kerosene	1	19.72	5.67	72.25	9.76
LPG (energy use)	1	17.19	3.861	62.98	5.79
Propane	1	17.2	3.824	63.02	5.74
Ethane	1	16.25	2.916	59.54	4.14
Isobutene	1	17.75	4.162	65.04	6.45
n-Butane	1	17.72	4.328	64.93	6.7
Residual Fuel Oil (#5 & 6)	1	21.49	6.287	78.74	11.8

Notes:

CARB and EIA factors are based on the fuel higher heating values (HHV); EU factors are based on net caloric value or lower heating value (LHV).

CARB calculates CO_2 emissions by multiplying the carbon content per MMBtu by 3.664 (molecular weight ratio of CO_2 to C). EIA uses a molecular weight ratio of 44/12. The different rounding of the ratios and different oxidation factors will result in different emissions, even though the carbon content in terms of MMBtu is the same.

Data Sources:

CARB factors are from U.S. EPA, Inventory of Greenhouse Gas Emissions and Sinks: 1990-2005 (2007), Annex 2.1, Tables A-31, A-32, A-35, and A-36, except: Heat Content factors for Unspecified Coal (by sector), Coke, Naphtha (<401 deg. F), Other Oil (>401 deg. F) (from U.S. Energy Information Administration, Annual Energy Review 2005 (2006), Tables A-1, A-4, and A-5), Heat Content factors for Coal (by type), LPG, and all factors for Wood and Wood Waste, Landfill Gas, and Wastewater Treatment Biogas (from EPA Climate Leaders, Stationary Combustion Guidance (2004), Tables B-1 and B-2).

Petroleum Refineries Notes: Default Emission Factors

Fuel CO2 - EIA

Fuel Type	EIA Fraction Oxidized	EIA Default CO_2 Emission Factor (HHV)	EIA Default Carbon Emission Factor (HHV)	EIA Default CO_2 Emission Factor (HHV)	EIA Default Heat Content (HHV)
Natural Gas (By Heat Content)		**kg CO_2 / MMBtu**	**kg C / MMBtu**	**kg CO_2 / Standard cub. ft.**	**Btu / Standard cubic foot**
975 to 1,000 Btu / Std cubic foot	0.995	53.74	14.66	n/a	n/a
1,000 to 1,025 Btu / Std cubic foot	0.995	52.65	14.36	n/a	n/a
1,025 to 1,050 Btu / Std cubic foot	0.995	52.79	14.4	n/a	n/a
1,050 to 1,075 Btu / Std cubic foot	0.995	52.93	14.51	n/a	n/a
1,075 to 1,100 Btu / Std cubic foot	0.995	53.18	14.5	n/a	n/a
Greater than 1,100 Btu / Std cubic foot	--	--	--	--	--
Unspecified (weighted U.S. average)	--	--	--	--	--
Unspecified (IPCC)	--	--	--	--	--
Other Gas		**kg CO_2 / MMBtu**	**kg C / MMBtu**	**kg CO_2 / Standard cub. ft.**	**Btu / Standard cubic foot**
Refinery Fuel Gas	0.98 or 0.99	--	17.42	--	--
Low Btu Gas	--	--	--	--	--
Petroleum Products		**kg CO_2 / MMBtu**	**kg C / MMBtu**	**kg CO_2 / gallon**	**MMBtu / Barrel**
Diesel Fuel / Distillate Fuel Oil (#1, 2, & 4)	0.99	72.32	19.8	10.15	5.825
Jet Fuel	0.99	70.87	19.33	9.57	5.67
Kerosene	0.99	71.23	19.58	9.76	5.67
LPG (energy use)	0.99	62.47	17.04	--	--
Propane	0.99	62.44	17.03	--	3.824
Ethane	0.99	58.98	16.09	--	2.916
Isobutene	0.99	64.43	17.57	--	4.162
n-Butane	0.99	64.32	17.54	--	4.328
Residual Fuel Oil (#5 & 6)	0.99	78.8	21.49	11.8	6.287

Notes:

CARB and EIA factors are based on the fuel higher heating values (HHV); EU factors are based on net caloric value or lower heating value (LHV).

CARB calculates CO_2 emissions by multiplying the carbon content per MMBtu by 3.664 (molecular weight ratio of CO_2 to C). EIA uses a molecular weight ratio of 44/12.

The different rounding of the ratios and different oxidation factors will result in different emissions, even though the carbon content in terms of MMBtu is the same.

Data Sources:

EIA factors are from EIA, Documentation for Emissions of Greenhouse Gases in the United States 2003, May 2005, Tables 6-5, 6-6, and 6-9.

Petroleum Refineries Notes: Default Emission Factors

Fuel CO2 - EU

Fuel Type	EU Fraction Oxidized	EU Default CO_2 Emission Factor (LHV)	EU Default Heat Content (LHV)	Converted EU Default CO_2 Emission Factor (HHV)
Natural Gas (By Heat Content)		**t CO_2 / Tj**	**Tj/Gg**	**kg CO_2 / MMBtu**
975 to 1,000 Btu / Standard cubic foot	--	--	--	--
1,000 to 1,025 Btu / Std cubic foot	--	--	--	--
1,025 to 1,050 Btu / Std cubic foot	--	--	--	--
1,050 to 1,075 Btu / Std cubic foot	--	--	--	--
1,075 to 1,100 Btu / Std cubic foot	--	--	--	--
Greater than 1,100 Btu / Std cubic foot	--	--	--	--
Unspecified (weighted U.S. average)	--	--	--	--
Unspecified (IPCC)	1	56.1	48	53.27530693
Other Gas		**t CO_2 / Tj**	**Tj/Gg**	**kg CO_2 / MMBtu**
Refinery Fuel Gas	1	51.3	49.5	48.7169919
Low Btu Gas	--	--	--	--
Petroleum Products		**t CO_2 / Tj**	**Tj/Gg**	**kg CO_2 / MMBtu**
Diesel Fuel / Distillate Fuel Oil (#1, 2, & 4)	1	74	43	74.14476733
Jet Fuel	--	--	--	--
Kerosene	1	71.8	43.8	71.94046344
LPG (energy use)	1	63	47.3	59.82788479
Propane	--	--	--	--
Ethane	1	61.6	46.4	61.72050902
Isobutene	--	--	--	--
n-Butane	--	--	--	--
Residual Fuel Oil (#5 & 6)	1	77.3	40.4	77.45122317

Notes:
CARB and EIA factors are based on the fuel higher heating values (HHV); EU factors are based on net caloric value or lower heating value (LHV).
EU emission factor converted to kg/mmBtu (HHV) assuming that LHV are 10% lower for gaseous fuels and 5% lower for liquid fuels. 1 Btu = 1,055.06 j.

Data Sources:
EU factors are from the 2006 IPCC Guidelines for National Greenhouse Gas Inventories

Petroleum Refineries Notes: Default Emission Factors

Fuel CH4 and N20

Fuel Type	CARB Default CH4 Emission Factor gCH4/MMBtu (HHV)	CARB Default N2O Emission Factor gN2O/MMBtu (HHV)	EIA Default CH4 Emission Factor[1] kgCH4/MMBtu (HHV)	EIA Default N2O Emission Factor[1] kgN2O/MMBtu (HHV)	IPCC Default CH4 Emission Factor kgCH4/Tj (LHV)
Natural Gas	0.9	0.1	0.043	0.000853	1
Refinery Fuel Gas	0.9	0.1	--	--	1
Diesel Fuel / Distillate Fuel Oil (#1, 2 & 4)	3.0	0.6	0.018	0.005	3
Jet Fuel	3.0	0.6	0.018	0.005	3
Kerosene	3.0	0.6	0.018	0.005	3
LPG (energy use)	1.0	0.1	--	--	1
Propane	1.0	0.1	--	--	--
Residual Fuel Oil (#5 & 6)	3.0	0.6	0.018	0.005	3

Notes:

[1]The EIA default emssion factors are presented as the factors appear in the Technical Guidelines in units of kg/MMBtu instead of g/MMBTU. The factors appear to be incorrect, not matching the referenced IPCC values.

[2]The basis of the IPCC factors were converted to g/MMBtu (HHV) based on a conversion factor of 1,055.06 j per Btu, and assumptions that natural gas LHV is 10% less than HHV and oil 5% less.

Data Sources:

Both CARB and EIA values reference the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. CARB and EIA converted the IPCC values based on LHV to HHV values. CARB assumed gaseous fuel HHV is 10% higher than LHV, and 5% higher for liquid fuels.

The IPCC emission factors reference Air CHIEF, Version 12, EPA 454/C-05-001, U.S. EPA, OAQPS, Washington, DC, 2005. IPCC converted the EPA values based on HHV to LHV based on OECD/IEA assumptions that HHV is 10% higher than LHV for natural gas, and 5% higher for oil.

EPA CH4 and N2O factors are from the U.S. EPA, Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Stationary Combustion Sources, Table A-1, November 2007.

Petroleum Refineries Notes: Default Emission Factors

Fuel CH4 and N20 (continued)

Fuel Type	IPCC Default N2O Emission Factor kgN2O/Tj (LHV)	IPCC Default CH4 Emission Factor Converted[2] to gCH4/MMBtu (HHV)	IPCC Default N2O Emission Factor Converted[2] to gN2O/MMBtu (HHV)	EPA CH4 Emission Factor gCH4/MMBTU (HHV)	EPA N2O Emission Factor gN2O/MMBtu (HHV)
Natural Gas	0.1	1	0.1	1	0.1
Refinery Fuel Gas	0.1	1	0.1	--	--
Diesel Fuel / Distillate Fuel Oil (#1, 2 & 4)	0.6	3.0	0.6	3	0.6
Jet Fuel	0.6	3.0	0.6	3	0.6
Kerosene	0.6	3.0	0.6	3	0.6
LPG (energy use)	0.1	1	0.1	--	--
Propane	--	--	--	--	--
Residual Fuel Oil (#5 & 6)	0.6	3.0	0.6	3	0.6

Notes:

[1]The EIA default emssion factors are presented as the factors appear in the Technical Guidelines in units of kg/MMBtu instead of g/MMBTU. The factors appear to be incorrect, not matching the referenced IPCC values.

[2]The basis of the IPCC factors were converted to g/MMBtu (HHV) based on a conversion factor of 1,055.06 j per Btu, and assumptions that natural gas LHV is 10% less than HHV and oil 5% less.

Data Sources:

Both CARB and EIA values reference the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. CARB and EIA converted the IPCC values based on LHV to HHV values. CARB assumed gaseous fuel HHV is 10% higher than LHV, and 5% higher for liquid fuels.

The IPCC emission factors reference Air CHIEF, Version 12, EPA 454/C-05-001, U.S. EPA, OAQPS, Washington, DC, 2005. IPCC converted the EPA values based on HHV to LHV based on OECD/IEA assumptions that HHV is 10% higher than LHV for natural gas, and 5% higher for oil.

EPA CH4 and N2O factors are from the U.S. EPA, Climate Leaders Greenhouse Gas Inventory Protocol Core Module Guidance, Direct Emissions from Stationary Combustion Sources, Table A-1, November 2007.

Coke Burn Rate K Values

Coke Burn Rate Material Balance and Conversion Factors

	(kg min)/hr dscm %)	(lb min)/(hr dscf %)
K1	0.2982	0.0186
K2	2.088	0.1303
K3	0.0994	0.00624
CARB Source: US EPA 40 CFR 63.1564		

Summary of GHG Reporting Programs and Protocols for Phosphoric Acid Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Canada, Australia, EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Phosphoric Acid production		No protocol given for phosphoric acid production									
IPCC	Phosphoric Acid production	CO2	Acid-induced release of CO2 from acidification of carbonate-containing materials is considered to be small. Therefore, specific estimation methods are not presented.									http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf
US Inventory	Phosphoric Acid production	CO2	Process emissions from acidulation of phosphate rock, which contains some calcium carbonate, to produce phosphoric acid	NA	Sector	NA (activity data records)	Multiply phosphate rock consumed by inorganic carbon content (see attached sheet for factors and equations)	National Inventories	National phosphate rock consumption data (Source: USGS Minerals Yearbook), Inorganic carbon content (Source: FIPR, see attached sheet)	NA, not an industry-reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads/08_Industrial.pdf

Summary of GHG Reporting Programs and Protocols for Phosphoric Acid Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
NESHAP	Phosphoric Acid production	HAP	Process vents	Major sources (>25 tons total HAP/yr or >10 tons of single HAP/yr)	Unit (each process line)	Phosphate-bearing material feed NOTE: The rule has numeric emission limits for total fluorides based on wet scrubber control. In addition to the phosphate-bearing material feed monitoring, the control device operating parameters are monitored. However, the control device parameters are not useful for GHG calculations.	Monitoring system that measures the hourly total mass flow of phosphate-bearing feed material. Monitoring system design is not specified, but the sytesm must have 5% accuracy.	Mandatory compliance	Phosphate-bearing material feed mass flow	NA, monitoring and recordkeeping requirement only. NOTE: Annual and semi-annual reports are required but they don't include phosphate-bearing material feed flow rate data. It is retained as a record.		40 CFR 63 Subpart AA

[a] -- Industry trade groups include: The Fertilizer Institute (TFI), Florida Institute of Phosphate Research (FIPR), European Fertilizer Manufacturers Association (EFMA), and International Fertilzer Industry Association (IFA)

US GHG Inventory emission factors and methodology : Phosphoric Acid production (phosphate rock acidulation)

Methodology: Multiply phosphate rock consumption by percent inorganic carbon (as CO_2)

- Methodology assumes all inorganic carbon is converted to CO_2.
- Inorganic carbon (weight percent (% wt) as carbon) is converted to CO_2 basis (i.e. multiply by 44/12)
- based on data from the Florida Institute of Phosphate Research, these percentages are:

Source of Phosphate Rock	Inorganic Carbon (% wt as CO_2)
Central Florida	3.67
North Florida	3.43
North Carolina (calcined)	1.5
Idaho (calcined)	1
Morocco	5

- Due to lack of regional production data from USGS, the US GHG Inventory assumed Florida phosphate rock inorganic carbon percentages for all domestic phosphate rock.

Example calculation for facility using Central Florida phosphate rock:	
A. Tons of phosphate rock consumed:	900,000
B. Inorganic carbon content (% wt as CO_2):	3.67
Multiply A x (B/100) to get tons CO_2.:	33,030

Summary of GHG Reporting Programs and Protocols for Pulp and Paper Manufacturing

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
US Inventory, IPCC, Canada, Australia, DOE 1605(b), California, New Mexico, RGGI	Pulp and Paper		No protocol given									
WRI/WBCSD with the National Council for Air and Stream Improvement (NCASI)	Pulp and Paper	CO_2	Emissions from fossil fuel-based make-up carbonates (calcium carbonate and/or sodium carbonate) for lime production	NA	Not specified	NA (activity data records)	Multiply amount of make-up carbonates by 0.440 ton CO_2/ton (if using calcium carbonate) or 0.415 ton CO_2/ton (if using sodium carbonate)	Voluntary	Amount of make-up carbonate (calcium carbonate or sodium carbonate) purchased	NA. Not an industry reporting program	NA	http://www.ghgprotocol.org/downloads/calcs/Pulp_and_Paper_Guidance.pdf http://www.ghgprotocol.org/downloads/calcs/Pulp%20and%20Paper%20Tool.xls

Notes: IPCC lists the pulp and paper industry as a potential emitter of CO_2 and CH_4, but does not provide any methodological guidance.
EPA Climate Leaders guidance directly references the WRI/WBCSD/NCASI guidance presented here.
The Climate Registry Reporting Protocol references the WRI/WBCSD/NCASI guidance presented here.
The Official Journal of the European Union (EU) presents a protocol identical to the WRI/WBCSD/NCASI guidance presented here.
DOE 1605(b) guidance addresses emissions from the pulp and paper industry, but considers all the emissions addressed to be biogenic.
Emissions from fossil-based make-up carbonates are not discussed.

Assumptions: GHG emissions from other sources at pulp and paper mills are not included here, but may be found on other source category tables.
These additional sources may include combustion sources (including fossil fuel and pulping (black) liquor combustion); wastewater treatment; landfills; and mobile sources

Summary of GHG Reporting Programs and Protocols for Silicon Carbide Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Silicon Carbide	CO2, CH4	Silicon Carbide - Production	NA	Tier 1: Source category Tier 2: Facility Tier 3: Facility	NA (activity data records)	Tier 1: Based on default values and national statistics. (See attached sheet for factors and equations.) Tier 2: Based on plant-level production statistics. (See attached sheet for factors and equations.) Tier 3: Based on plant-level petroleum coke input. (See attached sheet for factors and equations.)	National Inventories
US Inventory	Silicon Carbide	CO2	Silicon Carbide - Production	NA	Source category	NA (activity data records)	IPCC emission factors (see attached sheet for factors and equations)	National Inventories
US Inventory	Silicon Carbide	CO2	Silicon Carbide - Consumption (Non-metallurgical and other non-abrasive uses)	NA	Source category	NA (activity data records)	Stoichiometric calculations	National Inventories
Canada, Australia, EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Silicon Carbide	No protocol given						

[a] Industry trade groups include: Assocation of Industrial Metalizers, Coaters, and Laminators; Institute of Materials, Minerals and Mining; Society for the Advancement of Material and Process Engineering

Summary of GHG Reporting Programs and Protocols for Silicon Carbide Production

Reporting Program/Guidance	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Tier 1: Production/consumption data. Tier 2: Production data. Tier 3: Consumption data.	NA, not an industry reporting program	National inventory compiler responsible for QA/QC (guidance for QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf (Section 3.6)
US Inventory	National production data. Source: USGS Minerals Yearbook	NA, not an industry-reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf (Section 4.14)
US Inventory	National consumption data. Source: USGS Minerals Yearbook	NA, not an industry-reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads/08_CR.pdf (Section 4.14)
Canada, Australia, EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	No protocol given			

[a] Industry trade groups include: Assocation of Industrial Metalizers, Coaters, and Laminators; Institute of Materials, Minerals and Mining; Society for the Advancement of Material and Process Engineering

IPCC Emission Factors and Calculation Methods for Silicon Carbide Production

Tier 1. CO2/CH4 Emission Estimation Method - Carbide Production

$E_{CO2} = M_{carbide} * EF_{CO2}$

$E_{CH4} = M_{carbide} * EF_{CH4}$

Tier 1. CO2 Emission Estimation Method - Petroleum Coke Consumption

$E_{CO2} = M_{coke} * EF$

Tier 2. CO2/CH4 Emission Estimation Method - Carbide Production (Facility Level)

$E_{CO2} = M_{carbide} * EF_{CO2}$

$E_{CH4} = M_{carbide} * EF_{CH4}$

Tier 3. CO2 Emission Estimation Method - Petroleum Coke Consumption (Facility Level)

$E_{CO2} = M_{coke} * EF$

Tier 1. CO2/CH4 Emission Factors - Carbide Production

Carbide Type	CO2 Emission Factor (ton/ton product)	CH4 Emission Factor (ton/ton product)
Silicon Carbide	2.62	0.0116

Tier 1. CO2 Emission Factors - Petroleum Coke Consumption

$EF = (1 - 0.35) * CCF_{default} * COF_{default} * (44/12)$

0.35 = default carbon content of carbide product

$CCF_{default}$ = default carbon content factor (in coke)

$COF_{default}$ = default carbon oxidation factor (in coke)

44/12 = conversion from C to CO2

Tier 2. CO2/CH4 Emission Factors - Carbide Production (Facility Level)

Carbide Type	CO2 Emission Factor (ton/ton product)	CH4 Emission Factor (ton/ton product)
Silicon Carbide	2.62	0.0116

Tier 3. CO2 Emission Factors - Petroleum Coke Consumption (Facility-Level)

$EF = (1 - C_{product}) * CCF * COF * (44/12)$

$C_{product}$ = carbon content of carbide product

CCF = carbon content factor (in coke)

COF = carbon oxidation factor (in coke)

44/12 = conversion from C to CO2

U.S. Inventory Emission Factors and Calculation Methods for Silicon Carbide Production/Consumption

CO2/CH4 Emission Estimation Method - Carbide Production

$E_{CO2} = M_{carbide\ production} * EF_{CO2}$

$E_{CH4} = M_{carbide\ production} * EF_{CH4}$

CO2 Emission Estimation Method - Carbide Consumption

$E_{CO2} = M_{carbide\ consumption} * MF * MWR_C * MWR_{CO2}$

MF = metallurgical fraction of SiC consumption (approximately 50%).

MWR_C = molecular weight ratio of carbon to silicon carbide

MWR_{CO2} = molecular weight ratio of carbon dioxide to carbon

CO2/CH4 Emission Factors - Carbide Production

Carbide Type	CO2 Emission Factor (ton/ton product)	CH4 Emission Factor (ton/ton product)
Silicon Carbide	2.62	0.0116

Summary of GHG Reporting Programs and Protocols for Soda Ash Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
American Petroleum Institute Compendium, California Mandatory GHG Reporting Program, The Climate Registry, EPA Climate Leaders Program, EU Emissions Trading Scheme, Greenhouse Gas Protocol Initiative, International Aluminium Institute, New Mexico Mandatory GHG Reporting Program, and Regional Greenhouse Gas Initiative	No protocol given for soda ash production					
2006 IPCC Guidelines	Soda ash manufacturing	CO2	Production process emissions	None	Tier 1: Sector-based; Tiers 2 and 3: Facility-level emissions, summed to national estimate	Not specified

Summary of GHG Reporting Programs and Protocols for Soda Ash Manufacturing

Reporting Program/ Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
American Petroleum Institute Compendium, California Mandatory GHG Reporting Program, The Climate Registry, EPA Climate Leaders Program, EU Emissions Trading Scheme, Greenhouse Gas Protocol Initiative, International Aluminium Institute, New Mexico Mandatory GHG Reporting Program, and Regional Greenhouse Gas Initiative	No protocol given for soda ash production					
2006 IPCC Guidelines	Tier 1 (national-level data): CO2 emission factor (0.097 ton CO2/ton of Trona ore consumed; or 0.138 ton CO2/ton natural soda ash produced) * activity data (Trona ore used in production, or amount of natural soda ash produced) Tier 2 (facility-level data): Site-specific CO2 emission factor * site-specific Trona ore or natural soda ash production data (default emission factor is used where site-specific data are not available) Tier 3: (facility-level data): CO2 data obtained through direct measurement	National inventories required from industrialized countries participating in the United Nations Framework Convention on Climate Change (UNFCCC)	Tier 1: National aggregate data on tons Trona ore consumed, or tons soda ash produced Tier 2: Plant-level Trona ore consumption data or soda ash production data (records) and site-specific emission factors Tier 3: Plant-level CO2 data obtained through direct measurement (no details provided)	Not applicable (not an industry reporting program)	National inventory compiler responsible for QA/QC (guidance for QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf

Summary of GHG Reporting Programs and Protocols for Soda Ash Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
DOE 1605(b) Voluntary Reporting Program	Soda ash production and use	CO2, CH4, N2O, perfluorocarbons, hydrocarbons, sulfur hexafluoride (reported as CO2 equivalents). Chlorofluorocarbons are reported separately but not registered.	Production process emissions	None	Businesses, institutions, organizations, government agencies, corporations, and households	Approach 1: Not applicable (activity data records) Approach 2: Not specified
California Climate Action Registry	Soda ash production and use	CO2 (for first 3 years of participation); CO2, CH4, N2O, HFCs, PFCs, SF6 beginning in fourth year	Production process emissions	GHG emissions from sources that comprise 5% or less of an entities total GHG emissions are considered de minimis	Businesses, government agencies, and non-profit organizations participating in the California Climate Action Registry	Not specified

Summary of GHG Reporting Programs and Protocols for Soda Ash Manufacturing

Reporting Program/ Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
DOE 1605(b) Voluntary Reporting Program	Approach 1: CO2 emission factor (0.097 ton CO2/ton of Trona ore consumed) * activity data (Trona ore used in production) Approach 2: Direct emissions measurement	Voluntary inventory and emission reduction reporting program	Emission factors (based on limited direct measurements of source or representative sample) or default emission factors and measured or estimated activity data (i.e., Trona ore use). Continuous direct measurement of emission source or emission factors based upon multiple, recent, regularly repeated, on-site, direct measurements of sources, multiplied by measured activity data.	Annual	Not explicitly specified (QA/QC procedures are the responsibility of the inventory compiler or reporter)	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf
California Climate Action Registry	Program document refers to the procedures contained in the "Guidelines for the Measurement and Reporting of Emissions in the UK Emissions Trading Scheme" and "Guidance to the California Climate Action Registry"	Voluntary GHG registry	Not specified	Annual GHG emission reports	Third party verification - approved certifier conducts completeness and QA/QC checks	http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html

Summary of GHG Reporting Programs and Protocols for Soda Ash Manufacturing

Reporting Program/ Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
U.S. Greenhouse Gas Inventory Reports	Soda ash manufacture and use	CO2	Production process emissions	None	National level	Not specified
Gov't of Canada - Greenhouse Gas Reporting	Industrial processes (soda ash manufacture is not explicitly identified)	CO2, CH4, N2O, hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride	Production process emissions	100,000 metric tons CO2e	Facility level	Not specified
Australian National Greenhouse and Energy Reporting System	Soda Ash Production and Use	CO2e	Production process emissions	Registration and reporting required for corporations if: they control facilities that emit at least 25,000 metric tons of CO2e, or produce or consume at least 100 terajoules of energy; or their corporate group emits at least 125,000 metric tons CO2e, or it produces or consumes at least 500 terajoules of energy.	Facility level	Not specified

Summary of GHG Reporting Programs and Protocols for Soda Ash Manufacturing

Reporting Program/ Guidance	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
U.S. Greenhouse Gas Inventory Reports	This report presents estimates by the United States government of U.S. anthropogenic greenhouse gas emissions and sinks for the years 1990 through 2006. CO2 emissions from soda ash production were calculated using a stoichiometric CO2 emission factor (0.097 tons CO2/ton of Trona ore consumed) and annual activity data (Trona ore production) at the national level.	National inventory	Stoichiometric CO2 emission factor and Trona ore production (from U.S. Geological Survey)	Not applicable (not an industry reporting program)	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/usinventoryreport.html
Gov't of Canada - Greenhouse Gas Reporting	No specific emission estimation protocols are specified; however, methodologies should be consistent the methodologies approved by the UNFCCC and developed by the IPCC	Mandatory	Procedures consistent with IPCC	Annual emission estimates	The program does not require third-party review of emission estimates	http://www.ghgreporting.gc.ca/GHGInfo/Pages/page15.aspx
Australian National Greenhouse and Energy Reporting System	Methods for estimating emisssions from soda ash manufacture follow the IPCC procedures.	Mandatory	Procedures consistent with IPCC	Annual reports using the Online System for Comprehensive Activity Reporting	QA/QC procedures developed by inventory reporters	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Electric Power Systems	SF6	Industrial Processes	All (no deminimis)	National		**Tier 1: Default Emission Factors** Total emissions = manufacturing emissions + equipment installation emissions + equipment use emissions + equipment disposal emissions where, *Manufacturing emissions* = manufacturing emission factor * total SF6 consumption by equipment manufacturers *Equipment installation emissions* = installation emission factor * total nameplate capacity of new equipment filled on site (not at the factory) *Equipment use emissions* = use emission factor * total nameplate capacity of installed equipment. The "use emission factor" includes emissions due to leakage, servicing, and maintenance as well as failures. *Equipment disposal emissions* = total nameplate capacity of retiring equipment * fraction of SF6 remaining at retirement Note: All emissionf factors refer to regional default emission factors, as given in the 2006 IPCC guidelines (See Note 1)	To meet the inventory reporting requirements of Parties to the UNFCCC)
2006 IPCC Guidelines	Electric Power Systems	SF6	Industrial Processes	All (no deminimis)	National		**Tier 2: Country-Specific Emission Factor** This approach uses the same equation as the Tier 1 approach, but uses country-sepcific default emission factors instead of region-specific default emission factors. Emissions factors should be calculated using data collected from manufacturers and utilities that track emissions by life cycle stage, using a mass balance method for at least one year. The disposal factor should also account for emissions that occur downstream of the utility site. The Tier 2 approach includes a term for the emissions at equipment at disposal, which accounts for SF6 recovery at retirement and disposal as follows: Equipment disposal emissions = Total nameplate capacity of retiring equipment * fraction of SF6 remaining at retirement * (1-fraction of retiring equipment whose SF6 is recovered * recovery efficiency * fraction of recovered SF6 recycled, reused with no further treatment, or destroyed)	To meet the inventory reporting requirements of Parties to the UNFCCC)

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Electric Power Systems	**Tier 1 Inputs:** (1) total SF6 consumption by equipment manufacturers; (2) total nameplate capacity of new equipment filled on site; (3) total nameplate capacity of installed equipment; (4) total nameplate capacity of retiring equipment; (5) Region-specific default factors (i.e., manufacturing emission factor, installation emission factor, use emission factor, fraction of SF6 remaining at retirement of equipment).	NA, not an industry reporting program	General QA/QC procedures outlined national inventory compiler	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf
2006 IPCC Guidelines	Electric Power Systems	**Tier 2 Inputs:** (1) total SF6 consumption by equipment manufacturers; (2) total nameplate capacity of new equipment filled on site; (3) total nameplate capacity of installed equipment; (4) total nameplate capacity of retiring equipment; Country-specific default factors (i.e., fraction of SF6 remaining at retirement of equipment, fraction of retiring equipment whose SF6 is recovered, recovery efficiency, fraction of recovered SF6 recycled or reused with no further treatment or destroyed, manufacturing emission factor, installation emission factor, use emission factor).	NA, not an industry reporting program	General QA/QC procedures outlined national inventory compiler	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Electric Power Systems	SF6	Industrial Processes	All (no deminimis)	National		**Tier 3: Hybrid Methods--Emissions By Life Cycle Stage of Equipment** For the Tier 3 approach a pure mass-balance approach is preferred, except in certain processes that have very low emission rates (see Note 2). At facilities where these low emission rate processes occur, it is acceptable to use a hybrid approach where a combination of an emissions factor and mass-balance approach is used. There are different mass-balance and hybrid equations for each state in the life-cycle of emissions (e.g., equipment manufacturing, equipment installation, equipment use, equipment disposal and final use, and emissions from SF6 recycling and destruction).For countries where SF6 emissions during equipment installation, use, and disposal account for 3 percent or more of facility level gas flows, where electrical equipment has been used for 10-20 years or more, and where emissions from sealed-pressure equipment are negligible, a simplified utility-level mass-balance approach can be used to estimate emissions from equipment installation, use, and disposal with little or no loss in accuracy. (see Note 3 for specific equations).	To meet the inventory reporting requirements of Parties to the UNFCCC)

