U.S.A.-Specific Emission Factor Development

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15th Expert Meeting on Data for the IPCC Emission Factor Database
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Paris, France
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PRIMARY REFERENCE

U.S. Environmental Protection Agency,
April 15, 2015
Inventory of U.S. Greenhouse Gas Emissions and Sinks
EPA 430-R-15-004
Annex 2.2
Methodology for Estimating the Carbon Content of Fossil Fuels

https://www.epa.gov/sites/production/files/2016-03/documents/us-ghg-inventory-2015-annexes.pdf

Overview

- IPCC emission factor overview
- US institutional arrangements for data collection
- US methodology for developing carbon contents
  - Coal
  - Natural gas
  - Petroleum products
- Examination of regional factors
- Role of large point sources

Overview: Tier 1 vs. Tier 2 Emission Factors

Tier 1

- Default emission factors from IPCC Guidelines
- Analysis of available fuel characteristic data
- Do not account for country-specific circumstances

Tier 2

- National or regional emission factors
- Measure a reasonable number of sources that represent country conditions
- Consider fuel type and composition, quality, carbon content

US Energy Consumption Data Collection

- US energy consumption statistics *mandated* by the Federal Energy Administration Act of 1974
  - Created the Energy Information Administration (EIA), with authority to collect energy data
  - EIA uses surveys to collect fuel statistics varying by fuel type, timeframe
  - Collect, assemble, evaluate, and analyze energy information

Data Collection Survey Examples

Survey Form	Description
Quarterly report on coal consumption and quality	Collects coal consumption data from U.S. manufacturers, transformation and processing plants, and commercial and institutional users.
Annual report of natural and supplemental gas supply and disposition	Collects data on origin of natural gas supplies and disposition of natural gas on a state basis. Responses are from gas producers, processers, distributors, and storage.
Annual fuel oil and kerosene report	Collects data on sales of distillate and residual fuel oils and kerosene by end use and state of destination.
Annual refinery report	Collects data on fuel, electricity and steam purchased for consumption at the refinery; refinery receipts of crude oil by method of transportation; current and projected capacities for atmospheric crude oil capacity.

US Mineral Resource Data Collection

- US mineral resource research is conducted by the United States Geological Survey
  - Assesses the location, quantity, and quality of mineral and energy resources
  - Developed coal databases to characterize the location, quantity, physical attributes, and chemistry of US coal and coal-related deposits

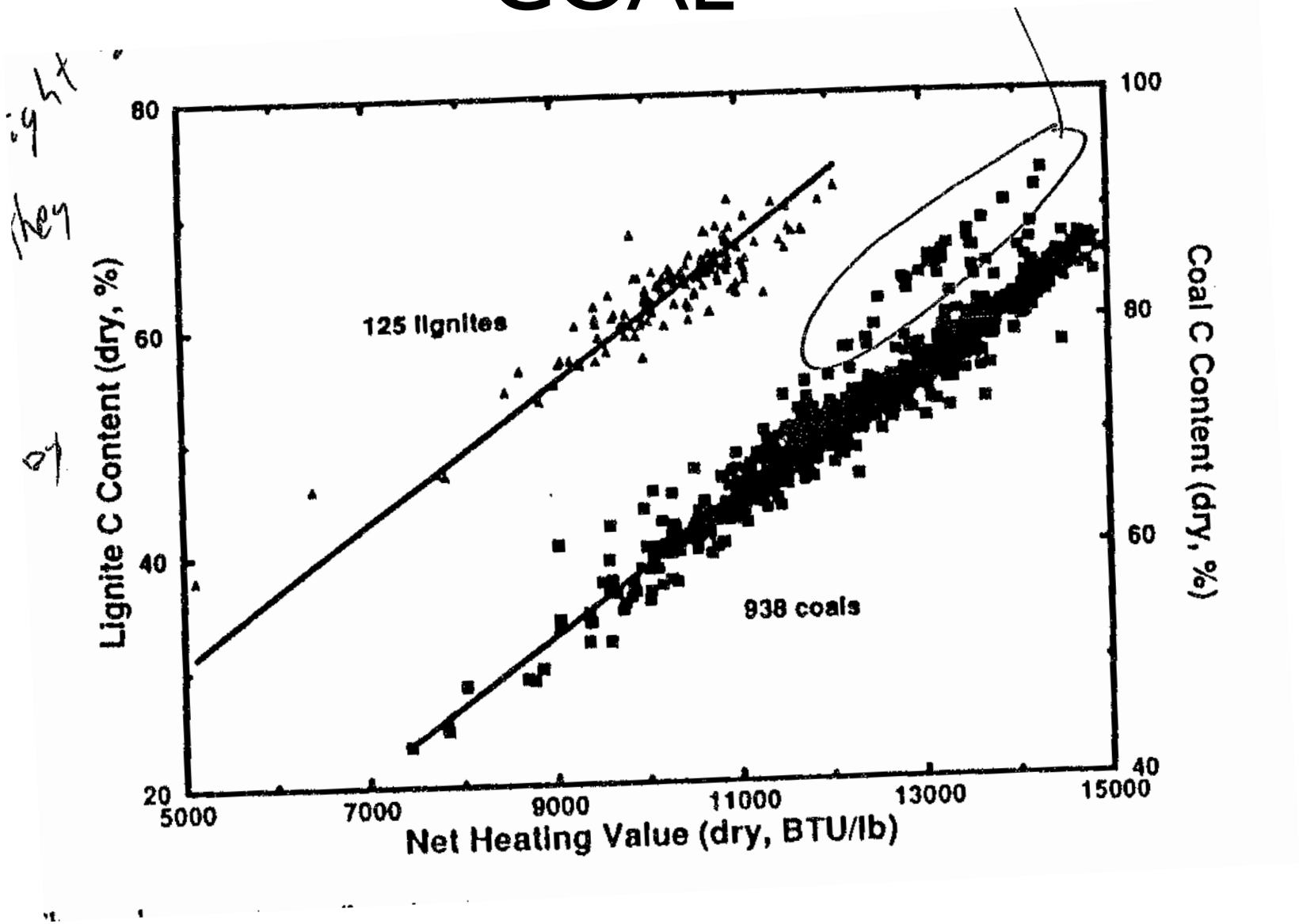
USGS
science for a changing world

Carbon Content Development

- Fuel types all follow the same basic approach
  - Fuel quantities are converted to units of mass using density factors
  - Carbon content and heat content are derived from fuel sample data
- Specific methodologies vary for coal, natural gas, and petroleum

