Methodology for Big Sky Regional CO_2 Point-Source Emissions

Big Sky Carbon Sequestration Partnership
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1. Introduction

In partial fulfillment of our commitments made under Phases I and II 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, 2003). In the summer of 2007, the inventory of point source data for large emitters (>10,000 t CO_2/year) and the estimation methodologies were compiled, reviewed and updated by GIS staff at Montana State University's Big Sky Institute and submitted for inclusion in the National Carbon Atlas. In preparation for the third revision of the Carbon Atlas in 2010, the GIS staff at BSCSP reviewed the point sources compiles in 2007, modifying locations and emissions and adding attributes to the data layer to document the data source for each point, year of most recent emission values, and location information previously lacking in the data layer.

The final product may be regarded as a composite inventory, representing a range of years (between 1997 and 2009) 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, 2007) 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 (**E**missions and **G**eneration **R**esource **I**ntegrated **D**atabase) most recent database, which includes 2005 data (eGRID2007 Version 1.1, released October 16, 2008). The EPA reports GHG emissions at a variety of levels including regional, state, facility, and individual unit level. The eGRID2007 database contained 369 facility level records for our region of interest, 88 of which had significant annual CO_2 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 2007 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 CO_2 Emissions

eGRID (USEPA, 2007) is derived mostly from direct emissions monitoring (EPA, 2005) 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 2002 NEI database (11302007 file containing the final 2002 NEI data, Version 3.0) 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 CO_2 Emissions

CO_2 Emissions from petroleum refineries and natural gas processing facilities were estimated 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.

Table 1. Modified from USEPA, 2003.

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

Petroleum Storage and Transmission CO_2 Emissions

CO_2 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 CO_2 Producing Industrial Processes

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. With updated information gained in 2009 from the USGS as well as web-based searches for individual companies, 5 facilities were still operational in 2008, although due to falling aluminum prices in 2009 and the loss of electricity subsidies, Glencore International AG closed its Columbia Falls plant in October 2009. We still report this source and date emissions values appropriately in the case that these plants resume operations.

Primary Aluminum Facilities Locations

Geocoded addresses for these facilities were revised using company info from the websites and were also visually compared against aerial imagery in Google Earth to verify geographic coordinates (decimal degrees).

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 aluminum 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 aluminum produced.

Table 2. Modified from IAI, 2006.

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

Though annual proprietary aluminium production data is often unavailable as well, facility-specific annual production capacity data is published in the USGS Minerals Yearbook 2008 (Bray, 2009). According to the USGS (Bray, personal comm. 7/25/07), this capacity data is generally a sound estimate of annual production because most pot lines operate at 100% annual capacity. This renders the equation for CO_2 emissions from primary aluminum production as:

$\mathbf{E_{CO2} = C*E_{p,s}}$ where:

E_{CO2} = 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

There are two sources of GHG emissions from the primary production of soda ash. Emissions are produced from the combustion of fossil fuels in boilers and dryers and also from the production process itself. In Wyoming, primary soda ash is produced from underground mining and calcination of trona, a sodium carbonate mineral. The calcination process produces soda ash as well as CO_2 emissions as a by-product of the chemical reaction (see formula provided below). Total CO_2 emissions from primary soda ash production are equal to the sum of combustion emissions and production emissions for individual facilities.

Soda Ash Production Facility Locations

Of the Big Sky Partnership states (and the nation), Wyoming is the only state that produces primary soda ash from underground mining of trona. There are 5 operating trona mines and production facilities in Wyoming, all located near

Green River, WY. Geographic location and address data for these facilities were obtained from the 1999 NEI database and visually validated, as recommended by Gumennik (2007), against Google Earth imagery.

Soda Ash Facility Combustion CO_2 Emissions

Combustion emissions were determined from fuel use data obtained from the USEPA's National Emissions Inventory database (1999 NEI), which collects data on industrial emissions of criteria and hazardous air pollutants (USEPA, 2005). These fuel use data were used with a default emissions factor for specific fuels to convert fuel consumed to metric tons of CO_2 produced.

