GREENHOUSE GAS (GHG) INVENTORY METHODS

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What are Greenhouse Gases?

- Gases that allow sunlight to enter the atmosphere freely. When sunlight strikes the Earth's surface, some of it is re-radiated back towards space as infrared radiation (heat). Greenhouse gases absorb this infrared radiation and trap its heat in the atmosphere.
- If it were not for naturally occurring greenhouse gases, the Earth would be too cold to support life as we know it.

Greenhouse Gases of Concern

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Industrial Gases:
  - Hydrofluorocarbons (HFCs)
  - Perfluorocarbons (PFCs)
  - Sulfur hexafluoride (SF_6)

Sources of Greenhouse Gases

- United States GHG Inventory
  - 81% - carbon dioxide from combustion of petroleum, coal, and natural gas
  - 10% - methane from landfills, coal mines, oil and natural gas operations, and agriculture
  - 5% - nitrous oxide from use of nitrogen fertilizers, burning fossil fuels, and certain industrial and waste management processes
  - 2% - hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) released as byproducts of industrial processes and through leakage

Source: U.S. Energy Information Administration

WHY GHG Inventory?

- New EPA regulations requires reporting by certain entities
- Some states require reporting by certain entities
- Voluntary reduction of GHG emissions
- Business advantage or corporate policy

GHG Inventory – the Process

- Simple Concept; Complex Execution
  1. Decide which Standard or Protocol to follow
  2. Set Boundaries
  3. Collect Data
  4. Perform Calculations
  5. Report Results

1. Standards and Protocols

- GHG Protocol (WRI/WBCSD)
  - Corporate Accounting and Reporting Standard
  - Project Protocol
  - Product Life Cycle Accounting and Reporting Standard (draft)
  - Scope 3 Accounting and Reporting Standards (draft)
- ISO 14064 (three standards)
  - Organizational
  - Projects
  - Validation and Verification
- EPA Climate Leaders Greenhouse Gas (GHG) Inventory Guidance
- IPCC National Greenhouse Gas Inventories Programme
- Climate Registry Reporting Protocols

1. Standards and Protocols

KSU GHG Inventory

- American College & University Presidents Climate Commitment (ACUPCC) Reporting Instructions
  - GHG Protocol Corporate Accounting and Reporting Standard
  - Climate Registry Reporting Protocols

2. Set Boundaries

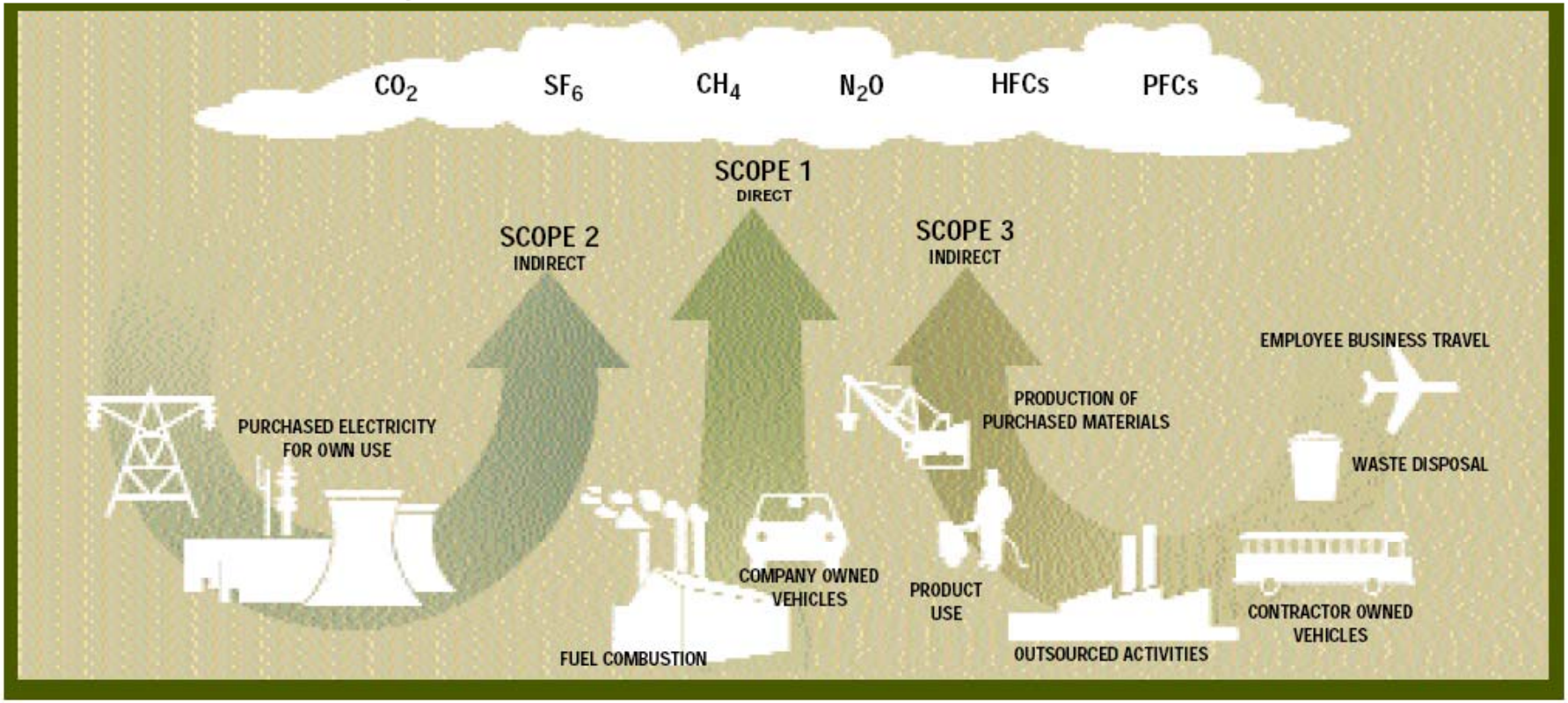
- Organizational Boundaries
  - Choose a consolidation methodology to account for partial ownership, operating licenses, leases, joint ventures, partnerships
    - Equity Share Approach
      - Account for GHG emissions according to share of economic interest
    - Operational Control Approach
      - Account for GHG emissions for operations under operational control
    - Financial Control Approach
      - Account for GHG emissions for operations under financial control