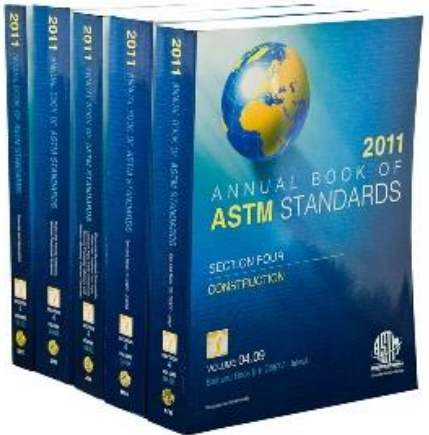


COAL

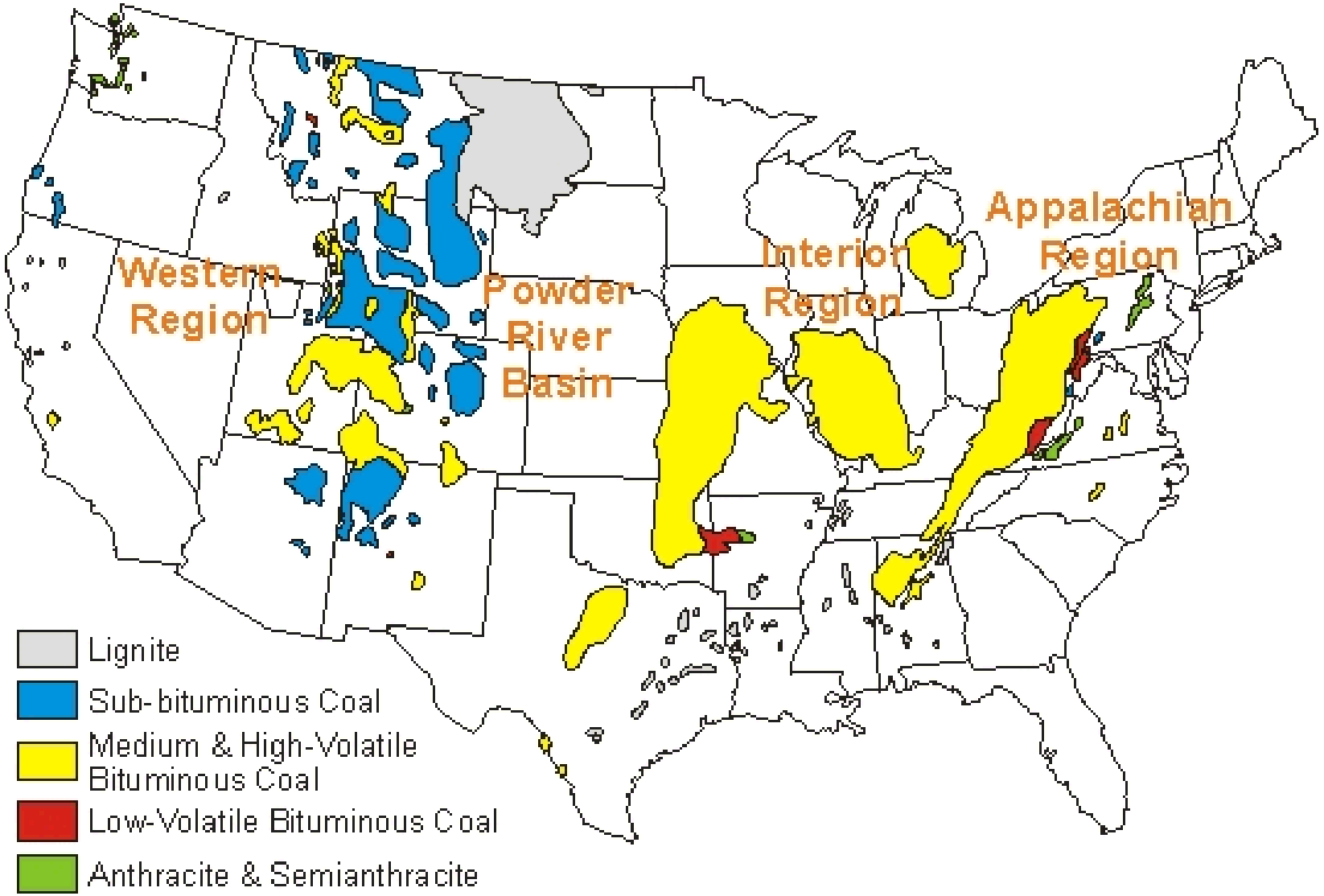

125 lignites
938 coals
Lignite C Content (dry, %)
Coal C Content (dry, %)
Net Heating Value (dry, BTU/lb)
20
40
60
80
40
60
80
100
5000
7000
9000
11000
13000
15000

Determine Carbon Content by Rank and State of Origin

- Carbon contents based on 7,092 coal samples
- Classified according to rank and state of origin
- Carbon and heat content calculated based on analyses of the samples
  - American Society for Testing and Materials: set standards to conduct analysis of fuels



Determine Carbon Content by Rank and State of Origin



Coal Emissions Factors by Consuming Sector

(Electric power, industrial coking, other industrial uses, residential and commercial)

