

Revised Extended Methodology for Estimating Big Sky Point-source CO₂ Emissions

Big Sky Carbon Sequestration Partnership
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1. Introduction

In partial fulfillment of our commitments made under Phase I of the Big Sky Regional Carbon Sequestration Partnership, the South Dakota School of Mines conducted greenhouse gas (GHG) emissions inventories and point source surveys of the three original Big Sky states (Montana, Idaho and South Dakota) during 2003-2004. In 2005 a similar inventory was performed by U. Wyoming, with assistance from SDSMT, for Wyoming. Of these four states, only Montana had previously initiated a GHG inventory (USEPA, 2003e). In the summer of 2007, the inventory of point source data for large emitters (>10,000 t CO₂/year) and the estimation methodologies were compiled, reviewed and updated by GIS staff at Montana State University's Big Sky Institute.

The final product may be regarded as a composite inventory, representing a range of years (between 1997 and 2006) rather than a single year. This is because the most recent available data were used for each emissions category, and data availability varies among these categories. The USEPA's Emissions Inventory Improvement Program (hereafter EIIP) guide to preparing state emission inventories (USEPA; 2003) provided the primary inventory methodology, with specific methodologies adopted from the EPA's U.S. Inventory of Greenhouse Gas Emissions and Sinks (USEPA, 2007b) and other divergences as noted.

2. Methods by Source Type

2.1 Power Generating Facilities

All emissions data on power generation facilities was obtained from the USEPA's eGRID (Emissions and Generation Resource Integrated Database) 2006 database, which includes 2004 data. The EPA reports GHG emissions at a variety of levels including, regional, state, facility, and individual unit level. The eGRID database contained 369 facility level records for our region of interest, 88 of which had significant annual CO₂ emissions. The remaining records were hydroelectric or wind generation facilities (USEPA, 2007).

Power Plant Locations

Plant geographic locations (decimal degrees) were derived directly from the eGRID EGRDPLNT file; the database was queried by state abbreviation to produce all records for states in our area of interest (ID, MT, ND, OR, SD, WA, WY). The original location data were derived for the eGRID 2006 database from EPA records, which note that when geographic coordinates were unavailable for a record, the geographic coordinates of the centroid of the county containing the facility were used as an approximation. To correct these locations and validate those for the entire dataset, coordinates were iteratively refined through visual comparison of reported locations against aerial imagery in Google Earth (<http://earth.google.com/>), following on a method assessed and recommended by Gumennik (2007).

Power Plant CO₂ Emissions

eGRID (USEPA 2007) is derived mostly from direct emissions monitoring (EPA, 2005b) but secondarily estimated from fuel consumption of each component (boiler, generator, etc.) and added to estimate the

plant emissions as a whole. This second method uses the Intergovernmental Panel on Climate Change (IPCC 2006) greenhouse gases (GHG) methodology using fuel consumption, a fuel-specific carbon coefficient, and the fuel-related fraction of carbon oxidized.

2.2 Petroleum Processing and Transmission

Montana and Wyoming are the two significant petroleum producing Big Sky states. There are 57 petroleum processing and transmission facilities in these two states as well as 24 surface coal mines (6 in Montana, 18 in Wyoming). Emissions data for these facilities were estimated using fuel use data obtained from the 1999 NEI database where available and the 1996 NAAQS database, which publishes this data where it is relevant to emissions of criteria air pollutants (CAPs; see 2.4 for more information)(USEPA, 2005; USEPA, 1998).

Facility Locations

Location data for petroleum processing and transmission facilities were obtained from the 1999 NEI database, then visually adjusted and validated using aerial imagery in Google Earth (per Gumennik 2007).

Petroleum Processing CO₂ Emissions

CO₂ Emissions from petroleum refineries and natural gas processing facilities were estimating using the sum of component fuel usage data from the 1999 NEI database in conjunction with standard emissions factors by fuel type as listed in the EIIP guide (Table 1)(USEPA, 2003). The fuel usage for each component (boilers, dryers, etc.) were used to calculate estimated emissions and these emissions were then added to produce a facility total.

Fuel Type	Heat content/scc	t CO ₂ /mmbtu	Fuel units (scc)	Carbon Coefficient
NG	1030	0.058	mmcf	0.995
gas	1030	0.058	mmcf	0.995
coal	0	0.106	ton	0.000
bitum coal	23.89	0.103	ton	0.990
subbit coal	17.14	0.106	ton	0.990
oil	138.0952381	0.082	kgal	0.990
distillate (diesel)	138.6904762	0.081	kgal	0.990
gasoline	125.0714286	0.078	kgal	0.990
LPG	95.5	0.069	kgal	0.990
residual oil	149.6904762	0.087	kgal	0.990

Table 1. Modified from USEPA, 2003.

