Estimated Carbon Dioxide Emissions in 2008

United States

C.A. Smith, A.J. Simon, R.D. Belles

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Estimated Carbon Dioxide Emissions in 2008: United States

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Abstract

Flow charts depicting carbon dioxide emissions in the United States have been constructed from publicly available data and estimates of state-level energy use patterns. Approximately 5,800 million metric tons of carbon dioxide were emitted throughout the United States for use in power production, residential, commercial, industrial, and transportation applications in 2008. Carbon dioxide is emitted from the use of three major energy resources: natural gas, coal, and petroleum. The flow patterns are represented in a compact "visual atlas" of 52 state-level (all 50 states, the District of Columbia, and one national) carbon dioxide flow charts representing a comprehensive systems view of national CO_2 emissions.

Introduction

Lawrence Livermore National Lab (LLNL) has published flow charts (also referred to as "Sankey Diagrams") of important national commodities since the early 1970s. The most widely recognized of these charts is the U.S. energy flow chart (http://flowcharts.llnl.gov). LLNL has also published charts depicting carbon (or carbon dioxide potential) flow and water flow at the national level as well as energy, carbon, and water flows at the international, state, municipal, and organizational (i.e. United States Air Force) level. Flow charts are valuable as single-page references that contain quantitative data about resource, commodity, and byproduct flows in a graphical form that also convey structural information about the system that manages those flows.

Data on carbon dioxide emissions from the energy sector are reported on a national level. Because carbon dioxide emissions are not reported for individual states, the carbon dioxide emissions are estimated using published energy use information. Data on energy use is compiled by the U.S. Department of Energy's Energy Information Administration (U.S. EIA) in the State Energy Data System (SEDS). SEDS is updated annually and reports data from 2 years prior to the year of the update. SEDS contains data on primary resource consumption, electricity generation, and energy consumption within each economic sector. Flow charts of state-level energy usage and explanations of the calculations and assumptions utilized can be found at: http://flowcharts.llnl.gov.

This information is translated into carbon dioxide emissions using ratios of carbon dioxide emissions to energy use calculated from national carbon dioxide emissions and national energy use quantities for each particular sector. These statistics are reported annually in the U.S. EIA's Annual Energy Review. Data for 2008 (US. EIA, 2010) was updated in August of 2010.

This is the first presentation of a comprehensive state-level package of flow charts depicting carbon dioxide emissions for the United States.

Estimated Alabama Carbon Dioxide Emissions in 2008: ~143 Million metric tons

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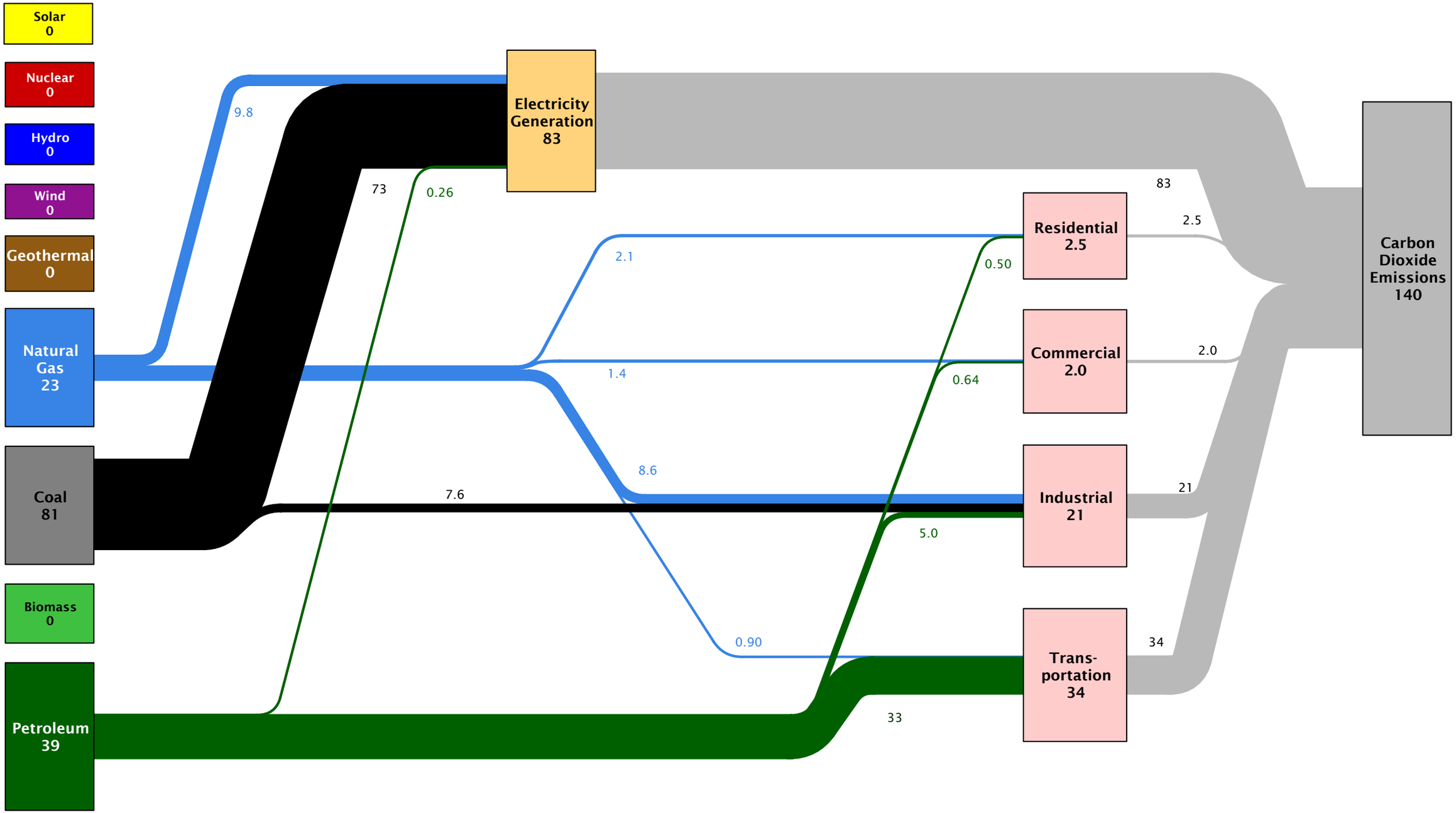
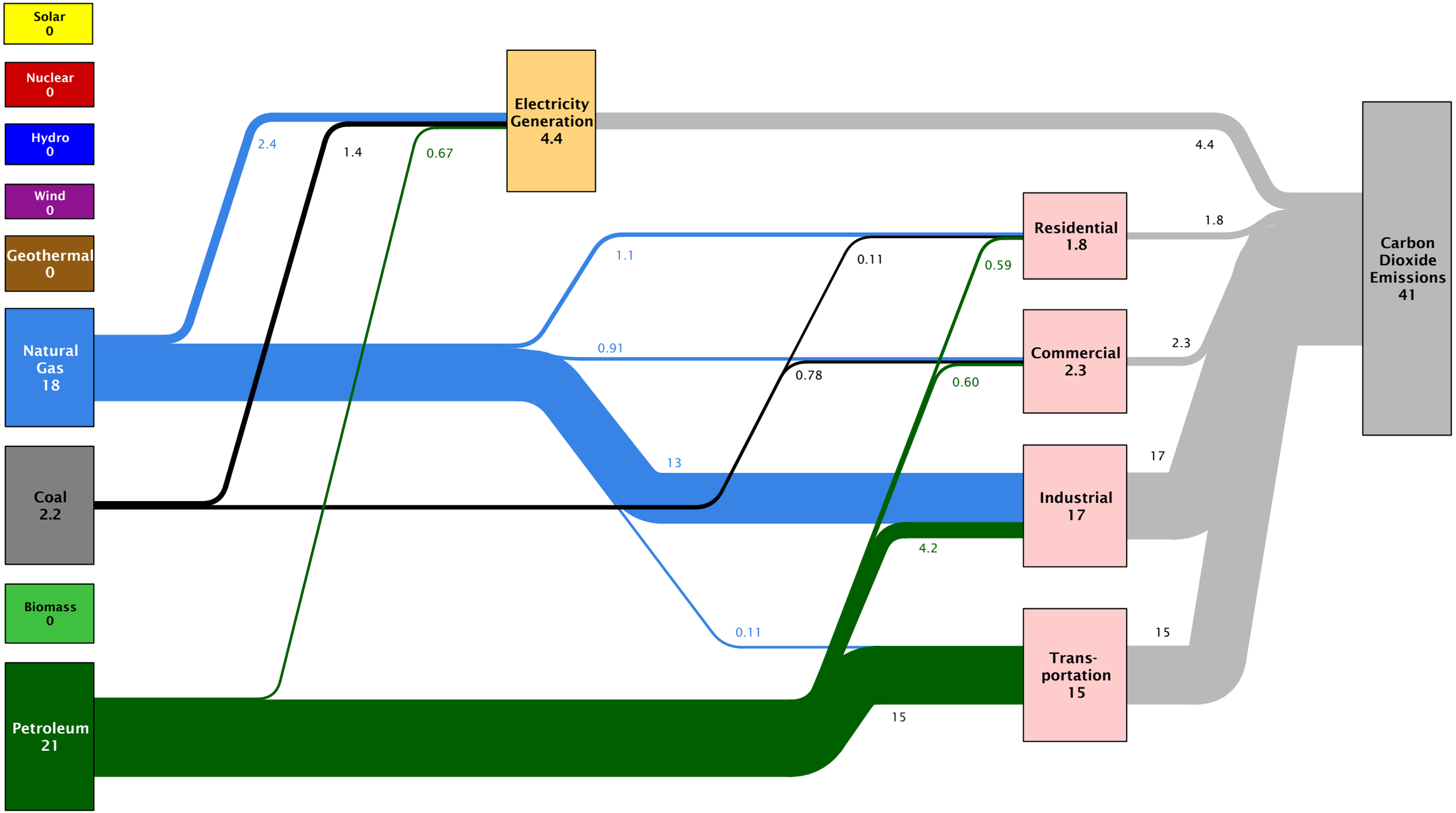


Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Alaska Carbon Dioxide Emissions in 2008: ~41 Million metric tons

Lawrence Livermore National Laboratory



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Estimated Arizona Carbon Dioxide Emissions in 2008: ~110 Million metric tons

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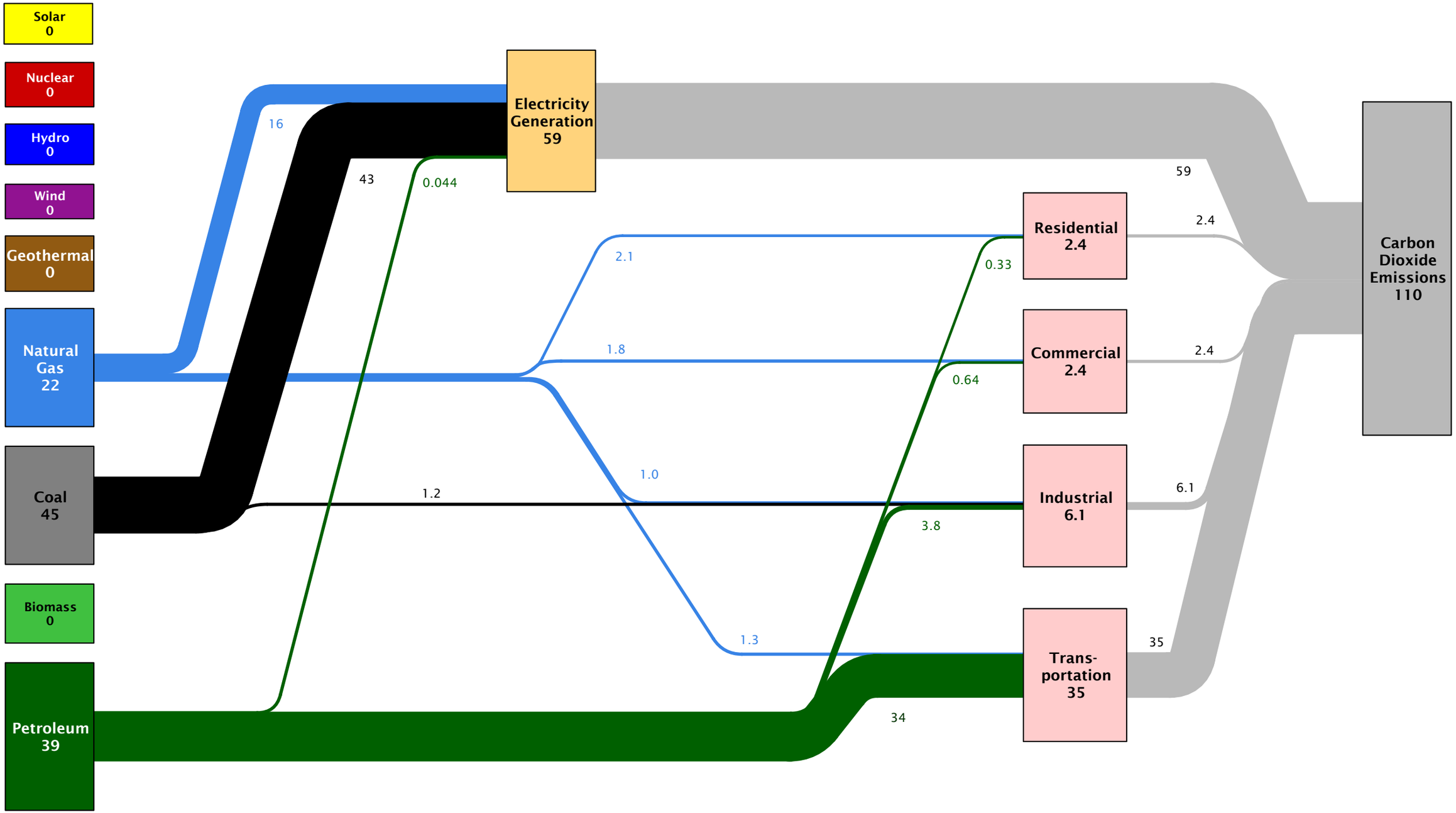

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Estimated Arkansas Carbon Dioxide Emissions in 2008: ~66 Million metric tons

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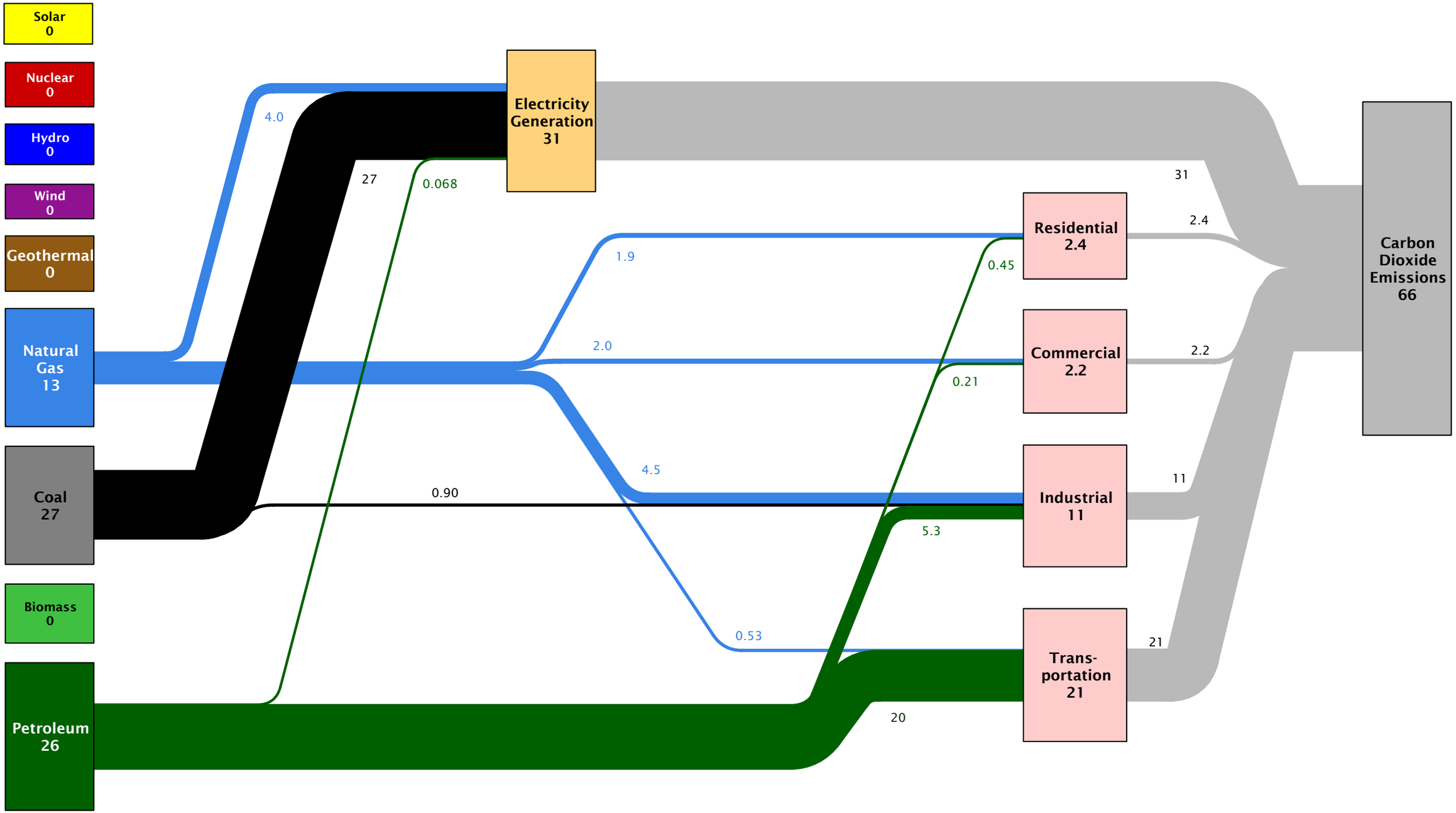

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Estimated California Carbon Dioxide Emissions in 2008: ~410 Million metric tons