Need to accommodate the format of the data – e.g. data on coal consumption

Data on 7092 coals classified according to rank and state of origin

1.) determine average carbon and heat content by state and rank

2.) determine weighted average carbon/heat content by state

3.) determine distribution of state of origin for each consuming sector

4.) determine weighted average carbon/heat content by consuming sector

Variability by coal rank across states

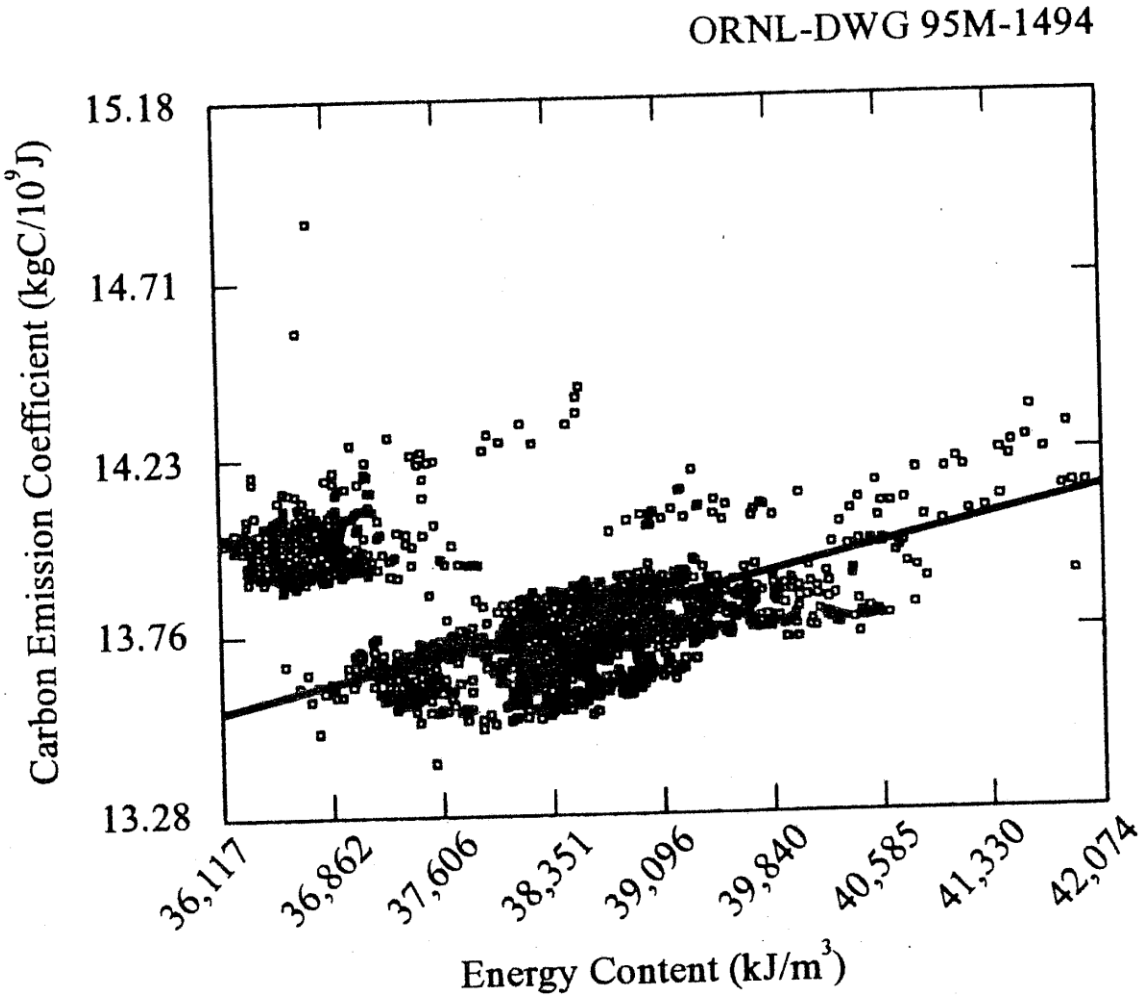
(kg C/10^9 joules)(LHV)

Rank	mean of states	range of states	national average
Bituminous	25.28	23.23 – 28.56	25.32
Sub bituminous	26.31	24.78 – 26.63	26.37
Lignite	26.77	25.64 – 28.92	26.52
Anthracite	28.30	26.74 – 31.16	28.14

Coal carbon contents by consuming sector. These are what actually get used in the Inventory:

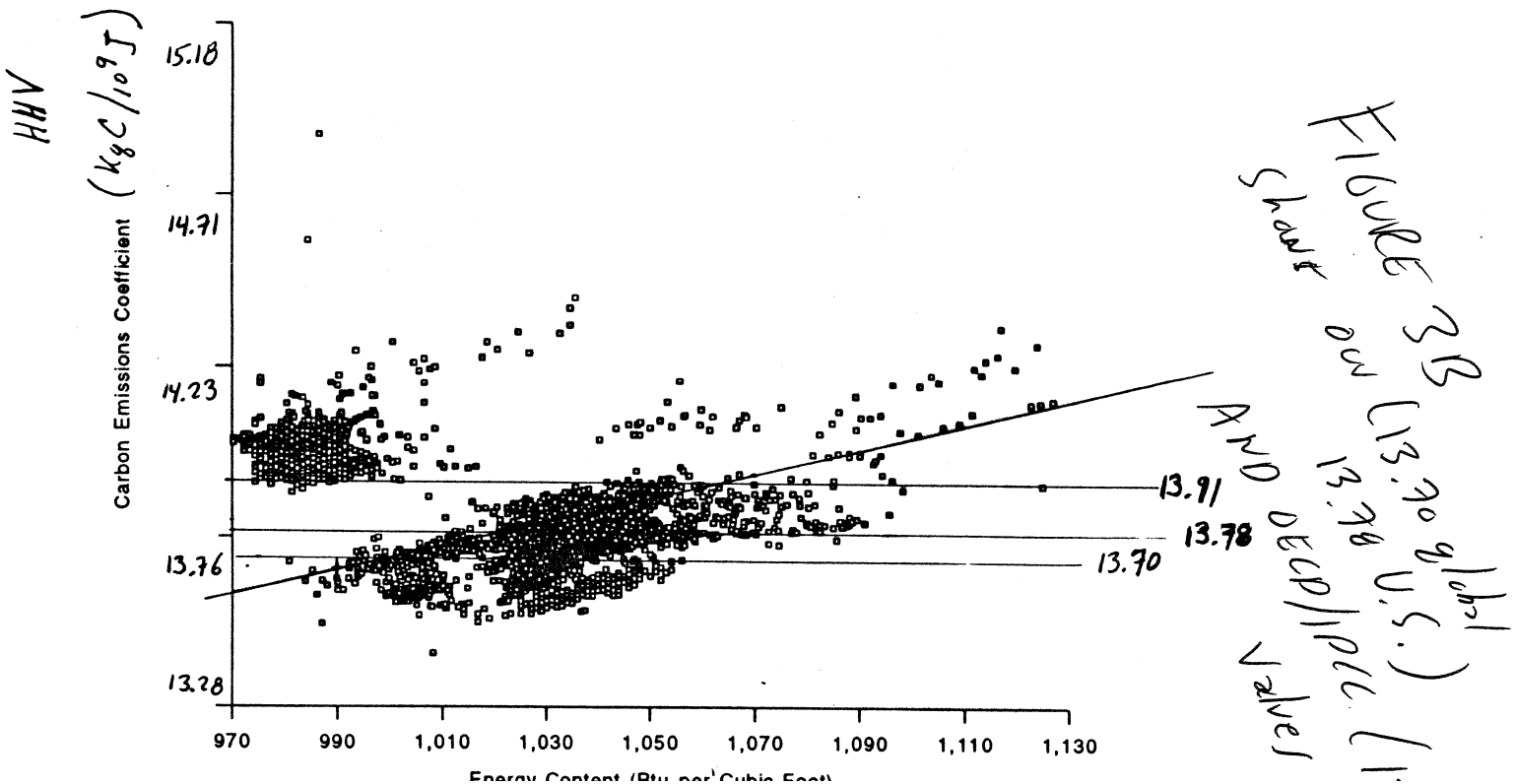
Type:	Kg C / 10^9 J (LHV)
Residential Coal	25.65
Commercial Coal	25.65
Industrial Other Coal	25.76
Electric Power Coal	25.99

NATURAL GAS (SI units, HHV)



NATURAL GAS (U.S. units, HHV)

Figure A1. Carbon Emissions Coefficients for Samples of Pipeline-Quality Natural Gas in the Gas Research Institute Database