2. Set Boundaries

- Operational Boundaries
  - Scope 1: Direct GHG emissions
    - Emissions from combustion in owned or controlled boilers, furnaces, vehicles, etc.
    - Emissions from chemical production in owned or controlled process equipment (example: lime from calcium carbonate)
  - Scope 2: Indirect GHG emissions from purchased electricity (also, purchased steam or heat, such as from heated water)
  - Scope 3: Other indirect GHG emissions
    - Travel, commuting, suppliers operations, customers activities

2. Set Boundaries

FIGURE 3. Overview of scopes and emissions across a value chain

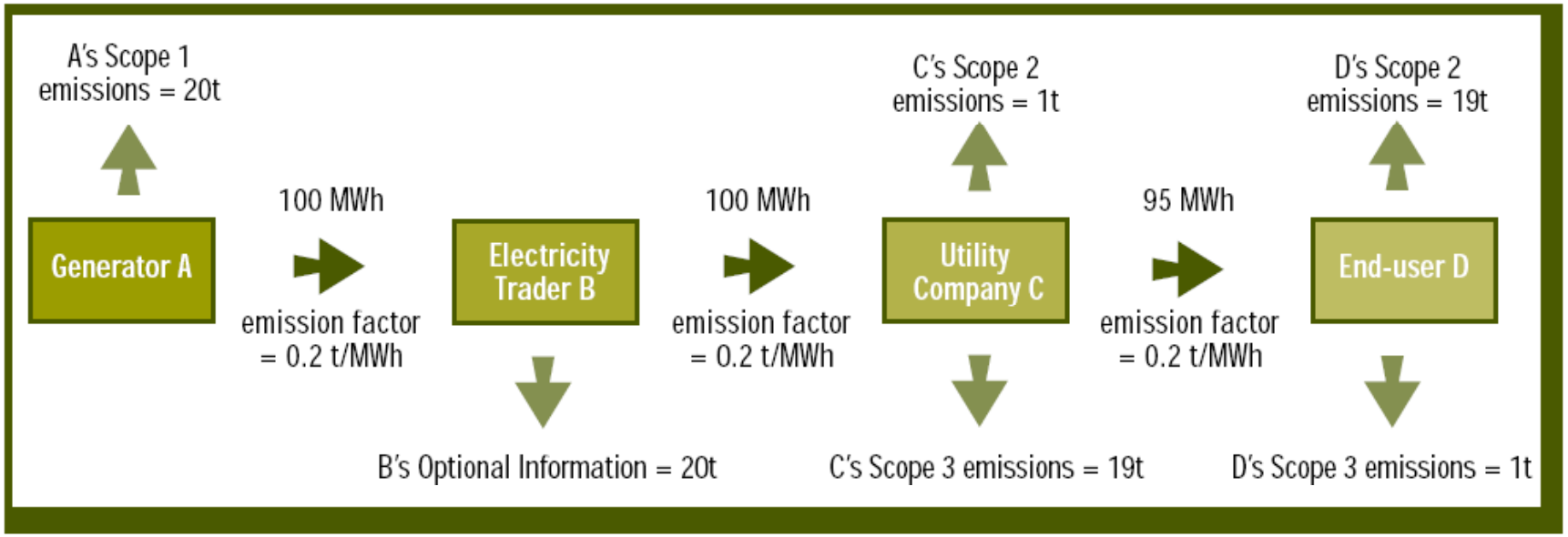


Source: The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (revised edition)

Why Scopes 1, 2, 3?