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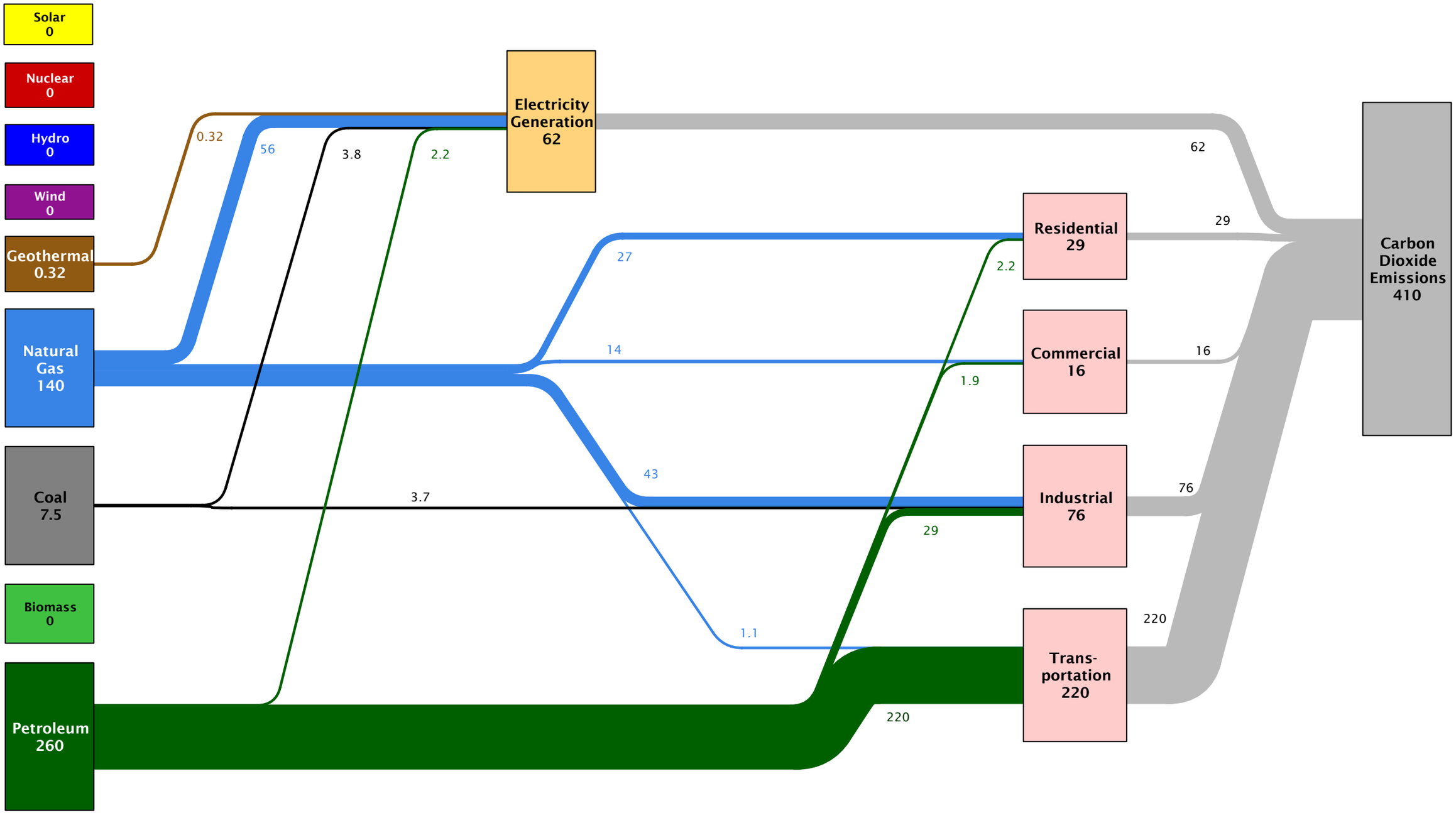

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Estimated Colorado Carbon Dioxide Emissions in 2008: ~99 Million metric tons

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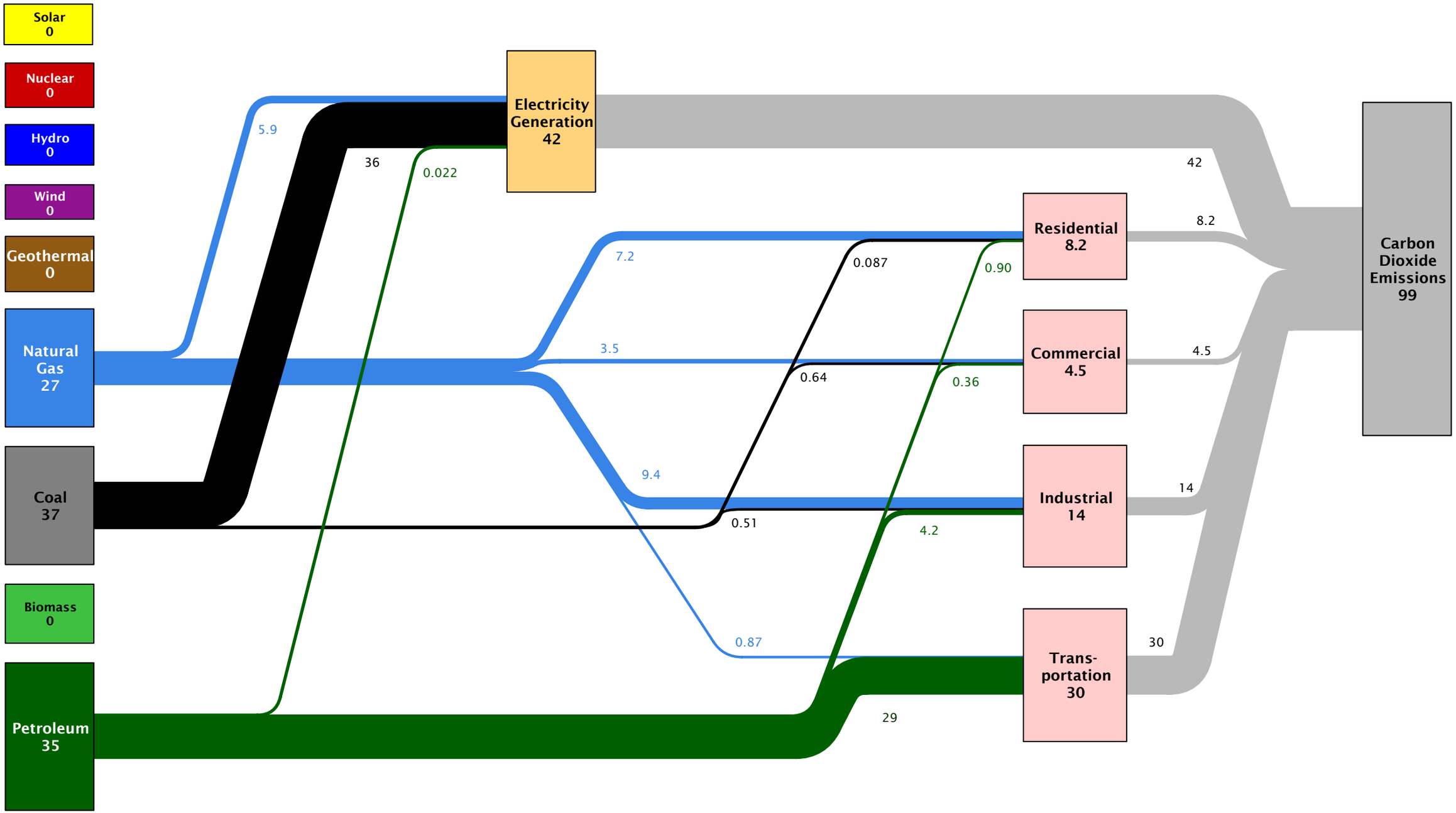

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Estimated Connecticut Carbon Dioxide Emissions in 2008: ~38 Million metric tons

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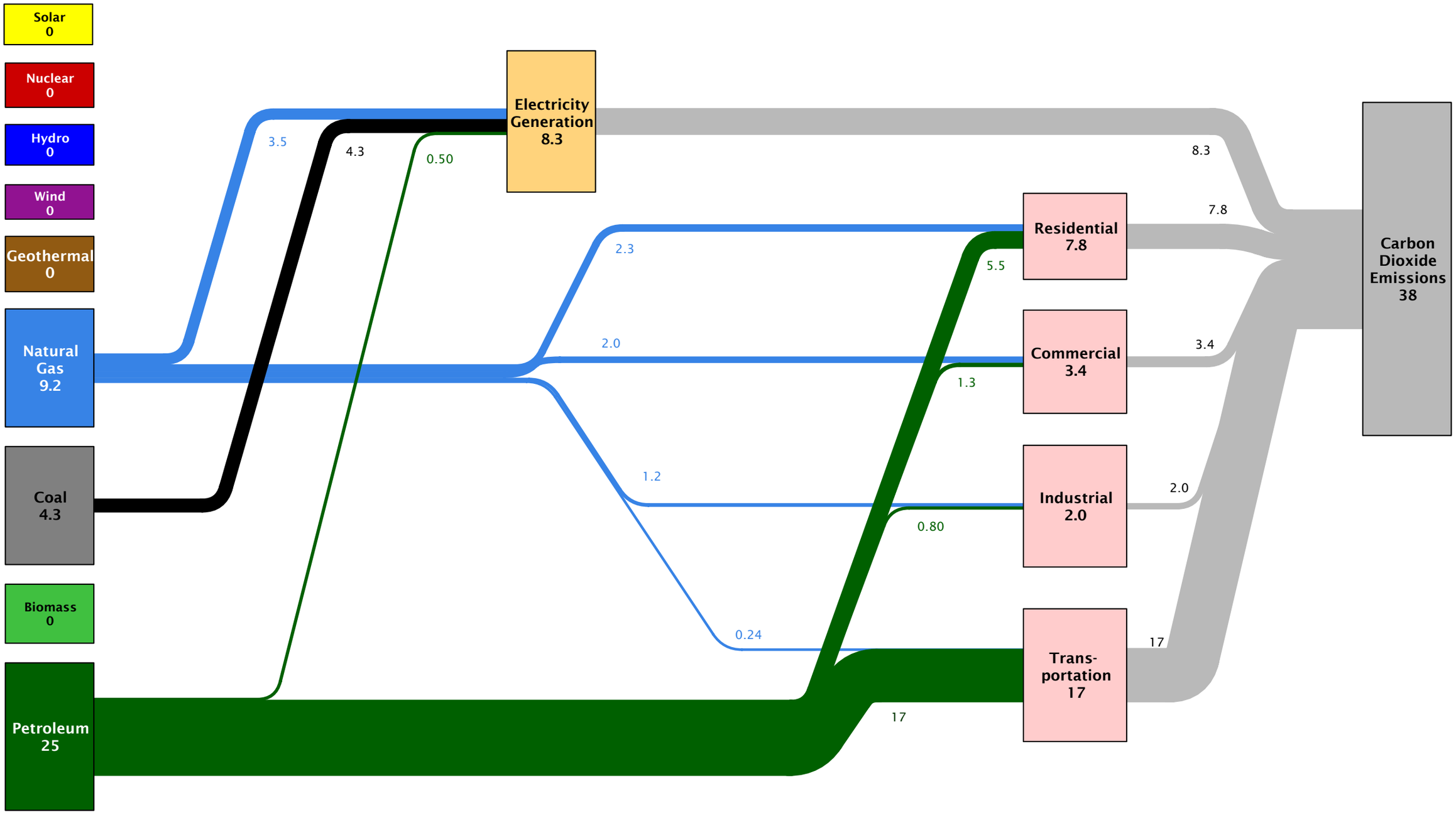

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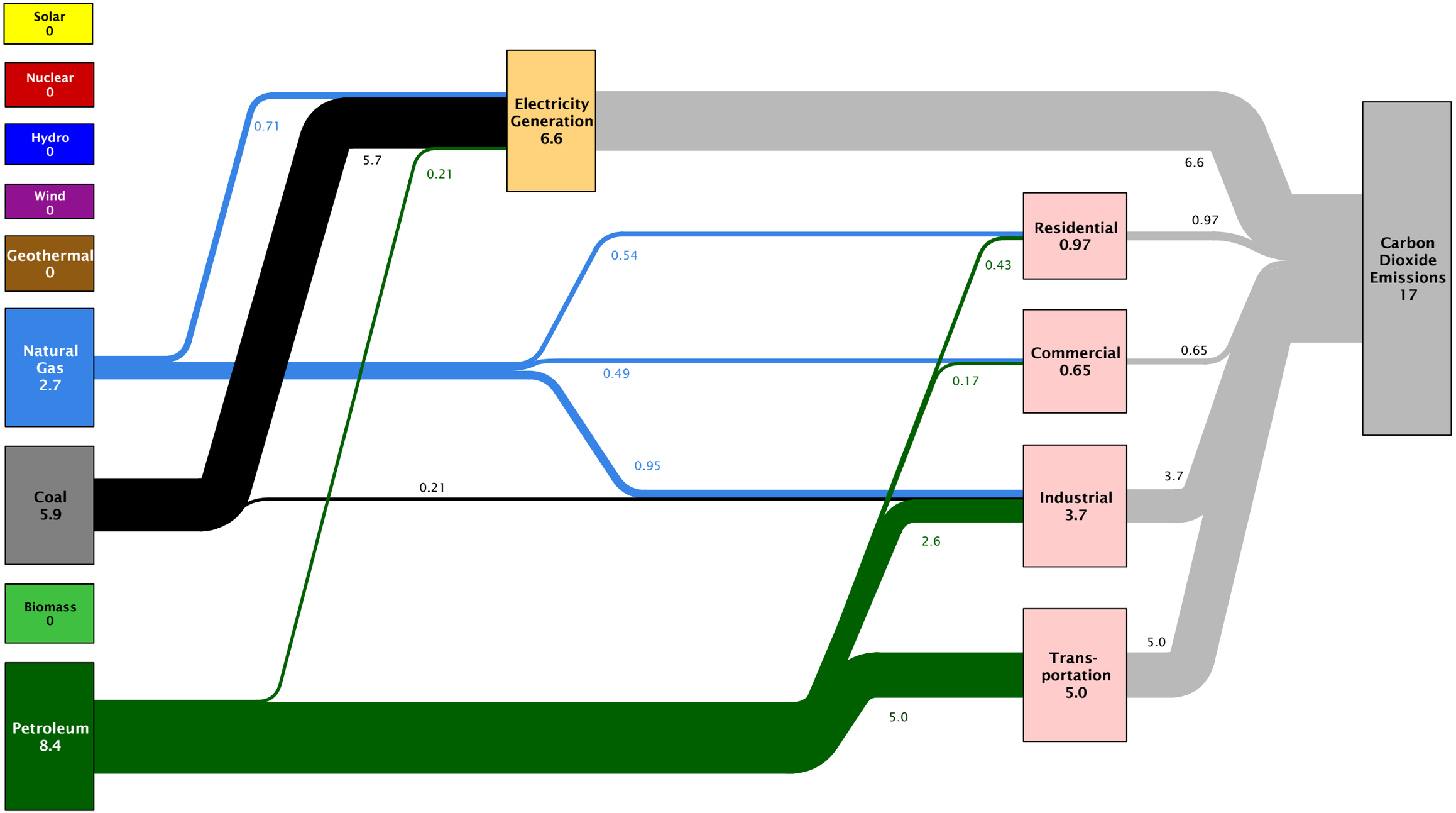
Estimated Delaware Carbon Dioxide Emissions in 2008: ~17 Million metric tons

Lawrence Livermore National Laboratory



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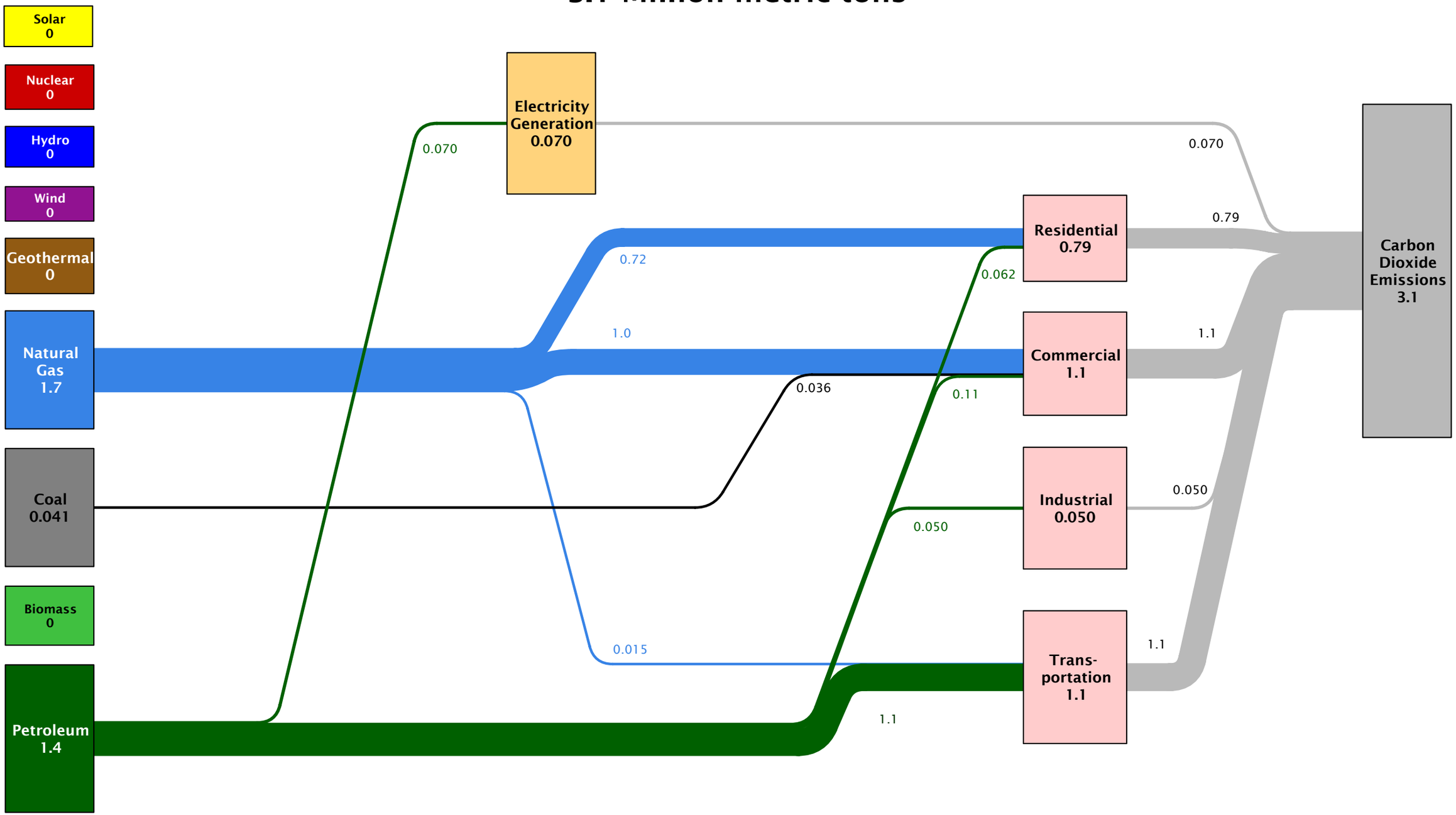
Estimated District of Columbia Carbon Dioxide Emissions in 2008: ~3.1 Million metric tons

Lawrence Livermore National Laboratory



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Estimated Florida Carbon Dioxide Emissions in 2008: ~240 Million metric tons

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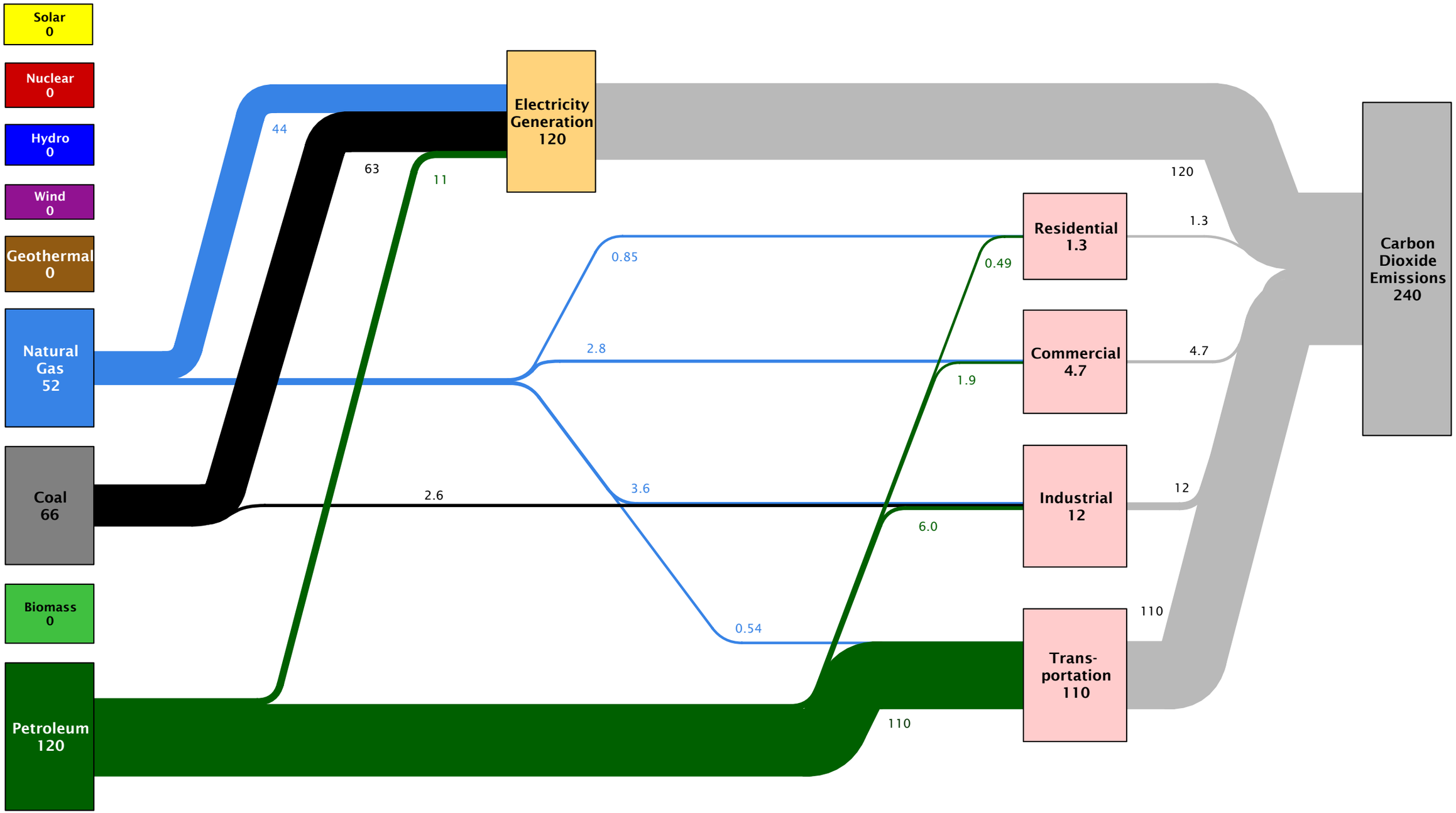