Carbon Content Development: Natural Gas

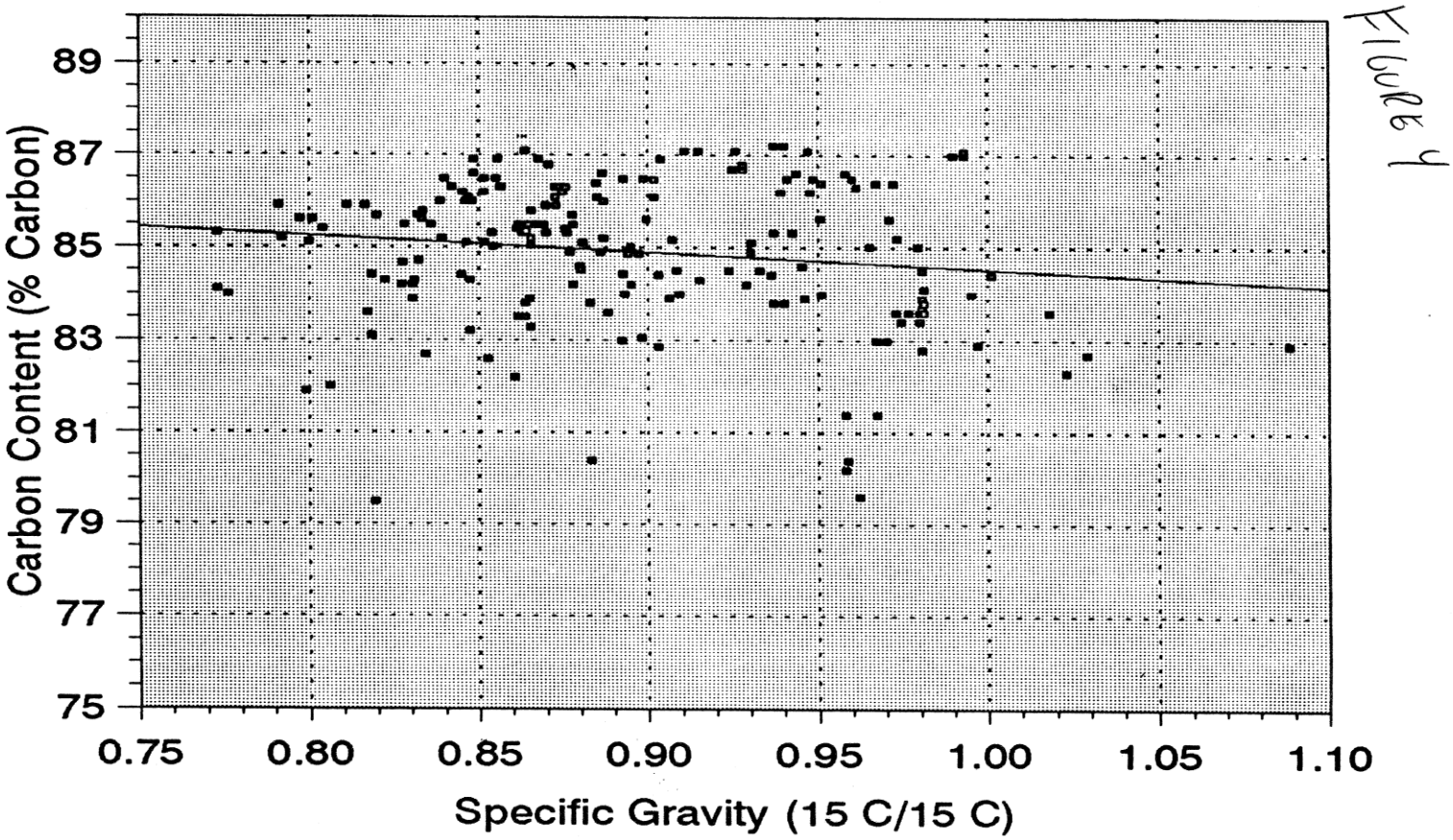
1. Define pipeline-quality natural gas
2. Define flared gas (if applicable)
3. Determine a relationship between carbon content and heat content
4. Apply carbon content to pipeline natural gas
5. Apply carbon content to flare gas

Natural Gas

14.46	=	13.70	=	15.21
MMT C/Q Btu(HHV)		Kg C/10^9 J (HHV)		Kg C/10^9 J (LHV)

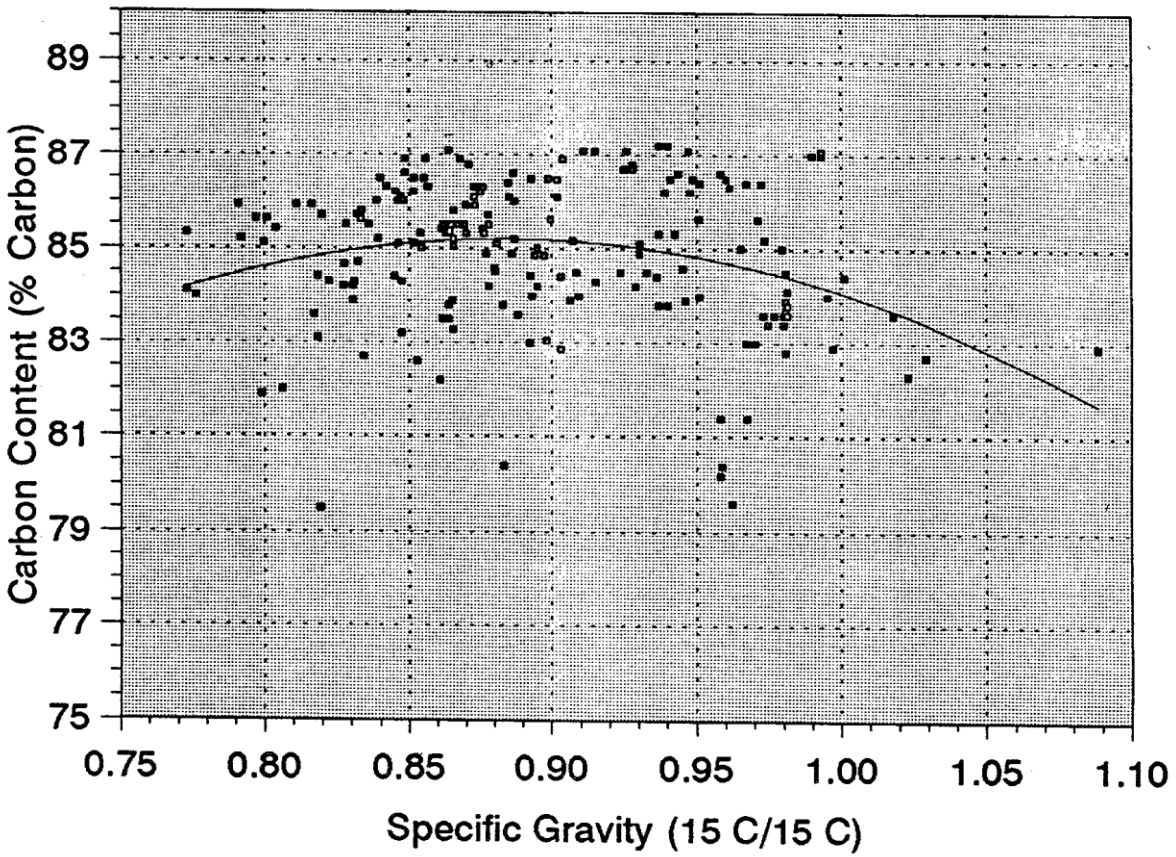
CRUDE PETROLEUM

(Linear)