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Electric Power Systems	**Tier 3 Inputs:** Emissions by Life Cycle State: --Equipment manufacturing: decrease in SF6 Inventory, acquisitions of SF6, disbursements of SF6, nameplate capacity of equipment undergoing each process (hybrid only), emissions factor for process (hybrid only). --Equipment installation: SF6 used to fill equipment, nameplate capacity of new equipment, installation emissions factor (hybrid only). --Equipment use emissions: SF6 used to recharge closed pressure equipment at servicing, SF6 recovered from closed pressure equipment at servicing, nameplate capacity of equipment that is installed (hybrid only), use emissions factor (hybrid only). --Equipment disposal and final use emissions: Nameplate capacity of retired closed-pressure equipment, SF6 recovered from retired closed-pressure equipment, nameplate capacity of retired sealed-pressure systems, SF6 recovered from retired sealed-pressure systems, use emissions factor (for hybrid only), lifetime of equipment (for hybrid only).	NA, not an industry reporting program	General QA/QC procedures outlined national inventory compiler	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Electric Power Systems	SF6	Industrial Processes	All (no deminimis)	National		Monitoring procedures: gas consumption can be measured by using flow meters, analysing records of transactions of SF6 gas and transactions of equipment that contains SF6 gas, or by weighing gas cylinders before and after filling/recovery operations or at the beggining and ending of the year.	To meet the inventory reporting requirements of Parties to the UNFCCC)
U.S. National Inventory	Electric Power Systems	SF6	Industrial Processes	All (no deminimis)	Country Level		**Partners:** Partner utilities estimate their emissions using the IPCC Tier 3 utility-level mass balance approach (see Note 4). Partners report their emissions to the US EPA, which is used to estimate the Partner share of total US emissions. **Non-Partners:** Non-Partner utilities' emissions are estimated using a country-specific default emission factors, according to the following equation: SF Emissions (lbs) = Emission Factor x transmission miles Where, the country-specific emission factor is developed using Partner reported data, and transmission miles are from the 2007 UDI Directory of Electric Power Producers and Distributors.	Mandatory

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Electric Power Systems	Recycling of SF6: recycling emission factor, quantity SF6 fed into recycling process. SF6 Destruction: destruction emission factor, quantity SF6 fed into destruction process For Emissions at Utility-level (Special Case of Tier 3): (1) SF6 stored in containers at the beginning of the year; (2) SF6 stores in containers at the end of the year; (3) SF6 purchased from chemical producers or distributors in bulk; (4) SF6 purchased from equipment manufacturers or distributors with or inside of equipment; (5) SF6 returned to site after off-site recycling; (6) SF6 contained in equipment that is sold to other entities; (7) SF6 returned to suppliers; (8) SF6 sent off-site for recycling; (9) SF6 destroyed; (10) nameplate capacity of new equipment; (11) nameplate capacity of retiring equipment	NA, not an industry reporting program	General QA/QC procedures outlined national inventory compiler	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_8_Ch8_Other_Product.pdf
U.S. National Inventory	Electric Power Systems	**Partners:** SF6 Emission Reduction Partnership for Electric Power Systems. **Non-Partners:** total transmission miles for non-Partners (2007 UDI Directory of Electric Power Producers and Distributors).	National emissions inventory for all GHGs reported to the UNFCCC.	General QA/QC procedures outlined for the national inventory compiler in 2006 IPCC Guidelines	http://www.epa.gov/electricpower-sf6/

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Climate Registry	Electric Power Systems	SF6	Industrial Processes	3% of total emissions can be considered deminimis. Total emissions refers to an "entity's total emissions," which include all emissions that occur with the entity's organizational boundaries. For example semiconductor manufacturing emissions would include not only process emissions, but other direct emissions (including transportation, on-site energy, etc).	Company level		Recommends the IPCC Tier 3 utility-level mass balance approach (see 2006 IPCC Guidelines)	Voluntary
DOE 1605b	Electric Power Systems	SF6	Industrial Processes	All (no deminimis)	Facility or company level. (Reporters must set reporting boundaries consistently across all reporting years.)		Suggests consulting the 2000 IPCC Tier 1, Tier 2, and Tier 3 approaches (see Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories) "A" Rating = 2000 IPCC Tier 3a (mass balance by life cycle stage of equipment) and Tier 3b (mass balance at the manufacturer and facility level) approaches. "B" Rating = 2000 IPCC Tier 2a (inference method by life cycle stage using emissions factors) "C" Rating = 2000 IPCC Tier 2b (inference method using non-life cycle emissions factors) "D" Rating = 2000 IPCC Tier 1 (regional wide default emissions factors).	Voluntary

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Climate Registry	Electric Power Systems	Recommends the IPCC Tier 3 utility-level mass balance approach	Annual GHG emissions (CO2 equivalents). Activity and throughput data for each of the entity's facilities. Information identifying the entity; whether the entity is participating as a transitional reporter; the consolidation approach(es) employed (i.e., operational control, financial control, equity share); the entity's base year; quantification methodologies and "tiers" employed for each source, including disclosure of all relevant assumptions made and data sources used, as well as identifying any changes to the data, inventory boundary, methods, or other relevant factors relative to prior-year reports; detailed descriptions of each of the entity's facilities and its emission sources.	Rigorous independent third-party verification system, based on the California Climate Action Registry's current approach to verification. The Registry's reporting software and database indicate whether reported emissions data in the system has been verified. (Page 7)	http://www.theclimateregistry.org/downloads/Draft_GRP.pdf
DOE 1605b	Electric Power Systems		Report direct and indirect emissions released into the atmosphere minus any sequestration of greenhouse gases from the atmosphere that occurred over the year covered by the inventory. Report emissions in metric mass units of gas, and subentity summations in metric mass units of CO2Eq. Average rating (Assign a rating to each category of emissions, where A=4, B=3, C=2, and D=1. Multiply the points of the rating by the share of each category in total emissions and sequestration. The inventory's average rating is the sum of the reporter's ratings for each category, weighted by each category's share in total emissions.). Report the approach used to establish organizational boundaries. Report the estimation methods and information sources necessary to estimate emissions. Also report type of entity, the entity's economic activities, and definition of the entity.	"The methods chosen, the application of the methods, and the data used should be, in principle, accessible to verification by a third party, whether or not such verification actually takes place." (Page 3) "Reporters to the Voluntary Reporting of Greenhouse Gases (1605(b)) Program that directly measure their emissions are expected to follow internal quality control assessments that verify the accuracy of their measurement systems." (page 83)	http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
SF6 Emission Reduction Partnership for Electric Power Systems	Electric Power Systems	SF6	Industrial Processes	Voluntary	Electric Utility		The following mass-balance approach is required: Total annual emissions = change in inventory of cylinders (beginning of year inventory - end of year inventory) + purchases/acquisitions of SF6 - sales/distribution of SF6 - change in total nameplate capacity of equipment (see Note 4)	Voluntary
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	SF6 from Electrical Equipment	SF6	Fugitive - electric generating facilities, electricity retail providers, electric power marketers	All (if deminimis [= <3%] can be calculated more simply using methods chosen by operator; however, such estimates are still subject to verification)	Facility (or aggregated if multiple facilities are owned)		EPA's mass-balance method: monitoring of 1) change in SF6 inventory, 2) purchases/acquisitions of SF6, 3) sales/disbursements of SF6, 4) change in total nameplate capacity of equipment. (see Note 4)	Mandatory
California Climate Action Registry (CCAR) - Power/Utility Reporting Protocol	SF6 from Electrical Equipment	SF6	Fugitive - electricity transmission and distribution	Up to 5% of entity's total emissions can be excluded as de minimis	Entity		EPA's mass-balance method: monitoring of 1) change in SF6 inventory, 2) purchases/acquisitions of SF6, 3) sales/disbursements of SF6, 4) change in total nameplate capacity of equipment. (see Note 4)	Voluntary

Review of Existing Programs Relevant to Source - Sulfur Hexafluoride (SF6) from Electrical Equipment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
SF6 Emission Reduction Partnership for Electric Power Systems	Electric Power Systems	**Change in Inventory:** inventory at beginning of year, inventory at end of year **Total Purchases/Acquisitions:** SF6 purchased from producers or distributors in cylinders, SF6 provided by equipment manufacturers with/inside equipment, SF6 returned to the site after off-site recycling **Total Sales/Disbursements:** sales of SF6 to other entities, including gas left in equipment that is sold, returns of SF6 to supplier, SF6 sent to destruction facilities, SF6 sent off-site for recycling **Change in Nameplate Capacity:** total nameplate capacity (proper full charge) of new equipment, total nameplate capacity (proper full charge) of retired or sold equipment **Emission Rate (optional):** emissions/ total nameplate capacity at end of year			http://www.epa.gov/electricpower-sf6/resources/index.html, http://www.epa.gov/electricpower-sf6/documents/partnersf6reporting_eform.xls
CA Mandatory GHG Reporting Program - Initial Statement of Reasons - 10/16/07 version with 12/06/07 updates	SF6 from Electrical Equipment	Inputs to the mass-balance equation: cylinders of SF6 at beginning and end of year, SF6 purchased from producers or distributors in cylinders, SF6 provided by equipment manufacturers with/inside equipment, SF6 returned to the site after recycling, sales of SF6, returns of SF6 to supplier, SF6 sent for destruction or recycling, total nameplate capacity for new and retired or sold equipment.			http://www.arb.ca.gov/regact/2007/ghg2007/isor.pdf
California Climate Action Registry (CCAR) - Power/Utility Reporting Protocol	SF6 from Electrical Equipment	Inputs to the mass-balance equation: cylinders of SF6 at beginning and end of year, SF6 purchased from producers or distributors in cylinders, SF6 provided by equipment manufacturers with/inside equipment, SF6 returned to the site after recycling, sales of SF6, returns of SF6 to supplier, SF6 sent for destruction or recycling, total nameplate capacity for new and retired or sold equipment.			http://www.climateregistry.org/resources/docs/protocols/industry/power-utility/CaliforniaRegistryPowerUtilityReportingProtocolVersion10APRIL2005.pdf

Review of Existing Programs Relevant to Source - Electrical Equipment

Note 1 - Tier 1 Emission Factors

Default emission factors should be chosen from countries and regions with equipment designs and SF6-handling practices similar to those of the country whose emissions are being estimated. Most electrical equipment is produced in Europe and Japan. Emission factors for the two countries (along with a few for the U.S.) are shown below:

Sealed pressure electrical equipment:
Manufacturing (fraction of consumption by manufacturers): Europe = 0.07 , Japan = 0.29
Use (fraction per year of nameplate capacity of all equipment installed): Europe = 0.002, Japan = 0.007
Disposal (fraction nameplate capacity of disposed equipment): Europe = 0.93, Japan = 0.95

Closed pressure electrical equipment:
Manufacturing (fraction of consumption by manufacturers): Europe = 0.085, Japan = 0.29
Use (fraction per year of nameplate capacity of all equipment installed): Europe = 0.026, Japan = 0.007, U.S. = 0.14 (includes emission from installation)
Disposal (fraction nameplate capacity of disposed equipment): Europe = 0.95, Japan = 0.95, U.S. (disposal emissions are included in use emission factor)

Gas insulated transformers:
Manufacturing (fraction of consumption by manufacturers): Japan = 0.29
Use (fraction per year of nameplate capacity of all equipment installed): Japan = 0.007
Disposal (fraction nameplate capacity of disposed equipment): Japan = 0.95
Source: IPCC, 2007. 2006 IPCC Guidelines on National Greenhouse Gas Inventories.

Note 2 - Cases when it is acceptable to use a country or facility specific emissions factor rather than a mass-balance approach:

(1) emission rates from a process are near or below the precision of the measurements required for the mass-balance approach (e.g., 3 percent of nameplate capacity per year or less)
(2) equipment is never serviced during its lifetime (as is expected to be the case for sealed pressure equipment)
(3) equipment stocks are growing very rapidly, as may be the case in countries where electrical equipment has been introduced within the last 10-20 years.
Source: IPCC, 2007. 2006 IPCC Guidelines of National Greenhouse Gas Inventories.

Note 3 - Pure mass-balance and mass-balance hybrid equations

Equipment manufacturing emissions, pure mass-balance: decrease in SF6 inventory + acquisitions of SF6 - disbursements of SF6

Equipment manufacturing emissions, hybrid: pure mass balance equation + ∑ Nameplate capacity of equipment undergoing each process (that isn't covered in pure mass balance) * emissions factor for that process

Equipment installation emissions, pure mass balance: SF6 used to fill equipment - nameplate capacity of new equipment

Equipment installation emissions, hybrid: pure mass balance equation + ∑ nameplate capacity of new equipment filled on site (that isn't covered in pure mass balance) * installation emissions factor

Equipment use emissions, pure mass balance: SF6 used to recharge closed pressure equipment at servicing - SF6 recovered from closed pressure equipment at servicing

Equipment use emissions, hybrid: pure mass balance equation + ∑ nameplate capacity of equipment installed (that isn't covered in pure mass balance) * use emissions factor

Equipment disposal and final use emissions, pure mass balance: emissions from closed-pressure equipment (nameplate capacity of retired closed-pressure equipment - SF6 recovered from retired closed-pressure equipment) + emissions from sealed pressure equipment (nameplate capacity of retired sealed-pressure systems - SF6 recovered from retired sealed-pressure systems)

Equipment disposal and final use emissions, hybrid: emissions from closed pressure equipment (nameplate capacity of retired closed pressure equipment - SF6 recovered from retired closed-pressure equipment) + emissions from sealed-pressure equipment [(Nameplate capacity of retired sealed-pressure systems) - (nameplate capacity of retired sealed-pressure systems * use emission factor * lifetime of equipment)] * (1-fraction of retiring equipment whose SF6 is recovered * recovery efficiency)

Emissions from recycling of SF6: recycling emission factor * Quantity SF6 fed into recycling process

Emissions from destruction of SF6: destruction emission factor * quantity SF6 fed into destruction process

Utility-level mass-balance approach: decrease in SF6 inventory + acquisitions of SF6 - disbursements of SF6 - net increase in the nameplate capacity of equipment

Decrease in SF6 Inventory = SF6 stored in containers at the beginning of the year - SF6 stored in containers at the end of the year

Acquisitions of SF6 = SF6 purchased from chemical producers or distributors in bulk + SF6 purchased from equipment manufacturers or distributors with or inside equipment + SF6 returned to site after off-site recycling

Disbursements of SF6 = SF6 contained in equipment that is sold to other entities + SF6 returned to suppliers + SF6 sent off-site for recycling + SF6 destroyed

Net Increase in Nameplate Capacity of Equipment = nameplate capacity of new equipment - nameplate capacity of retiring equipment

Note 4 - Calculating fugitive SF6 emissions in electrical systems

Method is based on the mass-balance methodology created by the US EPA SF6 Emissions Reduction Partnership for Electric Power Systems.

Emissions = (A1-A2) + (B1+B2+B3) - (C1+C2+C3+C4) - (D1-D2)

Where:

A1 = SF6 in inventory (beginning of year)
A2 = SF6 in inventory (end of year)
B1 = SF6 puchased from producers or distributors in cylinders
B2 = SF6 provided by equipment manufacturers with/inside equipment
B3 = SF6 returned to the site after off-site recycling
C1 = sales of SF6 to other entities including gas left in equipment that is sold
C2 = returns of SF6 to supplier
C3 = SF6 sent to destruction facilities
C4 = SF6 sent off-site for recycling
D1 = total nameplate capacity (proper full charge) of new equipment
D2 = total nameplate capacity (proper full charge) of retired or sold equipment
ALL IN LBS

SF6 should then be converted to metric tonnes CO2e using IPCC SAR GWPs

Review of Existing Programs -Titanium Dioxide Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Titanium dioxide production		No protocol given for titanium dioxide production				
Canada Mandatory GHG Reporting	Titanium dioxide production	CO2	Phase 1: Consistent with IPCC.	100,000 metric tons CO2e	Facility	NA (activity data records)	Phase 1: No prescribed estimation methods, but should be consistent with IPCC (prioritize by Tier-method based on emissions levels).
Australia National Mandatory GHG Reporting Program	Titanium dioxide production	CO2	Process emissions from production of titanium dioxide and synthetic rutile	Registration and reporting required for corporations if: they control facilities that emit at least 25,000 metric tons of CO2e, or produce or consume at least 100 terajoules of energy; or their corporate group emits at least 125,000 metric tons CO2e, or it produces or consumes at least 500 terajoules of energy.	Facility	NA (activity data records)	NGA default method: Based on carbon reductant usage (A), energy content of reductant (EC), and emission factor (EF) for reductant. E = ∑A * EC * EF / 1000 (See attached sheet for EC and EF default values.) Higher-order method: Facility-specific emission factors.
IPCC	Titanium dioxide production	CO2	Process emissions from production of titanium slag, synthetic rutile, and rutile titanium dioxide (chloride route)	NA	Tier 1: Source category Tier 2: Facility	NA (activity data records)	Tier 1: Based on production-based emission factor. Tier 2: Based on reducing agent usage (or carbothermal input), carbon content, and carbon oxidation factor. (See attached sheet for factors and equations.)
US Inventory	Titanium dioxide production	CO2	Process emissions from production of titanium dioxide	NA	Source category	NA (activity data records)	Emission factor: [0.4 tons CO2/ton TiO2 produced]

[a] Industry trade groups include: International Lead and Zinc Study Group, International Zinc Association, American Foundry Society, Natural Resources Canada - Minerals and Metals, Non-Ferrous Founders' Society (NFFS), and Centre for Sustainable Resource Processing

Review of Existing Programs -Titanium Dioxide Production

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Titanium dioxide production					
Canada Mandatory GHG Reporting	Titanium dioxide production	Mandatory	Phase 1: Consistent with IPCC input data needed based on Tier-method selected.	Annual emissions data (in CO2e).	Phase 1: Information should be verifiable. No third party verification required.	C:\GHG Reporting Rule\Review of Existing Rules\Canada\page2.mht
Australia National Mandatory GHG Reporting Program	Titanium dioxide production	Mandatory	NGA default method: Quantity of reducing agent or fuel consumed, and energy content of reducing agent or fuel. Higher-order method: Carbon content.	NGA default method: Annual production and amount of carbon reductant consumed. Higher-order method: Annual amount of carbon reductant consumed, facility-specific emission factors, and emissions.	QA/QC procedures developed by inventory compiler. Rating system for emission estimation methods and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf
IPCC	Titanium dioxide production		Tier 1: Production data. Tier 2: Total reductant use, total carbon electrode consumption, and total carbothermal input.	NA, not an industry reporting program	National inventory compiler responsible for QA/QC. (Guidance on QA/.QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf
US Inventory	Titanium dioxide production	National Inventories	National production data and % chloride process. Source: USGS Minerals Yearbook	NA, not an industry reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf

[a] Industry trade groups include: International Lead a
Natural Resources Canada - Minerals and Metals,

IPCC Emission Factors and Calculation Methods for Titanium Dioxide Production

Tier 1. Generic CO2 Emission Factors

Product	CO2 Emission Factor (ton/ton product)
Titanium slag	Not available
Synthetic rutile	1.43 (± 10%)
Rutile titanium dioxide (chloride route)	1.34 (± 15%)

Tier 2. CO2 Emission Estimation Method

$$E_{CO2} = \sum(AD * CFF * COF * 44/12)$$

where:
AD = Amount of reducing agent or carbothermal input
CCF= Carbon content factor of reducing agent or carbothermal input
COF= Carbon oxidation factor for reducing agent or carbothermal input

Austrialian NGA default emission factors

Fuel Combusted	Energy Content (gross) GJ/t	Emission Factor kg CO2e/GJ (all gases)
Lignite-Brown coal	10.2	93.2
Coking coal (metallurgical coal)	30.0	90.2
Black coal	27.0	88.5
Brown coal briquettes	22.1	93.6
Coke oven gas	27.0	117.4
Coal tar	37.5	81.3

Fugitives from Underground Coal Mining (Active)

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
2006 IPCC Guidelines	Coal Mining	CH_4	Fugitive		Individual mine		**Underground:** *Direct Measurements (**Tier 3**)* : = Ventilation (direct measurement data reported to MSHA) + degasification (directly measured) *Indirect estimation of degasification (**Tier 3/Tier 2 Hybrid**)* **:** Where ventilation measured (or can be estimated from measurements from similar mines in the same basin or region), but not degasification, estimate amount degassified (no methodology specified) and use appropriate methods for accounting for the disposition of the degassified methane (e.g.; vented, flared, sold, consumed on-site -- suggested approaches provided in the Guidelines). When mine-specific data are unavailable (Tier 2): use basin/region-specific emission factor multiplied by production (representative emissions factors provided in Guidelines; see Note 1). **Surface Mining and Post-Mining** (after both surface and underground mining) (Tier 1 or 2): Multiply the amount of coal produced at a given mine times a basin-specific emissions factor. Surface mining emissions factor recommended as a function of the depth of overburden, when known. (Recommended emissions factors are provided in the Guidelines; see Note 2). For post-mining emissions from underground mines, the emissions factor is estimated to be 30% of the in situ methane content in the basin, if no pre-drainage, and 10% if there is pre-drainage (See Note 3). For post-mining emissions from surface mines, sugggested emission factors are provided in the Guidelines (see Note 4). For Abandoned Underground Mines (Tier 1 or 2), an approach is recommended based on the elapsed time since abandonment, the mine's initial gassiness, and the extent to which the mines have become flooded. Recommendations for default assumptions and approaches are provided for emission factors for abandoned underground and surface mines and the portion of mines that are gassy.(See Note 5)	Inventory reporting requirements for Parties of the UNFCCC
Mine Safety and Health Administration (MSHA) Quarterly Ventilation Air Sampling	Coal Mining	CH_4	Fugitive		Each individual underground coal mine. Data **not** collected from surface coal mines, abandoned mines, or from post-mining activities.	Samples are collected from mine ventilation systems; according to procedures described in the MSHA Handbook Series (see link and Note 7).	Monitoring must be performed by a qualified person using methane monitoring devices approved by MSHA (under 30 CFR Parts 18,21,22,23,27, and 29); and are maintained in permissible and proper operating condition and calibrated with a known methane-air mixture at least once every 31 days.	Mandatory sampling conducted as part of quarterly MSHA mine inspections.

Fugitives from Underground Coal Mining (Active)

Reporting Program/Guidance	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
2006 IPCC Guidelines	Input data used to calculate emissions for Tier 2 and Tier 1 approaches include coal production and estimated emission factors, as specified in the IPCC Guidelines (see Notes 1-5) For Tier 3 apprahces, MSHA ventilation air sample data is used as input, along with operator-reported volumes and disposition of gas produced from degasificaiton systems.			http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf
Mine Safety and Health Administration (MSHA) Quarterly Ventilation Air Sampling	MSHA inspectors also collect information on the presence and types of degasification systems in some mines, but not quantitative data on the amount of CH_4 liberated. Mine operators also report mine-specific coal production quarterly. Mine operators generally collect data on gas liberated or recovered through degasifications systems, especially if the methane is captured and productively used (sold or consumed on-site).	MSHA inspectors instructed to report air sample data (if methane > 50 ppm) (see Note 6) and ventilation air volumes (See Note 7)	MSHA inspectors must be trained and certified	http://www.msha.gov/30CFR/75.0.htm; http://www.msha.gov/30CFR/57.0.htm; and http://www.msha.gov/READROOM/HANDBOOK/HANDBOOK.HTM

Fugitives from Underground Coal Mining (Active)

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
DOE 1605(b) Voluntary Reporting of Greenhouse Gases Program	Coal Mining	CH_4	Fugitive	<10,000 metric tons is a "small emitter"- simplified procedures for reporting and registration under the program	Individual mine		**Underground:** *Direct Measurements*: Ventilation (direct sample measurement data reported to MSHA) + degasification (directly measured) *Indirect estimation of degasification*: Where ventilation measured, but not degasiffication, assume degasification is 40% of total liberated, so multiply ventilation emissions by 1.667 *For mines with undetectable methane levels:* Reporters can calculate ventilation emissions by multiplying a flow rate of 3,000 cubic feet per minute by an assumed methane concentration of 0.05% to derive a methane emissions flow rate. (Annual CH_4 emissions = 3,000 ft3/min * 0.05% CH4 * 60 * 8760 = 788,400 ft3 CH4) **Surface and Post-Mining:** Reporters can multiply the amount of coal produced at a given mine annually by a region-specific emissions factor. The surface mining emissions factor can be estimated as twice the in situ methane content in the basin, and the post-mining emissions factor is estimated to be 32.5% of the in situ methane content in the basin. In many cases, basin-specific emissions factors are also available. **Abandoned Mines**: Not addressed.	Voluntary Reporting
Inventory of U.S. GHG Emissions and Sinks 1990-2005	Coal Mining	CH_4	Fugitive	Depending on year, EPA obtained data from mines emitting at least 0.5 MMcfd (est. 94.1% of total emisisons from coal mine ventilation systems) or 0.1 MMcfd (97.8% of total emissions). In 1997, data from all mines were collected.	Individual mine		***Underground Mines***: Uses MSHA data and company-specific reporting on degasification and methane recovered/used. Estimates are developed for degasification and recovery/use where companies do not supply data. to EPA. ***Surface Mines and Post-Mining Activities***: Uses basin-specific emission factors and coal production. ***Abandoned Mines***. Not addressed. Specific assumptions for emission factors provided in Annex F. (See Note 8)	Development of U.S.emissions inventory
API Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry	Coal Mining	CH_4	Fugitive		Individual mine		Recommends using emissions factor approach based on that in *EPA's Inventory of U.S. GHG Emissions and Sinks 1990-2005 (see above)*	Voluntary Company Reporting

Fugitives from Underground Coal Mining (Active)

Reporting Program/Guidance	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
DOE 1605(b) Voluntary Reporting of Greenhouse Gases Program	Input data used to calculate emissions include coal production and estimated emission factors, MSHA ventilation air sample data, and operator-reported volumes and disposition of gas produced from degasificaiton systems.			http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf
Inventory of U.S. GHG Emissions and Sinks 1990-2005	Input data used to calculate emissions include coal production and estimated emission factors, MSHA ventilation air sample data, and operator-reported volumes and disposition of gas produced from degasificaiton systems.			http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/LHOD5MJT9J/$File/2003-final-inventory_annex_f.pdf
API Compendium of Greenhouse Gas Emissions Methodologies for the Oil and Gas Industry				http://www.api.org/ehs/climate/new/upload/2004_COMPENDIUM.pdf

Review of Existing Programs Relevant to Source - Fugitives from Underground Coal Mining (Active)

Notes for Fugitives from Underground Coal Mines (Active):

1

Emission factors for underground mining in IPCC Guidelines for Tier 1 reporting:
• Low CH4 Emission Factor = 10 m3 metric ton-1
• Average CH4 Emission Factor =18 m3 metric ton-1
• High CH4 Emission Factor = 25 m3 metric ton-1
Countries using the Tier 1 approach should consider country-specific variables such as the depth of major coal seams to determine the emission factor to be used. As gas content of coal usually increases with depth, the low end of the range should be chosen for average mining depths of <200 m, and for depths of > 400 m the high value is appropriate. For intermediate depths, average values can be used.

2

Emissions Factor for surface mining in IPCC Guidelines for Tier 1/Tier 2 reporting:
• Low CH4Emission Factor = 0.3 m3 metric ton-1
• Average CH4 Emission Factor = 1.2 m3 metric ton-1
• High CH4 Emission Factor = 2.0 m3 metric ton-1
For the Tier 1 approach, it is good practice to use the low end of the specific emission range for those mines with average overburden depths of less than 25 meters and the high end for overburden depths over 50 meters. For intermediate depths, average values for the emission factors may be used. In the absence of data on overburden thickness, it is good practice to use the average emission factor, namely 1.2 m3/metric ton

3

Emission Factor for post mining activities of underground mines:
• Low CH4 Emission Factor = 0.9 m3 metric ton-1
• Average CH4 Emission Factor =2.5 m3 metric ton-1
• High CH4 Emission Factor = 4.0 m3 metric ton-1
Tier 2 methods to estimate post-mining emissions take into account the in situ gas content of the coal. Measurements on coal as it emerges on a conveyor from an underground mine without degasification prior to mining indicate that 25-40 percent of the in situ gas remains in the coal (Williams and Saghafi, 1993). For mines that practice pre-drainage, the amount of gas in coal will be less than the in situ value by some unknown amount. For mines with no pre-drainage, but with knowledge of the in situ gas content, the post-mining emission factor can be set at 30 percent of the in situ gas content. For mines with pre-drainage, an emission factor of 10 percent of the in situ gas content is suggested

4 Emission Factor for post mining activities of surface mines:
• Low CH4 Emission Factor = 0 m3 metric ton-1
• Average CH4 Emission Factor = 0.1 m3 metric ton-1
• High CH4 Emission Factor = 0.2 m3 metric ton-1
The average emission factor should be used unless there is country-specific evidence to support use of the low or high emission factor.

5 Detailed methodology for estimating emissions in abandoned underground coal mines described in
http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_4_Ch4_Fugitive_Emissions.pdf; pp 4.20 to 4.32
No method currently exists for estimating emissions from abandoned surface mines.

6 The quantity of airflow shall be measured and samples of mine air collected for analysis to determine the quality of the air at the following locations:
1. In each of the working section return entries, outby and as close as practical to the last permanent stopping (to determine section face liberation); and
2. At all locations where air leaves the mine (to determine total mine methane liberation). On blowing ventilation systems this may include roadways, belt conveyor entries, and/or other areas where air leaves the mine.
Samples of mine air shall also be collected and submitted for analysis where methane is detected at or above 1.0 percent on a hand-held methane detector at a rock dust survey or spot sampling location. Samples may also be collected at other locations deemed necessary to evaluate air quality.
Documentation required includes the quantity of airflow measured, the hand-held methane and oxygen readings in percentile, the bottle number of samples collected, and the location of the measurement or collection shall be documented in the hard-copy notes. Additionally, where it will be considered for total liberation of methane at the mine the bottle number and location description shall be entered by the inspector into the Inspectior

7 The direction and quantity of airflow shall be determined and tests for the presence of methane and oxygen deficiency shall be made at the following locations:

1. In the last open crosscut of each set of entries or rooms on each section.
2. Areas where mechanized mining equipment is being installed or removed;
3. On a longwall or shortwall, including areas where longwall or shortwall equipment is being installed or removed, in the intake entry or entries at the intake end of the longwall or shortwall;
4. At each end of the longwall or shortwall face at the locations specified in the approved ventilation plan;
5. At the intake end of any pillar line;
6. Where air enters the mine at each main intake;
7. In each intake split that ventilates a working section;
8. In the return of each split of air that ventilates a working section, immediately before it enters the main returns;
9. Where the air leaves the main returns;
10. The point where bleeder air enters a return;
11. In the entry nearest each set of seals, immediately after the air passes the seals (airflow measurement not required);
12. At the measurement points specified in the mine ventilation plan for evaluating bleeders systems and worked-out areas, including where air ent
13. In at least one location in each outby aircourse traveled during an inspection day (tests for oxygen deficiency and methane only).