- Prevents double counting when adding GHG emissions from different inventories
  - Example: Electricity sales and purchases

FIGURE 4. GHG accounting from the sale and purchase of electricity



Source: The Greenhouse Gas Protocol: A Corporate Accounting and Reporting Standard (revised edition)

2. Set Boundaries

- Temporal Boundaries
  - 12-month period is standard practice
    - Fiscal year is acceptable
    - Calendar year is required by Climate Registry

3. Collect Data

Scope 1 Sources

- Stationary combustion
  - Boilers, furnaces, heaters, burners, flares, etc.
    - Fuel purchase records - natural gas, fuel oil, coal
- Mobile combustion
  - Trucks, buses, cars, airplanes, boats, ships, barges, etc.
    - Fuel purchase records or annual vehicle mileage and type of fuel
- Process emissions
  - Catalytic cracking of petroleum, calcination step in cement manufacture, etc.
    - Measured or calculated annual emissions; Requires knowledge of process
- Fugitive emissions
  - Equipment leaks, coal piles, onsite wastewater treatment, onsite landfills, etc.
    - Typically estimated based on knowledge of the source of emissions

3. Collect Data

Scope 2 Sources

- Purchased electricity, steam, heating, cooling
  - Utility bills

Scope 3 Sources

- Air travel
- Employee commuting
- Solid waste (incineration or decomposition offsite)
- Emissions from upstream or downstream of owned or controlled operations (purchased raw materials; use of products sold)

4. Calculations

- Goal – calculate total GHG emissions in units of carbon dioxide-equivalents (CO_2-e) for the processes and activities within the chosen boundaries
  - CO_2-e is the measure of the global warming potential (GWP) of a gas compared to carbon dioxide. For example, methane has a GWP of 21. The CO_2-e measure for 1 kilogram of methane is 21 kg CO_2-e.

4. Calculations

- Choose a Calculation Tool
  - Clean Air-Cool Planet Campus Carbon Calculator
  - GHG Protocol Initiative Sector Tool Set
  - EPA Climate Leaders Tools for Developing an Inventory and Tracking and Reporting Emissions
  - Proprietary Databases and Models

4. Calculations

- Direct measure of GHG emissions by concentration and flow rate (most accurate; most uncommon)
- Mass balance or stoichiometric basis specific to the facility or process (more common)
- Application of documented emission coefficients (most common)
  - Fuel use is multiplied by published emission factors such as the EPA AP-42 emission factors
    - Example: 100 lbs coal x 2.86 lbs CO_2 per lb coal burned = 286 lbs CO_2

4. Calculations

- Choose a Source of Emission Coefficients
  - Emission coefficients are used to calculate the amount of GHG gases produced
    - Fuel combustion x emission coefficient = quantity of GHG emitted
    - Industrial processes and fugitive emissions;
      activity level x emission coefficient = quantity of GHG emitted

4. Calculations

- Sources for emissions coefficients
  - Clean Air-Cool Planet Campus Carbon Calculator contains emission coefficients
  - The Greenhouse Gas Protocol Initiative Calculation Tools (http://www.ghgprotocol.org/)
  - EPA AP-42 emission factors (http://www.epa.gov/ttn/chief/ap42/)
  - Department of Energy – Energy Information Administration (http://www.eia.doe.gov/)

4. Calculations

- Convert all GHG emissions to the units of CO_2-e and sum for a final total
  - Results are typically reported in metric units (required by UNFCCC and Kyoto Protocol)

4. Calculations

- IPCC Global Warming Potentials (GWPs)
  - The ratio of radiative forcing (degree of warming the atmosphere) for one unit of a specific GHG compared to one unit of carbon dioxide (CO_2).
  - Three choices
    - SAR – IPCC Second Assessment Report
      - Required by United Nations Framework Convention on Climate Change (UNFCCC) and Kyoto Protocol
    - TAR – IPCC Third Assessment Report
      - Already incorporated into the CA-CP calculator
    - FAR – IPCC Fourth Assessment Report
      - Most recent estimates

4. Calculations - GWP

- Global Warming Potential (GWP)
  - 1 gram Carbon dioxide (CO_2)= 1 g CO_2-equivalents
  - 1 gram methane (CH_4) = 21 g CO2-equiv
  - 1 gram nitrous oxide (N_2O) = 310 g CO_2-equiv
  - 1 gram sulfur hexafluoride (SF_6) = 23,900 g CO_2-equiv

100-year values from IPCC SAR 1996 report. Updated twice, but many still using these numbers. Important to know which report is used when comparing products.