CRUDE PETROLEUM

(parabolic)

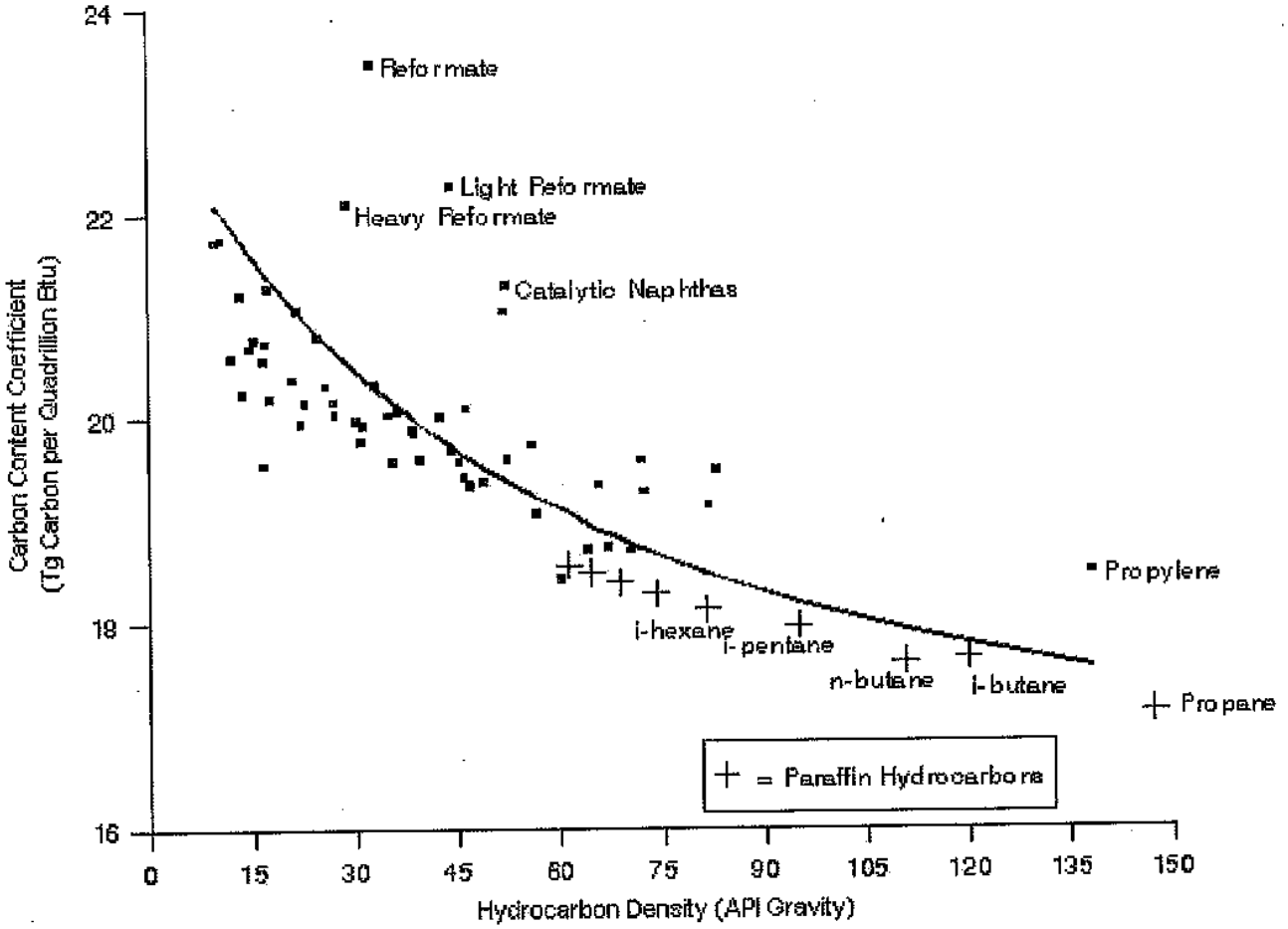


Petroleum Products

$$C_{fuel} = (D_{fuel} \times S_{fuel})/E_{fuel}$$

C = carbon coefficient	(kg C/joule)
D = density	(kg oil/volume)
S = mass fraction of carbon	(kg C/kg oil)
E = heat content	(joules/volume)

Figure A-2: Estimated and Actual Relationships Between Petroleum Carbon Content Coefficients and Hydrocarbon Density