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Estimated Georgia Carbon Dioxide Emissions in 2008: ~180 Million metric tons

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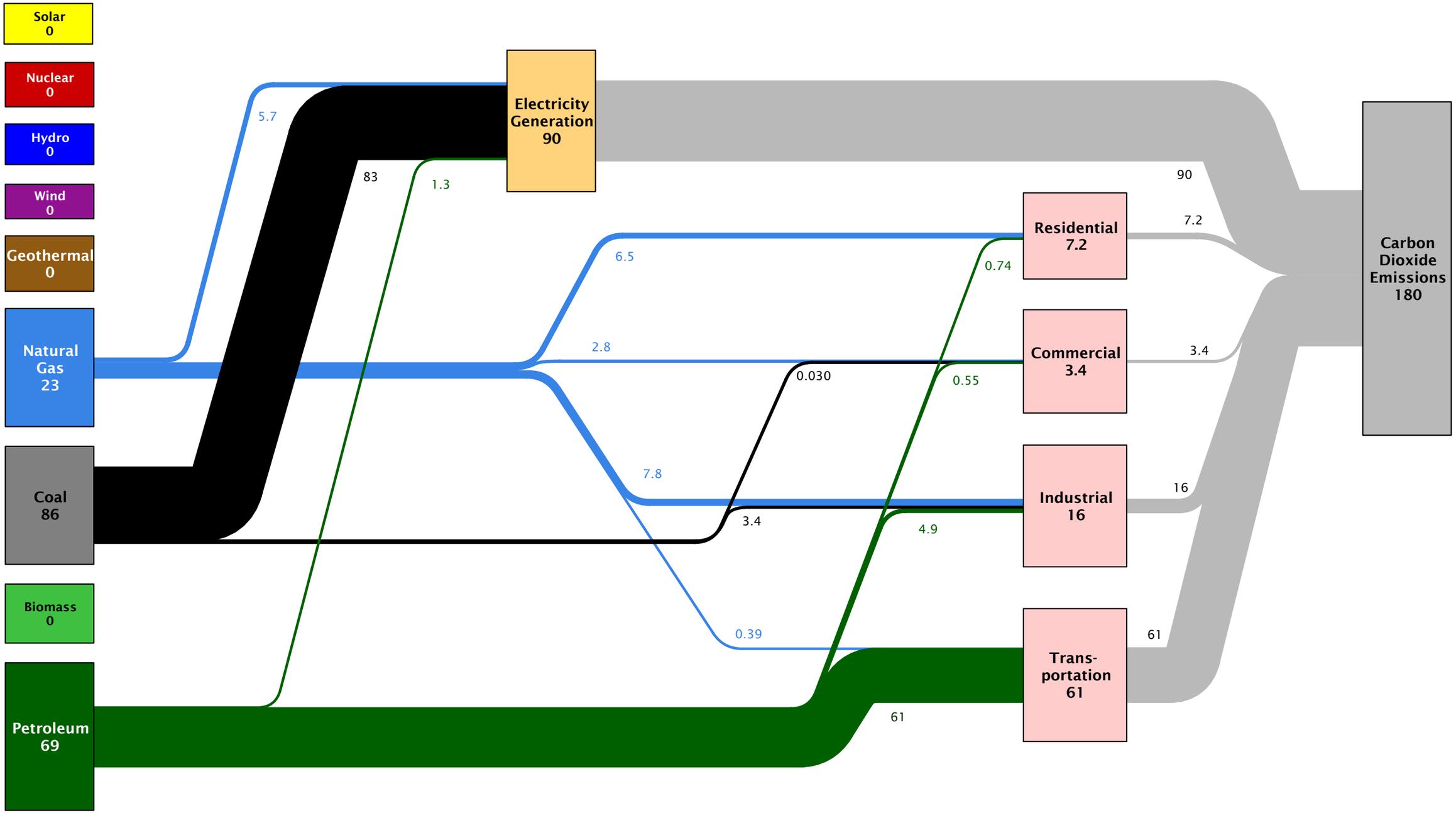

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Estimated Hawaii Carbon Dioxide Emissions in 2008: ~21 Million metric tons

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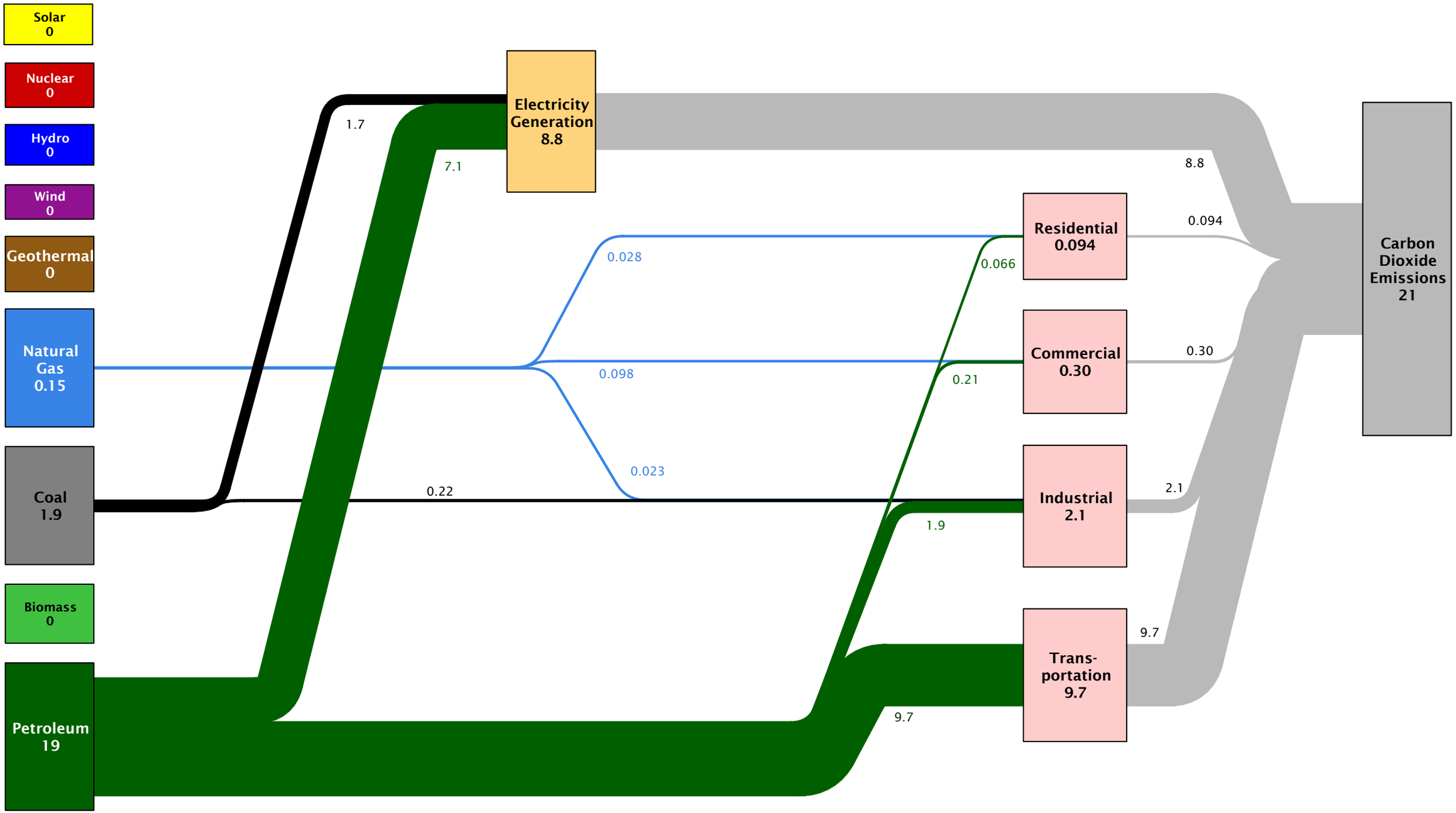

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Estimated Idaho Carbon Dioxide Emissions in 2008: ~16 Million metric tons

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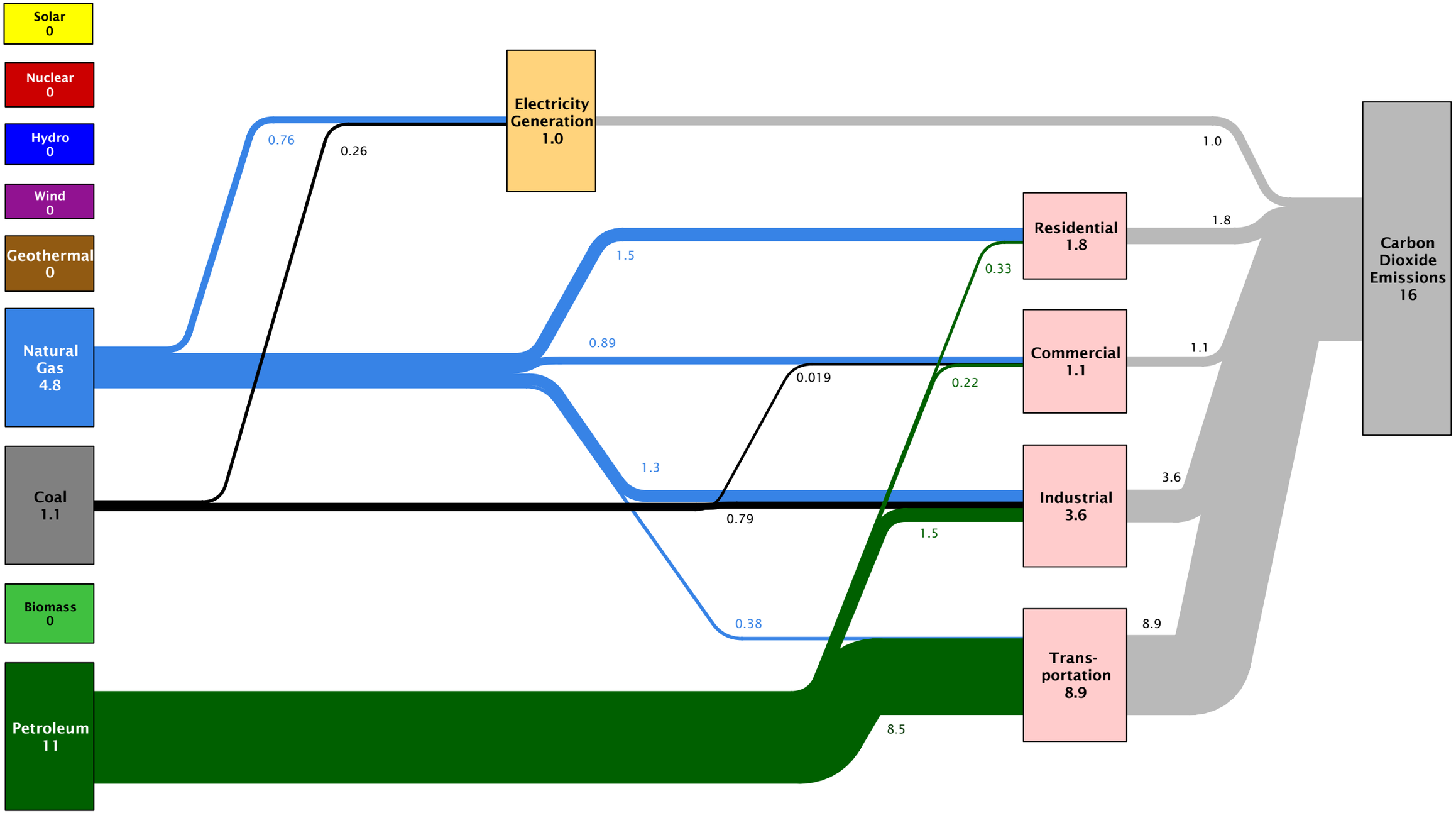

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Estimated Illinois Carbon Dioxide Emissions in 2008: ~250 Million metric tons

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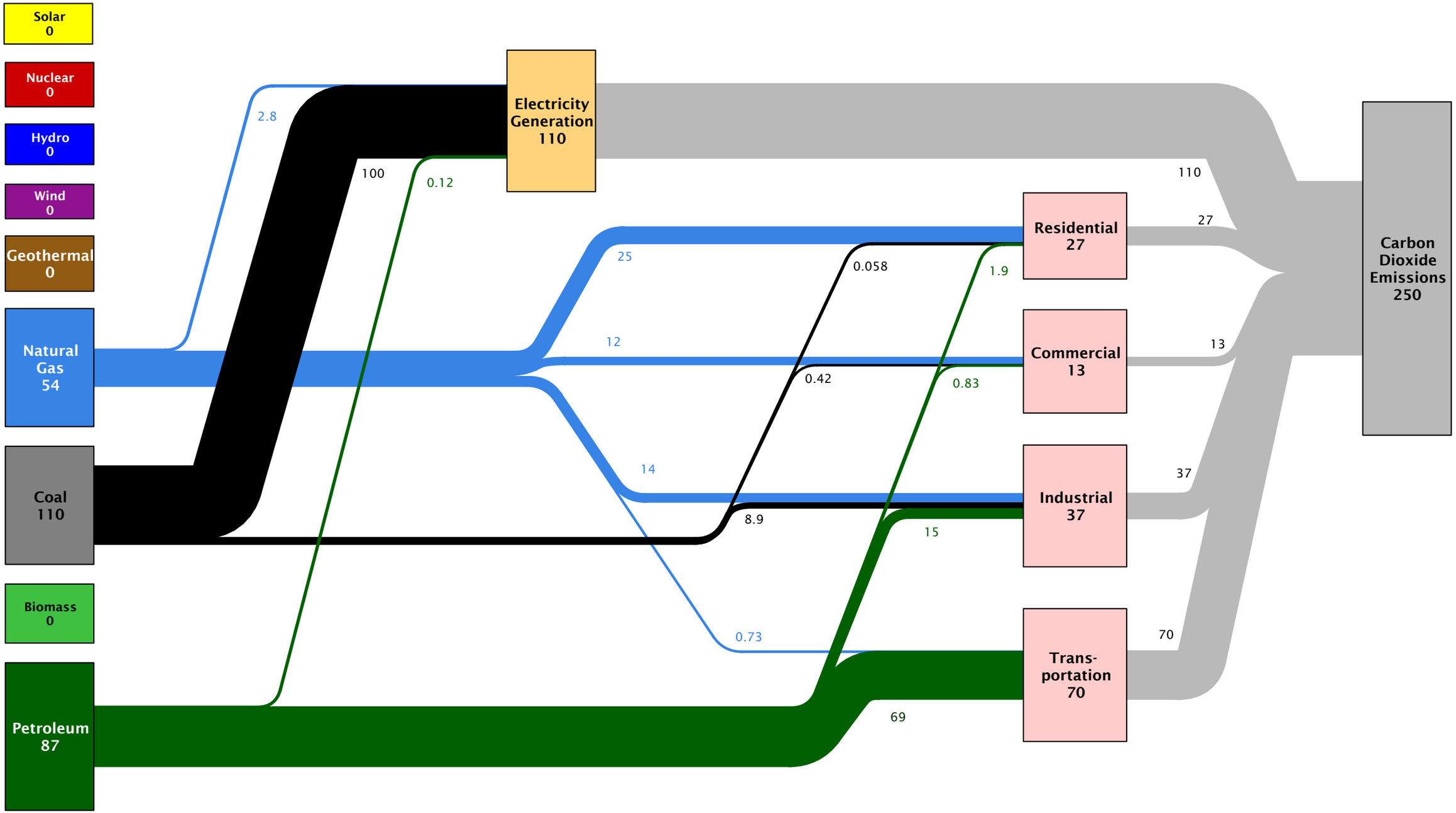

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Estimated Indiana Carbon Dioxide Emissions in 2008: ~230 Million metric tons

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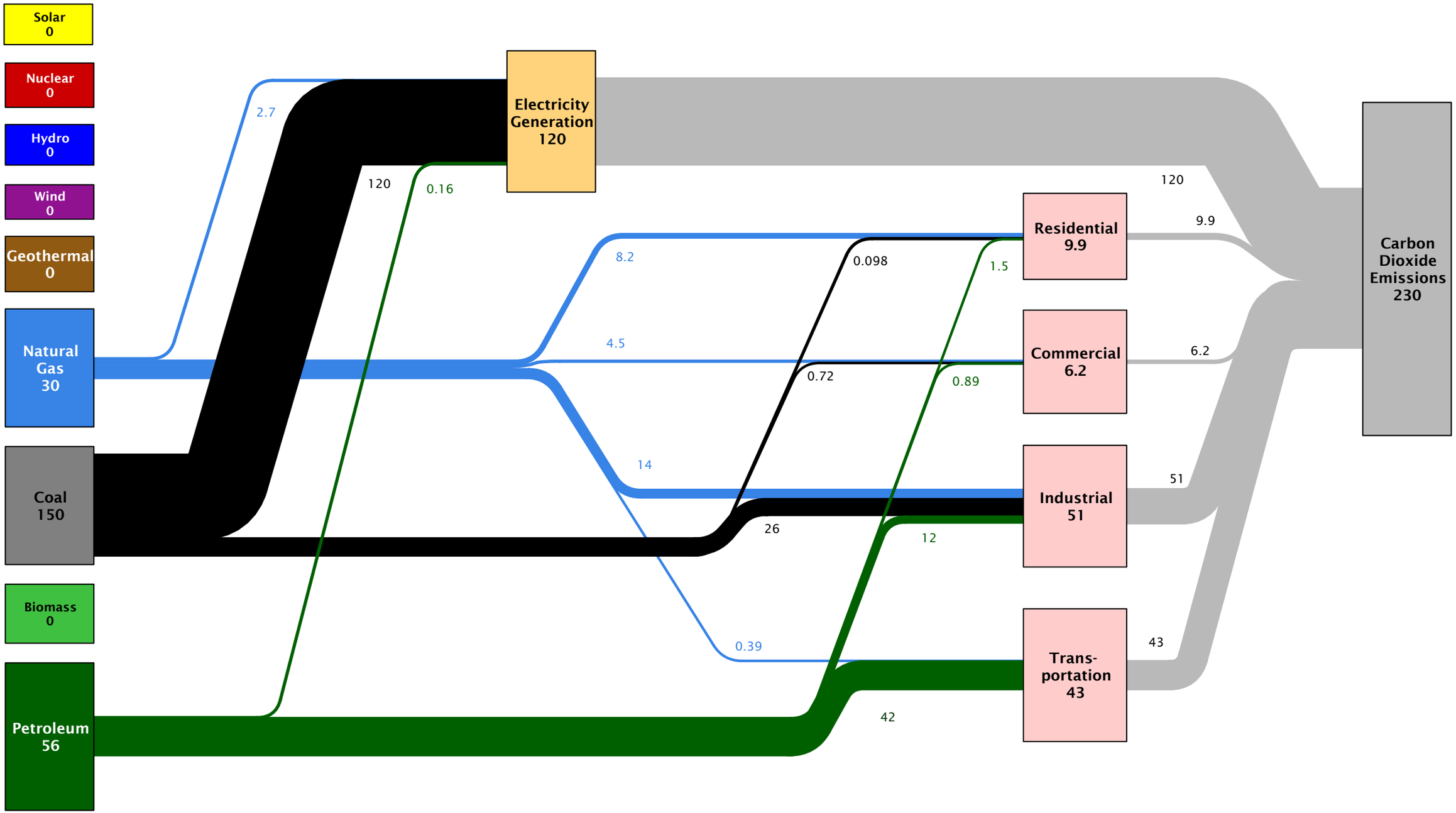