4. Calculations

- Example

Emission Factors

		CO2	CH4	N2O
Fuel	100 gal	20 lb/gal	3 lb/gal	0.1 lb/gal

Pounds of Emissions

		CO2	CH4	N2O
Fuel	100 gal	2000	300	10
GWP factor		**1**	**21**	**310**

CO2 Equivalents

		CO2	CH4	N2O
Fuel	100 gal	2000	6300	3100

Total CO2-equiv	**11400**	pounds
	5.2	metric tonnes

5. Report Results

- Corporate results
  - Companies may need to gather and summarize data from multiple facilities, possibly in different countries and business divisions

Facility-level Reporting

- Document annual GHG emissions
  - Process energy
    - Fuels used at facility – natural gas, fuel oil, etc.
    - Electricity - Source of electricity (emissions from fuels used)
  - Transportation energy
    - Vehicles used onsite
    - Transportation of raw materials to facility (optional)
    - Transportation of products from facility (optional)
    - Business travel (optional)
    - Employee commuting (optional)
  - Direct process emissions
    - For example, a facility that manufactures lime from limestone

5. Report Contents

- What might be included:
  - A brief description of the emission sources
  - A list and justification of specific exclusion or inclusion of sources
  - Comparative information from previous years
  - The reporting period covered
  - Any trends evident in the data
  - Progress towards any business targets
  - A discussion of uncertainties
  - A description of events and changes that have an impact on reported data

5. A University Report

- ACUPCC Reporting System
  - Start date of 12-month period covered
  - Consolidation methodology choice
    - Explain any facilities omitted
  - Emissions calculation tool used
  - Version of IPCC GWPs used
  - Who conducted the emissions inventory
  - Process of conducting the inventory
  - Describe any emissions sources classified as de minimis
  - Describe data limitations
  - Report Scope 1 GHG emissions by stationary combustion, mobile combustion, process, fugitive,

5. A University Report

- ACUPCC Reporting System
  - Report Scope 2 GHG emissions by purchased electricity, heat, cooling, and/or steam
  - Report Scope 3 GHG emissions for regular commuting of students and employees, air travel paid for by university, GHG emissions due to incineration or decomposition of solid waste, GHG emissions from up to 3 additional custom sources

5. A University Report

- ACUPCC Reporting System
  - Biogenic emissions: Total CO_2 emissions from the combustion of biomass and biomass-based fuels (wood, biodiesel, ethanol, landfill gas, etc.)
    - From stationary combustion
    - From mobile combustion

5. A University Report

- ACUPCC Reporting System
  - Mitigation Data
    - Carbon offsets
    - Renewable Energy Certificates (RECs)
    - Sequestration and carbon storage
      - Land use
      - Composting
- Contextual data
  - Number of students, employees, building space, etc.

Summary

- GHG inventory is a beginning step for reducing GHG emissions
- Concern about climate change is driving business decisions
  - In the United States, it seems to be mostly a consumer/stakeholder/stockholder initiative
- There is not one standard protocol
- Uncertainty exists
  - Emissions from fuel is typically not measured
  - Fuel emissions factors may vary depending on entity publishing standards or guidance
  - GWP factors from IPCC and other sources vary with time
  - Acquiring “green” electricity can be a major factor in inventory results

Questions?

GHG Inventory – Example

- Company A plans to perform a Corporate GHG inventory for all their facilities. They own 2 pulp/paper mills in the United States and lease forested land in Canada from which they supply their mills with wood.

GHG Inventory – the Process

- Simple Concept; Complex Execution
  1. Decide which Standard or Protocol to follow
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1. Standards and Protocols

Company A GHG Inventory

- GHG Protocol Corporate Accounting and Reporting Standard
  - Why?
    - Accepted internationally
    - Most commonly used in the industry
    - CEO recommendation

2. Set Boundaries

- Organizational Boundaries
  - Equity Share; Operational Control; Financial Control
- Operational Boundaries
  - Required: Scope 1 and Scope 2
  - Optional: Scope 3
- Temporal Boundaries
  - Required: “Base year”
    - Choose and report a base year for which verifiable emissions data are available and specify why this year was chosen