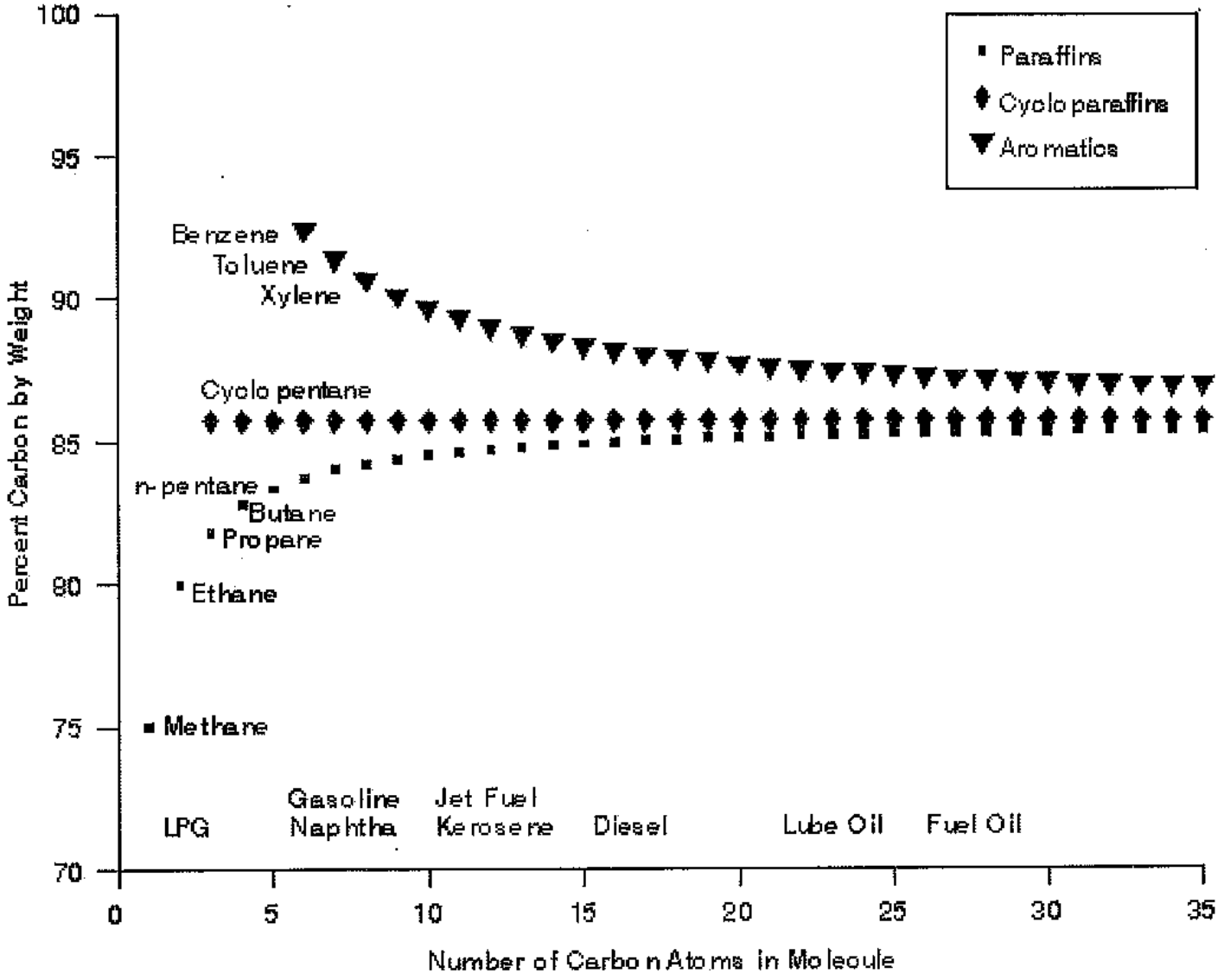


API Gravity

API gravity is an arbitrary scale expressing the density of liquid petroleum products. The higher the API gravity the lighter the compound. Light crude oils generally exceed 38 degrees.

$$\text{API gravity} = (141.5/\text{specific gravity}) - 131.5$$

Figure A-3: Carbon Content of Pure Hydrocarbons as a Function of Carbon Number



% carbon by mass

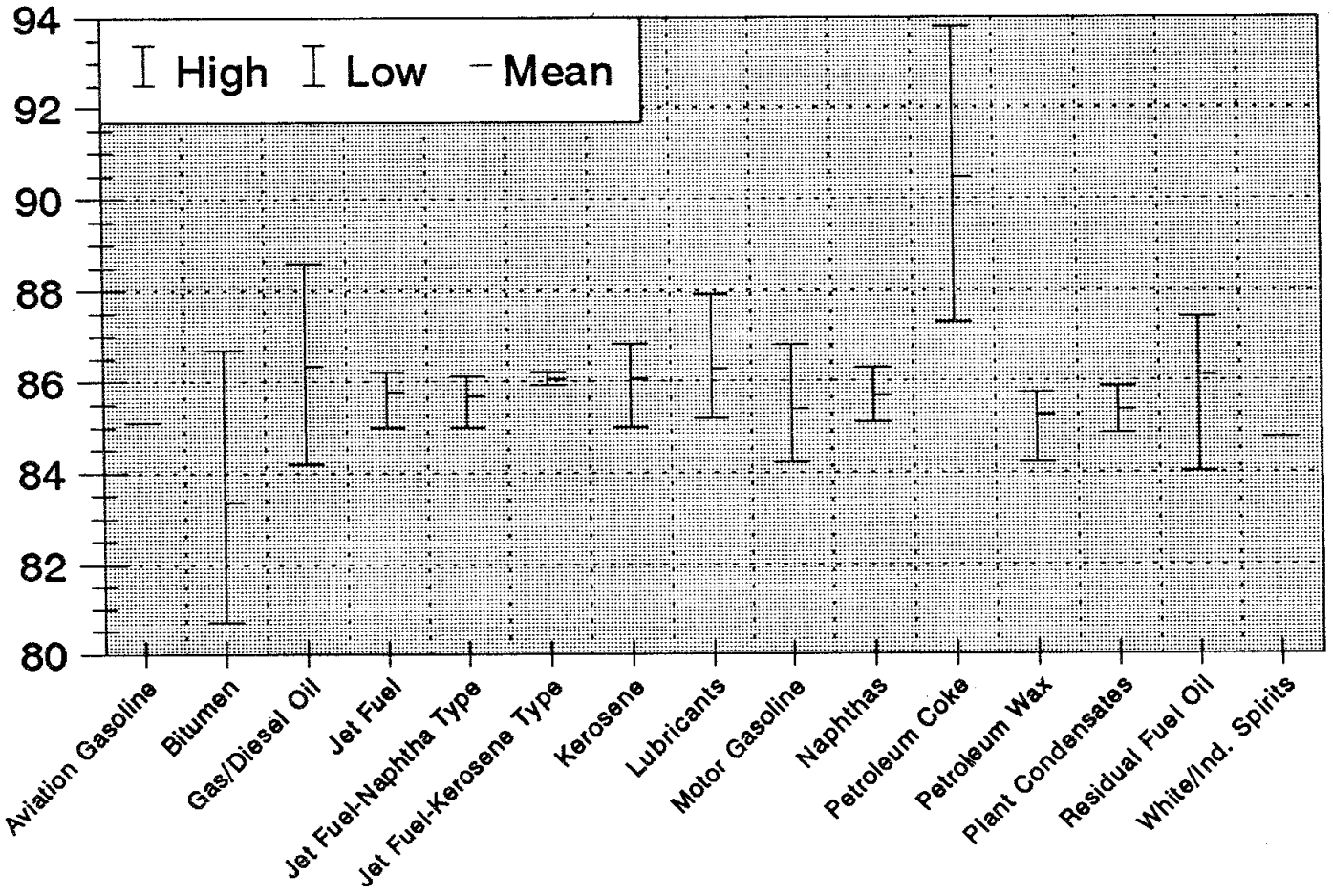


Table A-47: Carbon Content Coefficients and Underlying Data for Petroleum Products