Petroleum Storage and Transmission CO₂ Emissions

CO₂ emissions from oil and gas transmission are calculated in the same way as petroleum processing emissions; however, it is important to note that *emissions from natural gas compressor stations are only those resulting from the fossil fuel engines used to power the compressors, not the natural gas throughput, and that this applies as well to petroleum storage tanks.*

2.3 Primary CO₂ Producing Industrial Processes

2.3.1 Primary Aluminum Production

Primary Aluminum Facilities Locations

In 2005, 7 primary aluminum production facilities were in operation in the region of interest. Montana had 1, Oregon had 2, and Washington had 4 according to the USGS Directory of aluminum plants worldwide (Plunkert, 1998). Geocoded addresses for these facilities were visually compared against aerial imagery in Google Earth to verify geographic coordinates (decimal degrees) for primary production site, following on the aforementioned method recommended by Gumennik (2007).

Primary Aluminum Production

Primary aluminum is produced from smelting of bauxite ore. The alumina (Al_2O_3) is separated from the ore by the Bayer Process, and then pure aluminium is separated from this using an energy exhaustive reduction process which produces significant CO_2 emissions from the consumption of the anodes as a by-product of the process.

Primary Aluminum CO_2 Emissions

Facility-specific information regarding the smelting reduction process and supporting processes, as well as specific production data is generally unavailable to the public. In the absence of specific process data, the International Aluminum Institute recommends using a reduction technology specific emissions factor to estimate CO_2 emissions as a function of aluminium produced.

Reduction Technology	Emissions Factor (tons CO_2 per ton aluminium)	Uncertainty
Prebaked	1.6	+/- 10%
Søderberg	1.7	+/- 10%

Table 2. Modified from IAI, 2006.

Though annual proprietary aluminium production data is unavailable as well, facility-specific annual production capacity data is published in the USGS Minerals Yearbook 2005 (Plunkert 2006). According to the USGS (Bray, personal comm. 7/25/07), this capacity data is generally a sound estimate of annual production because most potlines operate at 100% annual capacity. This renders the equation for CO_2 emissions from primary aluminum production as:

$$E_{CO_2} = C * E_{p,s} \text{ where:}$$

E_{CO_2} = CO_2 emissions estimate in tons/yr.

C = Facility-specific annual capacity in tons aluminium

$E_{p,s}$ = Technology-specific emissions factor for Prebaked (E_p) or Søderberg (E_s) reduction process

According to the IAI protocol this allows an estimate of CO_2 emissions from primary aluminum production facilities within 10% error. While this method is not ideal for reporting emissions, it is recommended for the available data.

2.3.2 Soda Ash Production

Soda Ash Production Facility Locations

According to the USGS 2006 Directory of Lime Plants, there are 18 lime producing facilities in the area of interest, 4 in Idaho and Wyoming, 3 in Montana and North Dakota, 2 in Oregon, and 1 in South Dakota. 13 of these are sugar production facilities. The facility street addresses were determined from the USGS 2006 Directory of Lime Plants (Miller, 2007), then validated against Google Earth aerial imagery, per the best practices recommendations of Gumennik (2007), to generate geographic coordinates and verify their accuracy.

Lime facility emissions are produced by combustion and the lime production process. Lime (CaO) is produced from limestone (CaCO₃) by thermal decomposition in a kiln, which produces CO₂ in proportion to the amount of limestone consumed and lime produced. Some important exceptions include:

Hydrating facilities - Some lime facilities only produce hydrated lime, which produces no CO₂, all they do is add water to quicklime (CaO) to produce hydrated lime [Ca(OH)₂].

Sugar Production Plants - Beet sugar is processed by adding lime slurry (liquid calcium hydroxide), usually called milk of lime, to the sugar beet juice and bubbling CO₂ captured from the lime kiln through the solution. The milk of lime and CO₂ react forming calcium carbonate (CaCO₃), which precipitates out of solution taking impurities from the sugar with it. Thus a significant amount of the CO₂ (EPA estimates 80%) emitted from a sugarmill lime kiln is captured and reacted with the lime to form CaCO₃, so the net CO₂ emission is from the fuel burned to power the kiln plus calcination release minus CO₂ used in the refining process (Miller, MM., personal comm. 07/25/2007).

Lime Facility Combustion CO₂ Emissions

CO₂ Emissions from lime facilities were estimating using the sum of component fuel usage data from the 1999 NEI database in conjunction with standard emissions factors by fuel type as listed in the EIIP guide (Table 1) (USEPA, 2005)(USEPA, 2003). The fuel usage for each component (boilers, dryers, etc.) were used to calculate estimated emissions and these emissions were then added to produce a facility total. For lime facilities, these were only available for part of the lime facilities listed.