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Estimated Iowa Carbon Dioxide Emissions in 2008: ~95 Million metric tons

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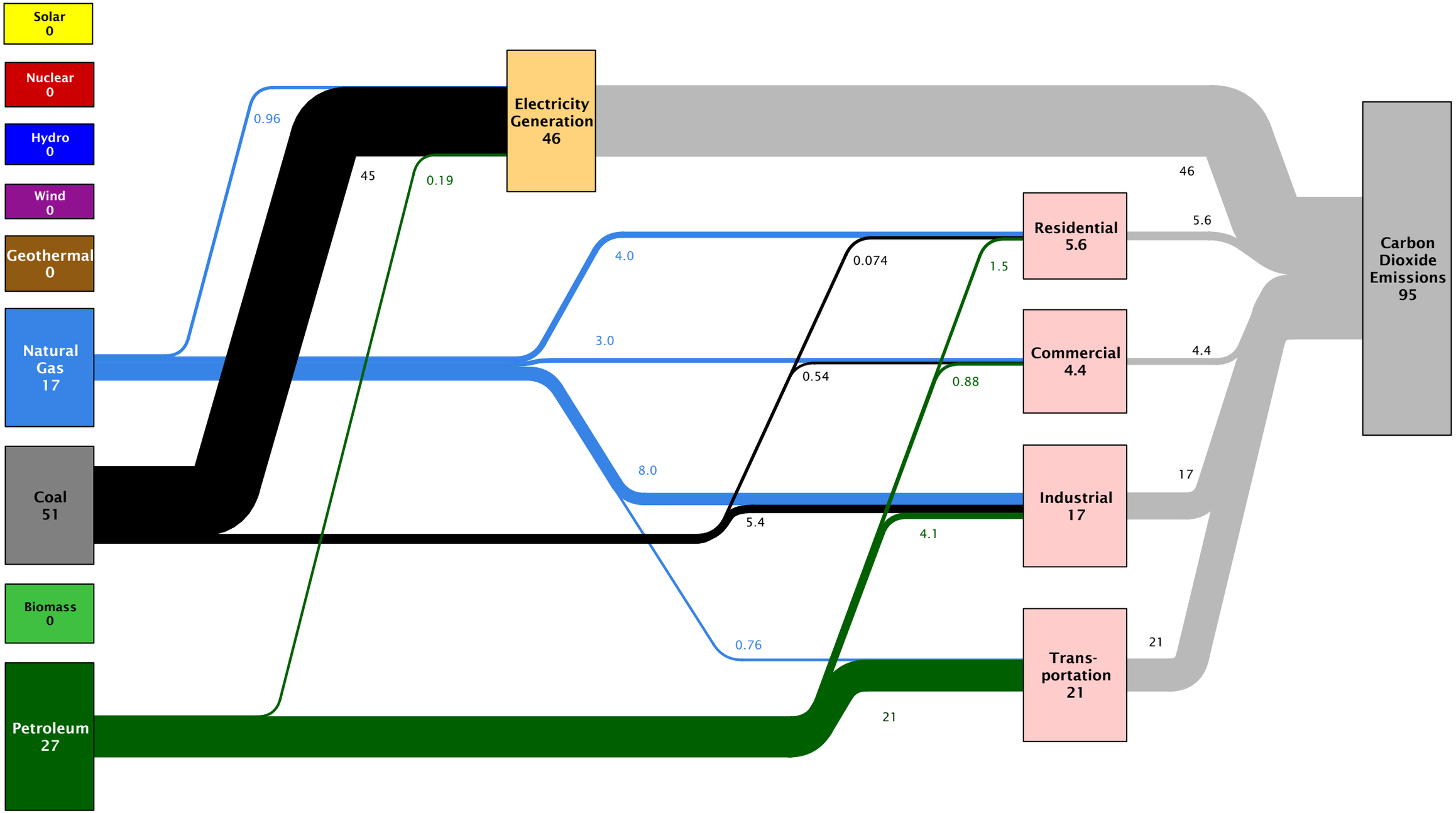

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Estimated Kansas Carbon Dioxide Emissions in 2008: ~78 Million metric tons

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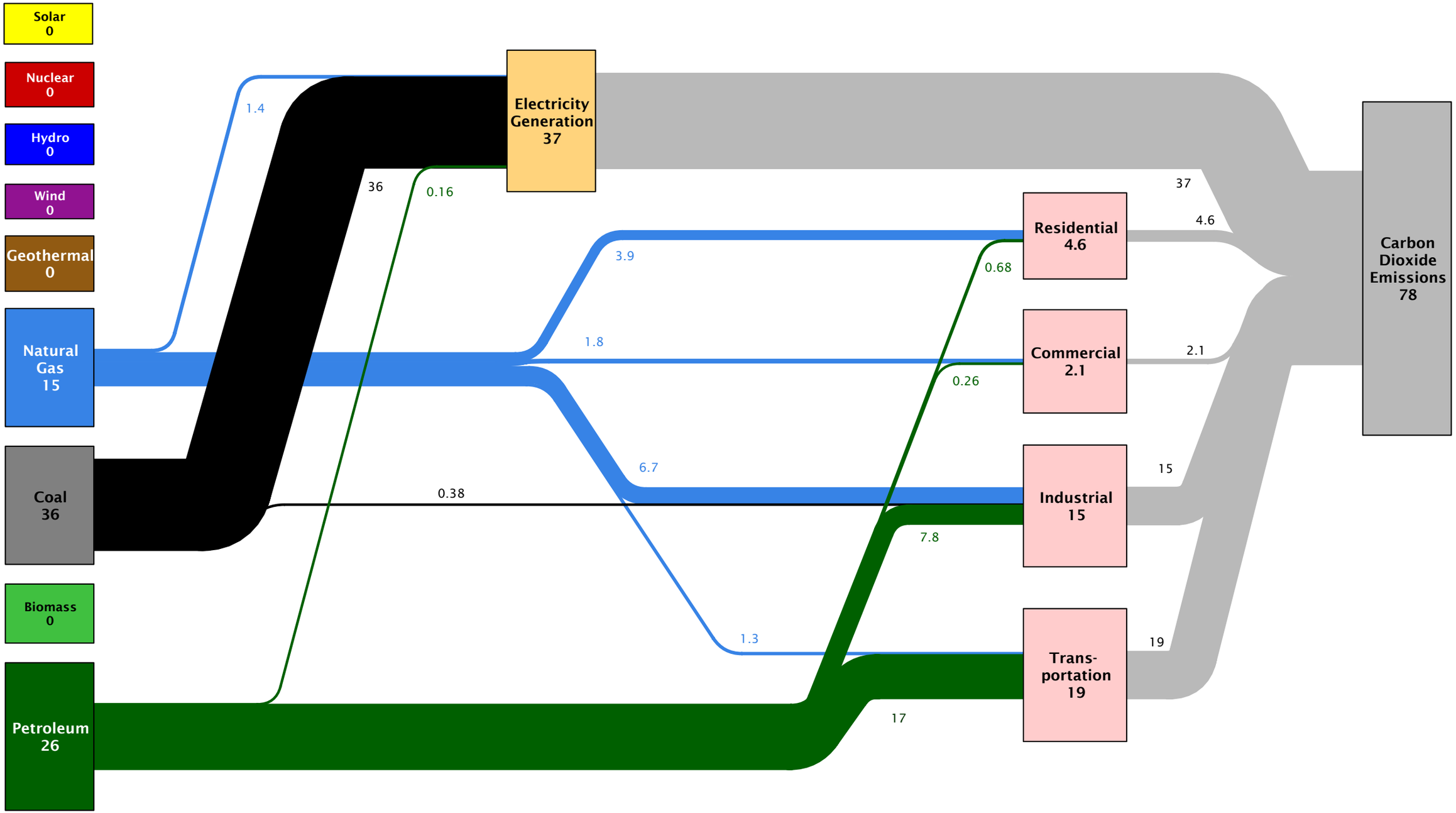

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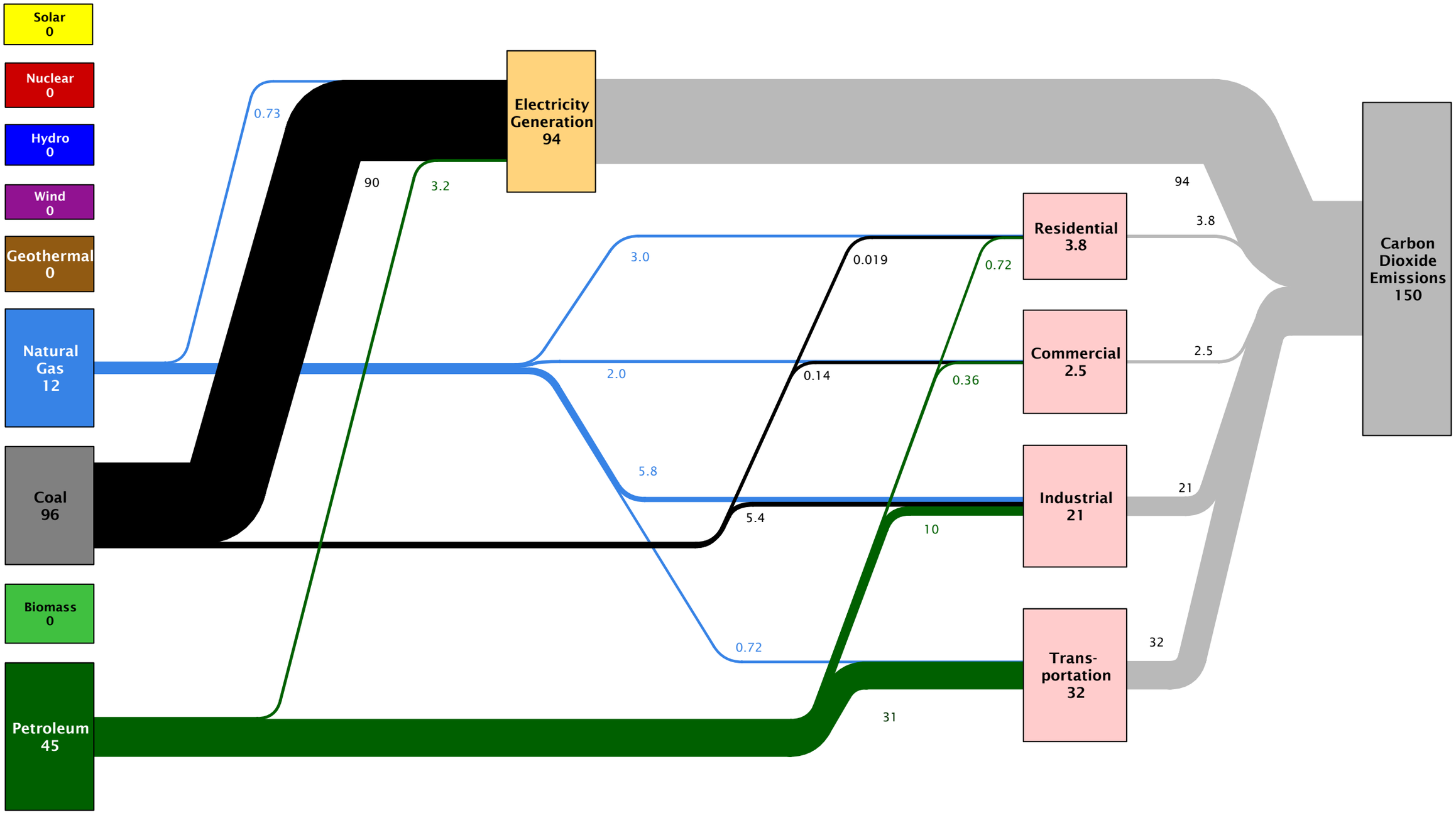
Estimated Kentucky Carbon Dioxide Emissions in 2008: ~150 Million metric tons

Lawrence Livermore National Laboratory



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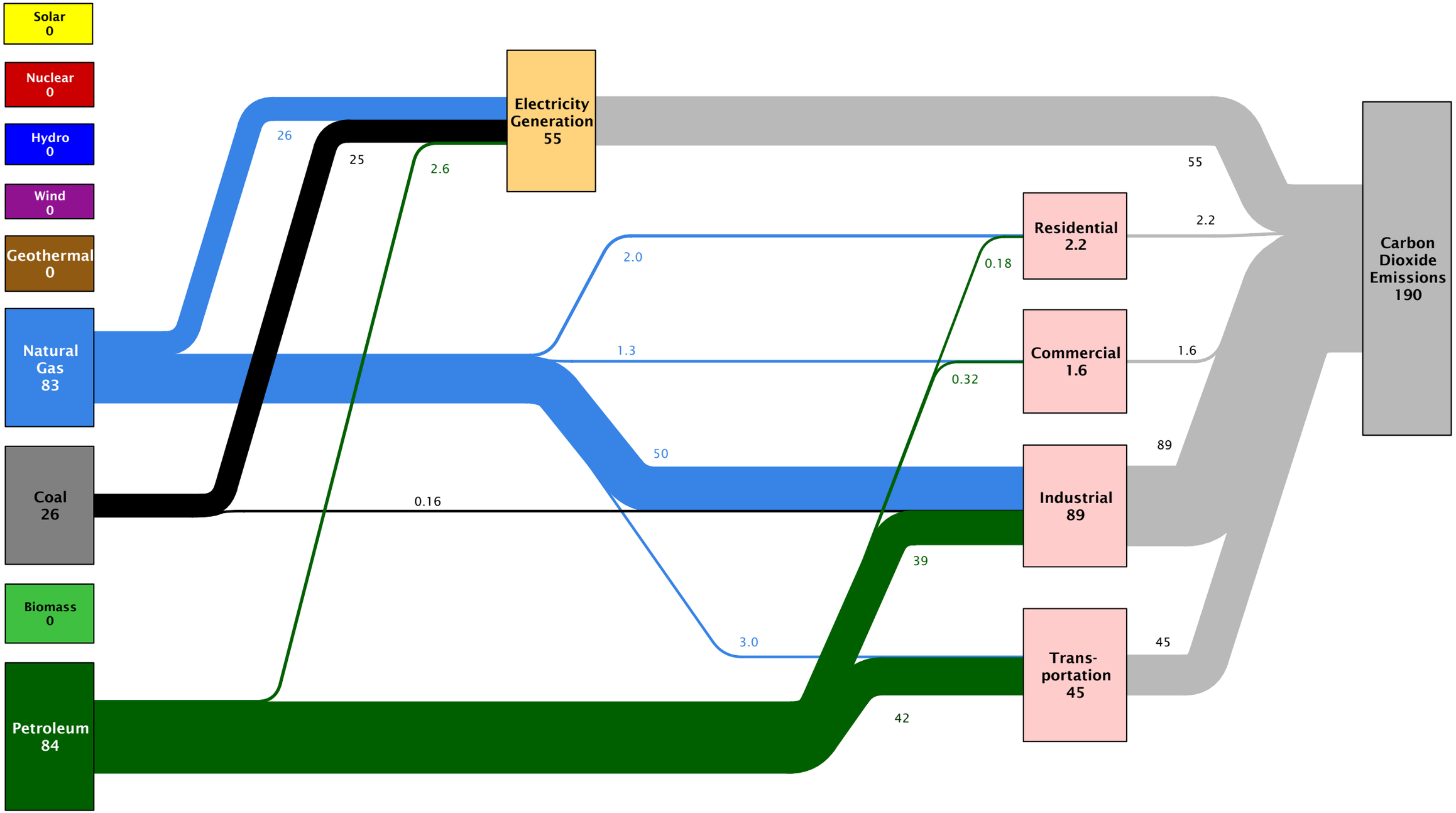
Estimated Louisiana Carbon Dioxide Emissions in 2008: ~190 Million metric tons

Lawrence Livermore National Laboratory



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Estimated Maine Carbon Dioxide Emissions in 2008: ~21 Million metric tons

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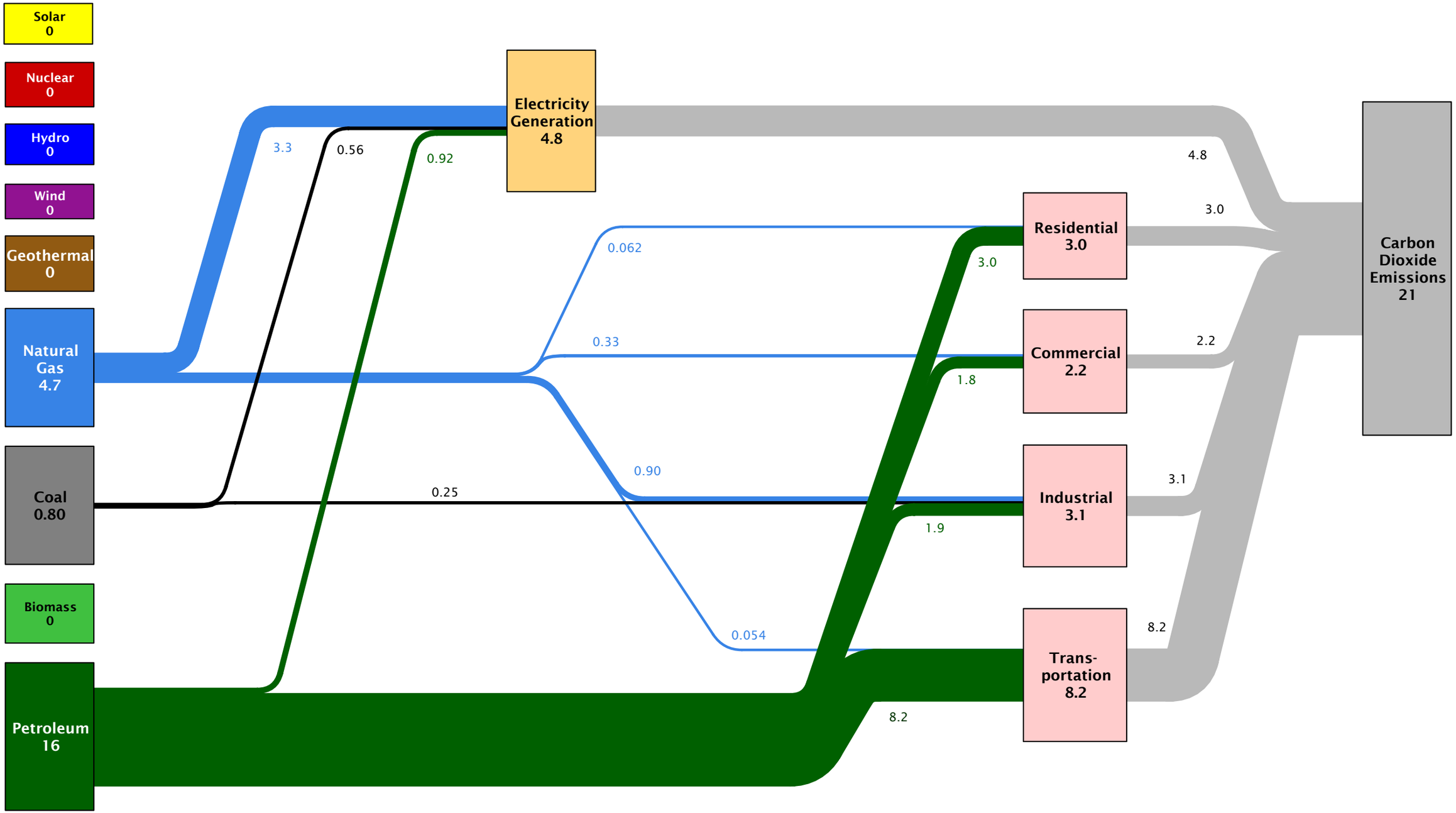