Fuel	2008 Carbon Content (MMT C/QBtu)	Gross Heat of Combustion (MMBtu/Barrel)	Density (API Gravity)	Percent Carbon
Motor Gasoline	19.46	[a]	[a]	[a]
LPG(total)	16.97	[b]	[b]	[b]
LPG (energy use)	16.83	[b]	[b]	[b]
LPG (non-energy use)	17.06	[b]	[b]	[b]
Jet Fuel	19.70	5.670	42.0	86.30
Distillate Fuel No. 1	19.98	5.822	35.3	86.40
Distillate Fuel No. 2	20.17	5.809	35.8	87.30
Distillate Fuel No. 4	20.47	6.135	23.2	86.47
Residual Fuel No. 5	19.89	5.879	33.0	85.67
Residual Fuel No. 6	20.48	6.317	15.5	84.67
Asphalt and Road Oil	20.55	6.636	5.6	83.47
Lubricants	20.20	6.065	25.7	85.80
Naphtha (< 400 deg. F)[c]	18.55	5.248	62.4	84.11
Other Oils (>400 deg. F)[c]	20.17	5.825	35.8	87.30
Aviation Gas	18.86	5.048	69.0	85.00
Kerosene	19.96	5.825	35.3	86.40
Petroleum Coke	27.85	6.024	-	92.28
Special Naphtha	19.74	5.248	52.0	84.75
Petroleum Waxes	19.80	5.537	43.3	85.30
Still Gas	18.20	6.000	-	77.70
Crude Oil	20.31	5.800	31.2	85.49
Unfinished Oils	20.31	5.825	31.2	85.49
Miscellaneous Products	20.31	5.796	31.2	85.49
Pentanes Plus	19.10	4.620	81.3	83.63

[a] Calculation of the carbon content coefficient for motor gasoline in 2008 uses separate higher heating values for conventional and reformulated gasoline of 5.253 and 5.150, respectively (EIA 2008a). Densities and carbon shares (percent carbon) are annually variable and separated by both fuel formulation and grade, see Motor Gasoline and Blending Components, below, for details.

[b] LPG is a blend of multiple paraffinic hydrocarbons: ethane, propane, isobutane, and normal butane, each with their own heat content, density and C content, see Table A-50.

[c] Petrochemical feedstocks have been split into naphthas and other oils for this inventory report. Parameters presented are for naphthas with a boiling temperature less than 400 degrees Fahrenheit. Other oils are petrochemical feedstocks with higher boiling points. They are assumed to have the same characteristics as distillate fuel oil no. 2.

- No sample data available

Sources: EIA (1994), EIA (2009a), EPA (2009b), and EPA (2010).

Table A-40: Annually Variable C Content Coefficients by Year (MMT C/QBtu)

Fuel Type	1990	1995	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
Residential Coal	26.20	26.13	26.01	26.00	25.98	26.04	25.91	26.09	26.29	25.94	25.71[a]	25.71[a]	25.71[a]	25.71[a]	25.71[a]	25.71[a]	25.71[a]	25.71[a]
Commercial Coal	26.00	26.13	26.01	26.00	25.98	26.04	25.91	26.09	26.29	25.94	25.71	25.71	25.71	25.71	25.71	25.71	25.71	25.71
Industrial Coking Coal	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00	31.00
Industrial Other Coal	25.82	25.80	25.74	25.66	25.57	25.55	25.56	25.80	25.84	25.82	25.82	25.82	25.82	25.82	25.82	25.82	25.82	25.82
Electric Power Coal	25.96	25.93	26.00	26.00	26.05	26.09	26.10	26.09	26.04	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05	26.05
Pipeline Natural Gas	14.45	14.46	14.47	14.46	14.46	14.44	14.46	14.46	14.46	14.46	14.46	14.46	14.46	14.46	14.46	14.46	14.46	14.46
LPG (energy use)	16.86	16.82	16.89	16.87	16.85	16.86	16.84	16.84	16.83	16.82	16.83	16.83	16.83	16.83	16.83	16.83	16.83	16.83
LPG (non-energy use)	17.06	17.09	17.09	17.10	17.09	17.09	17.07	17.06	17.06	17.05	17.06	17.06	17.06	17.06	17.06	17.06	17.06	17.06
Motor Gasoline	19.42	19.36	19.33	19.34	19.38	19.36	19.38	19.36	19.45	19.56	19.46	19.46	19.46	19.46	19.46	19.46	19.46	19.46
Jet Fuel	19.40	19.34	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70	19.70
MoGas Blend Components	19.42	19.36	19.33	19.34	19.38	19.36	19.38	19.36	19.45	19.56	19.46	19.46	19.46	19.46	19.46	19.46	19.46	19.46
Misc. Products	20.15	20.21	20.22	20.27	20.28	20.25	20.31	20.31	20.28	20.28	20.31	20.31	20.31	20.31	20.31	20.31	20.31	20.31
Unfinished Oils	20.15	20.21	20.22	20.27	20.28	20.25	20.31	20.31	20.28	20.28	20.31	20.31	20.31	20.31	20.31	20.31	20.31	20.31
Crude Oil	20.15	20.21	20.22	20.27	20.28	20.25	20.31	20.31	20.28	20.28	20.31	20.31	20.31	20.31	20.31	20.31	20.31	20.31

[a] EIA discontinued collection of residential sector coal consumption data in 2008, because consumption of coal in the residential sector is extremely limited. Therefore, the number cited here is developed from commercial/institutional consumption.

Carbon Content Development: Motor Gasoline

1. Disaggregate gasoline consumption by grade and type
2. Develop carbon content coefficients for each grade and type
3. Weight overall gasoline carbon content coefficient for consumption of each grade and type

Carbon Content by Grade and Type

- Gasoline grade, type, and season coefficients are derived from four parameters
  - Volumetric share of each constituent*
  - Density of the constituent
  - Share of the constituent that is C
  - Energy content of a gallon of the relevant formulation of the gasoline

** A constituent of gasoline can include the following: aromatics, olefins, benzene, saturates, MTBE, TAME, ETBE, DIPE and ethanol*