8 See http://yosemite.epa.gov/OAR/globalwarming.nsf/UniqueKeyLookup/LHOD5MJT9J/$File/2003-final-inventory_annex_f.pdf; particularly Table F-4.

Summary of GHG Reporting Programs and Protocols for Zinc Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Zinc production		No protocol given for zinc production					
Canada Mandatory GHG Reporting	Zinc production	CO2	Phase 1: Consistent with IPCC.	100,000 metric tons CO2e	Facility	NA (activity data records)	Phase 1: No prescribed estimation methods, but should be consistent with IPCC (prioritize by Tier-method based on emissions levels).	Mandatory

Summary of GHG Reporting Programs and Protocols for Zinc Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EU, DOE 1605(b), WRI/WBCSD, Climate Leaders, California, New Mexico, RGGI, Industry trade groups[a]	Zinc production				[a] Industry trade groups include: International Lead and Zinc Study Group, International Zinc Association, American Foundry Society, Natural Resources Canada - Minerals and Metals, Non-Ferrous Founders' Society (NFFS), and Centre for Sustainable Resource Processing
Canada Mandatory GHG Reporting	Zinc production	Phase 1: Consistent with IPCC input data needed based on Tier-method selected.	Annual emissions data (in CO2e).	Phase 1: Information should be verifiable. No third party verification required.	C:\GHG Reporting Rule\Review of Existing Rules\Canada\page2.mht

Summary of GHG Reporting Programs and Protocols for Zinc Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Australia National Mandatory GHG Reporting Program	Zinc production	CO2	Process emissions from production of zinc	Registration and reporting required for corporations if: they control facilities that emit at least 25,000 metric tons of CO2e, or produce or consume at least 100 terajoules of energy; or their corporate group emits at least 125,000 metric tons CO2e, or it produces or consumes at least 500 terajoules of energy.	Facility	NA (activity data records)	NGA default method: Based on carbon reductant usage (A), energy content of reductant (EC), and emission factor (EF) for reductant. E = ∑A * EC * EF / 1000 (See attached sheet for EC and EF default values.) Higher-order method: Facility-specific emission factors.	Mandatory
IPCC	Zinc production	CO2	Electro-thermic distillation, Imperial Smelting Furnace (ISF), electrolytic process	NA	Tier 1: Source category Tier 2: Source category or facility Tier 3: Facility	NA (activity data records)	Tier 1: Based on production-based emission factors. Tier 2: Based on carbon content of reducing agents and other process materials. (See attached sheet for factors and equations.) Tier 3: Based on direct measurements (method does not contain any details on point and method of monitoring).	
US Inventory	Zinc production (secondary)	CO2	Electro-thermic process	NA	Source category	NA (activity data records)	Emission factor: [3.66 tons CO2/ton zinc]	

Summary of GHG Reporting Programs and Protocols for Zinc Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Australia National Mandatory GHG Reporting Program	Zinc production	NGA default method: Quantity of carbon reductant consumed, and energy content of reductant. Higher-order method: Data needed to develop facility-specific emission factors.	NGA default method: Annual production and amount of carbon reductant consumed. Higher-order method: Annual production, amount of carbon reductant consumed, facility-specific emission factors, and emissions.	QA/QC procedures developed by inventory compiler. Rating system for emission estimation methods and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf
IPCC	Zinc production	Tier 1: Production data. Tier 2: Source category- or facility-specific carbon content of reducing agents and other process materials. Tier 3: Facility-specific emission measurements.	NA, not an industry reporting program	National inventory compiler reponsible for QA/QC (Guidance on QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf
US Inventory	Zinc production (secondary)	National production data and % electro-thermic process. Source: USGS Minerals Yearbook.	NA, not an industry reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf

Summary of GHG Reporting Programs and Protocols for Zinc Production

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
US Inventory	Zinc production (secondary)	CO2	Waelz Kiln process	NA	Source category	NA (activity data records)	Emission factor: [1.23 tons CO2/ton EAF dust]	
NESHAP	Zinc production (primary)	HAP	Melting furnaces, sintering machines	Area sources (<25 tons total HAP/yr or <10 tons of single HAP/yr)	Facility (furnace or sintering machine)	Air pollution control devices	Rule contains PM emission limits (as a surrogate for metal HAP) and requires PM emission tests and control device operating parameter monitoring, but these are not useful for GHG calculation	Mandatory compliance
NESHAP	Zinc production (secondary)	HAP	Melting furnaces, crushing and screening operations	Area sources (<25 tons total HAP/yr or <10 tons of single HAP/yr)	Facility (Furnace or crushing and screening process operations)	Air pollution control devices (i.e., baghouses)	Rule contains PM emission limits (as a surrogate for metal HAP) and requires baghouses. It requires PM emission tests and baghouse operating parameter monitoring, but these are not useful for GHG calculation	Mandatory compliance
NSPS	Zinc production (primary)	PM, SOx	Roaster and sintering machines		Facility	Air pollution control devices or vent stacks	Note that rule contains PM and Sox emission concentration limits and requires: A continuous monitoring system to monitor and record opacity. A continuous monitoring system to monitor and record sulfur dioxide emissions. However, these are not useful for GHG emission calculation.	Mandatory compliance

Summary of GHG Reporting Programs and Protocols for Zinc Production

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
US Inventory	Zinc production (secondary)	National production data and % Waelz Kiln process. Source: USGS Minerals Yearbook.	NA, not an industry reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads06/07CR.pdf
NESHAP	Zinc production (primary)	NA. Not useful for GHG calculation.	NA. Required reports are not useful for GHG calculation		40 CFR Part 63 Subpart GGGGGG
NESHAP	Zinc production (secondary)	NA. Not useful for GHG calculation.	NA. Required reports are not useful for GHG calculation		40 CFR Part 63 Subpart TTTTTT
NSPS	Zinc production (primary)	NA. Not useful for GHG calculation.	NA. Required reports are not useful for GHG calculation		40 CFR Part 60 Subpart Q

IPCC Emission Factors and Calculation Methods for Zinc

Tier 1. Generic CO2 Emission Factors

Process	Emission Factor (ton/ton Zinc produced)
Waelz Kiln	3.66
Pyrometallurgical (ISF)	0.43
Electro-thermic	Unknown
Default Factor (60% ISF, 40% Waelz Kiln)	1.72

Tier 2. Reducing agent usage method
Base estimates on amount of coke or reductant consumed.

Calculate CO2 emissions based on the carbon content of the metallurgical coke or other reductant consumed. Aggregate by process.

$$E_{CO2} = \sum [(M_{tons\ coke\ consumed}/M_{ton\ zinc\ produced}) * (M_{ton\ zinc\ produced}) * (Ccontent_{coke})] * 44/12$$

Assumptions to calculate amount of coke consumed in a Waelz Kiln furnace:

(0.4 tons coke/ton EAF dust consumed) * (1.23 ton EAF dust/ton zinc produced) = 0.492 tons coke consumed/ton zinc produced

No similar assumptions were given for ISF or electro-thermic processes.

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Australia Nat'l Mandatory GHG Reporting Program (draft)	Landfills	CH4	Biological process	25,000 metric tons CO2e per facility; or corporate group that emits 125,000 metric tons CO2e	Facility	Weigh station, flare	Methods contained in the Australia technical guidelines are consistent with the IPCC (2006) Tier 2 first order decay model (**see Note 1 for discussion of IPCC**) to estimate methane generated in from the landfill. Subtract the amount of methane recovered and combusted. For uncollected methane, reduce emissions by 10% soil oxidation factor. The Aus technical guidelines document (Vol 5, p. 115-117) provides waste composition data typical for Australia that landfills can use if they don't have site-specific waste composition data Factors for degradable organic content (DOC) are the same as IPCC. Default methane generation rate values (k) are listed by state/territory for food, paper, garden waste, and wood. The specific values are within the ranges listed in IPCC.	Mandatory
Canada Mandatory GHG reporting	Landfills	CH4	Biological process	100,000 metric tons CO2e (total facility)	Facility	Not specified	No specific protocols given, but reporters should use methods consistent with IPCC (**note 1**). Guidance references the 1996 IPCC guidelines and good practice guidelines	Mandatory
California mandatory GHG reporting rule (pursuant to AB 32) **[Details are not summarized here because they will be summarized by the stationary combustion working group]**	Stationary combustion of landfill gas	CH4, CO2, N2O	Large stationary combustion facilities burning any fuel, including landfill gas and indirect electricity and/or thermal energy purchased or acquired and consumed.	25,000 metric tons CO2e	Facility	Combustion unit	Combusted gas metered	Mandatory

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Australia Nat'l Mandatory GHG Reporting Program (draft)	Landfills	Emission factor method chosen, activity data method chosen, location of site, years in operation, average annual disposal for lifetime prior to first year of reporting (weigh scale records or other records to estimate past waste acceptance), estimated amount of waste disposed in the reporting year (e.g., weigh scale or similar records), methane recovered (specific measurement method not prescribed) HIGHER ORDER METHODS: time profile of total amount and type of disposal over the lifetime of the facility, estimated amt of MSW, commercial, industrial, and construction waste EVEN HIGHER: amount of paper/paperboard, wood/wood waste, garden/park, food/sludge, inorganics	Report all: Emission Factor method chosen, activity data method chosen, location of site, years in operation, average annual disposal for lifetime prior to first year of reporting, estimated amount of waste disposed in the reporting year, methane recovered, HIGHER ORDER METHODS: time profile of total amount and type of disposal over the lifetime of the facility, estimated amt of MSW, commercial, industrial, and construction waste, EVEN HIGHER: amount of paper/paperboard, wood/wood waste, garden/park, food/sludge, inorganics	QA/AC procedures developed by inventory reporters. Rating system for emission factors and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf
Canada Mandatory GHG reporting	Landfills	Consistent with IPCC. Would include waste acceptance information, emissions factors used, methane recovery HIGHER ORDER METHODS: time profile of total amount and type of disposal over the lifetime of the facility, estimated amt of MSW, commercial, industrial, and construction waste	1st time: facility and parent company identification and contact information. Ongoing: Total annual direct GHG emissions, calculation methodologies used	Phase 1. Information should be verifiable. No third party verification required.	http://www.ghgreporting.gc.ca/GHGInfo/Pages/page2.aspx?lang=E
California mandatory GHG reporting rule (pursuant to AB 32) **[Details are not summarized here because they will be summarized by the stationary combustion working group]**	Stationary combustion of landfill gas	Fuel consumption data including combusted landfill gas (from meter)		3rd party verification, EPA for title IV units	http://www.arb.ca.gov/cc/reporting/ghg-rep/ghg-rep.htm

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
California Climate Action Registry (CCAR) - offset protocol for landfill methane	Landfills	CO2, CH4	Voluntary landfill methane reduction (offset) projects	N/A	Facility	Gas collection system header pipe upstream of flare or landfill gas energy project (CH4 concentration, temperature, pressure, flow rate) Prior to any combustion device (flow rate)	Monitor flow rate (continuous, accuracy +/- 5%), temperature and pressure. Measure methane concentration with continuous analyzer, or weekly measurements using a calibrated portable gas analyzer (and a 10% discount factor is applied to the total amount of methane captured and combusted). Calculate annual project emissions (tonnes CO2e/yr) = (net amount of CH4 destroyed in each device/method x 21(CH4 potency) x 0.9 (soil oxidation factor) x discount factor (to account for uncertainties with monitoring equipment)) minus CO2/yr from combustion of fossil fuel in landfill gas combustion device minus CO2/yr indirect carbon emissions from consumption of electricity from the grid (i.e., amount consumed x emission factor from eGRID).	Voluntary
Chicago Climate Exchange (CCX) - offset protocol for landfill methane	Landfills	CH4	Voluntary landfill methane reduction (offset) projects	N/A	Facility	Gas collection system header pipe upstream of flare or landfill gas energy project **Alternate method for Electricity Generation Projects:** Electricity output from combustion unit	Monitor flow rate (continuous, flow meter such as differential pressure sensor or hot wire anemometer, accuracy +/- 5%) Measure methane concentration (at least monthly, use infrared gas analyzer with accuracy +/- 10%; collect sample by connecting sampling tube to port, or collect in Tedlar bag, Summa canister, or other EPA-approved method) Calculate daily CH4 recovered (scf/day) = monitored flow (scf/day) x % CH4. Sum to get monthly and yearly methane recovered. Convert annual value to Mg CH4 combusted: CH4 (Mg/yr)=[CH4 recovery (scf/yr)] x [16.04 (molecular wt)] x [1 Mg/10^6 g] x [1 mol/24.04L] x [28.32 L/1cf] Assume methane reduction = methane combusted (100% destruction efficiency) **Alternate Method for Electricity Generation Projects:** Use electical metering device (continuous). Obtain heat rate of combustion unit from manufacturer. Calculate CH4 recovery (scf/yr) = kWhr electricity produced/yr x heat rate (Btu/kWhr) / 1012 Btu/cf	Voluntary
California Integrated Waste Management Board (CIWMB), Solid Waste Information System (SWIS)	Landfills	N/A (not an emissions program)	Solid waste facilities, operations, and disposal sites in CA	California landfills required to obtain permits	Facility	N/A (fees paid based on tonnages of waste)	N/A. This is a database containing information on landfill capacities and quantities of waste accepted. It is not a GHG program, and GHG emissions are not estimated or measured.	Mandatory

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
California Climate Action Registry (CCAR) - offset protocol for landfill methane	Landfills	Amount of landfill gas delivered to combustion device (flare, IC engine or turbine, boiler, injection into natural gas transmission and distribution system), destruction efficiency, density of methane (based on metered temperature and pressure), amount of natural gas (and its CH4 content) used by combustion device.	Annual project GHG emission reductions achieved by project, in metric tons CO2e/yr. 3rd party verification. Other information to show project meets CCAR eligibility and additionality requirements. Monitoring/measurements data is required to be kept by project developers for 5 years following project verification, but not reported.	3rd party verification by CCAR-approved verifier	http://www.climateregistry.org/tools/protocols/project-protocols.html (refer to pages 15 - 18 for calculations)
Chicago Climate Exchange (CCX) - offset protocol for landfill methane	Landfills	Flow records: type of meter, installation date and location, procedures used to check accuracy, calibration dates and results, flow data, monthly tabulations of flow data, calculations. Methane concentration: type of instrument, calibration dates and results, CH4 measurement dates and results, monthly tabulations of CH4 concentration. For NSPS landfills getting offsets of early gas collection in new cells: age of cells and calculations. Other information to show project meets CCX eligibility criteria for offset projects. **Alternative method for electricity generation projects:** Type, make, model, and heat rate of combustion units, source test results showing measured heat rate, type of electrical metering device, device accuracy and calibration info, monthly and annual summary of electricity produced.	Methane reduction achieved by project, total gas flows to flare or energy recovery project, methane concentrations. 3rd party verification. Other information to show project meets CCX eligibility requirements. **Alternate method for electricity generation projects:** Methane reduction, total electricity generation, heat rate of combustion unit from manufacturer.	3rd party verification by CCX-approved verifier	http://www.chicagoclimatex.com/content.jsf?id=222
California Integrated Waste Management Board (CIWMB), Solid Waste Information System (SWIS)	Landfills	Landfill location, owner, operator, types of waste accepted, regulatory status, landfill capacity, waste throughput and units (e.g., tons/day), remaining capacity, fees paid, inspection and enforcement records	See input data	Local enforcement agency performs inspections and enforcement	http://www.ciwmb.ca.gov/Landfills/Tonnages/Default.aspx

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Climate Leaders (Core Module - Direct Emissions from Municipal Solid Waste Landfilling) Approach 1	Landfills	CH4, biomass CO2	Biological Process - MSW landfilling	All (no deminimis)	Corporate (but need to report emissions for each type of process source)	weigh station at disposal site	Monitor weight of waste accepted (weigh scale). Estimate annual waste acceptance rates from weigh scale records or other records of waste disposal history. Use LandGEM (**see Note 2**) to determine CH4 generation. Then use equation: Emissions = generation x (I - oxidation factor). Default soil oxidation factor is 10%.	Voluntary
Climate Leaders (Core Module - Direct Emissions from Municipal Solid Waste Landfilling) Approach 2--Alternate (preferred) method for LFs or areas of a LF with gas collection systems	Landfills	CH4, biomass CO2	Biological Process - MSW landfilling (refers to separate stationary combustion sources module for landfill gas combustion)	All (no deminimis)	Corporate (but need to report emissions for each type of process source)	Gas collection system header pipe, prior to combustion device	Monitor gas flow (continuous, flow meter). Monitor or test methane concentration (continuous, or periodic throughout year). Use monitoring to determine collected methane. If collected gas is combusted on-site, use Climate Leaders stationary combustion guidance (based on quantity combusted) for combustion emissions. Use collection efficiency (default 75%) and soil oxidation factor (default 10%) to determine fugitive LF methane emissions and fraction of gas vented to determine uncontrolled emissions during combustor down-time (**Note 3**).	Voluntary
Climate Leaders - Offsets (Draft Offset Protocol, October 2006, Project Type: Landfill Methane Collection and Combustion)	Landfills	CH4 reduction from landfill gas combustion; CO2, CH4, and N2O emissions from any project-related fossil fuel combustion or electricity use, and from leakage (fuel combustion outside project boundary)	Voluntary landfill methane reduction (offset) projects	N/A	Unit (specific landfill methane reduction project)	Gas collection system, as close to each combustion device as possible to measure gas into the combustion device. If landfill had a collection system prior to project, need to measure new (project) and existing gas collection system separately	Monitor flow to combustion device (flow meter, continuous or monthly), pressure and temperature at time of flow measurement, methane concentration (gas composition meter, continuous or monthly) Calculate CH4 combusted by the project (**see note 4**). Calculate actual project emission reduction by subtracting any gas combusted in the baseline and accounting for soil oxidation (**see note 4**) Calculate project-related energy emissions from project-related fossil fuel combustion and energy use [would use methods documented by stationary combustion group] Calculate leakage (GHG emissions from fuel combustion caused by the project, but not within the project boundary - would use methods documented by stationary combustion group)	Voluntary

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Climate Leaders (Core Module - Direct Emissions from Municipal Solid Waste Landfilling) Approach 1	Landfills	Year opened (site records), closed (site records), annual waste acceptance (weigh scale records, volumetric calcs, aerial photographs, LF annual reports), LF area covered by gas collection system (LFG system record drawings), Emission factors (all applicable sources), MSW composition (weigh scale records), average waste moisture content (waste records, climate data), average waste depth (contour maps, site data), meteorological data (local weather authority, or on-site meteorological station).	Base year and annual GHG emissions (CO2 equivalents). Inventory management plan documenting GHG estimation approaches, factors, and data sources that will be used.	EPA Climate Leaders review of inventory management plan and annual summary reports	http://www.epa.gov/climateleaders/resources/sector-specific.html
Climate Leaders (Core Module - Direct Emissions from Municipal Solid Waste Landfilling) Approach 2--Alternate (preferred) method for LFs or areas of a LF with gas collection systems	Landfills	Gas collection monitoring (flow meter). Methane concentration monitoring or testing (in-line chromatograph or gas analyzer, third party lab analysis). Emission factors (e.g, collection efficiency factor, all applicable sources)	Base year and annual GHG emissions (CO2 equivalents), biomass CO2 from combustion. Inventory management plan documenting monitoring systems, monitoring data management procedures, GHG estimation approaches, factors, and data sources that will be used.	EPA Climate Leaders review of inventory management plan and annual summary reports	http://www.epa.gov/climateleaders/resources/sector-specific.html
Climate Leaders - Offsets (Draft Offset Protocol, October 2006, Project Type: Landfill Methane Collection and Combustion)	Landfills	Gas flow, temperature, pressure, and methane concentration for landfill gas entering each combustion device (continuous meters or monthly measurements), destruction efficiency of combustion device. [fossil fuel use documentation would use methods summarized by the stationary combustion group] Information to show project meets eligibility criteria (i.e., is voluntary rather than required by rule) and to determine baseline level of gas collection and combustion if there is already a partial gas collection system.	Annual emissions from "optional" emission sources, including annual emissions reductions from landfill methane offset projects, may be reported on the annual inventory summary form. List the source of the emissions reduction and the amount (CO2e). The inventory management plan should document monitoring systems, monitoring data management procedures, GHG estimation approaches, factors, and data sources that will be used for offset projects.	EPA Climate Leaders review of inventory management plan and annual summary reports	http://www.epa.gov/climateleaders/documents/resources/draft_landfill_offset_protocol.pdf

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
EIA 1605(b)	Landfills	CH4	Biological process - landfill emissions; or reductions from LF methane reduction projects	N/A	Project, or corporate-wide	prior to combustion unit for LF methane reduction projects; also activity data records	For total landfill methane generation use LandGEM (**note 2**) with inventory default values of k and L_0 specified in LandGEM or site-specific values (or use a similar first order decay model such as IPCC (**note 1**)). Alternatively, use EMCON methane generation model, which captures a snapshot of total methane emissions from any given volume of waste landfilled. Default parameters from this model, in conjunction with estimates of volume of waste landfilled each year, is a simplified method of capturing the temporal profile of emissions. Then calculate emissions as CH4 emitted = (CH4 generated in year t - CH4 recovered in year t) x (1 - oxidation rate). Assume 10% soil oxidation. See pages 131- 135 and 284-285 of Technical Guidelines (Jan 2007). For methane recovery projects, determine volume of gas recovered, percent methane or heat content of gas, and disposition of the gas (e.g., volume flared, volume used in electricity and direct use projects). Method of monitoring volume, % CH4, and heat content are not specified.	Voluntary
IPCC	Landfills	CH4	Biological process - landfills	N/A	Source category (higher tiers could be applied to an individual landfill)	N/A (activity data records). Higher tiers could use measured data, e.g., for waste composition, acceptance rates, or gas collected	**See Note 1** for detailed equations and procedures.	Mandatory national reporting of inventory data

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
EIA 1605(b)	Landfills	Inputs to LandGEM or other first order decay model include landfill open and closure year, waste in place, annual waste acceptance rates, default or site-specific factors used (e.g., L_0, k for LandGEM, similar factors for IPCC). Method of determining annual waste acceptance not specified. For landfills with gas collection systems and flares or energy projects, total volume gas recovered, avg. heat content of gas recovered, volume of gas used off-site, volume of gas sold, electricity generated, volume of gas flared, acreage affected, waste in place affected, number of vertical wells, length of horizontal wells.	Report baseline and annual emissions and/or methane reductions achieved by methane reduction projects. For annual emissions, report estimated emissions, and calculation methods used and rating factor (e.g, A, B, C) For methane reduction projects, report annual methane reduction, total volume gas recovered, avg. heat content of gas recovered, volume of gas used off-site, volume of gas sold, electricity generated, volume of gas flared, acreage affected, waste in place affected, number of vertical wells, length of horizontal wells.	Emissions should be verifiable, but third party verification is not required. Technical Guidelines (Jan 2007) provide ratings factors for landfill emission estimation methods (A through D)	http://www.eia.doe.gov/oiaf/1605/January2007_1605bTechnicalGuidelines.pdf ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/FormEIA-1605_2005.pdf
IPCC	Landfills	Mass of waste disposed of in landfills, type of waste, equations and factors used (e.g., for degradable organic content (DOC) of waste, reaction constant (k), soil oxidation factor), amount of methane recovered and combusted	N/A. Not an industry reporting program	National inventory compiler responsible for QA/QC (Guidance on QA/QC plan elements is provided in IPCC documents)	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_SWDS.pdf http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
MSW Landfill NSPS & NESHAP MSW Landfill Emission Guidelines (implemented by state plans or the landfills Federal plan)	Landfills	Landfill gas (emission limits for NMOC as a surrogate for LFG, monitoring of surface CH4)	Biological process - air emissions from waste decomposition in landfills	LF design capacity >2.5 million Mg or m^3 **and** NMOC emissions >50 Mg/yr	Facility	surface CH4 emissions, gas collection system wellheads, control devices	Monitor methane emissions from surface of the landfill (quarterly in pattern traversing landfill surface at 30 meter intervals, protable organic vapor analyzer or flame ionization detector) Wellhead monitoring to ensure proper gas collection system operation (monthly at all wellheads for pressure; temperature; oxygen or nitrogen concentration) Use LandGEM (note 2) to annually calculate NMOC emissions until landfill reaches 50 Mg NMOC/yr and has to apply controls. Tier 1 defaults: L0 = 170 m3/Mg waste, k=0.05 (moist climates), 0.02 (arid climates), NMOC concentration in LFG = 4,000 ppmv. Tier 2: same L0 and k, but use site-specific NMOC conc based on testing. Tier 3: Use site specific k value based on testing. [Note that NSPS Tier 1 defaults are more conservative than LandGEM recommends for inventory purposes. This provides conservatively high estimates and errs on the side of regulating sources. Note that LandGEM also calculates CH4 emissions, but landfills don't record this.] Monitor control operating parameters for open flares (continuous, presence of pilot flame) and enclosed combustors (continuous, temperature)	Mandatory
Oregon	Landfills	No specific rule set	Biological processes landfills	All landfills permitted under certain state statutes would report, or if GHG > 2500 metric tonsCO2e	Not specific rule set	Not specified	The inventory methods would follow The Climate Registry protocols or other industry-appropriate protocols, as determined by rule or guidance	Mandatory
The Climate Registry (General Verification Protocol, isn't in General Reporting Protocol)	Landfills	CH4	Biological process	N/A	Facility	Not specified	None given. Reporters are to report direct emissions from waste disposal (if reporter has a landfill).	Voluntary

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
MSW Landfill NSPS & NESHAP MSW Landfill Emission Guidelines (implemented by state plans or the landfills Federal plan)	Landfills	Landfill design capacity, date landfill began accepting waste, mass of waste in landfill, annual waste acceptance rates, any areas of nondegradable waste, test results if testing done to determine site-specific NMOC or k value for use in LandGEM. Emission test results demonstrating control devices get 98% NMOC reduction or 20 ppmv outlet concentration Records of quarterly surface methane and monthly wellhead operating parameter monitoring results, dates of exceedances, and dates corrected. Records of continuous operating parameter monitoring for control devices and associated excedences and corrective actions. Records of collection system and control device malfunctions.	Initial and amended design capacity report. Annual NMOC emission rate reports until reach 50 Mg/yr. After reaching 50 Mg/yr, submit gas collection and control system design plan for approval. Report results of initial performance test for control devices (NMOC destruction efficiency). Submit semiannual reports of monitoring parameter excedences and corrective actions. Submit start-up, shutdown and malfunction reports (required by NESHAP rather than NSPS)	EPA or states that have taken delegation review reports and conduct enforcement activities.	40 CFR part 60 subparts Cc (emission guidelines) and WWW (NSPS) 40 CFR part 62 (state plans and landfills Federal Plan) 40 CRF part 63 subpart AAAA
Oregon	Landfills	Unknown	Unknown	Rely on existing verification methods (e.g., self-certification with periodic inspections by state inspectors)	http://www.deq.state.or.us/aq/climate/docs/finalrecommend.pdf
The Climate Registry (General Verification Protocol, isn't in General Reporting Protocol)	Landfills	Waste-in-Place Data, Waste Landfilled, Calculation Methodology, Emission Factors, Emissions Histories	No details given. Reporters are to report direct emissions from waste disposal if reporter has a landfill.	3rd party verification	http://www.theclimateregistry.org/Draft_General_Verification_Protocol.pdf

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
USEPA Landfill Methane Outreach Program (LMOP)	Municipal Solid Waste Landfills	CH4 (direct); also indirect CO2 reductions from avoided fossil fuel use for LFG energy projects (outside scope of this summary table)	Biological process - MSW landfills, and GHG reductions from LFG energy projects.	N/A	Facility (landfill), unit (LFG energy project)	LFG flare or energy project	National methane emissions for landfills without projects estimated based on waste in place and general emission factor. However, more accurate landfill-specific estimates prepared for Partners or candidate landfills are done with LandGEM (**note 2**) using default L_0 = 100 m^3/Mg; default k = 0.02 (arid climates < 20 inches rain/yr), 0.04 (20 - 40 in/yr), 0.065 (>40 in/yr); default methane conc = 50%. Methane reductions from flares based on LFG flow rate to flare and 50% methane conc. Methane reductions for direct use LFG energy projects calculated as flow rate to project (mmscf/day) x 0.0735 = methane reduction (MMTCO2e). (The 0.0735 factor represents unit of measure conversions and 50% CH4 conc) Methane reductions for LFG electricity projects calculated as MW capacity of generating unit x 0.0380 = methane reduction (MMTCO2e). (The 0.0380 factor represents unit conversions, default capacity use factor of 0.93, default combustion unit heat rate 11,700 Btu/kWhr and methane heating value of 1,012 Btu/cf methane)	Voluntary
USEPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (Feb 2008 draft)	Landfills (including MSW and industrial landfills)	CH4	Biological process - decomposition of waste in MSW and industrial landfills	N/A	Source category	N/A. Activity data records	National CH4 emissions from landfills = [CH4 generated by MSW landfills + CH4 generated by industrial waste landfills - CH4 recovered and combusted] - CH4 oxidized in landfill cover. CH4 emissions from MSW landfills are estimated using a first order decay model consistent with IPCC 2006 (**note 1**). Assumed L_0 = 100 m^3/Mg waste; k = 0.020 (areas < 20 inches rain/yr), 0.038 (20 - 40 inches rain/yr), and 0.057 (>40 inches rain/yr). For industrial landfills, organic waste originates mainly from food processing and pulp and paper industries. Used default values from IPCC (L_0 = 99 m^3/Mg for pulp & paper waste and 143 m^3/yr for food waste; k = 0.06 for paper waste and 0.185 for food waste). Estimated amount of landfill gas recovered and combusted per year based on data EPA collected from vendors of flare equipment, the LMOP database, and EIA's 1605(b) voluntary reporting database. Assumed destruction efficiency of 99% for combusted methane. Assumed 10% soil oxidation factor.	National estimate of GHG emissions

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
USEPA Landfill Methane Outreach Program (LMOP)	Municipal Solid Waste Landfills	For LandGEM need landfill open year, closure year, and waste in place or detailed and annual acceptance rates. For flares, landfill gas flow to flare. For LFG energy projects, flow to project or MW capacity of electricity generating units. Landfill and project data are provided and updated voluntarily by LMOP Partners and other organizations or obtained by LMOP from Web or other available sources.	Types of Partners that would have landfill and LFG energy project-specific data agree to voluntarily report data and provide annual updates. These include community Partners (landfill owners) and industry Partners who are LFG energy project developers. They report landfill and project information such as landfill design capacity, waste in place, annual waste acceptance rates, LFG energy project technology, MW capacity or LFG flow to project, project start date, and energy end user organization.	EPA reviews landfill and project data submitted and performs GHG calculations	http://www.epa.gov/lmop
USEPA Inventory of U.S. Greenhouse Gas Emissions and Sinks (Feb 2008 draft)	Landfills (including MSW and industrial landfills)	Information on national amount of waste deposited in municipal solid waste landfills, apportionment of landfill waste between 3 climate rainfall ranges, k and L_0 factors for U.S. MSW based on several U.S. studies. Information on national amount of food processing industry and pulp and paper industry waste landfilled, IPCC default values for k and L_0 of waste from these industries in moist, temperate climates. Information on national amount of landfill gas collected and combusted. Default methane destruction rate for combustion. Default soil oxidation factor.	N/A. Not an industry reporting program	Emission inventories are subject to EPA QAPP	http://www.epa.gov/climatechange/emissions/downloads/08_Waste.pdf http://www.epa.gov/climatechange/emissions/downloads/08_Annex_3.pdf