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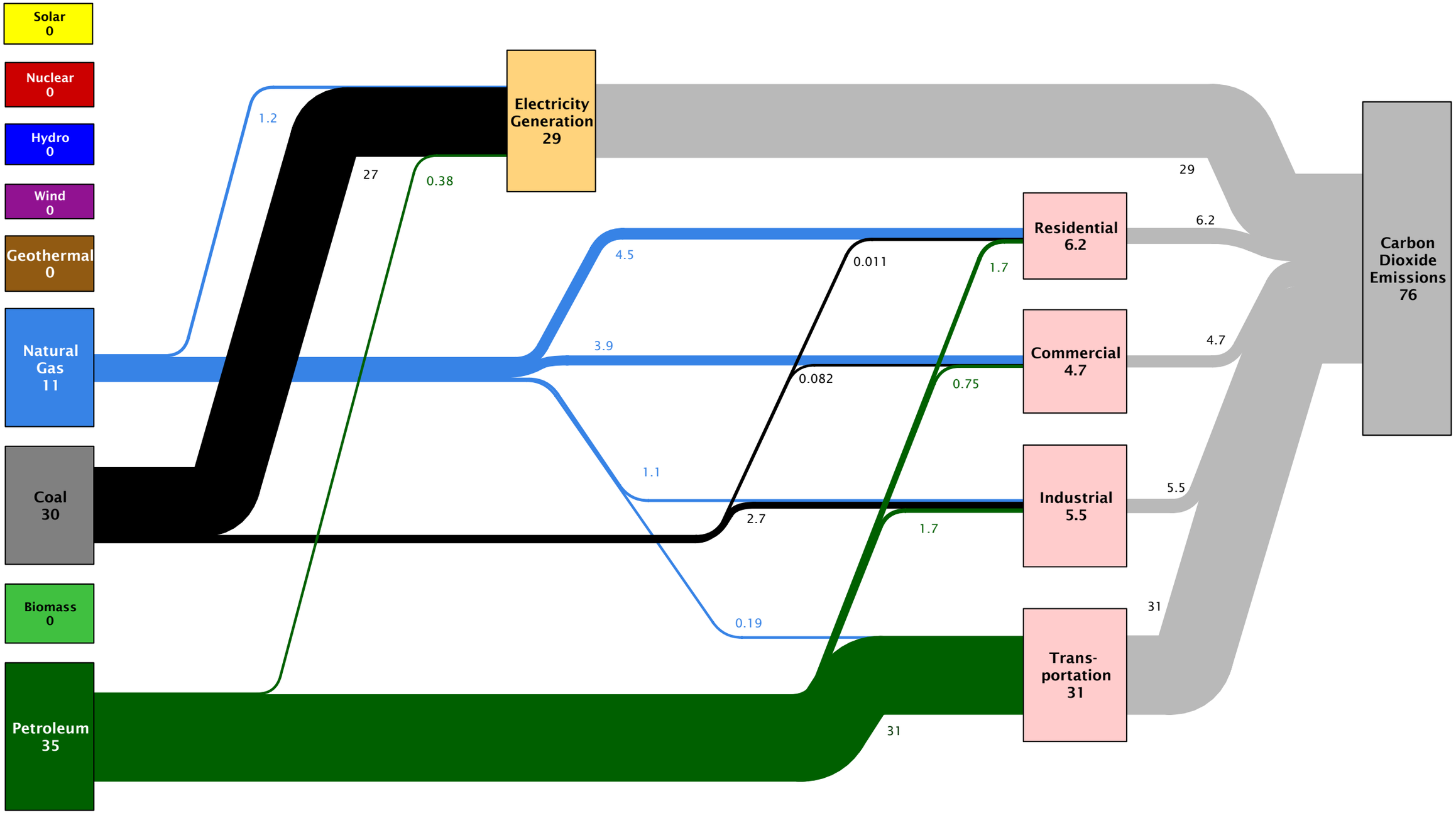
Estimated Maryland Carbon Dioxide Emissions in 2008: ~76 Million metric tons

Lawrence Livermore National Laboratory



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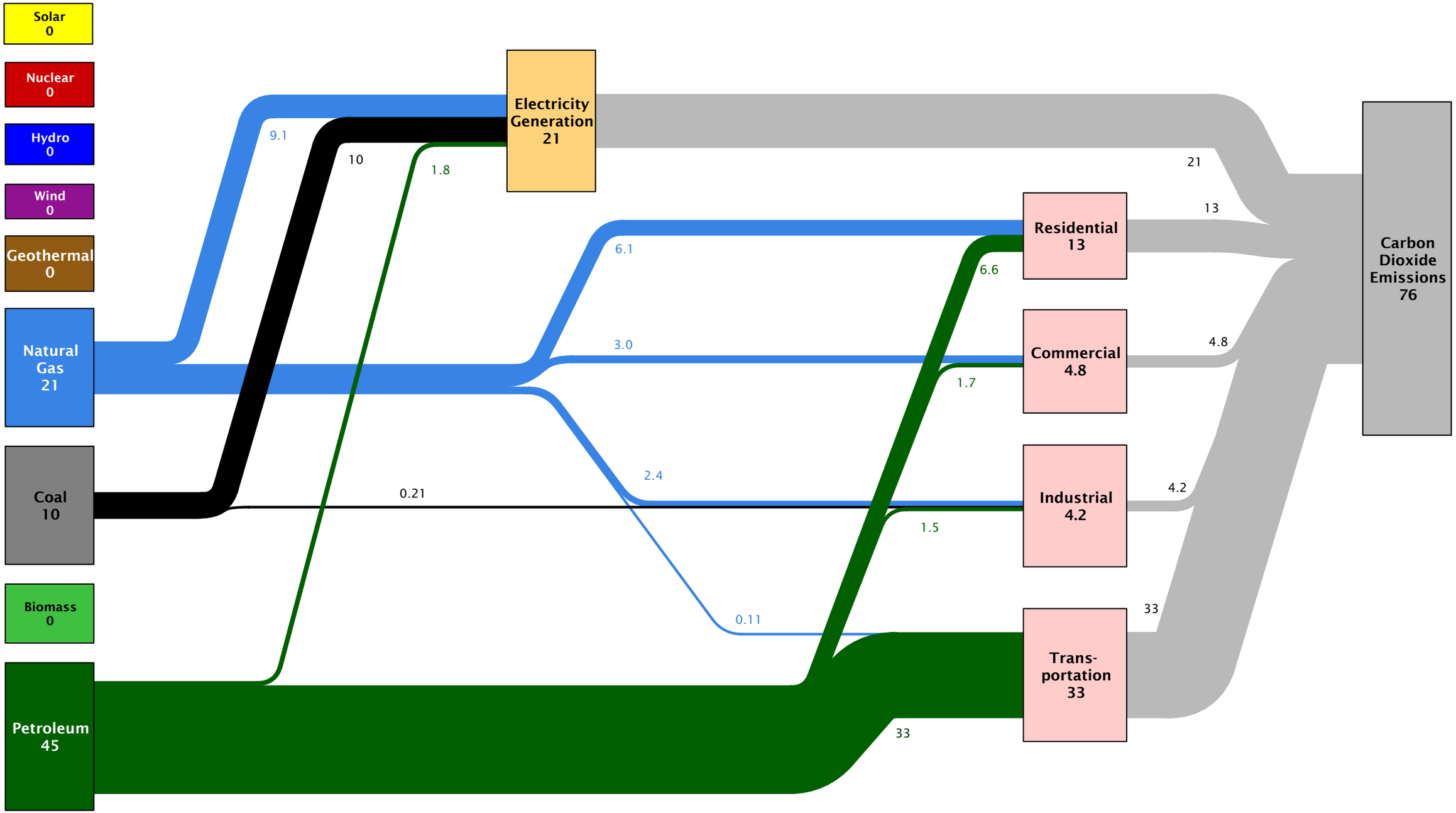
Estimated Massachusetts Carbon Dioxide Emissions in 2008: ~76 Million metric tons

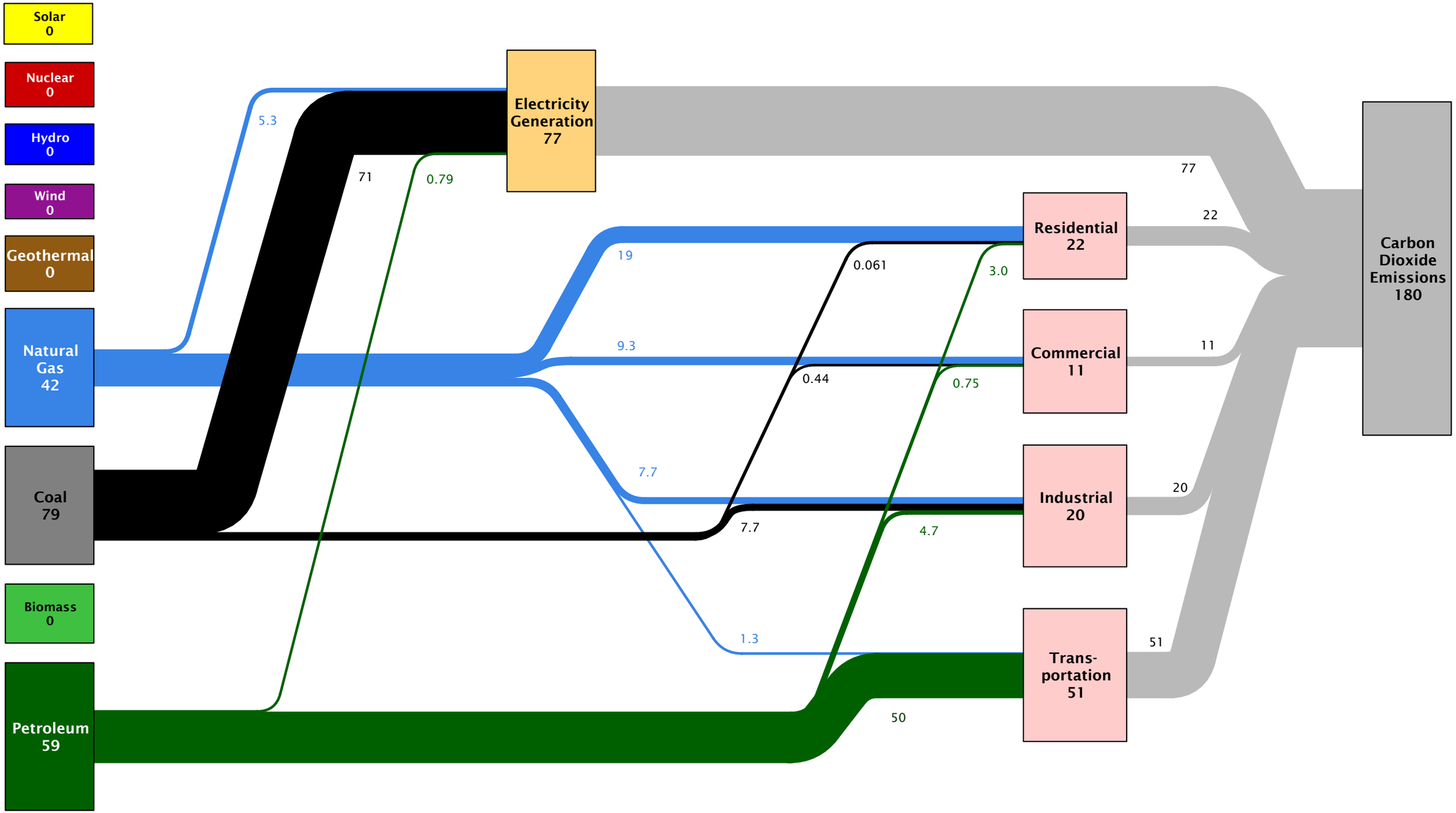
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Michigan Carbon Dioxide Emissions in 2008: ~180 Million metric tons

Lawrence Livermore National Laboratory



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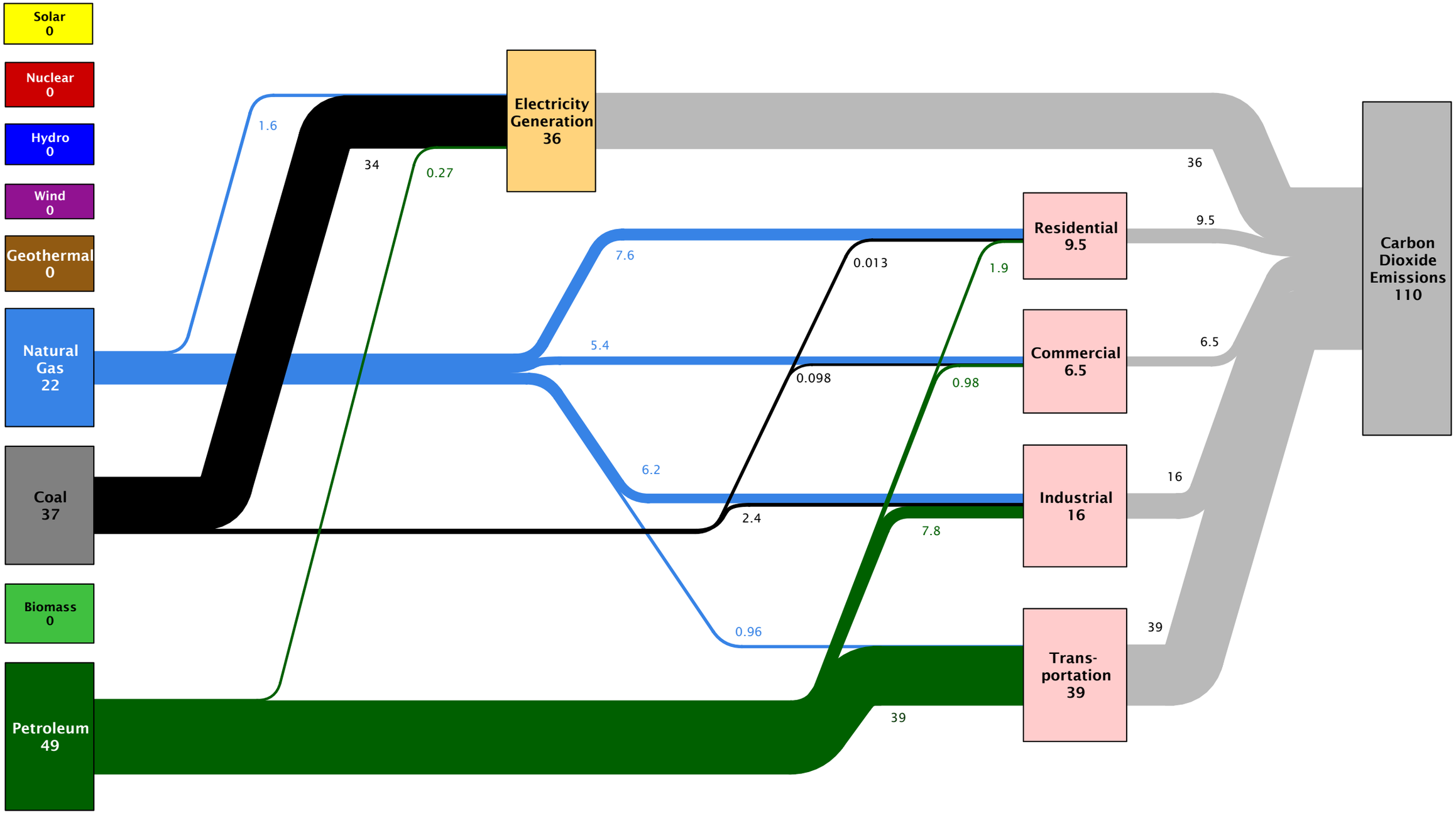
Estimated Minnesota Carbon Dioxide Emissions in 2008: ~110 Million metric tons

Lawrence Livermore National Laboratory



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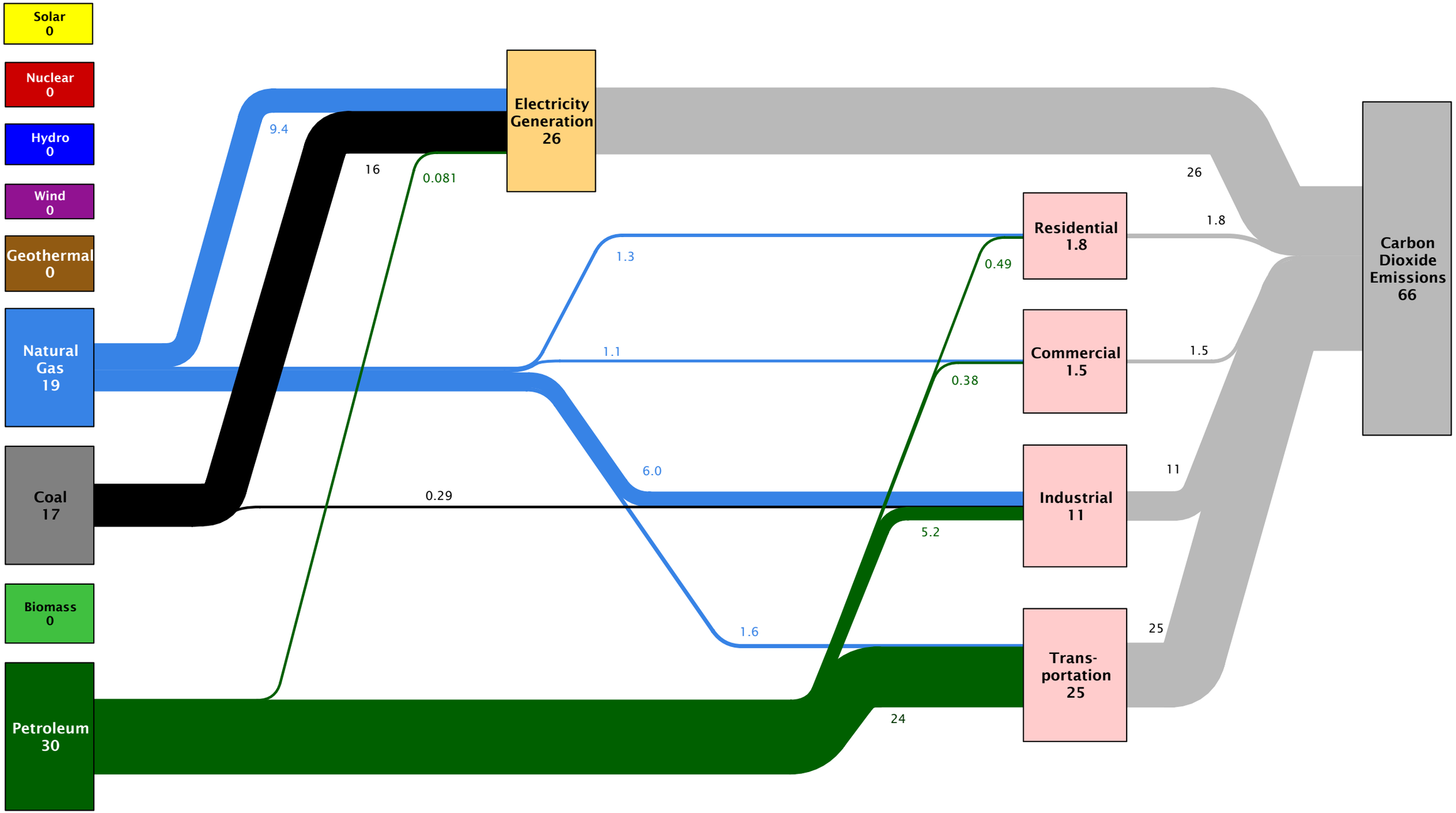
Estimated Mississippi Carbon Dioxide Emissions in 2008: ~66 Million metric tons