Soda Ash Facility Production CO_2 Emissions

As with most industrial commodities, soda ash production data is not available to the public however, nameplate capacities for each facility were obtained from the USGS Minerals Yearbook (Kostick, 2010) and trona production data for 2005 were obtained from the Wyoming State Inspector of Mines (Kostick, 2006). Soda ash is calcined from trona ore by the following chemical reaction:

$$\underset{\text{trona}}{2(Na_3H(CO_3)_2{*}2H_2O)} \rightarrow \underset{\text{soda ash}}{3Na_2CO_3} + 5H_2O + CO_2$$

By stoichiometry, this yields an emissions factor of 0.1383 tons of CO_2 for each ton of soda ash (Na_2CO_3) produced and 0.09737 tons of CO_2 for each ton of trona produced (see Table 3). Carbon dioxide emissions from soda ash manufacture from trona ore were calculated using the nameplate capacity where production data were unavailable (1 plant) and 2005 trona production data otherwise, using the stoichiometrically derived emissions factor as suggested by the EPA National Greenhouse Gas Inventory (USEPA, 2007).

Production Data	Stoichiometric Ratio X/CO_2	Emissions Factor tCO_2/tX
Trona	452/44	0.09737
Soda Ash	318/44	0.1383

Table 3.

2.3.3 Lime Production

Lime facility emissions are produced by combustion and the lime production process. Lime (CaO) is produced from limestone ($CaCO_3$) by thermal decomposition in a kiln, which produces CO_2 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 CO_2, 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 CO_2 captured from the lime kiln through the solution. The milk of lime and CO_2 react forming calcium carbonate ($CaCO_3$), which precipitates out of solution taking impurities from the sugar with it. Thus a significant amount of the CO_2 (EPA estimates 80%) emitted from a sugarmill lime kiln is captured and reacted with the lime to form $CaCO_3$, so the net CO_2 emission is from the fuel burned to power the kiln plus calcination release minus CO_2 used in the refining process (Miller, MM., personal comm. 07/25/2007).

Lime 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 Combustion CO_2 Emissions

CO_2 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 CO_2 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 factor and the content of lime (CaO) in the product (USEPA, 2007). For high calcium lime (all facilities in the region of interest produce high calcium lime), the calculation is as follows:

$\mathbf{E_{CO2} = C*E_l*R}$ = 0.75t CO_2/t lime produced where:

E_{CO2} = CO_2 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) CO_2/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 CO_2 emissions data for cement plants within our area of interest were obtained from NATCARB's records of national cement plants (NATCARB, 2007); locations were then visually checked and updated using aerial imagery in Google Earth. 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 are 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 production data for ethanol within our area of interest were obtained from reports by the Renewable Fuels Association, Washington, DC and Nebraska Energy Office, Lincoln, NE (http://www.neo.ne.gov/renew/ethanol.htm).

As of December 2009, there were 22 ethanol facilities within the Big Sky Partnership area. From published production data, we can calculate CO_2 emissions based on the amount of ethanol produced. Ethanol is produced from glucose fermentation following the reaction:

$$C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$$

Therefore,

$\mathbf{E_{CO2} = P * E_e}$ where:

$\mathbf{E_{CO2}}$= CO_2 emissions in metric tons per year
P= annual production of ethanol (gallons/yr)
$\mathbf{E_e}$**=** an emission factor based on the stoichiometry above (0.00288 mton of CO_2 per gallon of ethanol)

Location data were verified using Google Earth imagery.

2.4.2 Mining and Mineral Processing Operations

In Big Sky Partnership states, there are 19 mining and mineral processing operations with significant CO_2 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, and as of December 2009, there are 9 wood and paper processing operations with significant CO_2 emissions. CO_2 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 5 military institutions (Air Force, National Guard bases) and 4 academic (university central heating) institutions with significant CO_2 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) and the latest eGRID database.

2.4.5 Miscellaneous Large Emitters

In Big Sky Partnership states there are 3 additional points with large estimated CO_2 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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3.2 References by Source Type

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