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
WRI Protocol Approach 1: Using data from gas collection system (recommended for landfills with low permeability cap and effective collection system)	Pulp and Paper Landfills	CH4	Biological process - landfilling of pulp and paper mill waste	N/A	Facility	gas collection system header pipe prior to combustion	Monitor gas flow (type of meter not specified) to determine volume of gas collected. Use collection efficiency (default 75%) to determine the gas generated. Assume gas is 50% methane. Use the equation in **note 5** to determine methane emissions accounting for the fraction of collected gas that is combusted, and for soil oxidation of uncollected methane (assume 10% soil oxidation).	N/A
WRI Protocol Approach 2: Simplified first order decay equation (recommended if value of waste landfilled is relatively constant from year to year)	Pulp and Paper Landfills	CH4	Biological process - landfilling of pulp and paper mill waste	N/A	Facility	weigh station (or waste disposal records), gas collection system header pipe prior to combustion for systems with gas collection	Monitor weight of waste accepted (weigh scale) or use other records to determine average annual amount of waste landfilled. Use simplified first order decay equation (**see note 6**) to estimate methane generation. Calculate emissions using equation (**note 5**) to adjust for soil oxidation (assume 10%) and any gas that is collected and combusted.	N/A
WRI Protocol Approach 3: First order decay equation allowing for year-to-year variation in amount of waste accepted	Pulp and Paper Landfills	CH4	Biological process - landfilling of pulp and paper mill waste	N/A	Facility	weigh station (or waste disposal records), gas collection system header pipe prior to combustion for systems with gas collection	Monitor weight of waste accepted (weigh scale) or use other records to determine amount of waste landfilled in each year (can vary from year to year). Use LandGEM to estimate methane generation. Calculate emissions using equation to adjust for soil oxidation (assume 10%) and any gas that is collected and combusted (**see note 7**)	N/A

Summary of GHG Reporting Programs and Protocols for Landfills

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
WRI Protocol Approach 1: Using data from gas collection system (recommended for landfills with low permeability cap and effective collection system)	Pulp and Paper Landfills	gas quantity collected (flow meter, m^3/yr); methane content, collection efficiency, and soil oxidation factor (can use defaults for all of these); percent of collected gas that is combusted (site-specific, measurement method not specified)	N/A. Not a reporting program.	N/A	http://www.ncasi.org/programs/areas/climate/ghgtools/pulp_icfpa.aspx
WRI Protocol Approach 2: Simplified first order decay equation (recommended if value of waste landfilled is relatively constant from year to year)	Pulp and Paper Landfills	Annual waste disposal (average dry Mg/yr, from records); L_0 and decay rate (k) (can use defaults), years since landfill opened, years since landfill stopped receiving waste; soil oxidation factor (default); fraction of landfill gas that is collected; fraction of collected gas that is burned (site-specific, measurement method not specified)	N/A. Not a reporting program.	N/A	http://www.ncasi.org/programs/areas/climate/ghgtools/pulp_icfpa.aspx
WRI Protocol Approach 3: First order decay equation allowing for year-to-year variation in amount of waste accepted	Pulp and Paper Landfills	Waste disposal amount for each year (dry Mg/yr, from records); L_0 and decay rate (k) (can use defaults), years since landfill opened, year landfill stopped receiving waste; soil oxidation factor (default); fraction of landfill gas that is collected; fraction of collected gas that is burned (site-specific, measurement method not specified)	N/A. Not a reporting program.	N/A	http://www.ncasi.org/programs/areas/climate/ghgtools/pulp_icfpa.aspx

Notes on GHG Calculation Methods and Procedures for Landfills

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Note 1. IPCC

See 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 5, Waste, chapters 2 and 3 http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_SWDS.pdf and http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
(Equation 3.1)

where:
CH4 emission = CH4 emitted in year T, Gg
T = inventory year
x = waste category or type/material
R_T = recovered CH4 (collected for combustion) in year T, Gg
OX_T = oxidation factor in year T, (fraction) and is assumed to be 10%
To calculate methane generation, which is used in this equation, IPCC uses first order decay principles, which is the same basis as LandGEM (note 2). However, there are a number of ways to express first order principles in equations. IPCC presents the following series of equations to implement first order decay calculations:

1. Calculate mass of decomposable degradable organic carbon (DDOCm), Gg, in the mass of waste deposited using the following equation:

DDOCm = W x DOC x DOC_f x MCF (Equation 3.2)

where:
W = mass of waste deposited, Gg
DOC = degradable organic carbon in the year of deposition, fraction, Gg C/Gg waste
DOC_f = fraction of DOC that can decompose (fraction)
MCF = CH4 correction factor for aerobic decomposition in year of deposition, assumed to be 1.0 for modern sanitary landfills with compaction and cover practices used in the U.S.
Factors for total organic content and degradable organic carbon (DOC) content in types of waste and in materials commonly found in municipal solid waste (e.g., paper, textiles, food, wood, yard waste, rubber, plastics) are found in Table 2.4 of IPCC Vol 5.
[note that while L0 is not used in these equations, DDOCm is closely related to the L0 term in LandGEM which expresses first order decay in a different equation.
L0 = DDOCm x fraction of CH4 in landfill gas (the default is 0.50) x 16/12 (which is the molecular weight ratio of CH4/C)]

2. Calculate the mass of decomposable degradable organic carbon accumulated in the waste disposal site at the end of year T ($DDOCma_T$), Gg, and the carbon that has been decomposed at the end of year T ($DDOCm\ decomp_T$), Gg, using the following equations.

$DDOCma_T = DDOCmdT + (DDOC\ ma_{T-1} \times e^{-k})$ (Equation 3.4)

$DDOCm\ decomp_T = DDOCma_{T-1} \times (1-e^{-k})$ (Equation 3.5)

where:
DDOC maT-1 = DDOCm accumulated in the waste disposal site at the end of year (T-1), Gg
DDOCmdT = DDOCm deposited in the waste disposal site in year T, Gg
k = reaction constant, yr^{-1} [note that k is also used in the LandGEM first order decay equations]

3. Calculate the CH4 generated in year T ($CH4\ generated_T$) from the decayed DDOCm using the following equation:

$CH4\ generated_T = DDOCm\ decomp_T \times F \times 16/12$ (Equation 3.6)

where:
DDOCm decompT = DDOCm decomposed
F = fraction of CH4 in landfill gas (default is 0.50)
16/12 = molecular weight ratio of CH4/C

Note that implementing this series of equations and summing the years over time will provide essentially the same results as LandGEM.

The DOC default factors provided for different materials within the waste (table 2.4 of IPCC Vol 5) allow customization of the decomposible degradable organic carbon content (or the methane generation potential) depending on the waste composition. Also, IPCC provides multiple default values for k (see table 3.3 in Vol 5). The factors are provided by climate zone (boreal and temporate versus tropical, and dry versus wet). For each climate zone, defaults and ranges for k are provided for bulk waste, and broken down by component for slowly degrading waste (paper/textiles, wood), moderately degrading wastes (e.g. yard waste) and rapidly degrading waste (food waste or sewage sludge). This allows sources that know their waste composition to run the first order decay equations for each different waste component (with its approriate DDOCm and k value) and add them together to get a more accurate estimate than using the bulk waste default.

Note 2. LandGEM is EPA's spreadsheet-based model to determine landfill methane generation. It is based on a first order decay equation, and is consistent with the methods in section 2.4 of EPA's Compilation of Air Pollutant Emission Factors (AP-42). Inputs include annual waste acceptance rates for the life of the landfill. The equation is:

where:

Q_{CH4} = methane emission rate, m^3/yr

k = methane generation rate constant, $year^{-1}$

L_o = methane generation potential, m^3 of CH_4/Mg of refuse [Note: a megagram (Mg) is 1 metric ton]

M_i = mass of the waste in the ith section (annual increment), Megagrams (Mg)

t_i = age of the ith increment (or section) of waste, in years

Inventory default value for L_o = 100. Default k = 0.02 for arid climates (<25 inches rain/yr), 0.04 in other areas.

[Most recent version of LandGEM uses this same basic equation, but does summation in 1/10 year increments instead of annual increments, which provides more accurate results. User still enters annual waste acceptance.]

Note 3. Climate Leaders provides the following equation for calculating methane emissions for landfills with active gas collection system that determine the amount of collected gas through monitoring:

CH4 emissions = [((CH4 collected/collection system efficiency) - CH4 collected) x (i - oxidation factor)] + [CH4 collected x fraction vented]

Default collection efficiency = 75% (0.75). Sources must provide documentation to use a different factor.
Default fraction vented is 1% (0.01) for flares to account for maintenance and unscheduled downtime.

Note 4. Climate Leaders Offset Protocol provides equations for voluntary methane reduction projects at landfills.
The following equation is used to determine CH4 combusted by the project each month if flow and concentration are measure monthly. The same equation would be performed on a continuous basis if continuous integrated flow and concentration monitoring systems are used.

$$\text{CH4 Combusted}_{project} = V \times (C/100) \times 0.0422 \times (520/T) \times (P/1) \times (t) \times DE \times (0.454/1000)$$

where:

$\text{CH4 Combusted}_{project}$ = amount of methane destroyed during the month (metric tons)
V = volumetric flow in cfm
C = CH4 concentration of gas (in %)
0.0422 = lb CH4/scf (at 520R or 60F)
T = temperature at which flow is measured (degrees R)
P = pressure at which flow is measured (atm)
t = time period since last monthly measurement (min)
DE = destruction efficiency (default = 98%)
0.454/1000 = conversion factor, lbs to metric tons

A factor of 21 is used to convert methane combusted to CO2e

Actual project methane reductions are calculated as:

CH4 emission reductions = (CH4 $Combusted_{project}$ - CH4 $combusted_{baseline}$) x 0.90

where:
Gas $Combusted_{project}$ = CH4 reductions (CO2e)
Gas $Combusted_{baseline}$ = measured value of CH4 combustion in the baseline (CO2e) (If no combustion at baseline, then use 0)
0.90 = accounts for 10% soil oxidation when gas is not collected

The offset protocol also specifies that CO2, CH4 and N2O emissions from "project energy emissions" must also be calculated. This includes fuel and electricity use for project-related construction activities and operation of gas collection and combustion equipment. These are calculated from fuel quantities and emission factors (either site-specific emission factors or emission factors drawn from the latest version of EPA's Inventory of U.S. Greenhouse Gas Emissions and Sinks. In addition, "emissions from leakage" must be calculated. Leakage includes GHG emissions from fuel combustion caused by the project, but not within the project boundary.

Total estimated offset project emissions (TCO2e) = Emission reductions (of methane, expressed in TCO2e) - proj Emissions from leakage (TCO2e)

Note 5. WRI Calculation Tool for Pulp and Paper Mill Landfills provides the following equation for calculating methane emissions **for landfills with low permeability caps and efficient gas collection systems**. Gas flow measurements are used to determine the volume of gas collected, and the equation is used to determine total methane emissions from the landfill:

CH4 emitted (m^3/yr) = [(REC/FRCOLL) x (1-FRCOLL) x FRMETH x (1-OX)] + [REC x FRMETH x (1-FRBURN)]

where:
REC = amount of landfill gas collected, determined on a site-specific basis, m^3/yr
FRCOLL = fraction of generated landfill gas that is collected, default is 0.75
FRMETH = fraction of methane in landfill gas, default is 0.5
OX = fraction of methane oxidized in the surface layer of the landfill, default is 0.1
FRBURN = fraction of collected methane that is burned, site specific determination

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Note 6. WRI Calculation Tool for Pulp and Paper Mill Landfills provides the following **simplified first order decay** equation for calculating methane emissions for landfills if the volume of waste landfilled is relatively constant from year to year and the landfill design has not changed in ways that would substantially alter landfill gas releases:

CH4 generated from all waste in LF (m^3/yr) = R x L_0 (e^{-kC} - e^{-kT})

where:
R = average amount of waste sent to landfill per year, Mg/yr
L_0 = ultimate methane generation potential, m^3 CH4/Mg waste, default 100 m^3/Mg dry weight of waste
k = methane generation rate constant, 1/yr, default 0.03 for pulp and paper mill waste
C = time since landfill stopped receiving waste, yrs
T = time since landfill opened, yrs
(R and L_0 can be in units of wet weight, dry weight, degradable organic carbon, or other units, but the units of R and L_0 must be the same)

Then calculate CH4 emissions released to the atmosphere as:

CH4 (m^3/yr) released = [(CH4 generated - CH4 recovered) x (1-OX)] + [CH4 recovered x (1 - FRBURN)]

where:
CH4 recovered = amount of methane collected, determined on a site-specific basis
OX = fraction of methane oxidized in the surface layer of the landfill, default is 0.1
FRBURN = fraction of collected methane that is burned, site-specific determination

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Note 7. WRI Calculation Tool for Pulp and Paper Mill Landfills provides a **detailed first order decay approach** for landfills where there is significant variation in the quantity of waste landfilled from year to year. It uses the same equation at LandGEM (note 2) to determine methane generation. For pulp and paper mill waste, default values are k = 0.03 and L_0 = 100 Mg/m^3 dry weight of waste. Then it uses the second equation under note 6 to determine the amount of methane released to the atmosphere.

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Australia Nat'l Mandatory GHG Reporting Program (draft)	Domestic/Commercial Wastewater	CH4	Biological process	Emit >=25,000 metric tons CO2e or produce/consume >=100 terajoules of energy (facility); Emit >=125,000 metric tons CO2e or produce/consume >=500 terajoules of energy (corporate).	Facility; Corporate Group	N/A (Activity data on COD/BOD at treatment plant influent and in sludge)	Sum emissions from wastewater and sludge. In the absence of direct COD or BOD measurements, equations are used to calculate commercial and domestic release of CH4 (***1**). Domestic and commercial reporters may improve the estimated emissions with direct measurements of COD from wastewater entering the facility, calculated from facility operating data (volumetric influent rate and influent COD concentrations).	Mandatory
Australia Nat'l Mandatory GHG Reporting Program (draft)	Industrial Wastewater	CH4	Biological process	Emit >=25,000 metric tons CO2e or produce/consume >=100 terajoules of energy (facility); Emit >=125,000 metric tons CO2e or produce/consume >=500 terajoules of energy (corporate).	Facility; Corporate Group	N/A (Activity data on COD at treatment plant influent and in sludge)	Sum emissions from wastewater and sludge. In the absence of direct COD measurements, equations are used to calculate industrial release of CH4 (***2**). Industrial reporters may improve the emissions estimates with measurements of Chemical Oxygen Demand of wastewater entering the facility and estimates of the methane emission factors for wastewater and sludge.	Mandatory
Australia Nat'l Mandatory GHG Reporting Program (draft)	Domestic/Commercial Wastewater	N2O	Biological process	Emit >=25,000 metric tons CO2e or produce/consume >=100 terajoules of energy (facility); Emit >=125,000 metric tons CO2e or produce/consume >=500 terajoules of energy (corporate).	Facility; Corporate Group	N/A (Activity data on N at treatment plant influent, effluent, and in sludge)	Uses IPCC methodology (pop*protein*n in protein – Nout) × EF6 + Nout × EF7) (***3**)	Mandatory

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Australia Nat'l Mandatory GHG Reporting Program (draft)	Domestic/Commercial Wastewater	Emissions factor method chosen, activity data method chosen, population served by WWTP, COD/BOD entering system, COD/BOD removed in sludge, fraction COD/BOD anaerobically treated, fraction COD/BOD in sludge anaerobically treated, methane recovered. HIGHER ORDER: measured COD or BOD, facility-specific methane emission factors. HIGHER: methane emissions measured continuously.	Activity data as needed to support emission estimates. See Input Data column.	QA/QC procedures developed by inventory reporters. Rating system for emission factors and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf
Australia Nat'l Mandatory GHG Reporting Program (draft)	Industrial Wastewater	Annual production, wastewater generated per unit of production, COD concentration in wastewater entering facility, COD removed in sludge, fraction COD anaerobically treated, fraction COD in sludge anaerobically treated, facility-specific methane emission factor, methane recovered, HIGHER: COD measured, HIGHER: methane emissions measured continuously.	Activity data as needed to support emission estimates. See Input Data column.	QA/QC procedures developed by inventory reporters. Rating system for emission factors and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf
Australia Nat'l Mandatory GHG Reporting Program (draft)	Domestic/Commercial Wastewater	Protein intake per capita, population served, nitrogen entering system, nitrogen removed in sludge, nitrogen discharged from system.	No specific reporting requirements listed. Activity data as needed to support emission estimates. See Input Data column.	QA/QC procedures developed by inventory reporters. Rating system for emission factors and activity data collection methods.	http://www.greenhouse.gov.au/reporting/publications/pubs/nger-techguidelines.pdf

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Canada Mandatory reporting	Wastewater	CH4/N2O	Biological process	100,000 metric tons (facility) CO2e	Facility	N/A (Activity data on COD/BOD/N in wastewater influent and in sludge)	No specific protocols for calculation, but when reasonable, reporters should use methods consistent with IPCC. Guidance references the 1996 IPCC guidelines and Good Practice Guidelines.	Mandatory
CARB WW for petroleum refineries	Industrial Wastewater	CH4/N2O	Biological process (fugitive)	25,000 metric tons CO2e	Unit	Treatment plant influent and removals	Methods based on the 2006 IPCC Guidelines to calculate CH4 and N2O emissions resulting from refinery wastewater treatment operations. (***9 and *9a**) These methods require periodic measurement of wastewater Chemical Oxygen Demand (COD), wastewater volumetric flow, and the estimation of the mass of sludge removed from treatment facilities and the degree of anaerobic treatment that takes place. If methane is recovered from refinery wastewater treatment facilities and routed to a destruction device such as a flare and emissions from the flare device are accounted for in section 95113(f) of these regulations, CH4 emissions shall not be reported here to avoid double-counting.	Mandatory

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Canada Mandatory reporting	Wastewater	Organics (BOD/COD) and nitrogen in wastewater, BOD/COD and N removed in sludge, CH4 recovered, population, type of treatment system	1st time: reporting company's federal business number (BN) and relevant facility identifiers; main sector of activities and North American Industry Classification System (NAICS) code; parent company information (e.g. name, address, percent ownership, BN, D-U-N-S number,5 etc.); public contact and certifying official information (e.g. name, position, address, etc.); and National Pollutant Release Inventory (NPRI) identification number (if applicable). Ongoing: total direct GHG emissions.	Phase 1: Information should be verifiable. No third party verification required.	http://www.ghgreporting.gc.ca/GHGInfo/Pages/page2.aspx?lang=E
CARB WW for petroleum refineries	Industrial Wastewater	COD, sludge removal, N in effluent, wastewater volume, MCF, B0, emission factor	COD, sludge removal, N in effluent, wastewater volume	3rd party verification, EPA for Title IV units	http://www.arb.ca.gov/cc/ccei/reporting/GHGReportingReg8_10_07.pdf

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Clean Watersheds NEEDS Survey	Wastewater	N/A	Biological processes	N/A	Facility	State and municipal health departments, Onsite wastewater treatment engineers and installers, State offices responsible for rural issues, etc.	N/A	Voluntary (used by EPA to document national financial needs for ensuring clean water in a Report to Congress)
Climate Leaders **[Please note that ERG is not sure what reference was used for this entry and we have not verified the info at this time.]**	Anaerobic wastewater lagoons	CH4	Process	All (no deminimis)	Corporate (but need to report emissions for each type of process source)	Combustion device/influent?	Process- covered lagoons: daily and hourly monitoring of biogas production, reported to corporate on monthly basis. Uncovered lagoons: methodology based on BOD calculations; IPCC guidance	Voluntary
Climate Leaders (draft update) **[Please note that ERG has not verified this entry at this time.]**	Pulp and Paper Wastewater	CH4	Process (including biological process)	N/A	Corporate (but need to report emissions for each type of process source)	Combustion device/influent?	CH4 collection data * collection efficiency or IPCC-based	Voluntary
EIA 1605(b)	Wastewater	CH4	Project, or corporate-wide	N/A	Project/corporate-wide	Combustion device/influent?	Domestic Wastewater (***4**), Industrial Wastewater (***5**), Emission Factors (***6**)	Voluntary

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Clean Watersheds NEEDS Survey	Wastewater	No emissions are calculated, but data set includes useful activity data, including populations served, flow, effluent, and unit process information (including sludge digestion).	Varies, but generally costs, permit data, etc.	Not Noted	http://www.epa.gov/cwns/decentrneedsbpfinal.pdf
Climate Leaders **[Please note that ERG is not sure what reference was used for this entry and we have not verified the info at this time.]**	Anaerobic wastewater lagoons	BOD	Base year and annual GHG emissions (CO2 equivalents). Inventory management plan documenting GHG estimation approaches, factors, and data sources that will be used.	EPA Climate Leaders review of inventory management plan and annual summary reports	http://www.epa.gov/climateleaders/resources/sector-specific.html
Climate Leaders (draft update) **[Please note that ERG has not verified this entry at this time.]**	Pulp and Paper Wastewater	CH4 combusted, COD/BOD	Base year and annual GHG emissions (CO2 equivalents). Inventory management plan documenting GHG estimation approaches, factors, and data sources that will be used.	EPA Climate Leaders review of inventory management plan and annual summary reports	http://www.epa.gov/climateleaders/resources/sector-specific.html
EIA 1605(b)	Wastewater	CH4 emission, BOD, population Lower Order: Default emissions factors and general activity data Higher Order: Emissions factors derived from measured wastewater stream composition data	total volume gas recovered, avg. heat content of gas recovered, volume of gas used off-site, volume of gas sold, electricity generated, volume of gas flared, digester capacity, daily wastewater load, waste incinerated or processed., type of waste handled, CH4 emission	Not Noted	ftp://ftp.eia.doe.gov/pub/oiaf/1605/cdrom/pdf/FormEIA-1605_2005.pdf http://www.pi.energy.gov/enhancingGHGregistry/documents/January2007_1605bTechnicalGuidelines.pdf

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
Oregon	Wastewater	No specific rule set	No specific rule set	Sources permitted under certain state statutes would report, or if GHG > 2500 metric tons CO2E	No specific rule set	N/A	The inventory method would follow The Climate Registry protocols or other industry-appropriate protocols, as determined by rule or guidance.	Mandatory
WRI Protocol	Pulp and Paper Wastewater	CH4	Biological process	N/A	Facility	N/A (Activity data on COD/BOD at treatment plant influent and in sludge)	References use of use of the IPCC default methodology described in the May 2000 Good Practices document (***7 and *7a**). Where off-gases from anaerobic treatment operations are not collected and burned, it is necessary to estimate the releases of methane to the atmosphere. In some cases, for instance where the gases are released through a vent in a covered vessel, the releases can be measured directly. In most other cases, they must be estimated.	N/A
IPCC	Domestic/Commercial Wastewater	CH4/N2O	Biological process	N/A	National	N/A (Activity data on COD/BOD at treatment plant influent and in sludge)	See Note ***8 and *8a**	National Inventories
IPCC	Industrial Wastewater	CH4	Biological process	N/A	National	N/A (Activity data on COD/BOD at treatment plant influent and in sludge)	See Note ***8b**	National Inventories
EU Emissions Trading Scheme	Pulp and Paper Wastewater	(out of scope)	N/A	N/A	N/A	N/A	N/A	N/A

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Oregon	Wastewater	Unknown	Unknown	Rely on existing verification methods (e.g. self-certification with periodic inspections by ODEQ and LRAPA inspectors)	http://www.deq.state.or.us/aq/climate/docs/finalrecommend.pdf
WRI Protocol	Pulp and Paper Wastewater	BOD/COD in wastewater, CH4 captured and burned, type of treatment system	Whether included, direct emissions, and emission factor	N/A	http://www.ncasi.org/programs/areas/climate/ghgtools/pulp_icfpa.aspx
IPCC	Domestic/Commercial Wastewater	organics and nitrogen in wastewater, income group, emission factors, CH4 recovered, population, BOD, sludge removal	Emissions and supporting calculations	check numbers for accuracy against averages and expert judgment	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
IPCC	Industrial Wastewater	Production, wastewater generated, sludge removal, organics in wastewater, emission factors, CH4 recovered	Emissions and supporting calculations	check numbers for accuracy against averages and expert judgment	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
EU Emissions Trading Scheme	Pulp and Paper Wastewater	N/A	N/A	N/A	http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:059:0001:0074:EN:PDF http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2007:229:0001:0085:EN:PDF

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
California Climate Action Registry	Wastewater	CH4/N2O	Fugitive	N/A	Facility	Not Noted	N2O Emissions = Protein x FRACnpr x Population x EF Where: Protein = Annual per capita protein consumption FRACnpr = Fraction of nitrogen in protein (percent) EF = Emission factor (kg N20-N/kg sewage-N produced) CH4 Emissions = Population x D x FTA x EF x 365 Where: D = Organic Load in BOD per person (Default = 6 x 10^-8 Gg BOD/person/day) FTA = Fraction of BOD that degrades anaerobically (Default = 15 percent) EF = Emission Factor (Default = 0.6 Gg CH4/Gg BOD) 365 = To convert values to annual emissions	Voluntary
RGGI	(out of scope)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
The Climate Registry	no wastewater found	CH4/N2O	biological processes	N/A	Entity	Not Noted	N/A	Voluntary
New Mexico Mandatory GHG Reporting Program	Petroleum Refining Wastewater	CH4/N2O	N/A	Coverage is reserved	Facility	N/A	Based on 2006 IPCC Guidance	Mandatory, but reserved
API Compendium	Oil and Gas Wastewater - Petroleum Refining	CH4	Fugitive	N/A	Facility	N/A (Activity data on COD/BOD at treatment plant)	General approach uses either EPA AP-42 method or IPCC methodology. Suggests alternative to estimate TOC evaporative losses in wastewater using WATER9. EPA AP-42: Estimate CH4 = Flow* (lbBOD/ft3 wastewater)*(0.22lbCH4/lbBOD)* Fraction anaerobically digested * 365 days/yr For IPCC method, see **Note 8b**.	Voluntary

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
California Climate Action Registry	Wastewater	protein consumption, N in protein, emission factors, population, BOD per person, BOD degrading anaerobically	Varies, many data estimated	Not Noted	http://www.climateregistry.org/tools/protocols/general-reporting-protocol.html California Climate Action Registry General Reporting Protocol References methods for: - N2O emissions from wastewater: Appendix B page B-9; - CH4 emissions from wastewater: Appendix B page B-15.
RGGI	(out of scope)	N/A	N/A	N/A	http://www.rggi.org/docs/model_rule_corrected_1_5_07.pdf
The Climate Registry	no wastewater found	N/A	Not Noted	3rd party verification	http://www.theclimateregistry.org/Draft_General_Reporting_Protocol.pdf
New Mexico Mandatory GHG Reporting Program	Petroleum Refining Wastewater	N/A	N/A	N/A	http://www.nmenv.state.nm.us/aqb/GHG/documents/NM_GHGEI_quantif_proced2008.pdf
API Compendium	Oil and Gas Wastewater - Petroleum Refining	BOD5, wastewater flow, fraction anaerobically digested, days per year.	BOD5 if available, wastewater flow	Not Noted	http://www.api.org/ehs/climate/new/upload/2004_COMPENDIUM.pdf

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)
International Aluminum Institute	(out of scope)	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Inventory of U.S. GHG Emissions and Sinks 1990-2005	Domestic/Commercial Wastewater	CH4, N2O	Biological process	N/A	National	N/A (Activity data on COD/BOD at treatment plant influent and in sludge)	See the 2006 Inventory Wastewater chapter	National GHG Inventory
Inventory of U.S. GHG Emissions and Sinks 1990-2005	Industrial Wastewater	Ch4	Biological process	N/A	National	N/A (Activity data on COD/BOD at treatment plant influent and in sludge)	See the 2006 Inventory Wastewater chapter	National GHG Inventory
National Pollutant Discharge Elimination System	Wastewater	N/A	Biological processes	Facilities directly discharging to waters of the U.S.	Facility	N/A (Activity data on wastewater characterization)	N/A	Mandatory under Clean Water Act

Summary of GHG Reporting Programs and Protocols for Wastewater Treatment

Reporting Program/Guidance	Source Category (or Fuel)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
International Aluminum Institute	(out of scope)	N/A	N/A	N/A	http://www.climatevision.gov/sectors/aluminum/pdfs/ghg_protocol.pdf
Inventory of U.S. GHG Emissions and Sinks 1990-2005	Domestic/Commercial Wastewater	organics and nitrogen in wastewater, income group, emission factors, CH4 recovered, population, BOD, sludge removal	Emissions and supporting calculations	check numbers for accuracy against averages and expert judgment	http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html
Inventory of U.S. GHG Emissions and Sinks 1990-2005	Industrial Wastewater	Production, wastewater generated, sludge removal, organics in wastewater, emission factors, CH4 recovered	Emissions and supporting calculations	check numbers for accuracy against averages and expert judgment	http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterPublicationsGHGEmissionsUSEmissionsInventory2006.html
National Pollutant Discharge Elimination System	Wastewater	Wastewater flow, effluent wastewater characterization (e.g., BOD/COD/N)	Requirements vary by state and by facility. Discharge monitoring report data is reported on a monthly basis.	N/A	http://cfpub.epa.gov/npdes/home.cfm?program_id=45

Notes on Wastewater Reporting Program Data

Please note that many of these calculation procedures are based on the same basic methodology, which for methane estimates organic content in wastewater and sludge, how much is treated anaerobically, and applies an emission factor based on the type of treatment. For nitrous estimates, the methodologies all look at nitrogen content in wastewater effluent by estimating how much nitrogen enters the system and is removed via sludge, andthen applies an emission factor on the nitrogen discharged in effluent. This basic methodology originated with the 1996 IPCC guidelines, and various protocols either reference the 1996 Guidelines or the more updated 2006 Guidelines (which update default factors and include nitrous from certain types of centralized systems). The equations may be look slightly different because they are formatted and expressed differently in different reports/protocols, but produce similar results.