3. Collect Data

Scope 1 Sources

- Stationary combustion - Fuel purchase records
  - Natural gas – 14,000 MCF per year
  - Residual fuel oil – 2400 gallons per year
  - Coal – 50 short tons per year
- Mobile combustion - Fuel purchase records
  - Diesel – 2,000 gallons per year
    (company owns fleet that delivers logs to mill)
  - Gasoline – 300 gallons per year
  - LPG vehicles – 240 gallons per year
- Process emissions
  - Lime kiln – 20,000 lbs CO_2 per year
- Fugitive emissions
  - Onsite landfill – 2,000 lbs methane per year

3. Collect Data

Scope 2 Sources

- Purchased electricity, steam, heating, cooling
  - Electricity meters for pulp/paper mill
    - #1 - 2,100,000 kwh
    - #2 - 340,000 kwh
    - #3 - 5,780,000 kwh
    - #4 - 45,000 kwh
    - #5 - 17,800 kwh

4. Calculations

Stationary Sources

Fuel Type	Equipment ID/description	Quantity	Units	HHV (BTU/unit)	(CO2)	Units	CO2 (kg)
Coal[2]			lb				
Anthracite			lb	15,000	103.62	kg CO_2 / MMBtu	0
Bituminous	boiler #1	100,000	lb	12,700	93.46	kg CO_2 / MMBtu	118,694
Sub-bituminous			lb	10,500	97.09	kg CO_2 / MMBtu	0
Lignite			lb	7,000	96.43	kg CO_2 / MMBtu	0
Natural Gas	heating units	1,400,000	cuft	1,028	53.06	kg CO_2 / MMBtu	76,364
Petroleum Fuels[2]							
Middle Distillate Fuels (No. 1, No. 2, No. 4 fuel oil, diesel, home heating oil)			gal	138,700	73.15	kg CO_2 / MMBtu	0
Kerosene			gal	135,000	72.31	kg CO_2 / MMBtu	0
Heavy Fuel Oil (No. 5, 6 fuel oil), bunker fuel[1]	generator #1	2,400	gal	149,700	78.80	kg CO_2 / MMBtu	28,311
Ethane			gal	73,400	59.58	kg CO_2 / MMBtu	0
Propane			gal	91,300	63.10	kg CO_2 / MMBtu	0
							223,369

4. Calculations

Mobile Sources

Fuel Type	Equipment ID/description	Quantity	Units	HHV (BTU/unit)	(CO2)	Units	CO2 (kg)
Gasoline							
Conventional		300	gal	125,000	70.38	kg CO_2 / MMBtu	2,639
Reformulated			gal	122,600		kg CO_2 / MMBtu	0
Oxygenated			gal	122,600		kg CO_2 / MMBtu	0
Diesel		2000	gal	138,700	72.59	kg CO_2 / MMBtu	20,136
Jet Fuel (Jet A, JP-8)			gal	135,000	70.88	kg CO_2 / MMBtu	0
LPG		240	gal	91,300	62.33	kg CO_2 / MMBtu	1,366
							24,141

4. Calculations

Fugitive Emissions

					GWP (SAR) CO2-e			
					(CO2)	(CH4)	(N2O)	CO2-e (kg)
Fugitive Emission Source	**Units**	**(CO2)**	**(CH4)**	**(N2O)**	**1**	**21**	**310**	**Sum**
onsite landfill	lbs		2,000			19,048		**19,048**

4. Calculations

SCOPE 2 - PURCHASED ELECTRICITY								
		EGRID regional emission factors (lb/Mwh)			GWP (SAR)			
		SPNO-2005			(CO2)	(CH4)	(N2O)	CO2-e (kg)
Meter ID or other description of data source	kwh	(CO2)	(CH4)	(N2O)	1	21	310	Sum
1	2,100,000	1,960.94	0.02382	0.03209	1,867,562	476	9,474	1,877,512
2	340,000	1,960.94	0.02382	0.03209	302,367	77	1,534	303,978
3	5,780,000	1,960.94	0.02382	0.03209	5,140,242	1,311	26,077	5,167,630
4	45,000	1,960.94	0.02382	0.03209	40,019	10	203	40,232
5	17,800	1,960.94	0.02382	0.03209	15,830	4	80	15,914
								7,405,267

5. Report Results

- Explain study boundaries
- Summarize
  - Results for each mill
  - Results for wood harvesting (operational control)
- Transparency
  - Sources of emission coefficients
    - Stationary and mobile sources fuels – U.S. Energy Information Administration
    - Electricity – eGrid2007 version 1.1
  - Source of GWP – IPCC Second Assessment Report
  - Reliability of collected data (estimates or measured)