Lime Facility Process CO₂ Emissions

Lime production data at the facility level is company proprietary and not published, nor are nameplate capacities for these facilities. These data may only be obtained by written consent from the company. We hope to obtain these data by contacting individual producers in the future. For the one lime producer in South Dakota, process information was obtained from the South Dakota Department of Environment and Natural Resources and the methodology is as follows. The emissions from lime production are equal to the lime production multiplied by an emissions factors and by the content of lime (CaO) in the product (USEPA, 2007b). For high calcium lime (all facilities in the region of interest produce high calcium lime), the calculation is as follows:

$E_{CO_2} = C * E_l * R = 0.75t \text{ CO}_2/t \text{ lime produced where:}$

E_{CO_2} = CO₂ emissions estimate in tons/yr

C = Facility-specific annual production or capacity of lime in tons/yr

E_l = Emissions factor for lime type (stoichiometric ratio) CO₂/lime (44/56)

R = content of CaO in lime produced (EPA estimates 0.95 for high calcium lime)

2.3.4 Cement Production

Location and CO₂ emissions data for cement plants within our area of interest were obtained from NATCARB's records of national cement plants (NATCARB, 2006); locations were then visually checked and updated using aerial imagery in Google Earth, following on Gumennik (2007). There are 8 operating cement manufacturing facilities in the region.

2.4 Other Industrial Emissions Sources

There are several other miscellaneous large emitters of GHG's were also identified, which fall into several categories. These data were also derived from the 1999 NEI database (USEPA, 2005), which reports permitted facilities with respect to the 6 criteria air pollutants (CAPS). Fuel use data from these sources were used and supplemented by the 1996 NAAQS (USEPA, 1998) database, which also publishes fuel use (throughput) data related to emissions of criteria air pollutants, where 1999 NEI data were unavailable. Because these two national datasets were collected only with respect to criteria air pollutants, the EPA does not recommend the use of 1999 NEI or 1996 NAAQS for GHG emissions estimation. However, the use of imperfect or incomplete data seemed preferable to reporting no data at all. NATCARB provided ethanol data and the South Dakota Department of Environment and Natural Resources (SD DENR) provided fuel use and process data for 2001 permitted industrial facilities and therefore SD facility estimates are based on this dataset.

2.4.1 Ethanol Production

Both location and emissions data for ethanol production within our area of interest were obtained from NATCARB's Ethanol Plants excel worksheet (2006 data). There are 19 ethanol facilities in the region of interest. Location data were verified using Google Earth imagery. Materials and methods are available as supporting material on Science Online. Additional information is available, including the working EBAMM model, at <http://socrates.berkeley.edu/~Erael/EBAMM> (NATCARB, 2006).

2.4.2 Mining and Mineral Processing Operations

In Big Sky Partnership states, there are 16 mining and mineral processing operations with significant CO₂ emissions. Emissions from mining operations generally result from mobile diesel exhaust from machinery on the site, and minerals processing such as lead smelting, copper, antimony and silica processing generate emissions from fossil fuel-fired boilers and dryers. Locations for these were obtained from the 1999 NEI database and visually validated against Google Earth imagery (per Gumennik 2007). Emissions were calculated using fuel use data from the 1996 NAAQS database and the SD DENR (2001) in conjunction with standard emissions factors by fuel type as listed in the EIIP guide (Table 1)(USEPA, 2005; USEPA, 2003; USEPA, 1998).

2.4.3 Wood and Paper Processing

In Big Sky Partnership states, there are 11 wood and paper processing operations with significant CO₂ emissions. CO₂ emissions from wood and paper mills primarily result from burning of waste wood and sawdust, which are not included in GHG inventories, however there are fossil fuel emissions from machinery and some facilities operate dryers with fossil fuels as well as waste products. Emissions from wood and paper processing were obtained from fuel throughput data from the 1996 NAAQS database and process data from the SD DENR (2001) used with standard emissions factors by fuel type as listed in the EIIP guide (Table 1)(USEPA, 2005; USEPA, 2003; USEPA, 1998).

2.4.4 Military and Academic Institutions

In Big Sky Partnership states there are 4 military institutions (air force, national guard bases) and 2 academic (university central heating) institutions with significant CO₂ emissions. These emissions result from industrial boilers and generators used for independent heating and power generation for these facilities. Emissions were estimated using fuel use data from 1996 NAAQS and SD DENR used with standard emissions factors by fuel type as listed in the EIIP guide (Table 1)(USEPA, 2005; USEPA, 2003; USEPA, 1998).

2.4.5 Miscellaneous Large Emitters

In Big Sky Partnership states there are 3 additional points with large estimated CO₂ emissions. These include Idaho Supreme Potato in Idaho, the Park County Incinerator (waste incinerator) in Montana, and the John Morrell Company (animal products) in South Dakota. Emissions for these facilities were estimated using fuel use data from 1996 NAAQS database and SD DENR used with standard emissions factors by fuel type as listed in the EIIP guide (Table 1)(USEPA, 2005; USEPA, 2003; USEPA, 1998).

3. Appendix

3.1 Validation Method for Verifying Facility Locations

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