***1: CH4 from Domestic and Commercial Wastewater (Australia)**

CH4 Emissions:

$Ecw = ((CODw - CODsl) \times Fwwan \times EFw) + (CODsl \times Fslan \times EFsl) - R$

$CODw = P \times DCw$

Where:

Ecw is the methane emissions from commercial wastewater (and sludge) treatment (metric tons CO2-e). P is the population served and measured (in persons). DCw is the quantity in kilograms of Chemical Oxygen Demand (COD) per capita of wastewater; the default is set to 0.0585 metric tons per person. CODw is the Chemical Oxygen Demand (COD) in metric tons of COD in wastewater entering the facility - COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable). CODsl is the quantity of COD removed as sludge. EFw is the default methane emission factor for wastewater with value of 5.3 metric tons CO2-e per metric ton COD. EFsl is the default methane emission factor for sludge with value of 5.3 metric tons CO2-e per metric ton COD (sludge). Fwwan is the fraction of COD anaerobically treated: IPCC defaults for various types of treatment are:

- managed aerobic treatment: 0
- unmanaged aerobic treatment: 0.3
- anaerobic digester/reactor: 0.8
- shallow anaerobic lagoon (<2 metres): 0.2
- deep anaerobic lagoon (>2 metres): 0.8

Fslan is the fraction of COD in sludge anaerobically treated on-site (NGA default is 0.29). R is the quantity of CH4 recovered (metric tons CO2-e).

Reporters must choose a characterisation for Fan, the fraction of COD anaerobically treated, and estimate CODsl, the quantity of COD removed as sludge. The quantity of COD removed as sludge may be estimated using the following relationship:

$CODsl = VSsl \times 1.48$ Where VSsl is the estimated volatile solids in sludge.

***2: CH4 from Industrial Wastewater (Australia)**

CH4 Emissions:

$Eiw = CODw \times ((1 – Fsl) \times Fwaan \times EFw + Fsl \times Fslan \times EFsl) – R$

and

$CODw = Prod \times Wgen \times CODcon / 1000$

Where:

CODw is the Chemical Oxygen Demand (COD) in metric tons of COD in wastewater entering the facility

Prod is total production in metric tons

Wgen is the wastewater generation rate in cubic meters (m3) or kilolitres (kL) per metric ton of product. (1 m3 of water = 1 kL)

CODcon is Chemical Oxygen Demand concentration in kg COD per m3 of wastewater entering the facility

Fsl is the fraction of degradable organic component removed as sludge

EFw is the CH4 emission factor for industrial wastewater (default value of 5.3 metric tons CO2-e per metric ton COD)

EFsl is the CH4 emission factor for sludge (default is 5.3 metric tons CO2-e per metric ton COD)

Fwwan is the fraction of COD in wastewater anaerobically treated (NGA defaults are set out in Table 64)

Fslan is the fraction of COD in sludge anaerobically treated on-site

R is the quantity of CH4 recovered (metric tons CO2-e)

Chemical Oxygen Demand is estimated from production, the waste generation rate and the default Chemical Oxygen Demand of the wastewater.

***3: N2O from Domestic and Commercial Wastewater (Australia)**

N2O Emissions:

$Es = (Nin – Nout) \times EF6 + Nout \times EF7$

$Nin = Protein \times FracPr \times P$

Where

Es is the N2O emissions from human sewage (metric tons N2O expressed in CO2-e)

Nin is the load of nitrogen entering the facility (metric tons)

Nout is the load of nitrogen leaving the facility (metric tons)

Protein is the annual per capita protein intake (metric tons per person)

P is the population serviced by the treatment plant

EF6 is the emission factor for secondary treatment (default 4.9 metric tons of nitrous oxide, CO2-e per metric ton of N produced)

EF7 is the emission factor for nitrogen discharge (default 4.9 metric tons of nitrous oxide, CO2-e per metric ton of N produced), differentiated by discharge environment

FracPr is the fraction of nitrogen in protein (default = 0.16 metric tons N per metric ton of protein)

The NGA default per capita protein consumption is 0.036 metric tons per year.

***4: CH4 from Domestic Wastewater (1605b)**

TOCW (kg BOD / year) = W * DOCW * (1 – DS)
Where:
TOCW = total organic content of domestic wastewater, measured in kg BOD / year
W = quantity of domestic wastewater treated per year, measured in cubic meters
DOCW = degradable organic component of domestic wastewater, measured in kg BOD / cubic meters
DS = quantity of degradable organic content removed from domestic wastewater as sludge, as a percentage
In the absence of direct BOD measurements, reporters can estimate total DOC by multiplying the total population for which they are treating wastewater by an estimate of per capita DOC production:
TOCW (kg BOD / year) = P * DCP * (1 – DS)
Where:
TOCW = total organic content of domestic wastewater, measured in kg BOD / year
P = total population served by a single treatment facility, in thousands
DCP = degradable organic component production per thousand persons per year, measured in kg BOD
[If region-specific DOC production data are not available, reporters can use the national average value of 23.7 thousand metric tons BOD produced per person per year.]

Methane Emissions:
MWi (kg CH4) = TOCi * EFi
Where:
MWj = methane emissions from wastewater type i, measured in kg methane
TOCj = total organic content of wastewater type i, measured in kg COD or BOD / year
EFi = methane emissions factor for wastewater type i, measured in kg CH4 / kg TOC (where EF = B * MCF)

***5: CH4 from Industrial Wastewater (1605b)**

TOCi (kg COD / year) = Wi * Oi * DOCi * (1 – DS i)
Where:
TOCi = total organic content of industrial wastewater type i, measured in kg COD / year
Wi = quantity of wastewater type i produced per metric ton of industrial product, measured in cubic meters
Oi = annual output of industrial product, in tons
DOCi = degradable organic component of wastewater type i, measured in kg COD / cubic meter
DSi = quantity of degradable organic content removed from wastewater type i as sludge, as a percentage
MWi (kg CH4) = TOCi * EFi
Where:
MWj = methane emissions from wastewater type i, measured in kg methane
TOCj = total organic content of wastewater type i, measured in kg COD or BOD / year
EFi = methane emissions factor for wastewater type i, measured in kg CH4 / kg TOC (where EF = B * MCF)

***6: Emission Factors (1605b)**
EFi (kg CH4 / kg DOC) = Bi * MCFx
Where:
EFi = methane emissions factor for wastewater type i, measured in kg CH4 / kg DOC
Bi = maximum methane producing capacity of wastewater type i, measured in kg CH4 / kg DOC
MCFx = methane conversion factor of wastewater treatment system x
***7: Pulp and Paper anaerobic wastewater treatment (WRI)**
Anaerobic Treatment Plant Methane Emissions (kg/y) = (OC x EF) – B (Eq. 12)
where:
OC = BOD or COD of the feed to the anaerobic system, kg/year
EF = emission factor, default values = 0.25 kg CH4/kg COD in the feed or 0.6 kg CH4/kg BOD in the feed (or another BOD-based factor developed by multiplying the COD-based factor of 0.25 kg CH4/kg COD by the site-specific COD/BOD ratio)
B = methane captured and burned, kg CH4/year, determined on a site-specific basis
***7a: Pulp and Paper anaerobic sludge digestion (WRI)**
Anaerobic Sludge Digestion Plant Methane Emissions (kg/y) = (OCs x EFs) - B (Eq. 13)
where:
OCs = organic content of the sludge
EFs = emission factor, in units consistent with OCs - IPCC's default value is 0.25 kg CH4/kg COD in the sludge feed
B = methane captured and burned, kg CH4/yr, determined on a site-specific basis
***8: TOTAL CH4 EMISSIONS FROM INDUSTRIAL WASTEWATER (IPCC)**

CH4 Emissions = {Sum (i,j)[Ui*Tij*EFj]}*(TOW-S)-R
Where:
CH4 Emissions = CH4 emissions in inventory year, kg CH4/yr
TOW = total organics in wastewater in inventory year, kg BOD/yr
S = organic component removed as sludge in inventory year, kg BOD/yr
Ui = fraction of population in income group i in inventory year, See Table 6.5.
Tij = degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction i in inventory year, See Table 6.5.
i = income group: rural, urban high income and urban low income
j = each treatment/discharge pathway or system
EFj = emission factor, kg CH4 / kg BOD
R = amount of CH4 recovered in inventory year, kg CH4/yr
CH4 EMISSION FACTOR FOR
EACH DOMESTIC WASTEWATER TREATMENT/DISCHARGE PATHWAY OR SYSTEM
EFj = B0 * MCFj
Where:
EFj = emission factor, kg CH4/kg BOD
j = each treatment/discharge pathway or system
Bo = maximum CH4 producing capacity, kg CH4/kg BOD
MCFj = methane correction factor (fraction)
TOTAL ORGANICALLY DEGRADABLE MATERIAL IN DOMESTIC WASTEWATER
TOW = P*BOD*0.001*I*365
Where:
TOW = total organics in wastewater in inventory year, kg BOD/yr
P = country population in inventory year, (person)
BOD = country-specific per capita BOD in inventory year, g/person/day, See Table 6.4.
0.001 = conversion from grams BOD to kg BOD
I = correction factor for additional industrial BOD discharged into sewers
(for collected the default is 1.25, for uncollected the default is 1.00.)

***8a: N2O EMISSIONS FROM WASTEWATER EFFLUENT (IPCC)**
N2O Emissions = N effluent * EF effluent * 44/28
Where: N2O emissions = N2O emissions in inventory year, kg N2O/yr
N effluent = nitrogen in the effluent discharged to aquatic environments, kg N/yr
EF effluent = emission factor for N2O emissions from discharged to wastewater, kg N2O-N/kg N
The factor 44/28 is the conversion of kg N2O-N into kg N2O.
N effluent can be estimated as = (P * Protein * FNPR * FNON-CON * FIND-COM) - N sludge
Where:
N effluent = total annual amount of nitrogen in the wastewater effluent, kg N/yr;
P = human population;
Protein = annual per capita protein consumption, kg/person/yr;
FNPR = fraction of nitrogen in protein, default = 0.16, kg N/kg protein;
FNON-CON = factor for non-consumed protein added to the wastewater;
FIND-COM = factor for industrial and commercial co-discharged protein into the sewer system;
N sludge = nitrogen removed with sludge (default = zero), kg N/yr.
***8b: TOTAL CH4 EMISSIONS FROM INDUSTRIAL WASTEWATER (IPCC)**

CH4 emissions = (TOW-S) * EF-R
Where (for each industry sector):
CH4 Emissions = CH4 emissions in inventory year, kg CH4/yr;
TOW = total organically degradable material in wastewater from industry in inventory year, kg COD/yr;
S = organic component removed as sludge in inventory year, kg COD/yr;
EF = emission factor for industry, kg CH4/kg COD for treatment/discharge pathway or system(s) used in inventory year [if more than one treatment practice is used in an industry this factor would need to be a weighted average]; and
R = amount of CH4 recovered in inventory year, kg CH4/yr
***9: Methane Emissions from Industrial Wastewater (CARB)**
CH4 = [(Q x COD) – S] x B x MCF x metric ton/1000 kg
Where:
CH4 = emissions of CH4 (metric tons/yr)
Q = volume of wastewater treated (m3/yr)
COD = chemical oxygen demand of wastewater (kg/m3)
S = organic component removed as sludge (kg COD/yr)
B = methane generation capacity (default = 0.25 kg CH4/kg COD)
MCF = methane conversion factor for the anaerobic decay (0 – 1.0)
***9a: Nitrous Oxide Emissions from Industrial Wastewater (CARB)**
N2O = Neff x EFeff x 1.571 x metric tons/1000 kg
Where:
N2O = emission of N2O (metric tons/yr)
Neff = nitrogen in the effluent discharged (kg N/yr)
EFeff = emission factor for N2O emissions from wastewater (kg N2O-N/kg N)
1.571 = conversion factor - kg N2O-N to kg N2O
metric tons/1000 kg = conversion factor - kg to metric tons

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
World Resource Institute Greenhouse Gas Protocol; The Climate Registry; Australian National Greenhouse and Energy Reporting System; Gov't of Canada - Greenhouse Gas Reporting; California Mandatory GHG Reporting Program; EU Emissions Trading Scheme; New Mexico Mandatory GHG Reporting Program; Regional Greenhouse Gas Initiative	No protocols are provided for livestock manure management						
United Nations Framework Convention on Climate Change - Clean Development Mechanism	Livestock manure management	CO2, CH4, N2O	Manure management system with certain attributes (see Notes)	None	Project	Not specified	The program methodology contains very detailed equations for estimating baseline and project CH4 and N2O emissions (see site link, pp. 7-20)
AgSTAR Voluntary Program	Manure Management	CH4	Manure management system	Operating digesters	No reporting (EPA collects data from farm project reports, literature searches, etc. and estimates emissions)	N/A	EPA GHG inventory methods (based on IPCC) and FarmWare
Animal Plant Health Inspection Service	Agriculture (Livestock)	NA	NA	U.S. Farms	Farm	N/A	N/A

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
World Resource Institute Greenhouse Gas Protocol; The Climate Registry; Australian National Greenhouse and Energy Reporting System; Gov't of Canada - Greenhouse Gas Reporting; California Mandatory GHG Reporting Program; EU Emissions Trading Scheme; New Mexico Mandatory GHG Reporting Program; Regional Greenhouse Gas Initiative	No protocols are provided for livestock manure management	No protocols are provided for livestock manure management				
United Nations Framework Convention on Climate Change - Clean Development Mechanism	Livestock manure management	Offsets program under the Kyoto Protocol	Baseline CH4 emissions: Diagram of waste management system existing prior to project implementation; Methane conversion factor, Methane production potential, Fraction of volatile solid degraded in treatment method, N2O emission factor and the fraction of nitrogen excretion in manure waste that is reduced at baseline, Ambient temperature at site; Amount of electricity used for the treatment system at the baseline; Amount of fossil fuel used for the operation of the system in the baseline; Biogas based electricity exported to the grid (if emissions reduction for electricity generation from biogas are claimed); Data and parameters for estimating heat and electricity emission factors. Project emissions: Livestock populations by type; Methane conversion factor; Methane production potential; Fraction of volatile solid degraded in treatment method; N2O emission factor and the fraction of nitrogen excretion in manure waste; Default parameters required for estimating the volatile solids; Leakage from anaerobic digester (if used); Parameters required to estimate nitrogen excretion; Amount of electricity used in the project case. Fuel consumption for generation of heat (if used); Flow of biogas to the flare, heat generation, and electricity generation; Concentration of methane in biogas at outlet of anaerobic digester; Parameters used for determining the project emissions from flaring of the residual gas stream; Biogas leakage in project pipeline during transportation of biogas.	N/A	Procedures determined by project proponents	http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html
AgSTAR Voluntary Program	Manure Management	Voluntary	Farm/project name, location, digester type, operational status, year of operation, animal type, population feeding digester, biogas end use, installed generator capacity, system designer, baseline system, methane emission reductions	N/A	Informal QA/QC procedures	http://www.epa.gov/agstar/resources.html
Animal Plant Health Inspection Service	Agriculture (Livestock)	USDA programs charged with protecting the animals and plants in the agriculture industry (e.g., from agricultural pests, disease)	Surveys on animal production practices. No set frequency; depends on needs of industry. Focus is not on manure management, but surveys have collected more information on this topic over time. Varies by animal type.	N/A	NA	http://www.aphis.usda.gov/

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Chicago Climate Exchange (CCX) (offset protocol for manure management methane)	Manure management	CH4	Voluntary manure management methane emission reduction (offset) projects	NA	Farm/Project	Farm/combustion unit	Baseline estimate (i.e., estimate before biogas projects installed): Characterize the average livestock populations included in the anaerobic digester project for the reporting period; Characterize the baseline manure management system(s) for the project; For each livestock population category and baseline manure management system, multiply the number of animals by the appropriate emission factor for that state, by the appropriate solids separation correction factor, by the proportion of manure from those animals used in the digester, and by the number of days in the period (see Note 1); Sum the estimates for all population categories and baseline manure management systems; Multiply the total estimate of methane emission by the appropriate methane global warming potential for the reporting period (see Note 2).
							Approach for estimating emission reductions: Monitor biogas flow rate using flow metering device (differential pressure sensors, hot wire anemometers) upstream of control device and methane content using a gas analyzer instrument inside of digester or default concentration values
							Alternative method: Estimate methane combustion rates based on the amount of electricity generated [methane recovery, ft3 = (kwh of electricity produced from the biogas fuel) x (heat rate in Btu/kwh) / (1012 Btu/ft3 (HHV of methane))

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Chicago Climate Exchange (CCX) (offset protocol for manure management methane)	Manure management	Voluntary	Number of animals served by project; Methane emission factor; Solids separation correction factor; Fraction of livestock handled using manure management system; Number of days in the reporting period; Baseline CO2 emissions; Global warming potential of methane	The CCX Agricultural Methane Gas Project Guidelines do not explicitly identify reporting requirements - the assumption is made that the reporting requirements for Agricultural Methane are similar to those for Landfill Methane: Methane reduction achieved by project, total gas flows to combustion device or energy recovery project, methane concentrations; 3rd party verifications; Other information to show project meets CCX eligibility requirements; Alternate method for electricity generation projects: Methane reduction, total electricity generation, heat rate of combustion unit from manufacturer.	3rd party verification by CCX approved verifier	http://www.chicagoclimatex.com/docs/offsets/Agriculture_Methane_Protocol.pdf
			Flow Meter: Type of flow meter; Date and location of flow meter installation; Dates and results of flow meter calibration; Flow rate records; Number of hours/month the control device was shut down; Copies of field data used for flow measurement standardization; Monthly tabulations of hourly biogas flow rate standardization calculations and results; Information on the portable instrument and procedures used to check the installed flow meter accuracy; and Records of third-party verification of flow measurements and procedures. Methane Concentration Monitor: Accuracy, precision per manufacturer; Proof of initial calibration; Records of periodic instrument calibration; Capability to record methane concentrations at least every 15 minutes for entities not using default values for methane content.			
			Type, make, and model number of combustion unit(s); Number of combustion units that exclusively use biogas as fuel; Heat rate of combustion device(s) per manufacturer's specifications; Reproduction or quotation is expressly prohibited without written consent of CCX; Copy of a summary table from the most recent source test showing the measured heat rate of combustion device(s); Summary tables showing kwh of electricity produced from biogas per month over the annual period; Type of electrical metering device; and Accuracy, precision, and calibration information on the metering device per manufacturer			

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Energy Information Administration - Voluntary Greenhouse Gases Reporting Program (EIA 1605(b))	Livestock waste and enteric fermentation	CH4 and N2O for livestock waste, CH4 for enteric fermentation	Business, institution, organization, government agency, corporation, or household	Reporting entities may exclude particular sources if the total emissions excluded are < 3% of the total annual CO2 equivalent emissions of the entity	The highest level of aggregation for the entity	Farm/livestock waste management unit	GHG emissions are calculated using Inference: animal type, population, and emission factors (see Ag notes); Process models; or Direct measurement (e.g., flux chamber)
USDA Census of Agriculture	Agriculture (Livestock)	The Census covers land use and ownership, operator characteristics, production practices, income and expenditures and other areas of U.S. farms and ranches	N/A	All U.S. farms and ranches	Farm	N/A	N/A

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Energy Information Administration - Voluntary Greenhouse Gases Reporting Program (EIA 1605(b))	Livestock waste and enteric fermentation	Voluntary	Inference: Animal population, region, emission factors (if defaults used), gross energy intake, methane conversion factor, daily volatile solids excreted, average animal mass, maximum methane producing capacity, methane conversion factors; Input data not specified for direct measurement or process models	Report form 1605 requests GHG emission estimates; estimate rating; name and location of livestock operation; animal type and population; methane supplied to natural gas distribution network (if appl.)	The program encourages but does not require independent review of estimates	http//www.eia.doe.gov/oiaf/1605/January2007_1605bTechnicalGuidelines.pdf
USDA Census of Agriculture	Agriculture (Livestock)	Mandatory Reporting for USDA programs	Data collected is basic data on farm: size, location, # of animals, manure management system type.	Report forms are mailed from USDA to farms/ranches every 5 years and the results are summarized by USDA.	N/A	http://www.agcensus.usda.gov/

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
National Pollutant Discharge Elimination System [Note: the Federal requirements are undergoing reproposal and are not yet final. Information in this row reflects the latest information.]	Concentrated Animal Feeding Operations (CAFOs) (Nitrogen discharge)	N/A	Production areas and land application sites (Nitrogen discharge)	Large operations are designated as CAFOs by their size (number of animals). Medium operations are a certain size and either: - have a manmade ditch or pipe that carries manure or wastewater to surface water; or - the animals come into contact with surface water that passes through the area where they're confined. They are designated as CAFOs if they are a significant contributor of pollutants. The smallest operations can be designated as a CAFO if they are a significant contributor of pollutants.	CAFO	NA (Activity data on wastewater characterization)	N/A
California Climate Action Registry (CCAR) - offset protocol for livestock (manure management) methane	Agriculture (Livestock)	CH4, CO2 (from mobile and stationary combustion sources within the project boundary)	Waste production to disposal, including off-site manure disposal; Livestock manure biogas control systems	N/A	Farm	Gas pipeline between digester and combustion devices (CH4 concentration, flow rate), and farm-level population and manure management practice data	Monitor flow rate (continuous, calibrate instruments based on manufacturer's specifications; corrects for temperature and pressure). Methane concentration (quarterly, accuracy +/- 5%). Monthly baseline emissions (based on IPCC) minus monthly project emissions = annual GHG reductions. Monthly emissions are summed to estimate annual emissions.
EPA National Air Emissions Monitoring Study for Animal Feeding Operations	Agriculture (swine, poultry, dairy)	NH3, H2S, PM, VOC	Farms participating in EPA's Air Quality Compliance Agreement	N/A	Farm	Site-specific locations in animal confinement and manure management systems	Real-time, continuous measurements of emissions and process parameters

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
National Pollutant Discharge Elimination System [Note: the Federal requirements are undergoing reproposal and are not yet final. Information in this row reflects the latest information.]	Concentrated Animal Feeding Operations (CAFOs) (Nitrogen discharge)	Mandatory under Clean Water Act	Permit Application: Number of each kind of animal in confinement; structures used to contain or store manure, litter, and process wastewater and the total amount that each structure can store; estimate of the amount (tons or gallons) of manure, litter, and process wastewater your operation generates each year. Nutrient Management Plan: Records to be kept on site include nitrogen content of manure, litter, and process wastewater, and manure management practice descriptions. Water quality testing for nitrogen	Requirements vary by state and by facility. Discharge monitoring report data is reported on a monthly basis.	N/A	http://cfpub.epa.gov/npdes/home.cfm?program_id=45
California Climate Action Registry (CCAR) - offset protocol for livestock (manure management) methane	Agriculture (Livestock)	Voluntary	Extensive amount of data are needed to estimate baseline ("business as usual") and project emissions. See Notes.	Annual project GHG emission reductions achieved by project, in tonnes CO2e/yr. 3rd party verification. Other information to show project meets CCAR eligibility and additionality requirements.	3rd party verification by CCAR-approved verifier	http://www.climateregistry.org/tools/protocols/project-protocols.html. Calculation tool is available from CCAR for project developers.
EPA National Air Emissions Monitoring Study for Animal Feeding Operations	Agriculture (swine, poultry, dairy)	Voluntary	Emissions are directly measured using continuous emission monitors	Emissions and process data from participating farms are submitted to EPA periodically	EPA-approved Quality Assurance Project Plan for monitoring confinement and manure management processes	http://www.epa.gov/compliance/resources/agreements/caa/cafo-agr-0604.html

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
Inventory of U.S. GHG Emissions and Sinks 1990-2006	Manure Management	CH4, N2O	Biological process	N/A	National	N/A (Activity data on animal population, waste characteristics, and manure management system)	CH4 - Emissions calculated using default IPCC emission factors (for dry manure management systems) and van't Hoff-Arrhenius equation for liquid systems which model the average monthly ambient temperature, a minimum system temperature, the carryover of volatile solids (VS) in the system from month to month, and a factor to account for management and design practices that result in the loss of VS from lagoon systems.
							Direct N2O - Emissions estimated by determining total Kjeldahl nitrogen production for all livestock wastes using a national average N excretion rate for each animal group from USDA which was then multiplied by the average weight of the animal and the state-specific animal population. State- and WMS-specific direct N2O emission factors were then applied to total nitrogen production to estimate direct N2O emissions. Indirect N2O - Emissions calculated by first estimating the amount of nitrogen loss from volatilization and runoff/leaching by multiplying the N excreted by the FRacGas and FracRunoff/Leaching. The N losses were then multiplied by the indirect N2O emission factors to estimate indirect N2O emissions.
Inventory of U.S. GHG Emissions and Sinks 1990-2006	Enteric Fermentation	CH4	Biological process	N/A	National	N/A (Activity data on animal population, feed characteristics, and energy requirements)	To estimate CH4 emissions from all cattle types except bulls and calves younger than 7 months, the population was divided into state, age, sub-type (e.g., heifer and steer in feedlots), and production (e.g., pregnant, lactating) groupings. The transition matrix was used to simulate the age and weight structure of each sub-type on a monthly basis, to more accurately reflect the fluctuations that occur throughout the year. Cattle diet characteristics were then used in conjunction with Tier 2 equations from IPCC (2006) to produce CH4 emission factors for the various cattle types. To estimate emissions from cattle, population data were multiplied by the emission factor for each cattle type. Emission estimates for other animal types were based on average emission factors representative of entire populations of each animal type.

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Inventory of U.S. GHG Emissions and Sinks 1990-2006	Manure Management	National GHG Inventory	Volatile solids and nitrogen in wastewater, animal populations, emission factors, CH4 recovered, manure management system data	Emissions and supporting calculations	Check numbers for accuracy against averages and expert judgment	http://www.epa.gov/climatechange/emissions/usinventoryreport.html
Inventory of U.S. GHG Emissions and Sinks 1990-2006	Enteric Fermentation	National GHG Inventory	Animal populations, feed, energy, emission factors	Emissions and supporting calculations	Check numbers for accuracy against averages and expert judgment	http://www.epa.gov/climatechange/emissions/usinventoryreport.html

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)
2006 IPCC Guidelines	Manure Management	CH4/N2O	Biological process	N/A	National	N/A (Activity data on animal population, waste characteristics, and manure management system)	Tiers 1 and 2: see Notes; Tier III: Modeling or direct measurement
	Enteric Fermentation	CH4	Biological process	N/A	National	N/A (Activity data on animal population, feed characteristics, and energy requirements)	Tiers 1 add 2: see Notes; Tier III: Modeling or direct measurement
EPA Climate Leaders	Manure Management	CH4, N2O	Biological process	N/A	Farm/project	CH4: Livestock population and characteristics, manure management system, Monitor gas flow (continuous, flow meter). Monitor or test methane concentration (continuous, or periodic throughout year). Use monitoring to determine collected methane. If collected gas is combusted on-site, use Climate Leaders stationary combustion guidance (based on quantity combusted) for combustion emissions. N2O: N/A (Activity data on animal population, waste characteristics, and manure management system)	Baseline estimate (see Notes); Emission reductions calculated using direct emissions measurement, process modeling, or program methodology (see Notes)

Summary of GHG Reporting Programs and Protocols for Manure Management

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Manure Management	National Inventories	Volatile solids and nitrogen in wastewater, animal populations, emission factors, CH4 recovered, manure management system data	Emissions and supporting calculations	Check numbers for accuracy against averages and expert judgment	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
	Enteric Fermentation	National Inventories	Animal populations, feed, energy, emission factors	Emissions and supporting calculations	Check numbers for accuracy against averages and expert judgment	http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm
EPA Climate Leaders	Manure Management	Voluntary (offsets protocol)	CH4: Volatile solids in wastewater, animal populations, emission factors, CH4 recovered, manure management system data; N2O: Nitrogen in wastewater, animal populations, emission factors, CH4 recovered, manure management system data	N/A	None specified	http://www.epa.gov/climateleaders/resources/optional-module.html

Notes on the Types of Manure Waste Management Systems Covered Under the United Nations Clean Development Mechanism

The CDM methodology for estimating GHG emission reductions from manure management system is applicable to manure management projects with the following conditions:

- Farms where livestock populations, comprising of cattle, buffalo, swine, sheep, goats, and/or poultry, is managed under confined conditions.
- Farms where manure is not discharged into natural water resources (e.g. rivers or estuaries).
- In case of anaerobic lagoons treatments systems, the depth of the lagoons used for manure management under the baseline scenario should be at least 1 m.
- The annual average temperature in the site where the anaerobic manure treatment facility in the baseline existed is higher than 5°C.
- In the baseline case, the minimum retention time of manure waste in the anaerobic treatment system is greater than 1 month.
- The treatment system in the project case should ensure that no leakage of manure waste into groundwater takes place, e.g., the lagoon should have a non-permeable layer at the

Notes on GHG Calculation Methods and Procedures for Agriculture (Livestock) Sources for Chicago Climate Exchange

Note 1: The following equation is used to calculate methane emissions for all animal population categories and baseline manure management systems.

CH4 (manure) = Sum [(N)*(EF)*(SSCF)*(MS)*(P)]

Where:
CH4 (manure) = CH4 emissions from manure management (kg CH_4/period)
N = Number of animals in livestock species/category included in the project (head)
EF = Specific methane emission factor for livestock category, manure management system, and State (kg CH_4/(head-day))
SSCF = Solids separation correction factor for manure management system (unitless fraction)
MS = Fraction of livestock category's manure handled using manure management system (unitless fraction)
P = number of days in the reporting period (days)

Note 2: The following equation is used to calculate the CO2 equivalents from the manure management system's methane emissions.