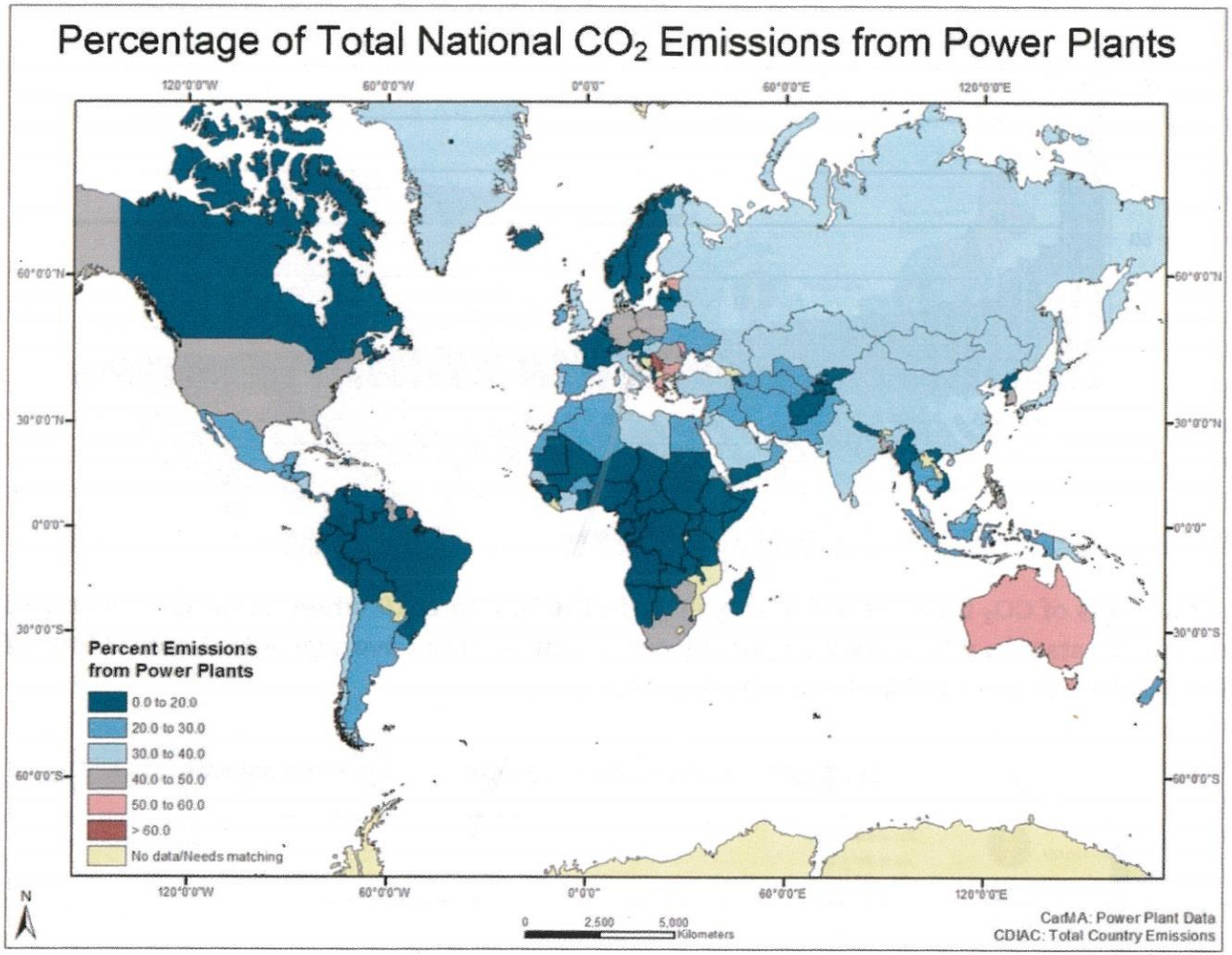


Fig. 1 – The percentage of national total anthropogenic CO_2 emissions (production based) that were from electric power generation in 2009.
National total emissions are from Boden et al. (2012) and power plant emissions are from CARMA (2013).

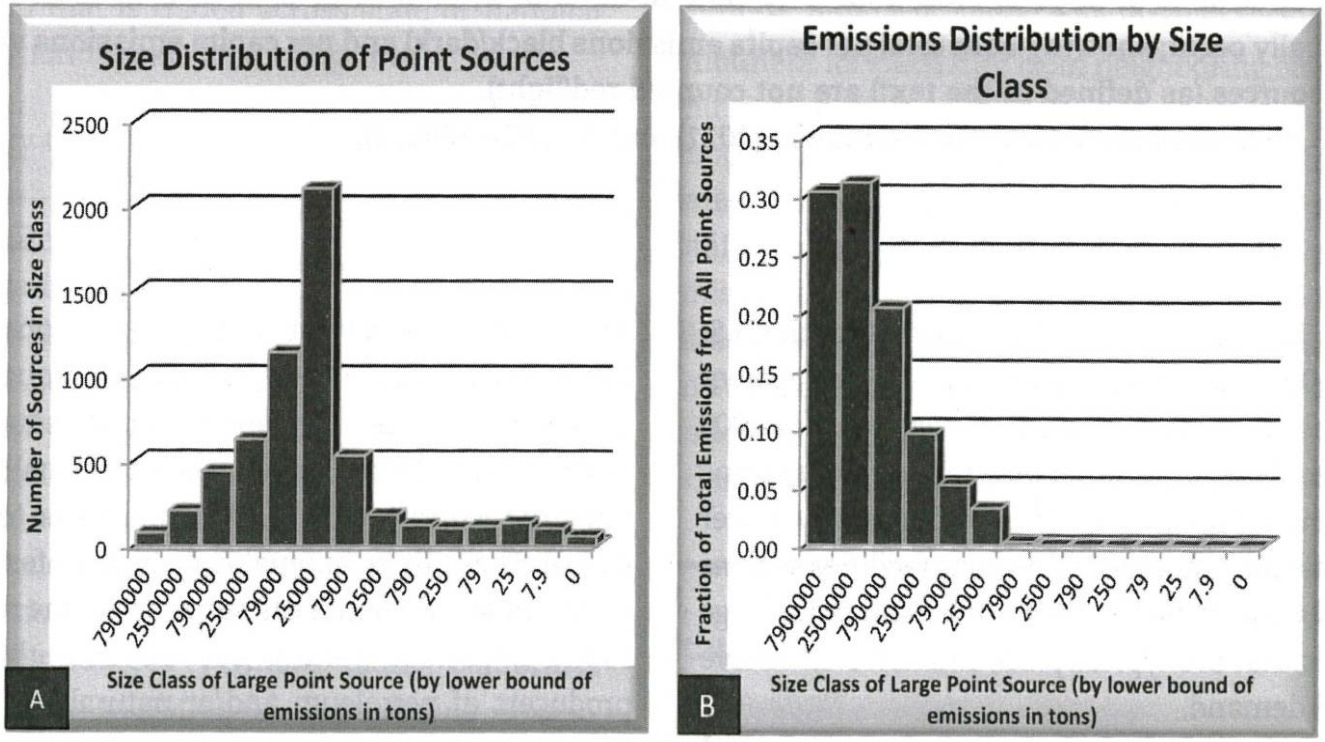


Fig. 2 – (A) The number of facilities per size class for large point sources of CO_2 emissions in the U.S. in 2011. (B) The mass of CO_2 emissions per facility size class from large point sources of CO_2 emissions in the U.S. in 2011. Note that the *x*-axis scale in both drawings is logarithmic. Values shown are the lower bound of the size class in metric tons of CO_2 per year per facility. Data are from U.S. EPA (2013a).

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U.S. EPA Inventory Information

https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks

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