Lawrence Livermore National Laboratory



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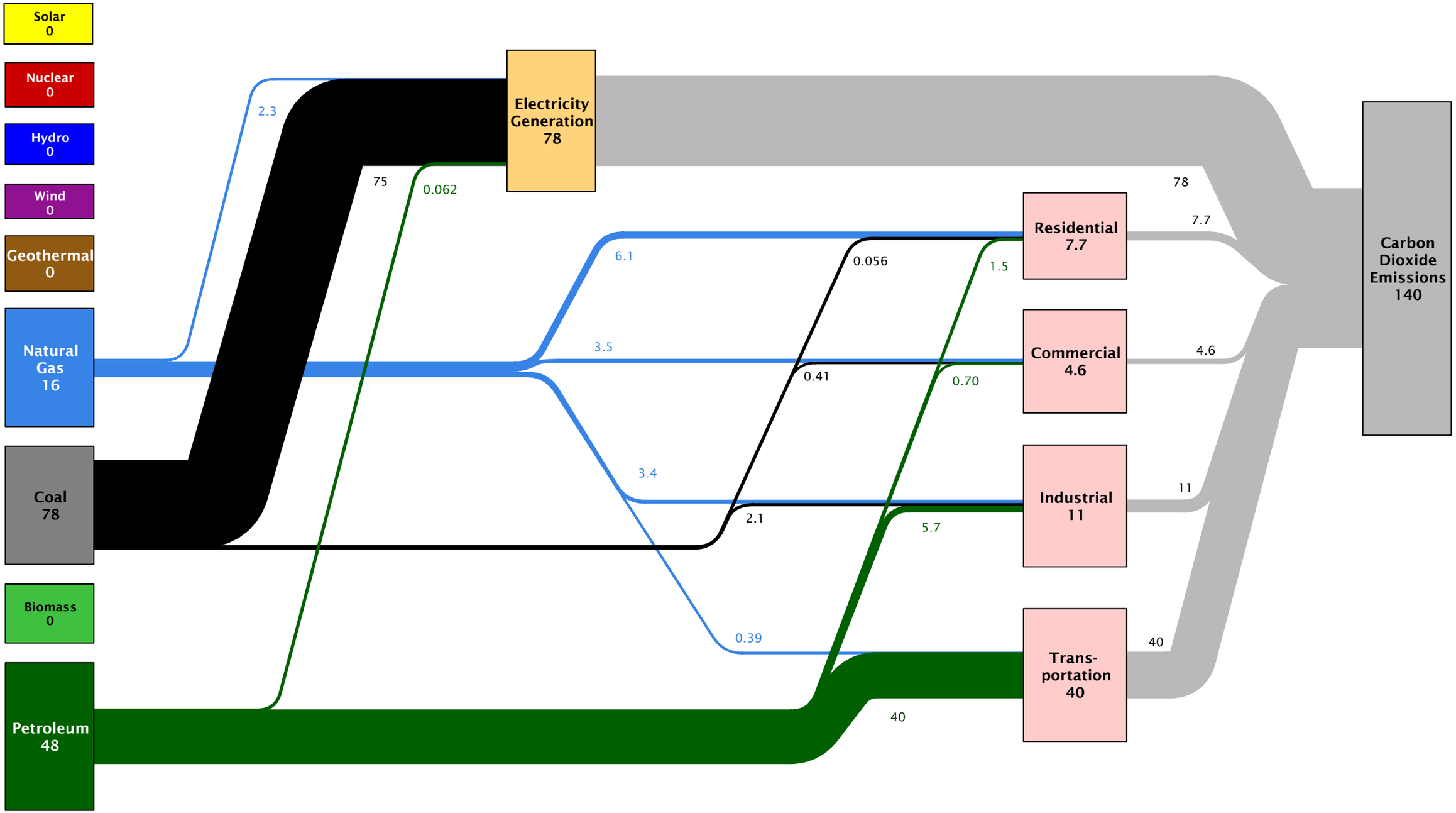
Estimated Missouri Carbon Dioxide Emissions in 2008: ~140 Million metric tons

Lawrence Livermore National Laboratory



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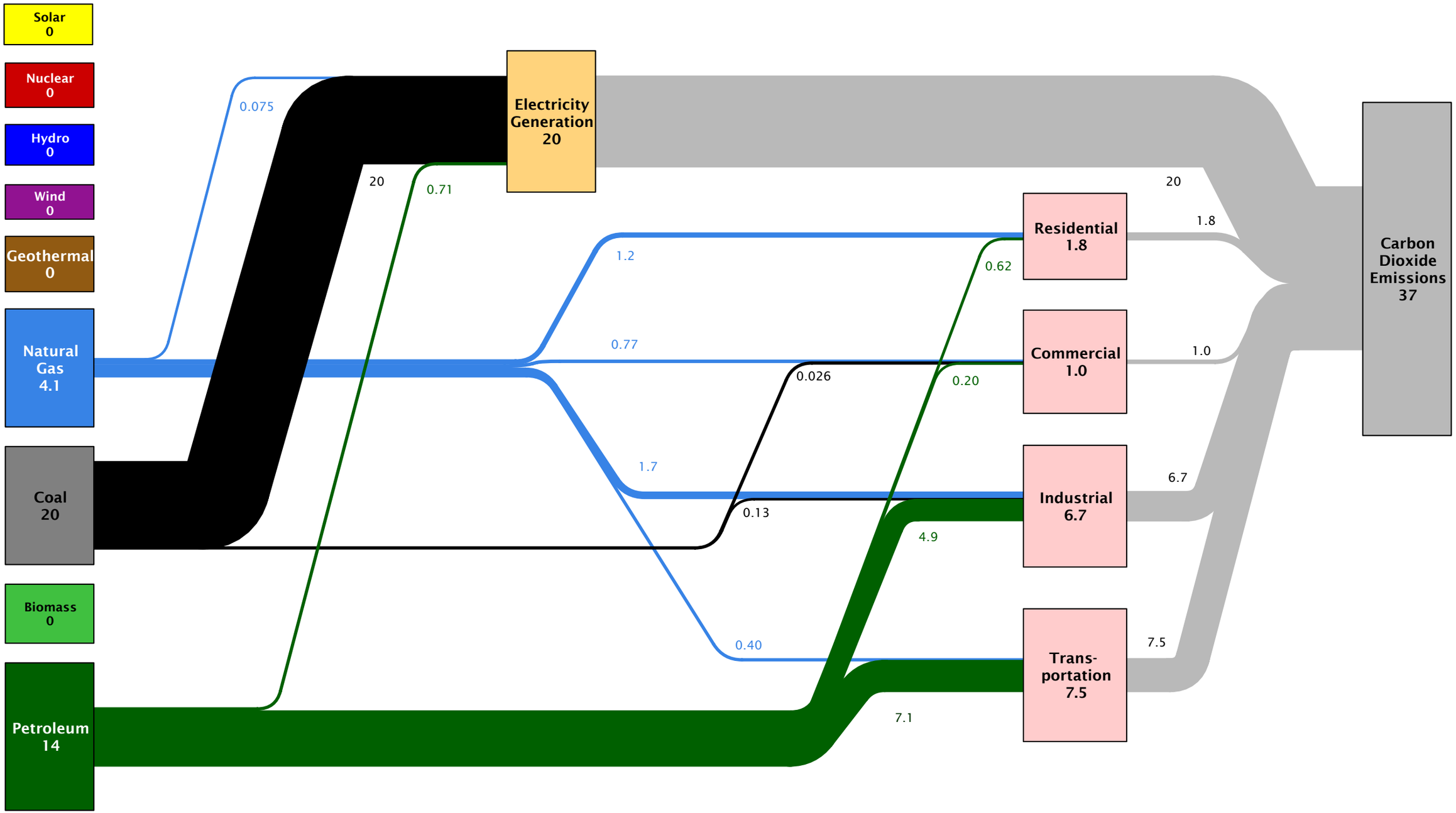
Estimated Montana Carbon Dioxide Emissions in 2008: ~37 Million metric tons

Lawrence Livermore National Laboratory



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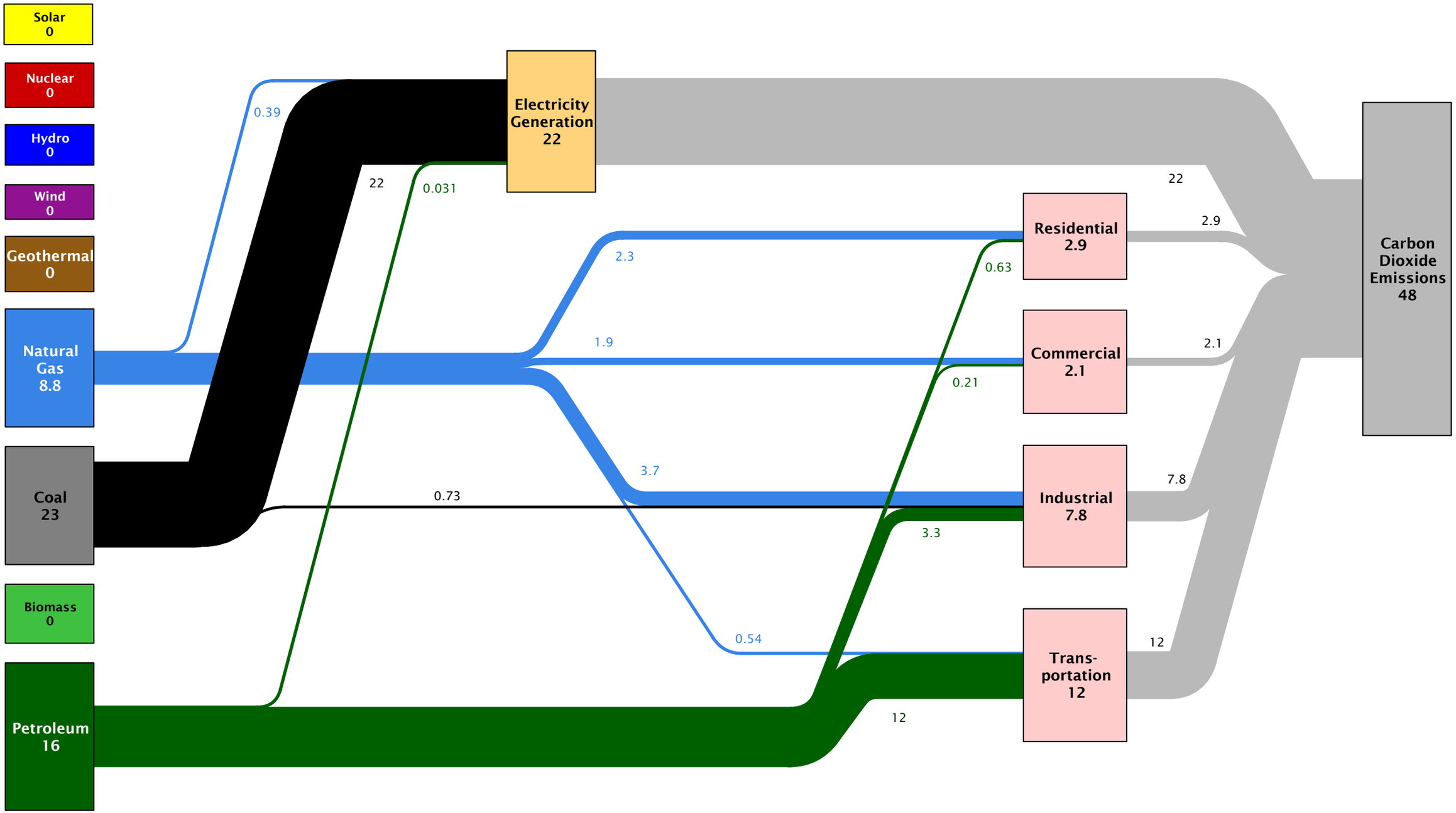
Estimated Nebraska Carbon Dioxide Emissions in 2008: ~48 Million metric tons

Lawrence Livermore National Laboratory



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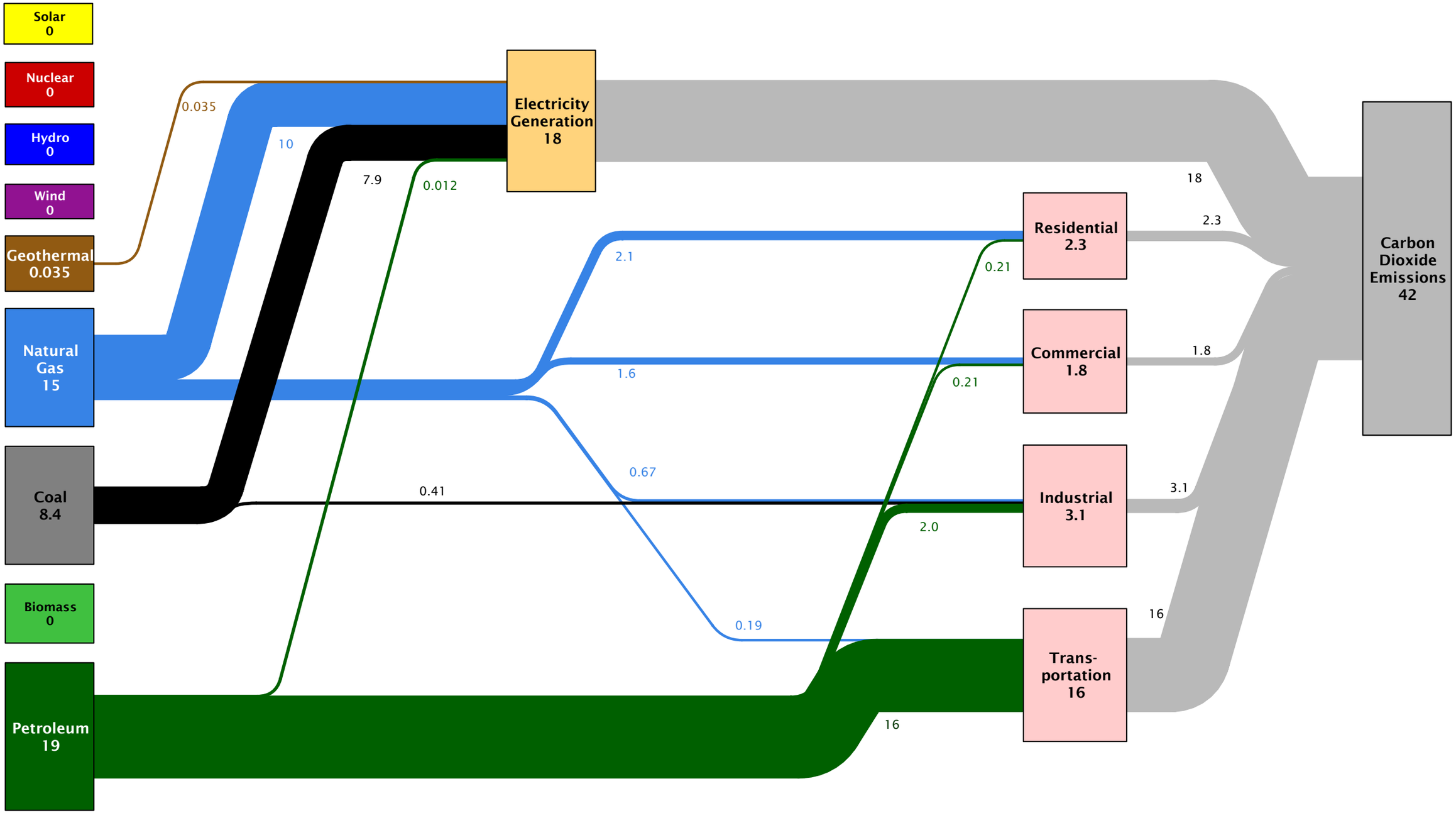
Estimated Nevada Carbon Dioxide Emissions in 2008: ~42 Million metric tons

Lawrence Livermore National Laboratory



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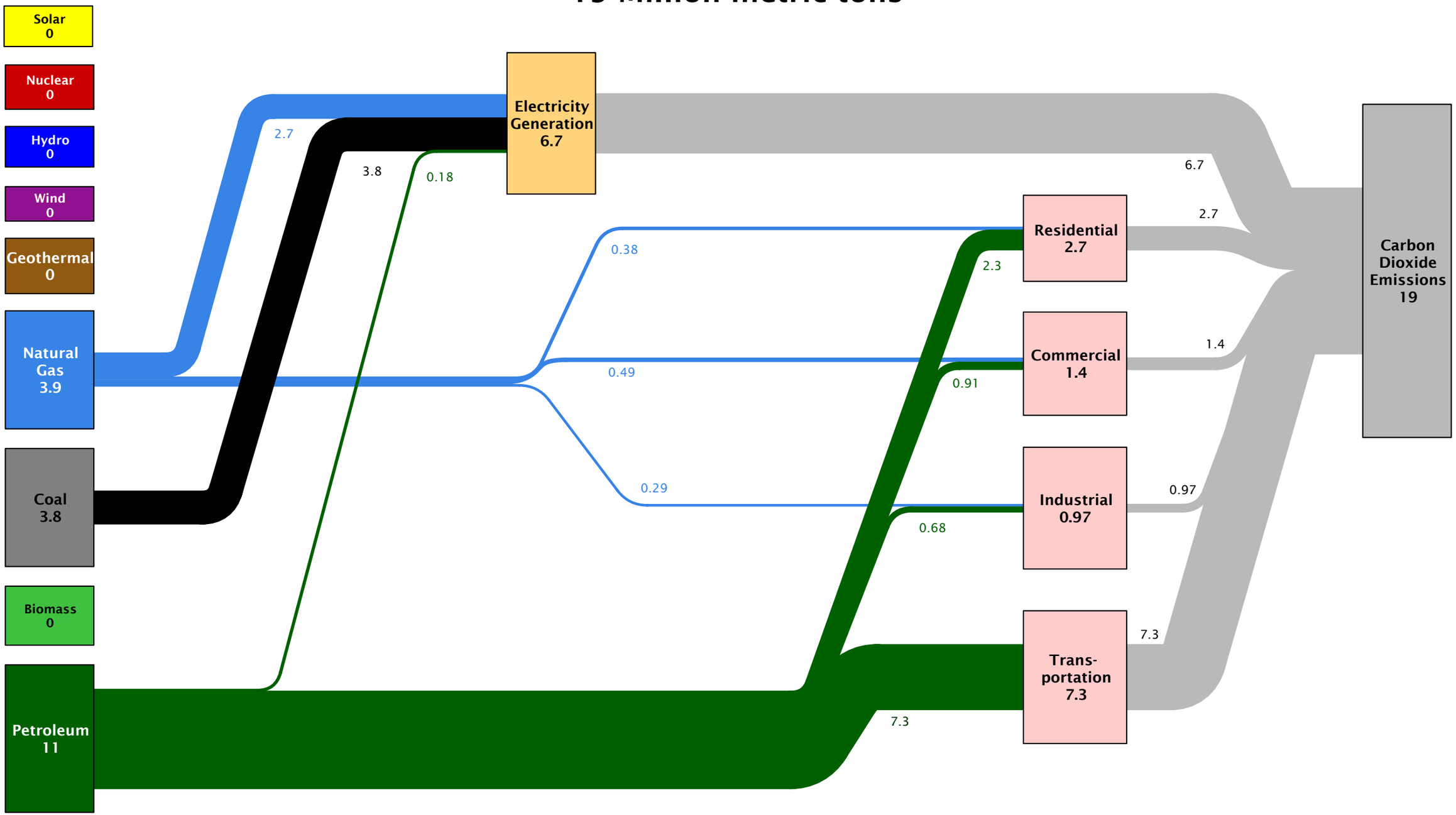
Estimated New Hampshire Carbon Dioxide Emissions in 2008: ~19 Million metric tons