CO2 equiv. @ baseline = [CH4 (manure)*(GWP)]/1000

Where:
CO2 equiv. @ baseline = Baseline emissions (Mg CO2 equivalents/period)
GWP = Global warming potential of methane (kg CO2e/kg CH4)
1000 = Mass conversion factor (kg CO2e/Mg CO2e)

Notes on Input Data Used to Calculate Emissions From Agriculture (Livestock) for California Climate Action Registry

General Baseline Parameters	Source of Information
Applicable regulations	Air and water management control boards or management districts, State, EPA
Livestock categories	Operating records
Manure management system components and % of manure managed by each component	Operating records
Animal population (head)	Operating records on herd size
Temperature (ambient)	National Weather Service
Maximum methane producing capacity by livestock category	ASAE standards, EPA Climate Leaders
Methane conversion factor for each system component	2006 IPCC Guidelines
Average daily gross energy intake for each livestock category	Operating and/or nutritionist data
Average digestible energy of the feed for each livestock category	Operating and/or nutritionist data
Urinary energy expressed as a fractions of average daily gross energy intake	Operating and/or nutritionist data
Ash content of the manure (calculated as a fraction of the dry matter feed intake)	Operating and/or nutritionist data
Average energy density of the feed	Operating and/or nutritionist data
Daily volatile solid excretion for each livestock category	ASAE standards, EPA Climate Leaders

Project Methane Calculation Variables	Source of Information
CH4 combusted	Meter reading (calculated from flow rate and CH4 fraction)
Biogas flow from digester to combustion device	Meter reading
CH4 fraction	Quarterly direct measurement using device with approach that yields +/- 5% accuracy
Biogas destruction efficiency	Manufacturer rating
Biogas capture efficiency	Manufacturer rating
For non-project emissions (e.g., mobile emissions)	Fuel usage and emission factors for fuel and combustion type(s)

Notes on GHG Calculation Methods and Procedures for Livestock for DOE's 1605b Program

Each method for estimating emissions from livestock requires an entity to first characterize livestock populations by determining the number of animals the entity owns within specific livestock

Enteric Fermentation (CH4) - Default Emission Factors

$CH4 = \sum Pi * EFi$

Where:

Pi = population size of livestock category i

EFi = emission factor for livestock category i (specific to entity region for cattle categories)

Enteric Fermentation (CH4) - Improved Emission Factors
EFi = (GE * Ym * 365 days/yr) / (55.65 MJ/kg CH4)
Where:
EFi = emission factor for cattle category i (kilograms of methane per head per year)
GE = gross energy intake (MJ/head/day)
Ym = conversion rate of gross energy intake to methane (specific to entity region and is the fraction of GE in feed converted to methane)

Livestock Waste (CH4) - Default Emission Factors
CH4 = ∑ Pi * EFi
Where:
Pi = population size of livestock category i
EFi = CH4 emission factor for livestock category i (specific to entity region for cattle categories)

Livestock Waste (CH4) - Improved Emission Factors
EFi,j = VSi (Mass) * 365 days/yr * Boi * 0.67 kg/m3 * MCFi,j
Where:
EFi,j = emissions factor for CH4 from waste for livestock category i in management system j (kilograms of methane per head per year)
VSi = daily volatile solid excreted per 1,000 kg mass by livestock category i (kilograms of volatile solids per 1,000 kg of animal mass per day)
Mass = average animal mass in 1,000 kg for livestock category i (1,000 kilograms of animal mass)
Boi = maximum CH4 producing capacity for manure produced by an animal in category i (cubic meters of methane per kilogram of volatile solids)
MCFi,j = methane conversion factor for livestock category i in management system j

Livestock Waste (N2O) - Default Emission Factors
CH4 = ∑ Pi * EFi
Where:
Pi = population size of livestock category i
EFi = N2O emission factor for livestock category i (specific to waste management system used)

Notes on GHG Calculation Methods and Procedures for Livestock for EPA's Climate Leaders Program

Baseline emissions, CH4 = SUM (over S) MCFs x 0.662 x 21 / 1000 x [SUM (over L) WL,S x VSL,S / 1000 x 365 x PopL,S x Bo,L]

Where:
Emissions baseline,CH4 = CH4 emissions for livestock managed in the baseline (TCO2e)
L = Livestock subgroup
S = Manure management system
WL,S = Average live weight for livestock subgroup L, managed in system S (kg/head)
VSL,S = Volatile solids produced daily by livestock subgroup L, managed in system S in the baseline (kg VS/day/1000 kg animal mass)
Bo,L = Maximum CH4 producing capacity per kg of VS for livestock subgroup L (m3 CH4/kg VS)
PopL,S = Population of livestock subgroup L managed in manure management system S
MCFS = CH4 conversion factor for manure management system S (See Appendix II, Tables II.c and II.d)
0.662 = kg CH4 per m3 CH4
21 = Global warming potential of CH4
1000 = kg per metric ton

Baseline emissions, N2O = SUM (over S) EFs x 44/28 x 310 / 1000 x [SUM (over L) WL,S x NexL,S / 1000 x 365 x PopL,S

Where:

Emissions baseline, N2O = N2O emissions livestock in the baseline (TCO2e)
L = Livestock subgroup
S = Manure management system
WL,S = Average live weight for livestock subgroup L, managed in system S (kg/head)
NexL,S = Kjeldahl nitrogen excreted daily by livestock subgroup L managed in system S in the baseline (kg N/day/1000kg animal mass)
PopL,S = Population of livestock subgroup L managed in manure management system S
EFS = N2O emission factor for manure management system S (kg N2O -N/kg N excreted)
44/28 = Conversion factor, N2O -N to N2O
310 = Global warming potential of N2O
1000 = kg per metric ton

Project emissions, CH4 = Sum[(Gas combusted$_{project}$)((1/(CE*0.98)-1)]

Where:

Emissions$_{project,CH4}$ = Annual CH_4 emissions for livestock managed in digester (TCO_2e/yr)
Gas Combusted $_{project}$ = Monitored gas combusted (TCO_{2e})
CE = Collection efficiency of the digester system
0.98 = Destruction efficiency

Project emissions, N2O = Sum[EF*844/28*310/1000]*[Sum($W_{L,S}$*$N_{exL,S}$/1000kg*365*$N_{exL,S}$)]

Where:

$Emissions_{project, N2O}$ = Annual N_2O emissions for livestock managed in project (TCO_2e)
L = Livestock subgroup
S = Manure management system
$W_{L,S}$ = Average live weight for livestock subgroup L, managed in system S (kg/head)
$N_{exL,S}$ = Kjeldahl nitrogen excreted daily by livestock subgroup L managed in system S in the baseline (kg N/day/1000kg animal mass)
C = Population of livestock subgroup L managed in manure management system S
EF_S = N_2O emission factor for manure management system S (kg N_2O -N/kg N excreted)
44/28 = Conversion factor, N_2O -N to N_2O
310 = Global warming potential of N_2O

Notes on GHG Calculation Methods and Procedures for Livestock for IPCC Guidelines (Manure Management)

Tier 1 - CH4 emissions from manure management, $CH4_{manure}$ = $Sum_T(EF_T*N_T)$/10^6

Where:

$CH4_{Manure}$ = CH4 emissions from manure management, for a defined population, Gg CH4 yr-1
EF_T = emission factor for the defined livestock population, kg CH4 head-1 yr-1
N_T = the number of head of livestock species/category T in the country
T = species/category of livestock

Tier 2 calculations use the same approach as Tier 1 except country-specific data are used.

Tier 2 - CH4 emissions from manure management, EF(T) = ($VS_{(T)}$ * 365)*[$Bo_{(T)}$* 0.67 * Sum($MCF_{(S,K)}$/100 * $MS_{(T,S,k)}$)]

Where:

EF(T) = annual CH4 emission factor for livestock category T, kg CH4 animal-1 yr-1
VS(T) = daily volatile solid excreted for livestock category T, kg dry matter animal-1 day-1
365 = basis for calculating annual VS production, days yr-1
Bo(T) = maximum methane producing capacity for manure produced by livestock category T, m3 CH4 kg-1 of VS excreted
0.67 = conversion factor of m3 CH4 to kilograms CH4
MCF(S,k) = methane conversion factors for each manure management system S by climate region k, %
MS(T,S,k) = fraction of livestock category T's manure handled using manure management system S in climate region k, dimensionless

Tier 1 - Direct N2O emissions from manure management, $N2O_{D(mm)} = Sum_S[Sum_T[N_{(T)}*Nex_{(T)}*MS_{(T,S)}]*(EF_{(S)}]*44/28$

Where:

$N2O_{D(mm)}$ = direct N2O emissions from Manure Management in the country, kg N2O yr-1

$N_{(T)}$ = number of head of livestock species/category T in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N animal-1 yr-1

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

$EF_{(S)}$ = emission factor for direct N2O emissions from manure management system S in the country, kg N2O-N/kg N in manure management system S

S = manure management system

T = species/category of livestock

44/28 = conversion of (N2O-N)(mm) emissions to N2O(mm) emissions

Tier 2 calculations use the same approach as Tier 1 except country-specific data are used.

Tier 1 - Indirect N2O emissions from manure management = $N2O_{G(mm)} = (N_{volatilization\ -MMS} * EF_4)* 44/28$

Where:

$N2O_{G(mm)}$ = indirect N2O emissions due to volatilization of N from Manure Management in the country, kg N2O yr-1

EF_4 = emission factor for N2O emissions from atmospheric deposition of nitrogen on soils and water surfaces, kg N2O-N (kg NH3-N + NOx-N volatilised)-1 ; default value is 0.01 kg

$N_{volatilization\text{-}MMS}$ = amount of manure nitrogen that is lost due to volatilization of NH3 and NOx, kg N yr-1

$N_{volatilization\text{-}MMS} = Sum_S[Sum_T[N_{(T)}*Nex_{(T)}*MS_{(T,S)}*(FracGas_{MS}/100)_{TS}]]$

Where:

$N_{(T)}$ = number of head of livestock species/category T in the country

$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N animal-1 yr-1

$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless

$FracGas_{MS}$ = percent of managed manure nitrogen for livestock category T that volatilizes as NH3 and NOx in the manure management system S, %

Tier 2 calculations use the same approach as Tier 1 except country-specific data are used.

Tier 2 - Indirect N2O emissions due to leaching from manure management, $N2O_{L(mm)} = (N_{leaching\text{-}mms} * EF)*44/28$

Where:

N2OL(mm) = indirect N2O emissions due to leaching and runoff from Manure Management in the country, kg N2O yr-1
EF = emission factor for N2O emissions from nitrogen leaching and runoff, kg N2O-N/kg N leached and runoff (default value 0.0075 kg N2O-N (kg N leaching/runoff)-1

$N_{leaching\text{-}mms} = Sum_S[Sum_T[N_{(T)}*Nex_{(T)}*MS_{(T,S)}*(Frac_{leachMS}/100)_{TS}]]$

Where:

$N_{leaching\text{-}mms}$ = amount of manure nitrogen that leached from manure management systems, kg N yr-1
$N_{(T)}$ = number of head of livestock species/category T in the country
$Nex_{(T)}$ = annual average N excretion per head of species/category T in the country, kg N animal-1 yr-1
$MS_{(T,S)}$ = fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless
$Frac_{leachMS}$ = percent of managed manure nitrogen losses for livestock category T due to runoff and leaching during solid and liquid storage of manure (typical range 1-20%)

Notes on GHG Calculation Methods and Procedures for Livestock for IPCC Guidelines (Enteric Fermentation)

Tier 1 - $CH4_{enteric} = EF_T * N_T/10^6$

Where:

$CH4_{enteric}$ = methane emissions from Enteric Fermentation, Gg CH4 yr-1
EF_T = emission factor for the defined livestock population, kg CH4 head-1 yr-1
N_T = the number of head of livestock species / category T in the country
T = species/category of livestock

Total CH4 emissions are the sum of CH4 emissions across all livestock categories.
Tier 2 calculations use the same approach as Tier 1 except country-specific data are used.

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
Energy Information Administration Coal Production Report; Form EIA-7A	Production	Coal; short tons	N/A	Greater than 10,000 short tons	Mine	Mine company reports
MSHA Quarterly Mine Employment and Coal Production Report; MSHA 7000-2	Production	Employees, work hours, coal production	N/A	All	Mine level	Mine company reports
Census Bureau EM545, IM145	Imports/Exports	Coal	N/A	All shipments	Shipment	At port / customs district
Energy Information Administration Quarterly Coal Consumption and Quality Report Manufacturing Plants; Form EIA-3	Distribution and Consumption	Anthracite, bituminous coal, subbituminous coal, lignite, or coal synfuel; short tons	N/A	Greater than 1000 short tons	Plant level	Manufacturing company reports
Energy Information Administration Quarterly Coal Consumption and Quality Report Coke Plants; Form EIA-5	Distribution and Consumption	Type of coal; short tons	N/A	All coke plants	Plant level	Coke company reports
Energy Information Administration Coal Distribution Report; Form EIA-6A	Distribution and Consumption	Coal; short tons	N/A	Greater than 50,000 short tons	Company	Mine company and wholesale or retail dealers report
Energy Information Administration Power Plant Report; Form EIA-906	Distribution and Consumption	Energy source, gross generation, fuel consumption	N/A	Plants greater than 1 MW capacity	Plant level	Plant operator reports

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods for Source/Fuel	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/ Quality Control Procedures
Energy Information Administration Coal Production Report; Form EIA-7A	Production	Self-reporting	Mandatory Reporting	Production, reserves, coal bed information	Not known
MSHA Quarterly Mine Employment and Coal Production Report; MSHA 7000-2	Production	Self-reporting	Mandatory Reporting	Production, hours worked	Not known
Census Bureau EM545, IM145	Imports/Exports	Self-reporting	Mandatory Reporting	Origin / Destination	Not known
Energy Information Administration Quarterly Coal Consumption and Quality Report Manufacturing Plants; Form EIA-3	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity, cost, source and characteristics	Not known
Energy Information Administration Quarterly Coal Consumption and Quality Report Coke Plants; Form EIA-5	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity, cost, source and characteristics	Not known
Energy Information Administration Coal Distribution Report; Form EIA-6A	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity and flows	Not known
Energy Information Administration Power Plant Report; Form EIA-906	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity and characteristics	Not known

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
Energy Information Administration Combined Heat and Power Plant; Form EIA-920	Distribution and Consumption	Fuel use, generation, disposition	N/A	Plants greater than 1 MW capacity	Plant level	Plant operator reports
Energy Information Administration Monthly Cost and Quality of Fuels for Electricity Plants; Form EIA-423	Distribution and Consumption	Coal mine type, supplier, ash content and costs	N/A	Plants greater than 50 MW capacity	Plant level	Plant operator reports
FERC Cost and Quality of Fuels for Electric Plants; FERC Form-423	Distribution and Consumption	Coal mine type, supplier, ash content and costs	N/A	All utility plants	Plant level	Plant operator reports
Energy Information Administration Power Plant Report; Form EIA-923 ***Replaces EIA-906, 920, 423 and FERC-423**	Distribution and Consumption	Energy source, gross generation, fuel consumption + Coal mine type, supplier, ash content and costs	N/A	Plants greater than 1 MW capacity	Plant level	Plant operator reports

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods for Source/Fuel	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/ Quality Control Procedures
Energy Information Administration Combined Heat and Power Plant; Form EIA-920	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity and characteristics	Not known
Energy Information Administration Monthly Cost and Quality of Fuels for Electricity Plants; Form EIA-423	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity, cost, source and characteristics	Not known
FERC Cost and Quality of Fuels for Electric Plants; FERC Form-423	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity, cost, source and characteristics	Not known
Energy Information Administration Power Plant Report; Form EIA-923 ***Replaces EIA-906, 920, 423 and FERC-423**	Distribution and Consumption	Self-reporting	Mandatory Reporting	Coal quantity, cost, source and characteristics	Not known

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods for Source/Fuel	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/Quality Control Procedures
EIA reporting for Imports	Petroleum Imports	Petroleum	N/A	Varied	Importer	Pipeline - at border Marine - at offload	Meters	Mandatory Reporting	N/A	Weekly and monthly data reconciled against each other for consistency
EIA reporting for Refineries	Petroleum Refineries	Petroleum	N/A	Varied	Refinery	Throughout refinery	Meters	Mandatory Reporting	N/A	800, 810, 820 data reconciled against one another for consistency
FERC reporting for Exports	Petroleum Exports	Petroleum	N/A	Based on revenue	Pipeline	At border	Meters	Mandatory Reporting	N/A	None currently
MMS reporting for Upstream Production	Petroleum Others	Petroleum	N/A	No threshold	Federal land lessee	Lease meter	Meters	Mandatory Reporting	N/A	Royalty information from OGOR and PASR compared
FHWA reporting for Consumption	Petroleum Others	Petroleum	N/A	N/A	State agency responsible for collection of motor fuel tax	Pump sales	Meters	Mandatory Reporting	N/A	None
Army Corps of Engineers reporting for Marine Movements	Petroleum Others	Petroleum	N/A	Trips less than 1 mile not required to be reported	Domestic commercial operator	Ports	Meters	Mandatory Reporting	N/A	Reconciliation with dock receipts
California Energy Commission reporting for Imports	Petroleum Imports	Petroleum	N/A	20,000 barrels per month	Importer	Marine - at offload Pipeline - at state border Rail - at tank Truck - at rack	Meters	Mandatory Reporting	N/A	Weekly and monthly data reconciled against each other for consistency
California Energy Commission reporting for Exports	Petroleum Exports	Petroleum	N/A	20,000 barrels per month	Exporter	Marine - at offload Pipeline - at state border Rail - at tank Truck - at rack	Meters	Mandatory Reporting	N/A	Weekly and monthly data reconciled against each other for consistency
California Energy Commission reporting for Refineries	Petroleum Refineries	Petroleum	N/A	No threshold	Refinery	Throughout refinery	Meters	Mandatory Reporting	N/A	Weekly and monthly data reconciled against each other for consistency
Texas Railroad Commission reporting for Refineries	Petroleum Refineries	Petroleum	N/A	No threshold	Refinery	Throughout refinery	Meters	Mandatory Reporting	N/A	None

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods for Source/Fuel	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/Quality Control Procedures
Texas Railroad Commission reporting for Upstream Production	Petroleum Others	Petroleum	N/A	No threshold	Producer	Lease meter	Meters	Mandatory Reporting	N/A	None
Texas General Land Office reporting for Upstream Production	Petroleum Others	Petroleum	N/A	No threshold	State land lessee	Lease meter	Meters	Mandatory Reporting	N/A	Audit against RRC
Alabama Oil and Gas Board reporting for Upstream	Petroleum Others	Petroleum	N/A	No threshold	Producer and transporter	Lease meter	Meters	Mandatory Reporting	N/A	Go by notarization
Mississippi Oil and Gas Board reporting for Upstream	Petroleum Others	Petroleum	N/A	No threshold	Producer and transporter	Lease meter	Meters	Mandatory Reporting	N/A	Field inspection
Mississippi Oil and Gas Board reporting for Refinery	Petroleum Refineries	Petroleum	N/A	No threshold	Refinery	Throughout refinery	Meters	Mandatory Reporting	N/A	Field inspection
Louisiana Office of Mineral Resources reporting for Upstream Production	Petroleum Others	Petroleum	N/A	No threshold	State royalty payor	Lease meter	Meters	Mandatory Reporting	N/A	Audit against third-party documents
Oil & Gas Journal Worldwide Refinery Survey	Petroleum Refineries	Petroleum	N/A		Refinery					None

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods for Source/Fuel
Energy Information Admin. Annual Report of the Origin of Natural Gas Liquids Production; Form EIA-64A	**Processing**	Natural Gas and Natural Gas Liquids	NA	All gas processing plants (does not include field separation units)	Facility	Not specified	Not specified
Energy Information Admin. Monthly Natural Gas Liquids Report; Form EIA-816	**Processing**	Natural Gas and Natural Gas Liquids	NA	All facilities that extract liquid hydrocarbons from a natural gas stream and/or separate a liquid hydrocarbon stream	Facility	Not specified	Not specified
Energy Information Admin. Annual Report of Natural and Supplemental Gas Supply & Disposition; Form EIA-176	**Processing**	Natural Gas and Natural Gas Liquids	NA	All entities listed below 1) Production operators 2) Processing plant companies 3) Interstate pipeline companies 4) Intrastate pipeline companies 5)Underground storage operators 6) Synthetic natural gas plant operators 7) LNG storage operators	Facility	Not specified	Not specified
Energy Information Admin. Annual Report of Natural and Supplemental Gas Supply & Disposition; Form EIA-176	**Transmission Pipelines**	Natural Gas	NA	All Pipelines, interstate and intrastate	Facility / Pipeline company	Companies report receipts and delieveries by company and state, determined from meter readings	Not specified

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/Quality Control Procedures
Energy Information Admin. Annual Report of the Origin of Natural Gas Liquids Production; Form EIA-64A	**Processing**	Mandatory Reporting	N/A	EIA does not mention any QA/QC process in the instructions to the form
Energy Information Admin. Monthly Natural Gas Liquids Report; Form EIA-816	**Processing**	Mandatory Reporting	N/A	EIA does not mention any QA/QC process in the instructions to the form
Energy Information Admin. Annual Report of Natural and Supplemental Gas Supply & Disposition; Form EIA-176	**Processing**	Mandatory Reporting	N/A	Revised reports have to be submitted by reporting entity if corrected data is over +/- 4% of previous filing
Energy Information Admin. Annual Report of Natural and Supplemental Gas Supply & Disposition; Form EIA-176	**Transmission Pipelines**	Mandatory	Production, storage injections/withdrawls, losses, and end-use deliveries/transfers.	Computer edit programs verify the report year, State code, and arithmetic totals. Further tests were made to ensure that all necessary data elements were present and that the data were reasonable and internally consistent. The computerized edit system produced error listings with messages for each failed edit test. To resolve problems, respondents were contacted and equired to file amended forms with corrected data where necessary.

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods for Source/Fuel
FERC Form 549 - Annual Intrastate Transportation Report	**Transmission Pipelines**	Natural Gas	NA	Some intrastate pipelines	Pipeline company	Not specified	Not specified
Energy Information Admin. EIA Form 176	**LDCs**	Natural Gas	NA	All LDCs	Form information includes respondent identification and state of operation.	City gate reciepts, deliveries & transfers to all end-use sectors.	Monitoring procedure determined by company.
Energy Information Admin. EIA Form 857	**LDCs**	Natural Gas	NA	A sample of all natural gas companies some of which are LDCs	Facility name and owner is reported, but this data is not released publicly.	Purchased Gas Received and Cost in Distribution Service Area (City Gate). Also, delivery volume & revenues to end-use sectors.	Monitoring procedure determined by company.
Energy Information Admin. EIA - Oil and Gas Survey Form 176	**Imports**	Natural Gas/LNG	NA	All pipeline and LNG imports	Facility	Metered at border	Not specified
Department of Energy Fossil Energy DOE-FE-- Natural Gas Imports by Pipeline	**Imports**	Natural Gas	NA	All Imports via pipeline	Importing company	At the border	Not specified

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/Quality Control Procedures
FERC Form 549 - Annual Intrastate Transportation Report	**Transmission Pipelines**	Mandatory	N/A	Unknown
Energy Information Admin. EIA Form 176	**LDCs**	Mandatory	Production, storage injections/withdrawls, losses	Computer edit programs verify the report year, State code, and arithmetic totals. Further tests were made to ensure that all necessary data elements were present and that the data were reasonable and internally consistent. The computerized edit system produced error listings with messages for each failed edit test. To resolve problems, respondents were contacted and equired to file amended forms with corrected data where necessary.
Energy Information Admin. EIA Form 857	**LDCs**	Mandatory	Heat content of gas	Unknown
Energy Information Admin. EIA - Oil and Gas Survey Form 176	**Imports**	Mandatory	N/A	Computer edit programs verify the report year, State code, and arithmetic totals. Further tests were made to ensure that all necessary data elements were present and that the data were reasonable and internally consistent. The computerized edit system produced error listings with messages for each failed edit test. To resolve problems, respondents were contacted and equired to file amended forms with corrected data where necessary.
Department of Energy Fossil Energy DOE-FE-- Natural Gas Imports by Pipeline	**Imports**	Mandatory	Quaterly data	Unknown

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods for Source/Fuel
Department of Energy Fossil Energy DOE-FE-- LNG Imports	**Imports**	Natural Gas/LNG	NA	All LNG imports	Importing company	At the border	Not specified
Customs Customs Form CF 3461 - Entry/Immediate Delivery	**Imports**	Natural Gas	NA	Pipeline Imports	Importing company	At the border	Not specified
Customs Customs Form CF 3461 - Entry/Immediate Delivery and Form CF 7501 Entry Summary	**Imports**	Natural Gas/LNG	NA	Pipeline Imports	Importing company	At the terminal	Customs can inspect cargo

Reporting Program/Guidance	Source Category (or Fuel)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Supplemental Data Reported (e.g., production, capacity, waste-in-place)	Quality Assurance/Quality Control Procedures
Department of Energy Fossil Energy DOE-FE-- LNG Imports	**Imports**	Mandatory	Quaterly data	
Customs Customs Form CF 3461 - Entry/Immediate Delivery	**Imports**	Mandatory	N/A	Unknown
Customs Customs Form CF 3461 - Entry/Immediate Delivery and Form CF 7501 Entry Summary	**Imports**	Mandatory	N/A	Customs can inspect cargo

Reporting Program/Guidance	Source Category	Coverage (Gases or Fuels)	Coverage (Who reports)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring (upstream, midstream, downstream, etc)
TSCA Inventory Update Reporting (40 CFR 710.43; www.epa.gov/oppt/iur)	Chemicals in Commerce	7,000 - 9,000 chemicals for volumes of 25,000 lbs or more per site; 3,000 chemicals for volumes of 300,000 lbs or more per site	manufacturers, including importers, of subject chemical	production (manufacture + import) volumes of 25,000 lbs or more at a site	site/facility	not specified
Australian Commonwealth Government Ozone Protection and Synthetic Greenhouse Gas Reporting Program	Industrial Gases	chlorofluorocarbons (CFCs), halon 1211, 1301, & 2402, carbon tetrachloride, methyl chloroform, hydrochlorofluorocarbons (HCFCs), hydrobromofluorocarbon (HBFC), methyl bromide, bromochlormethane (BCM), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs)	Manufacturers, Exporters, Imports of ozone depleting substances (ODS) and synthetic greenhouse gases (SGG)	all refrigerant imports, either in bulk or in precharged equipment, as well as exports, imports, and manufacture of controlled substances	Importers, manufacturers, exports, company level	not specified

Reporting Program/Guidance	Source Category	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., capacity, reactant consumption) (Source of Data). Is this reported?	What is Reported to Program	Verification Method
TSCA Inventory Update Reporting (40 CFR 710.43; www.epa.gov/oppt/iur)	Chemicals in Commerce	not specified	Mandatory Reporting	not specified	chemical identification (name & CASRN (most cases)), production volume, site limited status, activity (manufacture or import), maximum concentration, # of workers reasonably likely to be exposed, physical form of chemical, %PV in form; for larger volume chemicals (site PV of 300,000 lbs or more), additional processing & use information reported	Site audits by OECA, mostly regional staff
Australian Commonwealth Government Ozone Protection and Synthetic Greenhouse Gas Reporting Program	Industrial Gases	not specified	Mandatory Reporting	not specified	**PRECHARGED EQUIPMENT LICENSE**: Company name, liscense #, time to complete form, product name, product category, refrigerant, charge size, # imported. **CONTROLLED SUBSTANCES LICENSE (HFCs & PFCs)**: Imports(MT) & CO_2 equivalent for HFC-134a, other HFCs/PFCs (gases listed), exotic HFCs (non-specified to be no more than 5% of a company's imports, otherwise gas listed as other), for HCFCs heel deduction also included, gas(MT) & CO_2 equivalent being used in each industry sector, identify if for use in new equipment or relpacing leaks; **HCFCs**: Quantity of import (MT), heel deduction of import, country of origin, net imports(MT), net ODP tonnes imported; **Import of Controlled Substances for use as Feedstock**: substance name, ODP, country of origin, quantity(MT), heel deduction, net imports(MT), nature of use as feedstock; **HCFC Exports**: substance, quantity(MT), destination; **Methyl bromide**: quantity imported/exported(MT), country of origin/destination, imports for non-QPS (quarantine & pre-shipment), imports for QPS, description of export use, purity of export. **USED SUBSTANCES LICENSE** **(CFCs & HALONS)**: quantity imported(MT), country of origin, quantity(MT) of imported substance recycled and destroyed, quantity(MT) of recycled substances exported.	Ozone and Synthetic Gas Team checks all quarterly reports with data provided by the Australian Customs Service. Inaccurate reporting and late submissions are offences under the Act.

Reporting Program/Guidance	Source Category	Precision and Accuracy Requirements	Other Quality Assurance/Quality Control Procedures (e.g., calibration)	Frequency of Reporting	Method for Calculating/ Verifying Destruction of Materials	Method for Tracking Imports/ Exports (who reports, are products containing the material covered, coordination with customs, etc.)	Source of Information
TSCA Inventory Update Reporting (40 CFR 710.43; www.epa.gov/oppt/iur)	Chemicals in Commerce	PV reported to 2 significant figures, as long as within +/- 10% of actual	none stipulated	Every 5 years	not specified	Importers report (see "coverage" column); article exemption (unless chemical is intended to come out of article to function, such as for ink); chemical exemptions (unless subject to another TSCA rule): naturally occurring substances, microorganisms, polymers, certain forms of natural gas; no current coordination with customs; exports are not tracked	From Susan Sharkey/OPPTS (202-564-8789) 4/1/08
Australian Commonwealth Government Ozone Protection and Synthetic Greenhouse Gas Reporting Program	Industrial Gases	not specified	not specified	Quarterly (those licensed to import/export ODS only to those countries that have ratified the Montreal Protocol and relevant subsequent Amendments)	not specified	Importers, exporters and manufacturers report. Exemptions: The Minister may grant exemptions where the products are essential for medical, veterinary, defense, industrial safety or public safety purposes, and where no practical alternatives are available.	http://www.environment.gov.au/atmosphere/ozone/licences/licencereporting.html

Reporting Program/Guidance	Source Category	Coverage (Gases or Fuels)	Coverage (Who reports)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring (upstream, midstream, downstream, etc)
EU ETS	Industrial Gases not included in EU ETS scope	For the first two periods of the EU ETS (2005-2007 and 2008-2012), the only activities included are large combustion, refineries, coke ovens, ferrous metals, cement, glass, ceramics, pulp and paper; and only CO2 emissions (combustion and process) are included. Nevertheless, some countries (France and the Netherlands) have chosen to use the "opt-in" clause for N2O emissions from the production of nitric and adipic acid for the 2nd period (2008-2012). The European Commission, in its proposal for a directive to improve and extend the EU ETS post 2012, released on January 23rd, 2008, recommends including: - CO2 emissions from petrochemicals, ammonia and aluminium - N2O emissions from the production of nitric, adipic and glyoxalic acid production - PFC emissions from the aluminium sector No official EU ETS monitoring and reporting guidelines exist for these gases so far.				
ODS Title VI	Industrial Gases	Ozone-depleting substances including CFCs, HCFCs, Halons, methyl bromide and others	Producers, Importers, Exporters, Applicators (methyl bromide), transformers (who use ODS as feedstock), destruction facilities, trades of ODS	all ODS production, importation, and export data and all ODS transformation and destruction data (i.e., no threshold)	information gathered at facilities to develop reports that require data on a company-wide scale	Not specified

Reporting Program/Guidance	Source Category	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., capacity, reactant consumption) (Source of Data). Is this reported?	What is Reported to Program	Verification Method
EU ETS	Industrial Gases not included in EU ETS scope					Industrial Gases not included in EU ETS scope
ODS Title VI	Industrial Gases	specific monitoring equipment or methods to monitor production and import quantities not specified in regulations; however, it is possible that facilities refer to records (e.g., dated records of ODS produced at each facility, quantities imported), which are required by the regulations, to assist in monitoring production/import data	Mandatory Reporting	Not specified	all intentional bulk substance production, import, export and destruction (i.e., no threshold); substances contained in products not included	Ongoing site audits (part of EPA's Stratospheric Protection Division's standard operaing procedures (SOP))

Reporting Program/Guidance	Source Category	Precision and Accuracy Requirements	Other Quality Assurance/Quality Control Procedures (e.g., calibration)	Frequency of Reporting	Method for Calculating/ Verifying Destruction of Materials	Method for Tracking Imports/ Exports (who reports, are products containing the material covered, coordination with customs, etc.)	Source of Information
EU ETS	Industrial Gases not included in EU ETS scope						http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2003:275:0032:0046:EN:PDF
ODS Title VI	Industrial Gases	none stipulated	none stipulated	Quarterly, annually, and transactional level (trades)	one-time report is required on the methods used to record the volume destroyed; verification reports indicating intent to destroy, destruction efficiency, and period of time over which destruction will occur	no specific method or coordination with customs specified, tracking inherent to recordkeeping and reporting requirements reporting requirements include submitting bills of lading and import invoices when requesting additional consumption allowances; IRS certificates showing purchaser/recipient of imports that will be transformed; certification for heels; destruction verifications; certifications for laboratory and essential uses	From Dave, Staci 3/3/08; ICF 4/2/08; Title 40 Part 82 available at: http://www.access.gpo.gov/nara/cfr/waisidx_03/40cfr82_03.html

Reporting Program/Guidance	Source Category	Coverage (Gases or Fuels)	Coverage (Who reports)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring (upstream, midstream, downstream, etc)
2006 IPCC Guidelines for National Greenhouse Gas Inventories--Refrigeration and air-conditioning Tier 2a (This row describes the container management emissions protocol for refrigeration/air-conditioning, which is a sub-part of the Tier 2a emissions estimation approach for this sector). (Additionally, see Note 1 on notes tab.)	Refrigerant and Air-Conditioning	Emissions of refrigerant and air-conditioning gases (e.g., CFCs, HCFC, HFCs) during container management, which include: (1) gas transfer from the bulk containers to smaller containers or equipment; and (2) gas (e.g., heels) left in bulk containers	Countries	All (i.e. no deminimis)	National (although, countries may gather data at the facility or company level)	not specified

Reporting Program/Guidance	Source Category	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., capacity, reactant consumption) (Source of Data). Is this reported?	What is Reported to Program	Verification Method
2006 IPCC Guidelines for National Greenhouse Gas Inventories--Refrigeration and air-conditioning Tier 2a (This row describes the container management emissions protocol for refrigeration/air-conditioning, which is a sub-part of the Tier 2a emissions estimation approach for this sector). (Additionally, see Note 1 on notes tab.)	Refrigerant and Air-Conditioning	Econtainers,t = RMt × c / 100 where, Econtainers,t = Emissions from all refrigerant containers in year t [kg] RMt = Refrigerant market for new equipment and servicing all refrigeration application in year t [kg] c = Emission factor of refrigerant container management of the current refrigerant market [percent] The emission factor is the percent of the refrigerant emitted during container transfer and/or from the heels. This emission factor, which depends on each bulk container type, is multiplied by the amount of refrigerant contained within each bulk container (i.e., the Refrigerant market). The sum of fugitive emissions over all container types, results in the total fugitive emissions for container management.	To meet the inventory reporting requirements of Parties to the UNFCCC	Econtainers,t is the emissions from all refrigerant containers in year t, kg RMt is the refrigerant market for new equipment and servicing all refrigeration application in year t, kg c is the emission factor of refrigerant container management of the current refrigerant market, percent	No reporting requirements.	not specified

Reporting Program/Guidance	Source Category	Precision and Accuracy Requirements	Other Quality Assurance/Quality Control Procedures (e.g., calibration)	Frequency of Reporting	Method for Calculating/ Verifying Destruction of Materials	Method for Tracking Imports/ Exports (who reports, are products containing the material covered, coordination with customs, etc.)	Source of Information
2006 IPCC Guidelines for National Greenhouse Gas Inventories--Refrigeration and air-conditioning Tier 2a (This row describes the container management emissions protocol for refrigeration/air-conditioning, which is a sub-part of the Tier 2a emissions estimation approach for this sector). (Additionally, see Note 1 on notes tab.)	Refrigerant and Air-Conditioning	not specified	QA/QC procedures outlined for national inventory compiler to double check the national refrigerant/air-conditioning emissions estimates for year t, but no specific QA/QC outlines for container management emission estimates.	annual	not specified	not specified	IPCC guidelines: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_7_Ch7_ODS_Substitutes.pdf

Reporting Program/Guidance	Source Category	Coverage (Gases or Fuels)	Coverage (Who reports)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring (upstream, midstream, downstream, etc)
TRI	Industrial Gases	Approximately 650 toxic chemicals (a full list is available at www.epa.gov/tri/chemical/) (See Note 2 of Notes tab)	Facilities that manufacture (including import), process, or otherwise use any relevant chemical 23,000 facilities (SICs 20-39, 10, 12, 4911, 4931, 4939, 4953, 5169, 5171, and 7389)	**Form R** **Non-PBT Chemicals:** Report required for each chemical manufactured or processed > 25,000 lbs/year, or used > 10,000 lbs/year **PBT Chemicals:** A list of thresholds is found in the Notes section In each case, only facilities > 10 full-time (2,000 + hrs/year) equivalent employees, and within certain NAICS codes (found in Note 2), must report Note: all federal facilities must report releases, regardless of NAICS code **Form A:** Non-PBT Chemicals: Report required for total waste management < 5,000 lbs/year, releases (both on- and off-site) < 2,000 lbs/year, and manufacture/process/use < 1,000,000 lbs/year **PBT Chemicals:** Report required for total waste management < 500 lbs/year, releases (both on- and off-site) = 0, and manufacture/process/use < 1,000,000 lbs/year **Note:** Form A may not be used for dioxins	Facility	Not Specified
General: Fuel Metering	Oil and Gas	Oil and gas is mainly measured by the Lease meters, in place as the fuel leaves the lease. They are constantly checked to make sure that they are correct as it is at that point that royalties and taxes are determined. This is a measurement after the liquids have dropped out of the gas and after the crude oil has been in settling tanks.	THE REMAINDER OF THIS ROW HAS NOT YET BEEN INVESTIGATED BUT IS BEING CONSIDERED UNDER THE FUELS TO			THE REMAINDER OF THIS ROW HAS NOT YET BEEN INVESTIGATED BUT IS BEING CONSIDERED UNDER THE FUELS TO

Reporting Program/Guidance	Source Category	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g, mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., capacity, reactant consumption) (Source of Data). Is this reported?	What is Reported to Program	Verification Method
TRI	Industrial Gases	**Releases:** For each mixture, Release = MIX x FRchem, where MIX = total mixture manufactured/processed/used and FRchem = fraction of relevant chemical in that mixture **Environmental media:** No chemical-specific guidance. Releases can be calculated through monitoring data (either continuous or periodic/random), engineering estimates, rate meter data, media analyses, and mass balance equations using published emission factors	Mandatory Reporting	Not Specified	Facility information Chemical identification information (CAS #, mixture info, etc.) Facility-specific uses of chemical Maximum amount of chemical at facility at any one time Quantity of chemical released into environment on-site (both regular and accidental) Transfers of chemical in wastes to off-site locations (both publically-owned treatment works and other locations) On-site waste treatment methods and efficiency Source reduction and recycling activities	Voluntary EPA site surveys
General: Fuel Metering	Oil and Gas					N/A

Reporting Program/Guidance	Source Category	Precision and Accuracy Requirements	Other Quality Assurance/Quality Control Procedures (e.g., calibration)	Frequency of Reporting	Method for Calculating/ Verifying Destruction of Materials	Method for Tracking Imports/ Exports (who reports, are products containing the material covered, coordination with customs, etc.)	Source of Information
TRI	Industrial Gases	**Non-PBT chemicals:** Whole numbers, in pounds **PBT chemicals:** Tenths of a pound (non-dioxins), up to seven decimal places of a gram (dioxins)	Facilities must store all TRI reports from the previous 3 years	Annual	Not Specified	Imported material shall be counted as production	http://www.epa.gov/tri/report/rfi/TRI_RY2007%203.19.2008%20final.pdf
General: Fuel Metering	Oil and Gas	THE REMAINDER OF THIS ROW HAS NOT YET BEEN INVESTIGATED BUT IS BEING CONSIDERED UNDER THE FUELS TO					

Note 1.

Estimates for fugitive emissions vary. RTI estimates fugitive emissions from the production of HCFC-22 between 1-2 percent. (U.S. EPA (2008) "Verification of Emission Estimates of HFC-23 from the Production of HCFC-22: Emissions from 1990 through 2006, Final Report." Prepared by RTI International.) IPCC estimates fugitive emissions from complete container management between 2-10 percent (Note: this estimate is unique to the refrigeration/AC sector and may not apply to the F-gas production/import sector) (IPCC, 2007. 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Chapter 7; page 7.49). Available online at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.htm).

Note 2. TRI Data

PBT Chemical Thresholds		
Chemical or Chemical Category Name	**CAS # or chemical Category Code**	**Threshold (in pounds, unless otherwise noted)**
Aldrin	309-00-2	100
Benzo[g,h,i]perylene	191-24-2	10
Chlordane	57-74-9	10
Dioxin and dioxin-like compounds category (manufacturing; and the processing or otherwise use of dioxin and dioxinlike compounds category if the dioxin and dioxinlike compounds are present as contaminants in a chemical and if they were created during the	N150	0.1g
Heptachlor	76-44-8	10
Hexachlorobenzene	118-74-1	10
Isodrin	465-73-6	10
Lead (this lower threshold does not apply to lead when it is contained in stainless steel, brass or bronze alloy)	7439-92-1	100
Lead compounds	N420	100
Mercury	7439-97-6	10
Mercury compounds	N458	10
Methoxychlor	72-43-5	100
Octachlorostyrene	29082-74-4	10
Pendimethalin	40487-42-1	100
Pentachlorobenzene	608-93-5	10
Polychlorinated biphenyls (PCBs)	1336-36-3	10
Polycyclic aromatic compounds category (PACs)	N590	100
Tetrabromobisphenol A	79-94-7	100
Toxaphene	8001-35-2	10
Trifluralin	1582-09-8	100

Source: EPA (2008) Toxic Chemical Release Inventory Reporting Forms and Instructions, Revised 2007 Version. Available online at http://www.epa.gov/tri/report/rfi/TRI_RY2007%203.19.2008%20final.pdf

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Capture	CO_2	Process & Combustion	N/A	Project/Facility	**Capture** *Method 1* • Direct measurement of CO2 in emissions stream upstream from capture technology • Direct measurement of CO2 in emissions stream downstream from capture technology

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Capture	**Capture** (Fugitive Emissions from the Extraction of Carbon Dioxide from Anthropogenic Sources, p. 171)) *Method 1* The Technical Guidelines describe two methods for calculating the fugitive emissions from capture of CO2 released from anthropogenic sources, such as fossil fuel combustion in power plants and industrial processes. These methods estimate the amount of CO2 that remains in the waste stream after capture. The first method (Equation 1) is based on monitoring the amount of CO2 in the waste stream before and after the capture process, and subtracting these values. Ecap = Eupstream – Edownstream (1) Where: Ecap = Fugitive CO2 emissions during the capture process Eupstream = Direct measurement of CO2 in emissions stream upstream from capture technology Edownstream = Direct measurement of CO2 in emissions stream downstream from capture technology. This method can be used with continuous emissions monitoring data or annual emissions monitoring data. The continuous emissions method is more accurate and therefore desirable. *Method 2* The second method (Equation 2) can be used to calculate fugitive CO2 emissions from CO2 capture if em Ecap = (1 –η)Es (2) Where: Ecap = Fugitive CO2 emissions during the capture process η = Published efficiency of CO2 capture technology Es = Emissions from source, without capture process This method is less accurate than the above method (both for continuous and annual monitoring). The do	Voluntary [individual facilities are not required to report data]	**Capture** *Method 1* Eupstream, Edownstream *Method 2* η = Published efficiency of CO2 capture technology Es = Emissions from source, without capture process

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Capture	General guidance on reporting is given on p. 165-166 (this is primarily applicable to the geologic storage phase. DOE requires the following documentation to register emission reductions from geologic sequestration (p. 288): • Name and location of the source of the carbon dioxide. • Method of disposition for the carbon dioxide (e.g., long-term geologic storage or enhanced oil recovery). • Name and location of the geologic formation or other sink used to sequester the carbon dioxide. • Year of capture and permanent sequestration • Volume of carbon dioxide captured or transferred to the entity. • Volume of carbon dioxide permanently sequestered less leakage during the storage process. • The method used to estimate net sequestration (e.g., Federal/state or new life-cycle analysis or active monitoring approach). • Estimated volume permanently sequestered in the base year. • Estimated volume permanently sequestered in the current reporting year.	No information on QA/QC procedures for carbon capture activities were found in this document	U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	CO_2	Process & Combustion	N/A	Project/Facility	**Transport** Method 1 • Direct measurement of CO2 at pipeline input • Direct measurement of CO2 at pipeline endpoint
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	CO_2	Process & Combustion	N/A	Project/Facility	**Transport** *Method 2* • Direct measurement of CO2 at source, filling of tank • Direct measurement of CO2 at pipeline, delivery of tank

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	**Transport** - Fugitive Emissions from Transport and Processing (p. 172-174): *Method 1* There are several options available to reporters to quantify the amount of CO2 lost during transport. The first method (equation 3) can be used for CO2 transport in a pipeline. This method calculates the difference in CO2 at input into the pipeline and at the pipeline endpoint. The effect of differences in the surrounding temperatures at the beginning and endpoint would also need to be taken into account to adjust volumetric values according to cooler or warmer climates. This method is rated "A" (most accurate) by DOE. Etrans = Cin – Cout (3) Where: Etrans = Fugitive CO2 emissions from transportation via pipeline Cin = Direct measurement of CO2 at pipeline input Cout = Direct measurement of CO2 at pipeline endpoint	Voluntary [individual facilities are not required to report data]	**Transport** *Method 1* Cin = Direct measurement of CO2 at pipeline input Cout = Direct measurement of CO2 at pipeline endpoint
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	*Method 2* Calculating the difference in the amount of CO2contained in a tank (Equation 4), based on a measurement taken at the time the tank is filled and a measurement taken at the point the tank is delivered to the injection site, to determine the amount of CO2 lost to the atmosphere is also rated "A." Etrans = Cfill – Cdel (4) Where: Etrans = Fugitive CO2 emissions from transportation via tank Cfill = Direct measurement of CO2 at source, filling of tank Cdel = Direct measurement of CO2 at pipeline, delivery of tank *Method 3* The fugitive emissions from pipeline transport can also be estimated based on the amount of CO2 injected for ERR (Equation 6). This case of estimating the amount of CO2 emissions from pipeline transportation without measuring any CO2 quantities (Equation 6) is less accurate than the above methods. Etrans = Ecap – Creq (5) Where: Etrans = Fugitive CO2 emissions from transportation via pipeline Ecap = Estimation of CO2 capture based on Equation 2, above Creq = Amount of CO2 injected for enhanced resource recovery	Voluntary [individual facilities are not required to report data]	**Transport** *Method 2* Cfill = Direct measurement of CO2 at source, filling of tank Cdel = Direct measurement of CO2 at pipeline, delivery of tank *Method 3* Ecap = Estimation of CO2 capture based on Equation 2, above Creq = Amount of CO2 injected for enhanced resource recovery

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	General guidance on reporting is given on p. 165-166 (this is primarily applicable to the geologic storage phase. DOE requires the following documentation to register emission reductions from geologic sequestration (p. 288): • Name and location of the source of the carbon dioxide. • Method of disposition for the carbon dioxide (e.g., long-term geologic storage or enhanced oil recovery). • Name and location of the geologic formation or other sink used to sequester the carbon dioxide. • Year of capture and permanent sequestration • Volume of carbon dioxide captured or transferred to the entity. • Volume of carbon dioxide permanently sequestered less leakage during the storage process. • The method used to estimate net sequestration (e.g., Federal/state or new life-cycle analysis or active monitoring approach). • Estimated volume permanently sequestered in the base year. • Estimated volume permanently sequestered in the current reporting year.	No information on QA/QC procedures for carbon transport activities were found in this document	U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	General guidance on reporting is given on p. 165-166 (this is primarily applicable to the geologic storage phase. DOE requires the following documentation to register emission reductions from geologic sequestration (p. 288): • Name and location of the source of the carbon dioxide. • Method of disposition for the carbon dioxide (e.g., long-term geologic storage or enhanced oil recovery). • Name and location of the geologic formation or other sink used to sequester the carbon dioxide. • Year of capture and permanent sequestration • Volume of carbon dioxide captured or transferred to the entity. • Volume of carbon dioxide permanently sequestered less leakage during the storage process. • The method used to estimate net sequestration (e.g., Federal/state or new life-cycle analysis or active monitoring approach). • Estimated volume permanently sequestered in the base year. • Estimated volume permanently sequestered in the current reporting year.	No information on QA/QC procedures for carbon transport activities were found in this document	U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	CO_2	Process & Combustion	N/A	Project/Facility	**Transport** *Method 4*

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	*Method 4* Estimating fugitive emissions from CO2 pipelines may also be accomplished by using average emission factors that are based on industry guidance for estimating fugitive losses from natural gas pipelines, and have been adjusted to represent emissions from CO2 (Equation 6). (see API Compendium of Greenhouse Gas Emissions Estimation Methodologies for the Oil and Gas Industry and the Interstate Natural Gas Association of America (INGAA) Greenhouse Gas Emission Estimation Guidelines for Natural Gas Transmission and Storage: Volume 1 – GHG Emission Estimation Methodologies and Procedures.) Because the emissions factors are based on natural gas instead of CO2 pipelines the emission factors may overstate fugitive emissions. However, at this time, there is insufficient data to develop average emission factors specifically for CO2 pipelines. The method is the least accurate of the methods for estimating fugitive losses for transportation. Etrans = Σ EFi * i (6) Summation of EFi for all i component types Where: Etrans = Fugitive CO2 emissions from pipeline transport EFi = Average emission factor for component, i i = Pipeline and/or processing component (miles and/or station count)	Voluntary [individual facilities are not required to report data]	*Method 4* EFi = Average emission factor for component, i i = Pipeline and/or processing component (miles and/or station count)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Transport	General guidance on reporting is given on p. 165-166 (this is primarily applicable to the geologic storage phase. DOE requires the following documentation to register emission reductions from geologic sequestration (p. 288): • Name and location of the source of the carbon dioxide. • Method of disposition for the carbon dioxide (e.g., long-term geologic storage or enhanced oil recovery). • Name and location of the geologic formation or other sink used to sequester the carbon dioxide. • Year of capture and permanent sequestration • Volume of carbon dioxide captured or transferred to the entity. • Volume of carbon dioxide permanently sequestered less leakage during the storage process. • The method used to estimate net sequestration (e.g., Federal/state or new life-cycle analysis or active monitoring approach). • Estimated volume permanently sequestered in the base year. • Estimated volume permanently sequestered in the current reporting year.	No information on QA/QC procedures for carbon transport activities were found in this document	U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Injection	CO_2	Process & Combustion	N/A	Project/Facility	**Injection** *Method 1* • Use of a monitoring system to measure the loss of carbon dioxide during injection and recycling (most accurate).

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Injection	**Injection** (Fugitive Emissions from Injection and Extraction for Enhanced Resource Recovery (ERR), p. 174-175) *Method 1* Use of a monitoring system to measure the loss of carbon dioxide during injection and recycling (most accurate). *Method 2* This method calculates the amount of CO2 lost during the reporting period as the difference between the amount of CO2 needed for enhanced resource recovery and the estimated amount of CO2 stored. (Equation 7). In this case, no measurements are made, but rather, amounts of CO2 in storage and used for ERR are based on historical data and process needs, respectively. This method is considerably less accurate than method 1. Erec = Cstore – Creq (7) Where: Erec = Emissions during recycling of CO2 from storage Cstore = Amount of CO2 in storage at the beginning of the reporting period Creq = Amount of CO2 required for ERR during the reporting period	Voluntary [individual facilities are not required to report data]	**Injection** *Method 1* Use of a monitoring system to measure the loss of carbon dioxide during injection and recycling (most accurate). *Method 2* Cstore = Amount of CO2 in storage at the beginning of the reporting period Creq = Amount of CO2 required for ERR during the reporting period

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007	Carbon Injection	General guidance on reporting is given on p. 165-166 (this is primarily applicable to the geologic storage phase. DOE requires the following documentation to register emission reductions from geologic sequestration (p. 288): • Name and location of the source of the carbon dioxide. • Method of disposition for the carbon dioxide (e.g., long-term geologic storage or enhanced oil recovery). • Name and location of the geologic formation or other sink used to sequester the carbon dioxide. • Year of capture and permanent sequestration • Volume of carbon dioxide captured or transferred to the entity. • Volume of carbon dioxide permanently sequestered less leakage during the storage process. • The method used to estimate net sequestration (e.g., Federal/state or new life-cycle analysis or active monitoring approach). • Estimated volume permanently sequestered in the base year. • Estimated volume permanently sequestered in the current reporting year.	No information on QA/QC procedures for carbon injection activities were found in this document	U.S. DOE Technical Guidelines for Voluntary Reporting of Greenhouse Gases, (1605(b)) Program, 2007

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Carbon Capture	CO2	Process & Combustion	N/A	Facility	**Capture** Points of monitoring for carbon capture are not explicitly identified in the guidelines. Types of processes to be monitored (e.g., natural gas processing) are identified in the guidelines

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
2006 IPCC Guidelines	Carbon Capture	Guidelines for compiling inventories from the CO2 capture system depends on the nature of the CO2 source • Stationary combustion systems, natural gas processing units, and hydrogen production plants are in Vol 2, Ch 2 • Capture for other industrial processes are in Vol 2 (cement, methanol, ammonia, and iron and steel) **Capture** "Emissions (and reductions) associated with CO2 capture should be reported under the IPCC sector in which capture takes place (e.g. Stationary Combustion or Industrial Activities)" (p. 5.7)	Voluntary [individual facilities are not required to report data]	**Capture** Input data for carbon capture are not explicitly identified in the guidance.

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Carbon Capture	1) Prior to commencing storage, inventory compiler should obtain the following: • Report on methods and results of site characterization • Report on methods and results of modeling • Description of proposed monitoring program, including background measurements • Year of commencement of CO2 storage • Proposed sources of CO2 • Infrastructure involved in whole CCGS chain, between source and storage reservoir 2) To be received annually from each site: • Mass of CO2 injected during the reporting year • Mass of CO2 stored during the reporting year • Cumulative mass of CO2 stored at the site • Source(s) of CO2 and infrastructure involved in whole CCGS chain between source and storage • Report detailing rationale, methodology, monitoring frequency and results of the monitoring program (Include mass of any fugitive emissions of CO2 and other GHGs from the storage site) • Report on necessary adjustments of modeling or forward modeling of site, due to monitoring results • Descriptions of monitoring programs and monitoring methods used, monitoring frequency and their results • Results of third party verification of monitoring program and methods	• CO2 capture should not be reported without linking it to long term storage • Always check equality of mass balance equation for CO2 captured, stored and emitted • Good practice to compare monitoring methods and possible leakage scenarios between comparable site internationally • International cooperation would be advantageous in developing monitoring methodologies and technologies • Capture + Imports = Injection + Exports + Leakage • If (Capture + Imports) < (Injection + Exports + Leakage), check that: o Exports are not overestimated o Imports are not underestimated o Data for CO2 injection does not include EOR operations associated with storage • If (Capture + Imports) > (Injection + Exports + Leakage), check that: o Exports are not underestimated o Imports are not overestimated o CO2 capture designed for long-term storage is not actually going to other short-term emissive uses (e.g. products, EOR without storage, etc.)	2006 IPCC Guidelines

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Carbon Capture (Continued)	CO2	Process & Combustion	N/A	Facility	**Capture** Points of monitoring for carbon capture are not explicitly identified in the guidelines. Types of processes to be monitored (e.g., natural gas processing) are identified in the guidelines

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
2006 IPCC Guidelines	Carbon Capture (Continued)	Guidelines for compiling inventories from the CO2 capture system depends on the nature of the CO2 source • Stationary combustion systems, natural gas processing units, and hydrogen production plants are in Vol 2, Ch 2 • Capture for other industrial processes are in Vol 2 (cement, methanol, ammonia, and iron and steel) **Capture** "Emissions (and reductions) associated with CO2 capture should be reported under the IPCC sector in which capture takes place (e.g. Stationary Combustion or Industrial Activities)" (p. 5.7)	Voluntary [individual facilities are not required to report data]	**Capture** Input data for carbon capture are not explicitly identified in the guidance.

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Carbon Capture (Continued)	3) There may be additional reporting necessary if project is part of an emissions trading scheme 4) Reporting of cross-border CCS projects: • Use if CO2 is captured in one country (country A) and exported for storage in another (country B) • Country A reports: a) Amount of CO2 captured, b) Emissions from transport and/or temporary storage that takes place in country A, c) Amount of CO2 exported to country B • Country B reports: a) Amount of CO2 imported, b) Emissions from transport and/or temporary storage that takes place in country B, c) Emissions from injection and geological storage sites • If CO2 is injected to a storage site in country A, but leaks into country B, then country A is responsible for reporting all emissions from the site - If such leakage is anticipated based on site characterization and modeling, country A should make an arrangement with country B, to ensure appropriate standards for monitoring and/or estimation of emission are applied • If more than one country utilizes a common storage site, the country where geological storage takes place is responsible for reporting emissions from that site - Even if emissions occur outside of the country, the site country is still responsible for reporting all emissions, as described above • If storage site occurs in more than one country, countries concerned should make an arrangement whereby each reports and agreed fraction of emissions	• On site QA/QC o Regular inspection of monitoring equipment and site infrastructure. Monitoring equipment and programs subject to independent scrutiny by inventory compiler and/or regulatory agency o Inventory compiler should compare leak rates of storage facility against analogous sites. Explain reasons for difference in performance o Where applicable, relevant regulatory authority can provide verification of emissions estimates - If no such body exists, the site operator should provide the inventory compiler with the results of a peer review by a competent third party. From the outset of the project, this review should confirm that: Geological and numerical models are representative, Reservoir simulator is suitable, Modeling is realistic, Monitoring plan is suitable - As soon as they become available, site operator should compare results of monitoring program with predictive models. Adjust models, monitoring program and/or injection strategy appropriately. Site operator should inform inventory compiler of changes made.	2006 IPCC Guidelines

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Carbon Transport	CO_2	Process & Combustion	N/A	Facility	**Transport** Pipeline Inlet and Pipeline Outlet *[CO2 emissions are estimated from CO2 mass flow rate and CO2 emission factor]*

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
2006 IPCC Guidelines	Carbon Transport	**Transport** 1) Fugitive emissions - Equipment leaks, venting, ruptures or accidental releases from: Pipeline breaks, Seals, Valves Intermediate compressor stations on pipelines, Intermediate storage facilities, Ships transporting liquefied CO2, Ship loading and offloading facilities 2) Pipelines are most prevalent means of bulk CO2 transport • Must be monitored on a per plant basis • Size of system will be known - a) Size used to estimate emissions from transport b) On a mass-basis, CO2 emissions rate from pipelines if 1.66 times the emission rate of CH4 (Multiply relevant CH4 emissions factors (from Table 4.2.8) by 1.66, for default CO2 emission factors) • Table 5.2 lists Default Tier 1 Emission Factors for Pipeline Transport: Low = .00014 Gg/km per yr, Medium = .0014, High = .014, uncertainty of a factor of 2 • Number of leaks not necessarily correlated to length of pipeline • Unless CO2 is transported over long distances, emissions from pipeline will be essentially nil, compared to both initial capture/compression and ending injection 3) Transport by ship • Default emissions for CO2 transport by ship are not available • Amount of gas should be metered during loading and discharge - Use flow metering and losses reported 4) Intermediate storage facilities • Tank: Emission measured and treated as part of emissions from 1C1 c (other) • Geological storage reservoir is under category 1C3	Voluntary [individual facilities are not required to report data]	**Transport** CO2 flow rate into pipeline; CO2 flow rate out of pipeline

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Carbon Transport	1) Prior to commencing storage, inventory compiler should obtain the following: • Report on methods and results of site characterization • Report on methods and results of modeling • Description of proposed monitoring program, including background measurements • Year of commencement of CO2 storage • Proposed sources of CO2 • Infrastructure involved in whole CCGS chain, between source and storage reservoir 2) To be received annually from each site: • Mass of CO2 injected during the reporting year • Mass of CO2 stored during the reporting year • Cumulative mass of CO2 stored at the site • Source(s) of CO2 and infrastructure involved in whole CCGS chain between source and storage • Report detailing rationale, methodology, monitoring frequency and results of the monitoring program (Include mass of any fugitive emissions of CO2 and other GHGs from the storage site) • Report on necessary adjustments of modeling or forward modeling of site, due to monitoring results • Descriptions of monitoring programs and monitoring methods used, monitoring frequency and their results • Results of third party verification of monitoring program and methods	• CO2 capture should not be reported without linking it to long term storage • Always check equality of mass balance equation for CO2 captured, stored and emitted • Good practice to compare monitoring methods and possible leakage scenarios between comparable site internationally • International cooperation would be advantageous in developing monitoring methodologies and technologies • Capture + Imports = Injection + Exports + Leakage • If (Capture + Imports) < (Injection + Exports + Leakage), check that: o Exports are not overestimated o Imports are not underestimated o Data for CO2 injection does not include EOR operations associated with storage • If (Capture + Imports) > (Injection + Exports + Leakage), check that: o Exports are not underestimated o Imports are not overestimated o CO2 capture designed for long-term storage is not actually going to other short-term emissive uses (e.g. products, EOR without storage, etc.)	2006 IPCC Guidelines

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Carbon Transport (Continued)	CO_2	Process & Combustion	N/A	Facility	**Transport** Pipeline Inlet and Pipeline Outlet *[CO2 emissions are estimated from CO2 mass flow rate and CO2 emission factor]*

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
2006 IPCC Guidelines	Carbon Transport (Continued)	**Transport** 1) Fugitive emissions - Equipment leaks, venting, ruptures or accidental releases from: Pipeline breaks, Seals, Valves Intermediate compressor stations on pipelines, Intermediate storage facilities, Ships transporting liquefied CO2, Ship loading and offloading facilities 2) Pipelines are most prevalent means of bulk CO2 transport • Must be monitored on a per plant basis • Size of system will be known - a) Size used to estimate emissions from transport b) On a mass-basis, CO2 emissions rate from pipelines if 1.66 times the emission rate of CH4 (Multiply relevant CH4 emissions factors (from Table 4.2.8) by 1.66, for default CO2 emission factors) • Table 5.2 lists Default Tier 1 Emission Factors for Pipeline Transport: Low = .00014 Gg/km per yr, Medium = .0014, High = .014, uncertainty of a factor of 2 • Number of leaks not necessarily correlated to length of pipeline • Unless CO2 is transported over long distances, emissions from pipeline will be essentially nil, compared to both initial capture/compression and ending injection 3) Transport by ship • Default emissions for CO2 transport by ship are not available • Amount of gas should be metered during loading and discharge - Use flow metering and losses reported 4) Intermediate storage facilities • Tank: Emission measured and treated as part of emissions from 1C1 c (other) • Geological storage reservoir is under category 1C3	Voluntary [individual facilities are not required to report data]	**Transport** CO2 flow rate into pipeline; CO2 flow rate out of pipeline

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Carbon Transport (Continued)	3) There may be additional reporting necessary if project is part of an emissions trading scheme 4) Reporting of cross-border CCS projects: • Use if CO2 is captured in one country (country A) and exported for storage in another (country B) • Country A reports: a) Amount of CO2 captured, b) Emissions from transport and/or temporary storage that takes place in country A, c) Amount of CO2 exported to country B • Country B reports: a) Amount of CO2 imported, b) Emissions from transport and/or temporary storage that takes place in country B, c) Emissions from injection and geological storage sites • If CO2 is injected to a storage site in country A, but leaks into country B, then country A is responsible for reporting all emissions from the site - If such leakage is anticipated based on site characterization and modeling, country A should make an arrangement with country B, to ensure appropriate standards for monitoring and/or estimation of emission are applied • If more than one country utilizes a common storage site, the country where geological storage takes place is responsible for reporting emissions from that site - Even if emissions occur outside of the country, the site country is still responsible for reporting all emissions, as described above • If storage site occurs in more than one country, countries concerned should make an arrangement whereby each reports and agreed fraction of emissions	• On site QA/QC o Regular inspection of monitoring equipment and site infrastructure. Monitoring equipment and programs subject to independent scrutiny by inventory compiler and/or regulatory agency o Inventory compiler should compare leak rates of storage facility against analogous sites. Explain reasons for difference in performance. o Where applicable, relevant regulatory authority can provide verification of emissions estimates - If no such body exists, the site operator should provide the inventory compiler with the results of a peer review by a competent third party. From the outset of the project, this review should confirm that: Geological and numerical models are representative, Reservoir simulator is suitable, Modeling is realistic, Monitoring plan is suitable - As soon as they become available, site operator should compare results of monitoring program with predictive models. Adjust models, monitoring program and/or injection strategy appropriately. Site operator should inform inventory compiler of changes made.	2006 IPCC Guidelines

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Carbon Injection	CO_2	Process & Combustion	N/A	Facility	**Injection** Wellhead meters [injection flow rate of CO2]; surface equipment (e.g., compressors)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
2006 IPCC Guidelines	Carbon Injection	**Injection** 1) Fugitive emissions from activities and equipment at injection site • Surface facilities at injection site (storage facilities, distribution manifold, distribution pipelines to wells, additional compression facilities, measurement and control systems, wellhead(s) and injection wells) 2) Meters at wellhead • Since there are no Tier 1 or 2 emissions factors available for injection, good practice is to directly measure emissions at the injection well • Measure flow rate, temperature and pressure of injected CO2 • Wellhead safety features to prevent blowout of injected fluid	Voluntary [individual facilities are not required to report data]	**Injection** Input data for emissions calculations for injection are not explicitly identified in the guidance.