Lawrence Livermore National Laboratory



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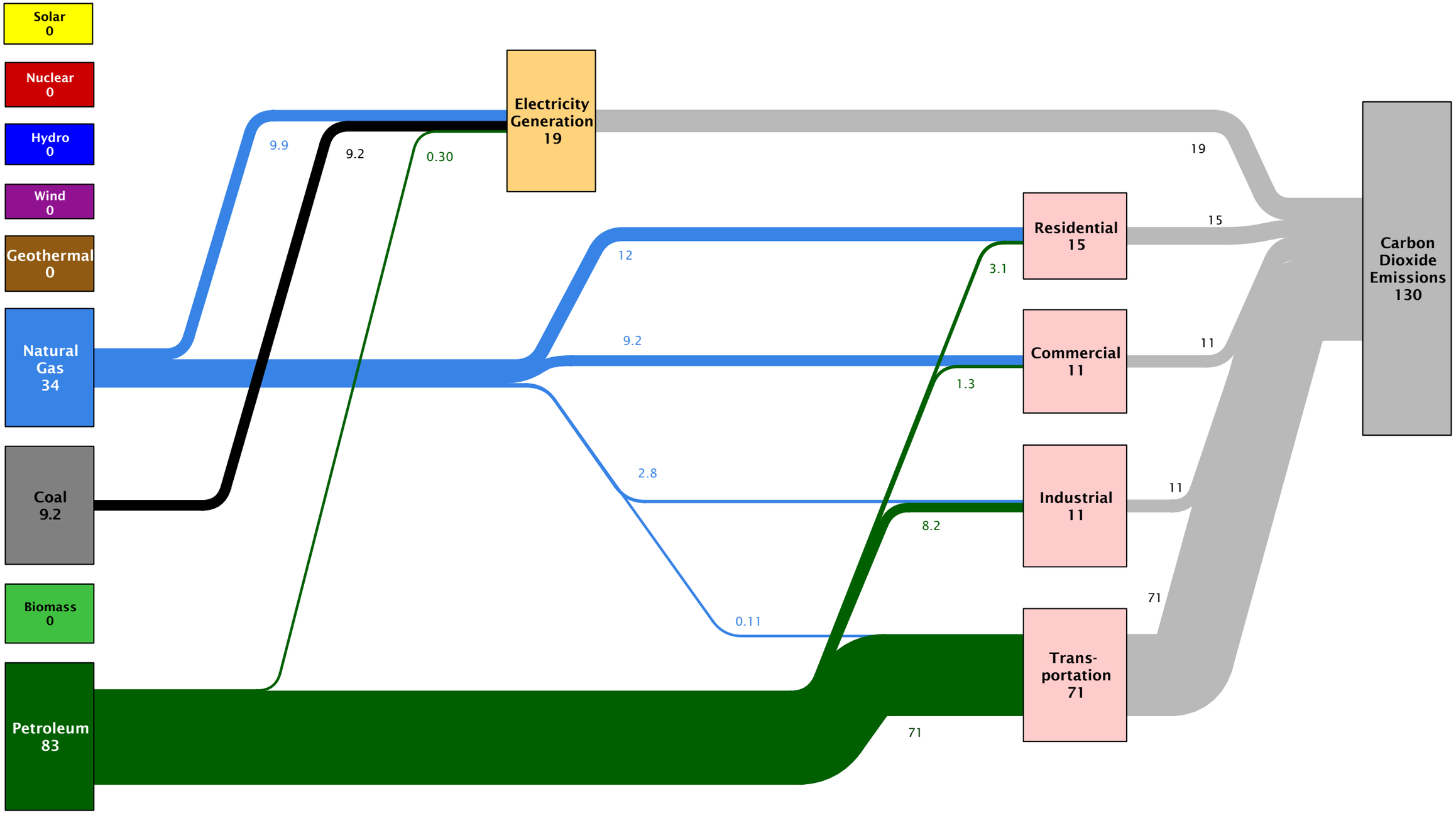
Estimated New Jersey Carbon Dioxide Emissions in 2008: ~130 Million metric tons

Lawrence Livermore National Laboratory



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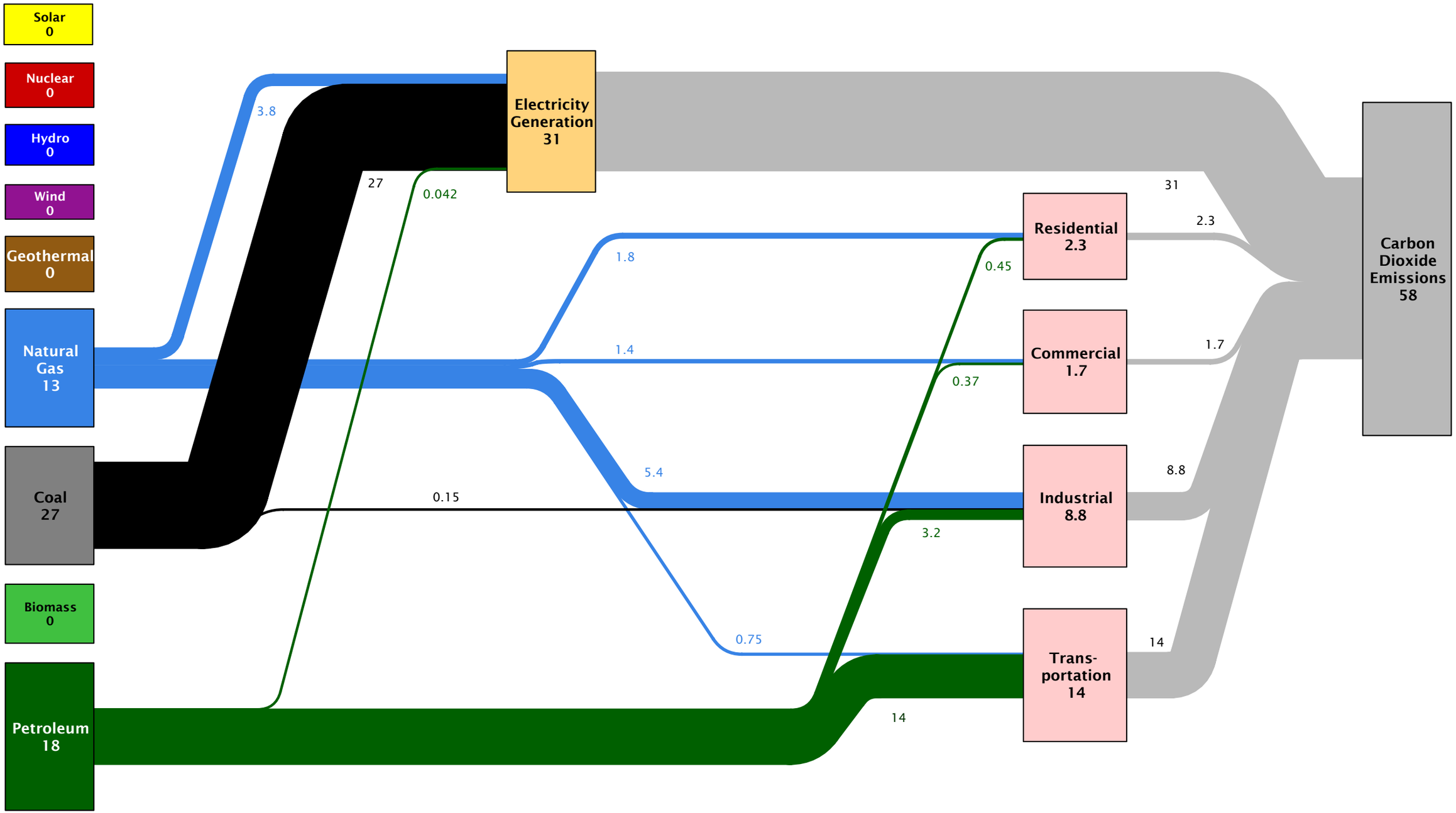
Estimated New Mexico Carbon Dioxide Emissions in 2008: ~58 Million metric tons

Lawrence Livermore National Laboratory



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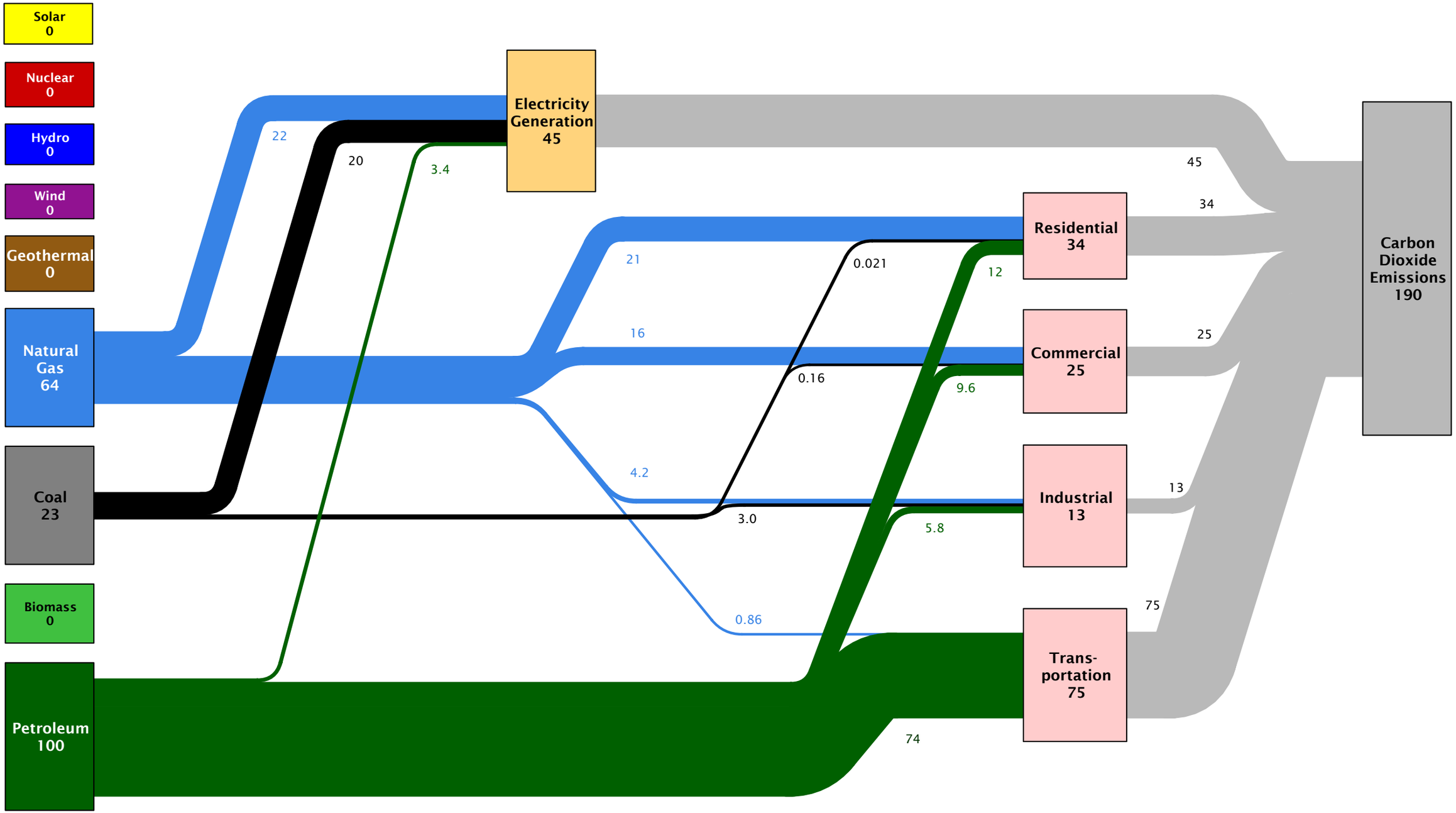
Estimated New York Carbon Dioxide Emissions in 2008: ~190 Million metric tons

Lawrence Livermore National Laboratory



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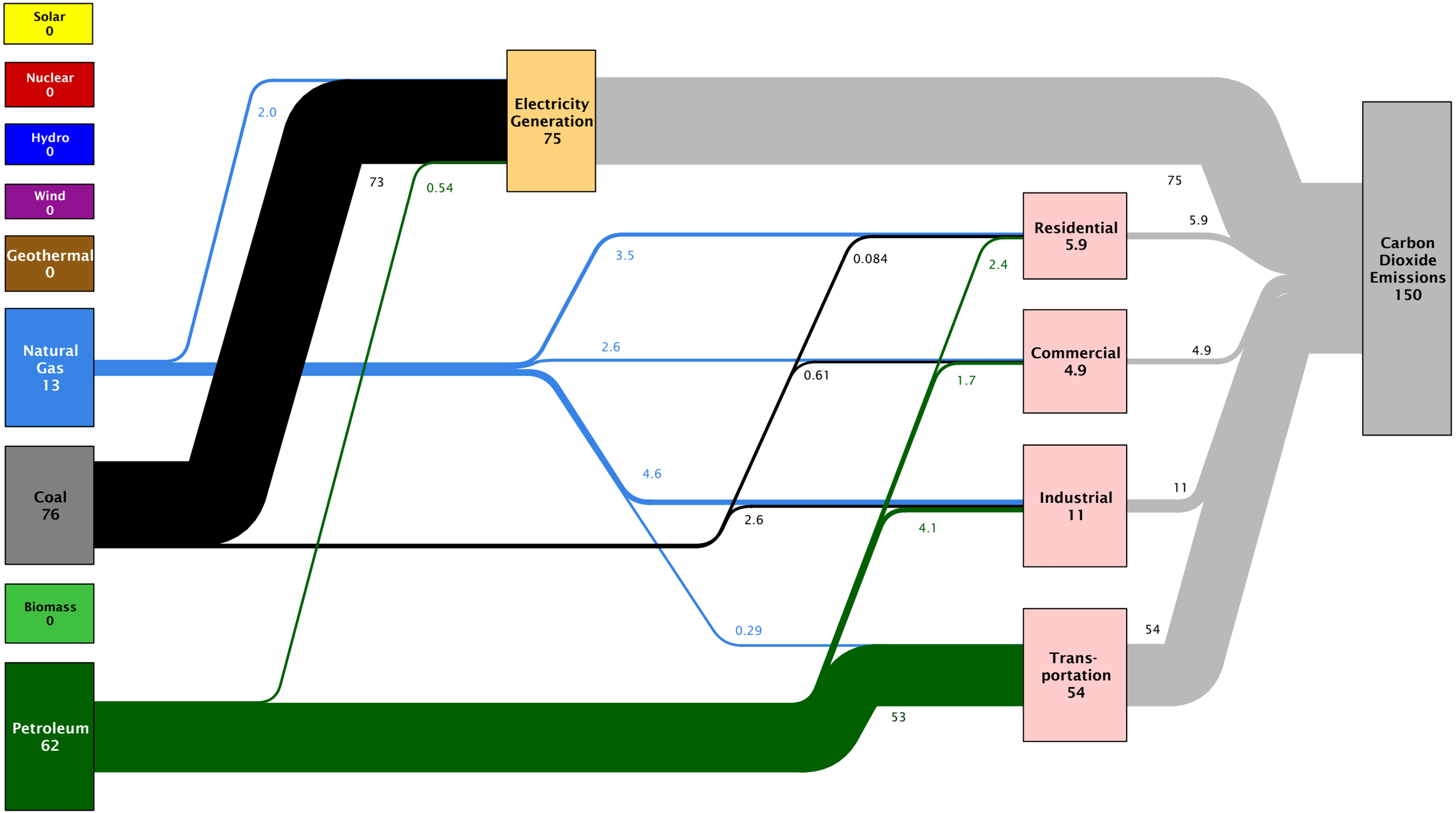
Estimated North Carolina Carbon Dioxide Emissions in 2008: ~150 Million metric tons

Lawrence Livermore National Laboratory



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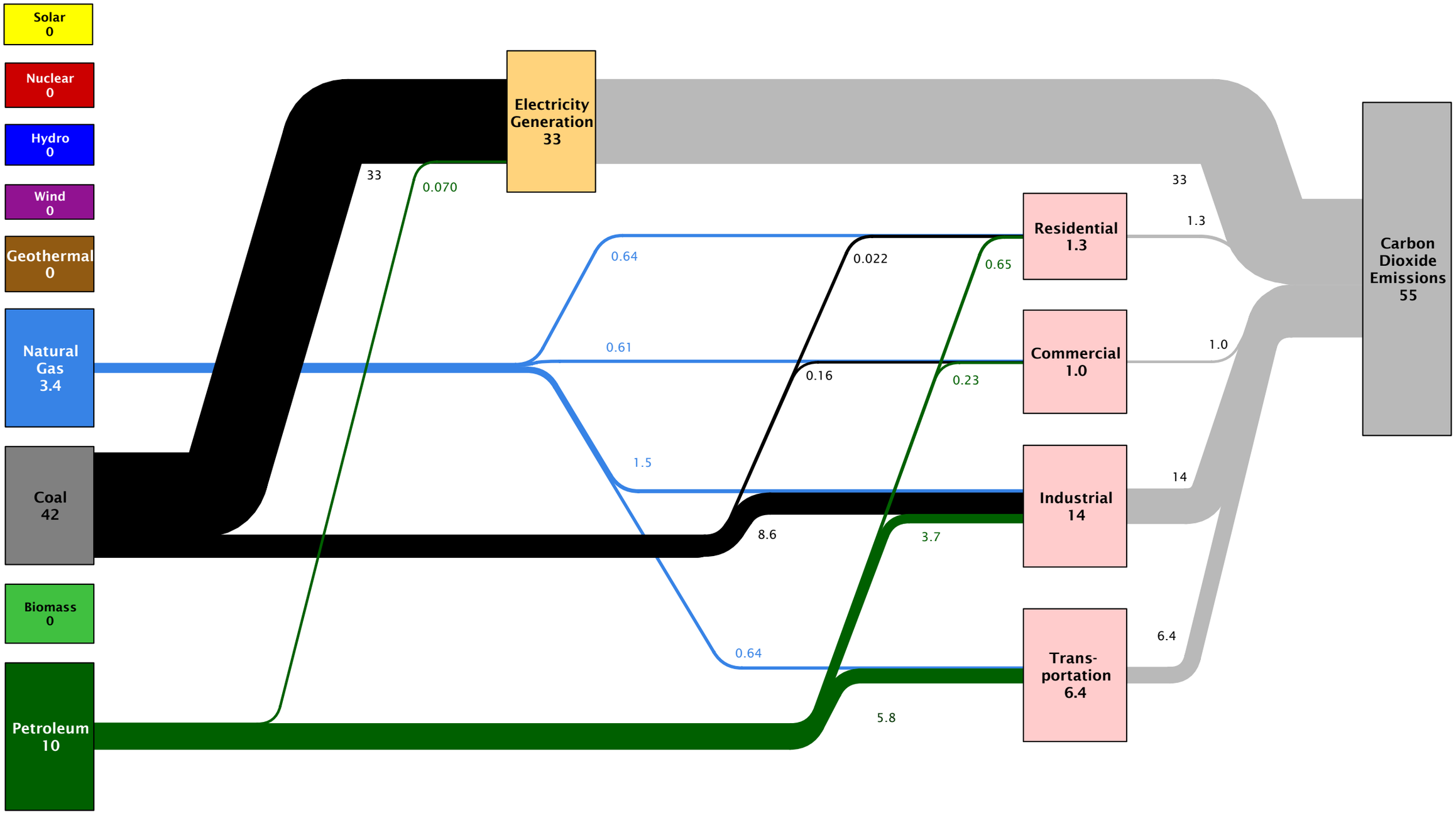
Estimated North Dakota Carbon Dioxide Emissions in 2008: ~55 Million metric tons