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Carbon Injection	1) Prior to commencing storage, inventory compiler should obtain the following: • Report on methods and results of site characterization • Report on methods and results of modeling • Description of proposed monitoring program, including background measurements • Year of commencement of CO2 storage • Proposed sources of CO2 • Infrastructure involved in whole CCGS chain, between source and storage reservoir 2) To be received annually from each site: • Mass of CO2 injected during the reporting year • Mass of CO2 stored during the reporting year • Cumulative mass of CO2 stored at the site • Source(s) of CO2 and infrastructure involved in whole CCGS chain between source and storage • Report detailing rationale, methodology, monitoring frequency and results of the monitoring program (Include mass of any fugitive emissions of CO2 and other GHGs from the storage site) • Report on necessary adjustments of modeling or forward modeling of site, due to monitoring results • Descriptions of monitoring programs and monitoring methods used, monitoring frequency and their results • Results of third party verification of monitoring program and methods	• CO2 capture should not be reported without linking it to long term storage • Always check equality of mass balance equation for CO2 captured, stored and emitted • Good practice to compare monitoring methods and possible leakage scenarios between comparable site internationally • International cooperation would be advantageous in developing monitoring methodologies and technologies • Capture + Imports = Injection + Exports + Leakage • If (Capture + Imports) < (Injection + Exports + Leakage), check that: o Exports are not overestimated o Imports are not underestimated o Data for CO2 injection does not include EOR operations associated with storage • If (Capture + Imports) > (Injection + Exports + Leakage), check that: o Exports are not underestimated o Imports are not overestimated o CO2 capture designed for long-term storage is not actually going to other short-term emissive uses (e.g. products, EOR without storage, etc.)	2006 IPCC Guidelines

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Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
2006 IPCC Guidelines	Carbon Injection (Continued)	CO_2	Process & Combustion	N/A	Facility	**Injection** Wellhead meters [injection flow rate of CO2]; surface equipment (e.g., compressors)

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
2006 IPCC Guidelines	Carbon Injection (Continued)	**Injection** 1) Fugitive emissions from activities and equipment at injection site • Surface facilities at injection site (storage facilities, distribution manifold, distribution pipelines to wells, additional compression facilities, measurement and control systems, wellhead(s) and injection wells) 2) Meters at wellhead • Since there are no Tier 1 or 2 emissions factors available for injection, good practice is to directly measure emissions at the injection well • Measure flow rate, temperature and pressure of injected CO2 • Wellhead safety features to prevent blowout of injected fluid	Voluntary [individual facilities are not required to report data]	**Injection** Input data for emissions calculations for injection are not explicitly identified in the guidance.

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
2006 IPCC Guidelines	Carbon Injection (Continued)	3) There may be additional reporting necessary if project is part of an emissions trading scheme 4) Reporting of cross-border CCS projects: • Use if CO2 is captured in one country (country A) and exported for storage in another (country B) • Country A reports: a) Amount of CO2 captured, b) Emissions from transport and/or temporary storage that takes place in country A, c) Amount of CO2 exported to country B • Country B reports: a) Amount of CO2 imported, b) Emissions from transport and/or temporary storage that takes place in country B, c) Emissions from injection and geological storage sites • If CO2 is injected to a storage site in country A, but leaks into country B, then country A is responsible for reporting all emissions from the site - If such leakage is anticipated based on site characterization and modeling, country A should make an arrangement with country B, to ensure appropriate standards for monitoring and/or estimation of emission are applied • If more than one country utilizes a common storage site, the country where geological storage takes place is responsible for reporting emissions from that site - Even if emissions occur outside of the country, the site country is still responsible for reporting all emissions, as described above • If storage site occurs in more than one country, countries concerned should make an arrangement whereby each reports and agreed fraction of emissions	• On site QA/QC o Regular inspection of monitoring equipment and site infrastructure. Monitoring equipment and programs subject to independent scrutiny by inventory compiler and/or regulatory agency o Inventory compiler should compare leak rates of storage facility against analogous sites. Explain reasons for difference in performance. o Where applicable, relevant regulatory authority can provide verification of emissions estimates - If no such body exists, the site operator should provide the inventory compiler with the results of a peer review by a competent third party. From the outset of the project, this review should confirm that: Geological and numerical models are representative, Reservoir simulator is suitable, Modeling is realistic, Monitoring plan is suitable - As soon as they become available, site operator should compare results of monitoring program with predictive models. Adjust models, monitoring program and/or injection strategy appropriately. Site operator should inform inventory compiler of changes made.	2006 IPCC Guidelines

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Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Capture	CO2	Process & Combustion	N/A	Project/Facility	**Capture** • Dehydration units, Compressors, Unit Operations with <100% efficiency

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Capture	Methodologies for monitoring can be direct or indirect and include estimation, modelling, measurements and/or calculation approaches" **Capture** o Metered fuel or electricity consumption rates o Metered gas flow rates o Carbon balance of large stationary sources (establishes baseline emissions) • Monitoring methods cannot be pre-defined for the life span of the project, and are best developed for specific applications by operators (p. 32)	Voluntary [individual facilities are not required to report data]	Monitoring (see points of monitoring)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Capture	• Provide sufficient transparency to enable the intended audience to make an informed decision on the credibility of the emission reduction;" • Provide a plausible and transparent account of the project, decisions, and assumptions • Maintain supporting documentation • Reporting prior to starting geological storage o Methods and results of the site characterization o Methods and results of modeling o Description of proposed monitoring o Year in which CO2 storage began or will begin o Proposed sources of CO2 (Including infrastructure involved in CCS chain between source and reservoir) • Annual Reporting o Mass of CO2 injected during reporting year o Mass of CO2 stored during reporting year and cumulative mass of CO2 stored at site o Source of CO2 and infrastructure involved in CCS chain between source and storage reservoir o Rationale, methodology, monitoring frequency and results of monitoring o Additional modeling or adjustments to the modeling based on monitoring data o Emission of CO2 and any other GHGs from storage sites o Results of third party verification	• Verification should "focus on quality assurance with the objective of improving the overall reliability of the reported emission reduction" (p. 34) • Assessment that project is not materially misrepresented • Evaluating implementation of approved monitoring methodology against reported project and baseline emissions • Determine whether data in report contain any omissions, misrepresentation, or errors that would lead to a misstatement of the reported information • Inclusion and correct quantification of emission associated with capture and transport activities • Integrity of the geological reservoir for long term storage • Amount of CO2 that is stored underground • Amount of CO2, if any, that is leaking back into the atmosphere • "According to the WRI/WBCSD Protocol for project accounting, modeling is an acceptable means of modeling and verifying GHG emissions reductions, as long as any uncertainties or assumptions in the modeling are transparent" (p. 34)	IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Transport	CO2	Process & Combustion	N/A	Project/Facility	**Transport** • Pressurized Equipment leaks, Equipment maintenance, Emergency releases, Intermediate Storage facilities, Loading/offloading, Compressor fuel consumption, Mobile source fuel consumption, Purchased electricity (for Compressor booster stations, Pump stations, and Cooling of CO2 for cryogenic ship transport)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Transport	Methodologies for monitoring can be direct or indirect and include estimation, modelling, measurements and/or calculation approaches" **Transport** o Current available technologies for monitoring volume of gas transported - Losses can be estimated from API Compendium procedures o Losses can be quantified from maintenance, operational or emergency releases • Monitoring methods cannot be pre-defined for the life span of the project, and are best developed for specific applications by operators (p. 32)	Voluntary [individual facilities are not required to report data]	Monitoring (see points of monitoring)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Transport	• Provide sufficient transparency to enable the intended audience to make an informed decision on the credibility of the emission reduction;" • Provide a plausible and transparent account of the project, decisions, and assumptions • Maintain supporting documentation • Reporting prior to starting geological storage o Methods and results of the site characterization o Methods and results of modeling o Description of proposed monitoring o Year in which CO2 storage began or will begin o Proposed sources of CO2 (Including infrastructure involved in CCS chain between source and reservoir) • Annual Reporting o Mass of CO2 injected during reporting year o Mass of CO2 stored during reporting year and cumulative mass of CO2 stored at site o Source of CO2 and infrastructure involved in CCS chain between source and storage reservoir o Rationale, methodology, monitoring frequency and results of monitoring o Additional modeling or adjustments to the modeling based on monitoring data o Emission of CO2 and any other GHGs from storage sites o Results of third party verification	• Verification should "focus on quality assurance with the objective of improving the overall reliability of the reported emission reduction" (p. 34) • Assessment that project is not materially misrepresented • Evaluating implementation of approved monitoring methodology against reported project and baseline emissions • Determine whether data in report contain any omissions, misrepresentation, or errors that would lead to a misstatement of the reported information • Inclusion and correct quantification of emission associated with capture and transport activities • Integrity of the geological reservoir for long term storage • Amount of CO2 that is stored underground • Amount of CO2, if any, that is leaking back into the atmosphere • "According to the WRI/WBCSD Protocol for project accounting, modeling is an acceptable means of modeling and verifying GHG emissions reductions, as long as any uncertainties or assumptions in the modeling are transparent" (p. 34)	IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Injection	CO2	Process & Combustion	N/A	Project/Facility	**Injection** • Distribution manifold, Distribution pipelines to wells, Injection wells, Compression equipment, Measurement and control systems, Monitoring and maintenance of storage reservoir

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Injection	Methodologies for monitoring can be direct or indirect and include estimation, modelling, measurements and/or calculation approaches" **Injection** o Need detailed understanding of naturally occurring or anthropogenic CO2 emissions sources already at site o Pre-operational evaluation should also include assessment of existing and abandoned wells in area, for potential leakage o Monitoring physical properties of well (such as wellhead pressures, formation pressures and temperatures) • Monitoring methods cannot be pre-defined for the life span of the project, and are best developed for specific applications by operators (p. 32)	Voluntary [individual facilities are not required to report data]	Monitoring (see points of monitoring)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family	Carbon Injection	• Provide sufficient transparency to enable the intended audience to make an informed decision on the credibility of the emission reduction;" • Provide a plausible and transparent account of the project, decisions, and assumptions • Maintain supporting documentation • Reporting prior to starting geological storage o Methods and results of the site characterization o Methods and results of modeling o Description of proposed monitoring o Year in which CO2 storage began or will begin o Proposed sources of CO2 (Including infrastructure involved in CCS chain between source and reservoir) • Annual Reporting o Mass of CO2 injected during reporting year o Mass of CO2 stored during reporting year and cumulative mass of CO2 stored at site o Source of CO2 and infrastructure involved in CCS chain between source and storage reservoir o Rationale, methodology, monitoring frequency and results of monitoring o Additional modeling or adjustments to the modeling based on monitoring data o Emission of CO2 and any other GHGs from storage sites o Results of third party verification	• Verification should "focus on quality assurance with the objective of improving the overall reliability of the reported emission reduction" (p. 34) • Assessment that project is not materially misrepresented • Evaluating implementation of approved monitoring methodology against reported project and baseline emissions • Determine whether data in report contain any omissions, misrepresentation, or errors that would lead to a misstatement of the reported information • Inclusion and correct quantification of emission associated with capture and transport activities • Integrity of the geological reservoir for long term storage • Amount of CO2 that is stored underground • Amount of CO2, if any, that is leaking back into the atmosphere • "According to the WRI/WBCSD Protocol for project accounting, modeling is an acceptable means of modeling and verifying GHG emissions reductions, as long as any uncertainties or assumptions in the modeling are transparent" (p. 34)	IPIECA Oil and Natural Gas Industry Guidelines for Greenhouse Gas Reductions Projects: Part II: Carbon Capture and Geological Storage Emission Reduction Family

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
CDM - Executive Board, 2004 Clean Development Mechanism, Proposed New Methodology: Monitoring (CDM-NMM)	Carbon Capture, Injection, and Storage	CO2	Process & Combustion	N/A	Project	CO2 will be measured at the following points: A) CO2 measured (metered) at a point soon after the stack B) CO2 measured (metered) after the compression and dehydration process C) CO2 measured (metered) at the injection well D) CO2 measured (metered) after separation from oil E) The final amount of recycled CO2 measured (metered) before reintroduction to the main CO2 injection line GHG monitoring from energy used in project • Where fossil fuel is used, monitor a) Amount and type of fossil fuels used, b) CO2 emission coefficient of fossil fuel (COEF) • Where grid electricity (GE) is used, monitor a) GE used , b) All items specified in ACM0002, to calculate combined margin (CM) • Where electricity is supplied by a single, identifiable plant (SPE), monitor: a) Electricity used from plant, b) Data required to calculate the CEF of the plant • Monitor flaring (F)/venting (V) of CH4 in waste gas (WG) collected from separator and CO2 recycle plant • Monitor emissions factor in regards to CH4 escaping from pipelines

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
CDM - Executive Board, 2004 Clean Development Mechanism, Proposed New Methodology: Monitoring (CDM-NMM)	Carbon Capture, Injection, and Storage	Step 1 – Determine CO2 loss that occurred between monitoring points A and B (see monitoring points) Step 2 – Determine CO2 loss that occurred between monitoring points B and C Step 3 – Determine the amount of CO2 at point D which is recycled (metered) Step 4 – Determine CO2 loss that occurred between monitoring points D and E Step 5 – Determine total project emissions due to CO2 loss (sum of steps 1-4) The amount of CO2 at each monitoring point is determined as follows: Amount of CO2 at monitoring point (t CO2/yr) = Amount of gas measured (m^3 gas/yr) x Fraction of CO2 in gas (m^3 CO2/m^3 gas) x Density of CO2 in gas (t CO2/m^3 CO2) For the purpose of PDD production, the following formula is to be used to provide an estimate for project emissions due to CO2 loss: Predicted total amount of loss = CO2 emissions from the source X the sum of: Portion of time project is not operating, percentage loss during CO2 capture, percentage CO2 loss due to venting/flaring and other processes CO2 estimates from energy consumed should be determined by IPCC methodology Plan to use pipeline emission factor from IPCC and length of pipeline to estimate emissions from transport.	Mandatory [but only for facilities voluntarily participating in the CDM]	Emissions estimated by monitoring (see monitoring points and methods)

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Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
CDM - Executive Board, 2004 Clean Development Mechanism, Proposed New Methodology: Monitoring (CDM-NMM)	Carbon Capture, Injection, and Storage	All data should be archived electronically	• Use receipts to insure accuracy • Double check carbon contents against IPCC defaults • Flow meters should be subject to a regular maintenance and testing regime to ensure efficiency • The gas analyzers should be subject to a regular maintenance and testing regime to ensure efficiency • In the case of onshore CCS projects, abnormal death of surface vegetation could indicate significant release of CO2	CDM - Executive Board, 2004 Clean Development Mechanism, Proposed New Methodology: Monitoring (CDM-NMM)

Review of Existing Programs Relevant to Carbon Capture, Transport, Injection, and Storage

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring
Greenhouse Gas Emission Reduction Protocol for the Monell and Salt Creek Enhanced Oil Recovery (EOR) Project, Battelle, 2004	Carbon Capture, Injection, and Storage	CO2 and CH4	Process & Combustion	N/A	Project	Specific points of monitoring are not discussed in this document.

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Reporting Program/Guidance	Source Category (or Fuel)	Monitoring Methods and/or GHG Calculation Methods (What is monitored including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data Used to Calculate Emissions (e.g., production, capacity, waste-in-place) (Source of Data)
Greenhouse Gas Emission Reduction Protocol for the Monell and Salt Creek Enhanced Oil Recovery (EOR) Project, Battelle, 2004	Carbon Capture, Injection, and Storage	The Salt Creek Project is estimating fugitive emissions from surface equipment: Additional sources of GHG emissions that will result at the oil field from the implementation of the EOR project include losses of the CO2 in the injection system. These include fugitive emissions from the compressors and piping system as well as emissions that result from process upsets. The latter source of emissions will occur when venting of the injection system occurs as a result of over-pressure in the piping, for example, or when unplanned shutdowns of the vapor recovery units result in gas being vented or flared. See Notes page for more detailed discussion on methods.	Voluntary	EFc = applicable emission factor for component MF = mass fraction CO2 or CH4 in the stream Nc = number of components in the stream

Reporting Program/Guidance	Source Category (or Fuel)	Reports to Program	Quality Assurance/Quality Control Procedures	Source
Greenhouse Gas Emission Reduction Protocol for the Monell and Salt Creek Enhanced Oil Recovery (EOR) Project, Battelle, 2004	Carbon Capture, Injection, and Storage	Reporting of emissions reduction (Protocol Section 5.0) The protocol states that GHG emission reductions from the EOR process should be quantified and reported regularly. The protocol states that quarterly reporting is sufficient and provides examples of reporting forms (Figures 4 and 5)	QA/QC (Protocol Section 6.0) This section emphasizes that the intent is the protocol is to provide a conservative lower bound estimate of the actual CO2 emissions reduction, rather than the best estimate of the actual emissions reduction, which would have greater uncertainty. The most important data source is the meter that measures the quantity of CO2 that enters the injection system at the Salt Creek PRS. The quality of the emission reductions calculated with this protocol is assured in two principal ways: 1. Where emissions are based on measured values, accurate metering and cross checks will be used to ensure that the data are accurate. 2. Where metering is not conducted or is not practicable, activity data are estimated in such a way that baseline emissions will be understated and project emissions overstated, leading to an understatement of the emission reductions. The most important source of metered data is the quantity of CO2 received at the Salt Creek PRS, as this is used to determine the baseline emissions. The quality of the data collected by this meter will be ensured in several ways: • The meter output will be continuously checked with the meter at the Baroil custody transfer station 11 miles south of Jeffrey City, Wyoming to ensure that the pipeline is working properly • The meter will be as accurate as a custody transfer meter, and will be regularly calibrated • The quantity of gas injected will be measured at the injection wells, allowing a rough check of the amount injected to be made after the quantity of recycled gas is subtracted.	Greenhouse Gas Emission Reduction Protocol for the Monell and Salt Creek Enhanced Oil Recovery (EOR) Project, Battelle, 2004

Carbon Capture and Sequestration Notes

The Salt Creek Project is estimating fugitive emissions from surface equipment:
Additional sources of GHG emissions that will result at the oil field from the implementation of the EOR project include losses of the CO_2 in the injection system. These include fugitive emissions from the compressors and piping system as well as emissions that result from process upsets. The latter source of emissions will occur when venting of the injection system occurs as a result of over-pressure in the piping, for example, or when unplanned shutdowns of the vapor recovery units result in gas being vented or flared.

Fugitive Emissions from pipelines (Protocol Section 4.2.2)
According to the Salt Creek Protocol, fugitive emissions from pipelines are estimated using gas flow metering equipment at each end of the pipeline. Note that the gas captured from the Shute Creek plant contains some CH_4 as well as the CO_2.

The quantity of CO_2 acquired will be measured with a high-accuracy meter located at the pressure reducing station (PRS) at the entrance of the pipeline to the Salt Creek field. Regular sampling will be done to determine the purity of the CO_2 and the CH_4 content. Since any pipeline losses that may occur between the gas plant and the field would have occurred as vented emissions in the absence of the project, the measurement of the CO_2 stream entering the field provides a reliable means for quantifying that part of the baseline associated with the gas plant emissions.

Fugitive Emissions from surface equipment (Protocol Section 4.2.3, Table 1: Fugitive Emission Factors for Gas Service)
According to the Salt Creek Protocol, the emissions from surface equipment are estimated using emission factors for oil and gas systems (this is roughly the same procedure that the IPCC used to estimate the CO_2 emission factor for CO_2 pipelines in the 2006 IPCC Greenhouse Gas Inventory Guidelines for CCS):

Fugitive emissions result from equipment leaks from valves, flanges, compressor seals, etc. The estimated fugitive emissions will be based on the actual number of particular components at the facility. Emission factors for fugitive CO_2 emissions have not been developed; therefore, emission estimation methods for equipment leaks of organic compounds in gas service for an oil and gas production facility will be used for estimating CO_2 and CH_4 emissions. Oil and gas production equipment-specific emission factors are based on total organic compound (TOC) emissions and the assumption that the all of the emissions are TOC.

Therefore, when estimating fugitive CO_2 and CH_4 emissions, the emission factor must be multiplied by mass fraction of CO_2 or CH_4 in the stream. Since the composition of both the purchased CO_2 and the recycled gas stream will be monitored, the mass fractions should be readily available. Because it may be difficult to separate the component counts for the purchased CO_2 and the recycled gas, in applying this protocol, the composition of the recycled gas may be used for all streams. Since the recycled gas will also contain CH_4, which has a much greater global warming potential than CO_2, this will result in a conservative (high) estimate of fugitive GHG emissions.

The following equation is used in the calculation of fugitive emissions from pipeline components:

$Ec = EFc \times MF \times Nc$
where:
Ec = mass emissions of CO_2 or CH_4 from component
EFc = applicable emission factor for component
MF = mass fraction CO_2 or CH_4 in the stream
Nc = number of components in the stream

Refer to Table 1 for emissions factors for valves, connectors, pump seals, and flanges used in making this calculation. The emissions factors are from U.S. EPA (1995) for TOC emissions from components in gas service at oil and gas production.

Residual CO_2 content of finished oil and produced water (Protocol Section 4.2.6)

A small amount of CO_2 may remain dissolved in the oil as it leaves the oil tanks and is pumped into the pipeline. To the extent that the CO_2 concentration in the oil is greater than that normally present in oil (oil produced without CO_2 EOR), the dissolved CO_2 represents incremental emissions of CO_2. At the start of the EOR project, Howell Petroleum plans to sample the CO_2 content of the finished oil to determine the quantity of CO_2 that it contains. Periodic (e.g., quarterly sampling of the content will continue until the level stabilizes, at which point the content will be sampled annually.

Protocol section 4.2.7 includes calculations for estimating CO_2 emissions from non-routine events (e.g., emergency flares.)
See “Table 2 Excerpt” file for data elements identified in the Salt Creek Protocol for emissions from surface equipment, finished oil and produced water, and non-routine events.

Carbon Capture and Sequestration Notes (continued)

Table 1:

Component Type	Total Emissions (kg/hr-component)
Valves	4.50E-03
Connectors	2.00E-04
Flanges	3.90E-04
Pump Seals	2.40E-03
Others	8.80E-03

Source: U.S. EPA (1995) for TOC emissions from components in gas service at oil and gas production facilities.

Table 2 Excerpt:

Emission Source	Activity Data Needed	Data Source
1. Baseline Emissions of Gas at Shute Creek	a. Quantity of gas received at Monell b. Gas composition	a. Meter or meters at entrance to Monell field b. Periodic gas analysis
2. Indirect Emissions from CO2 Compression at Shute Creek Gas Plant	Quantity of CO2 compressed for Monell EOR	Custody transfer meter
3. Fugitive CO2 and CH4 Emissions from Monell EOR Operations	a. Component counts b. Gas composition	a. Field inspection or from as-built engineering drawings b. Analyses of purchased and recycled gas, or assume purchased gas is 100% CO2
4. Direct Emissions from EOR Field Fuel Combustion	Quantity of natural gas consumed	Monell field gas meter or bills
5. Indirect Emissions from EOR Field Electricity Consumption	Total electricity consumption for EOR operation	Monell field electricity meter or bills
6. Emissions of CO2 contained in the sales gas	a. Quantity of gas produced at Monell b. Gas composition	a. Volumes sold to gas plant as measured by custody transfer meter b. Regular gas analyses for CO2
7. Emissions from CO2 remaining in the crude oil	Crude oil produced	a. CO2 concentration in the oil b. Quantity of oil produced for sale as measured by the LACT units
8. Non-routine releases to flare	a. Fas flow rate to flare b. Gas composition c. Flare ignition	a. Engineering estimates b. Operating records c. Recorded observations
9. Non-routine releases to the atmosphere	a. Maximum volume b. CO2 fraction c. CH4 fraction	a. Estimated from design data b & c. Historical stream composition data

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Mandatory Direct Downstream Reporting												
Washington Law to Develop Reporting Program	Mobile	All 6 gases (not specified for mobile)	Combustion, possibly fugitive	>2,500 metric tons CO2e for highway fleets; >10,000 metric tons CO2e for other mobile sources	Fleet	TBD	TBD	Mandatory	TBD	TBD		http://apps.leg.wa.gov/documents/billdocs/2007-08/Pdf/Bills/House%20Passed%20Legislature/2815-S2.PL.pdf
Wisconsin Reporting Law	Mobile	CO2	Combustion	>100,000 tons CO2	Facility			Mandatory				http://www.pewclimate.org/what_s_being_done/in_the_states/state_legislation.cfm#reg
Connecticut Reporting Law	Mobile	All 6 gases (not specified for mobile)	Combustion, possibly fugitive	>10,000 metric tons CO2e	Entity and Facility			Mandatory				http://www.pewclimate.org/docUploads/CT-SB595%20climateactionplan%202004.pdf
Australian National Greenhouse and Energy Reporting Law/Proposal	Mobile	CO2, CH4, N2O	Combustion	Corporations >125,000 metric tons CO2e or with operational control of a facility >25,000 metric tons CO2e [Must report each facility >3000 metric tons CO2e)]. Will ratchet down corporate threshold to >50,000 metric tons CO2e by FY11.	Corporate- and facility-level. Entities report entire fleet as a facility and fuel purchased in each state as a sub-facility if transportation is their principle industry activity; entities report the fleet associated with a stationary facility if transportation is their secondary/ancillary activity). Operational control.			Mandatory				www.greenhouse.gov.au/reporting/index.html

Reporting Program/Guidance	Source Category (or Fuel)	Coverage (Gases or Fuels)	Coverage (Emissions Types)	Coverage (Threshold)	Level of Reporting (e.g., facility, unit)	Points of Monitoring	Monitoring Methods and/or GHG Calculation Methods (What is monitoried including frequency and equipment; equations and emission factors used to calculate GHG emissions)	Purpose of Method (e.g., mandatory reporting, voluntary reporting, etc)	Input Data used to calculate emissions (e.g., production, capacity, waste-in-place) (Source of Data)	Reports to Program	Quality Assurance/ Quality Control Procedures	Source
Voluntary Direct Downstream Reporting												
Climate Registry, CCAR	Mobile	CO2, CH4, N20, HFCs	Combustion, Fugitive	sources >3% of entity emissions	Facility		Climate Registry Protocol	Voluntary or Mandatory			3rd party verification	
Climate Leaders (Core Module - Direct Emissions from Mobile Combustion)	Mobile	CO2, CH4, N20, HFCs	Combustion, Fugitive	All (no deminimis)	Corporate		EPA Protocol, based on GHG Protocol	Voluntary	Fuel consumption, miles traveled, and EPA default emissions factors.	Base year and annual GHG emissions (CO2 equivalents). Inventory management plan documenting GHG estimation approaches, factors, and data sources that will be used.	EPA Climate Leaders review of inventory management plan and annual summary reports	http://www.epa.gov/climateleaders/resources/sector-specific.html
SmartWay	Mobile (HD Trucks, Rail)	CO2	Combustion	All (no deminimis)	Corporate/Fleet		EPA Protocol; SmartWay FLEET Model	Voluntary	Truck and rail companies report consumption by fuel type; distance traveled; tons carried; idle hours; and technologies and strategies employed. Truck companies also report configuration and model year of trucks. SmartWay model calculates CO2 emissions based on default emissions factors.	Baseline year and annual updates.	EPA SmartWay review of FLEET model submissions. [rail model is in development; company submissions to date have been via email and excel]	www.epa.gov/smartway/smartway_fleets_software.htm