Lawrence Livermore National Laboratory



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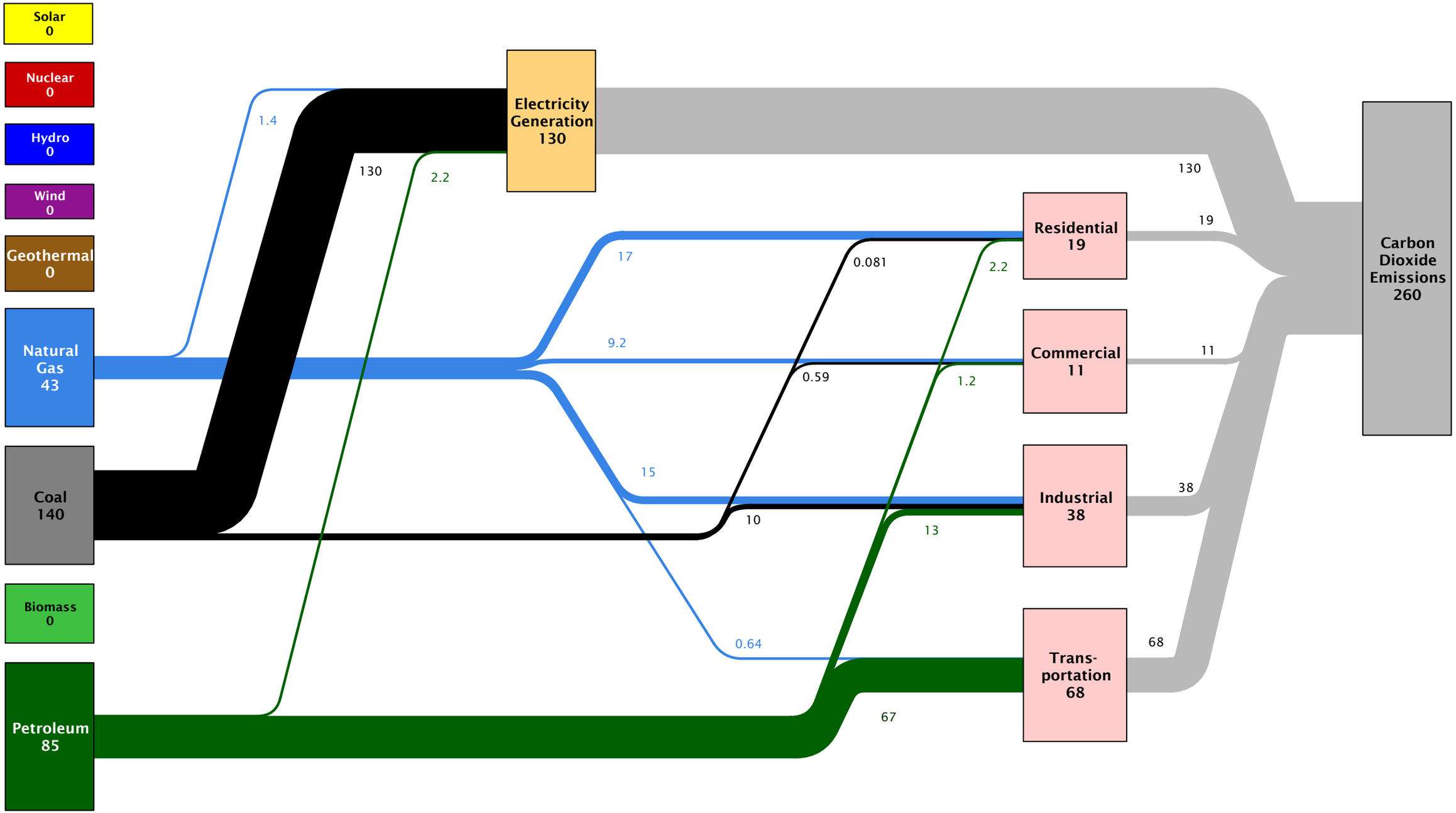
Estimated Ohio Carbon Dioxide Emissions in 2008: ~260 Million metric tons

Lawrence Livermore National Laboratory



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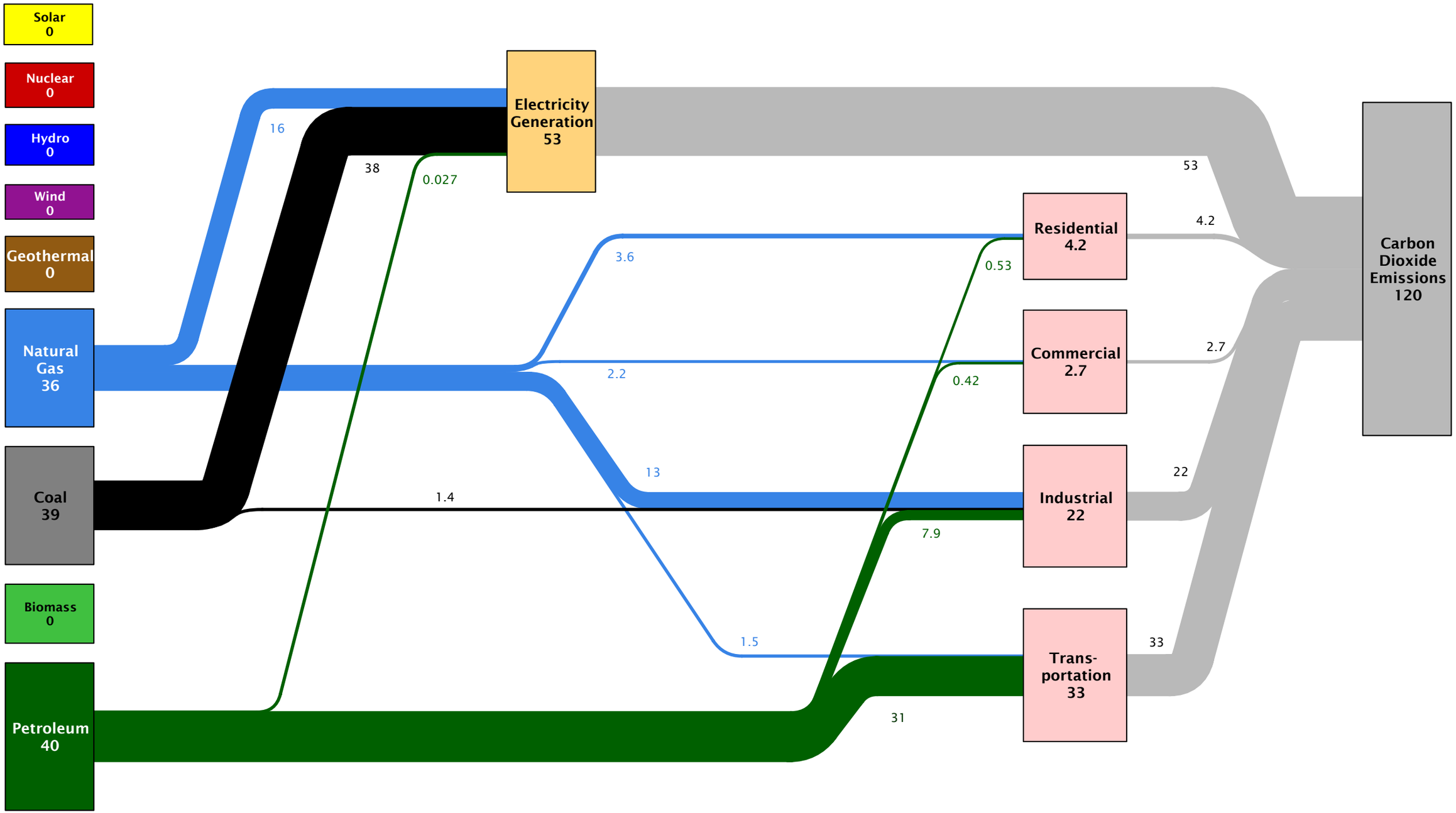
Estimated Oklahoma Carbon Dioxide Emissions in 2008: ~120 Million metric tons

Lawrence Livermore National Laboratory



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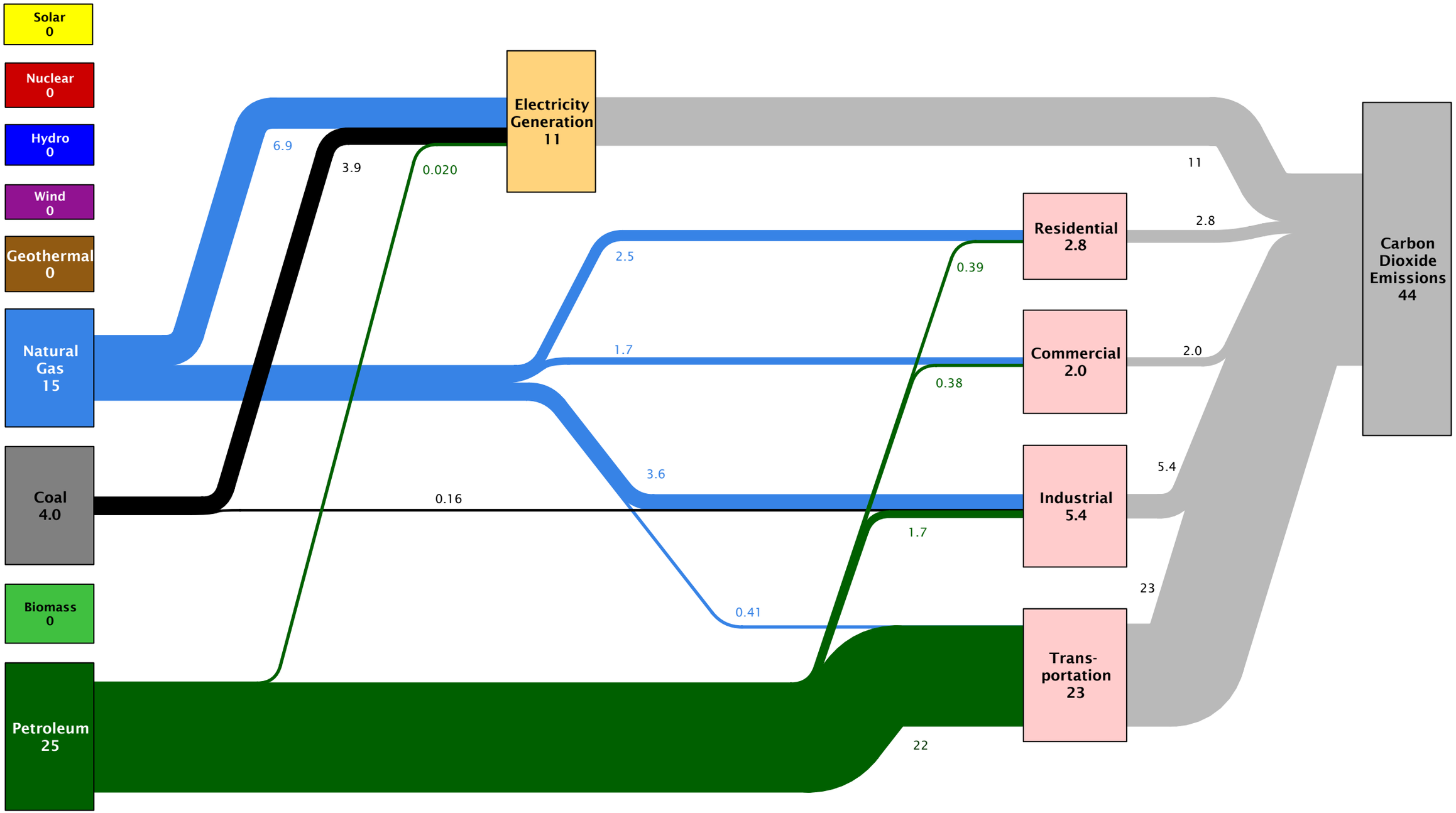
Estimated Oregon Carbon Dioxide Emissions in 2008: ~44 Million metric tons

Lawrence Livermore National Laboratory



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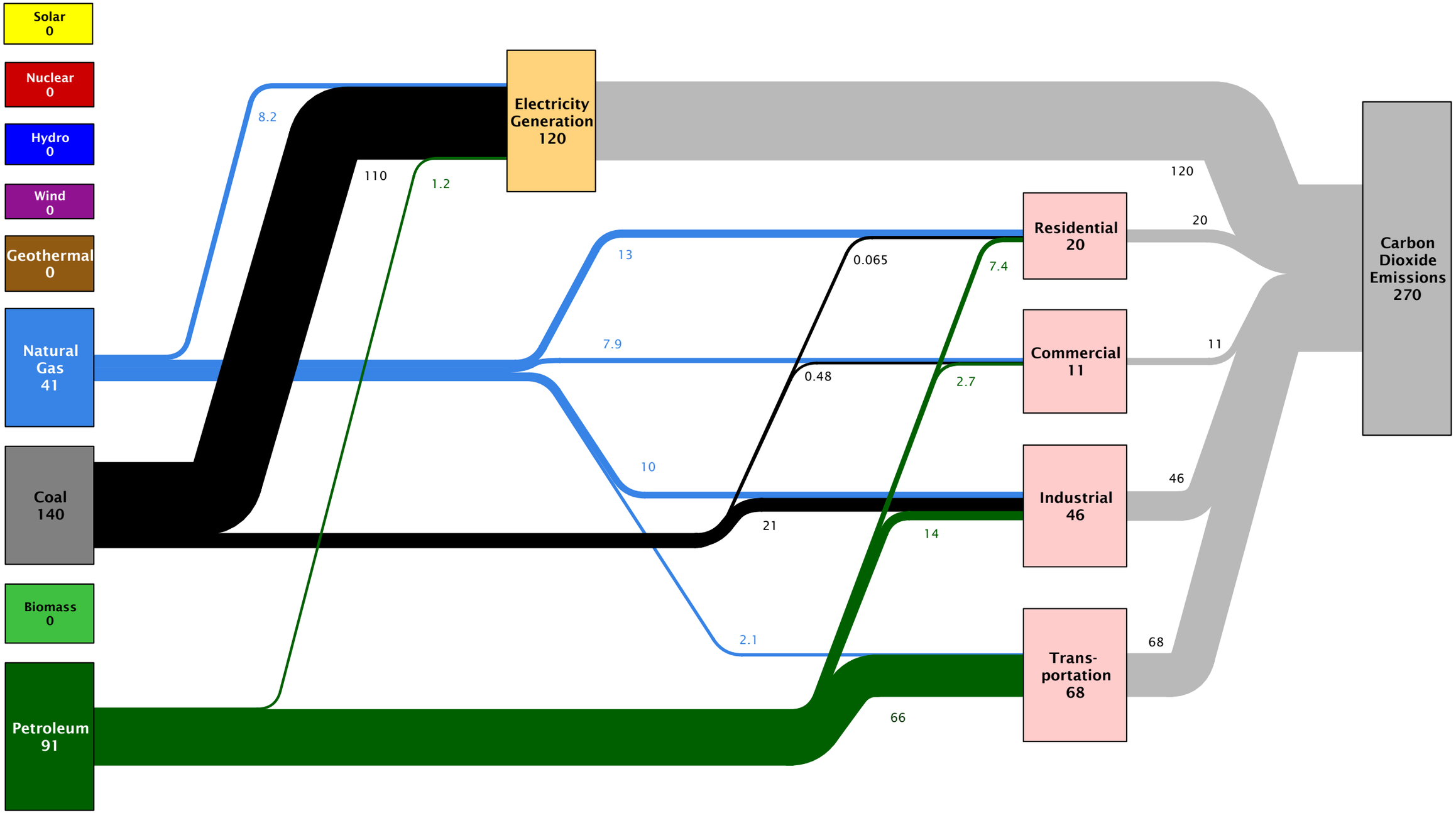
Estimated Pennsylvania Carbon Dioxide Emissions in 2008: ~270 Million metric tons

Lawrence Livermore National Laboratory



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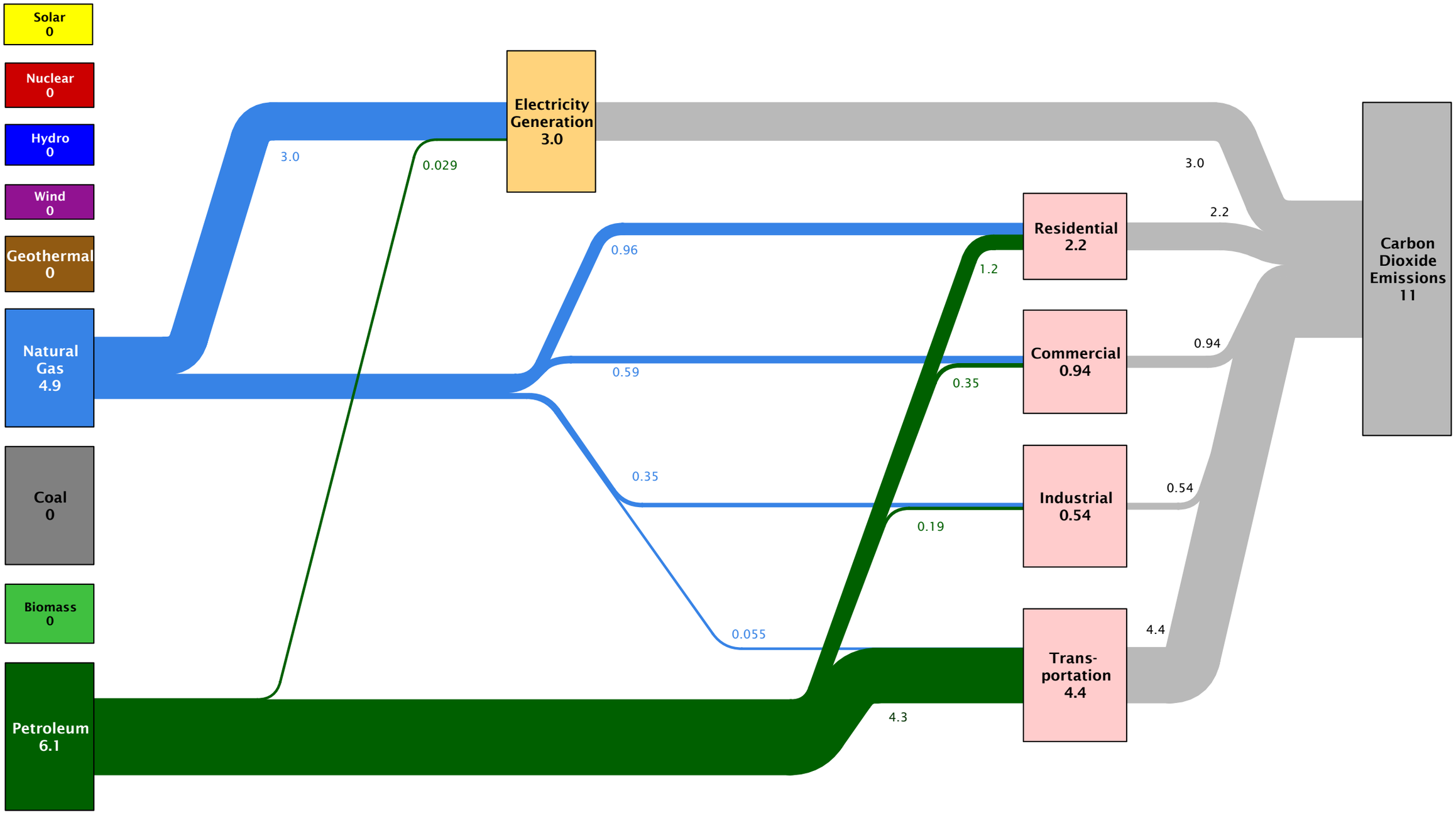
Estimated Rhode Island Carbon Dioxide Emissions in 2008: ~11 Million metric tons

Lawrence Livermore National Laboratory



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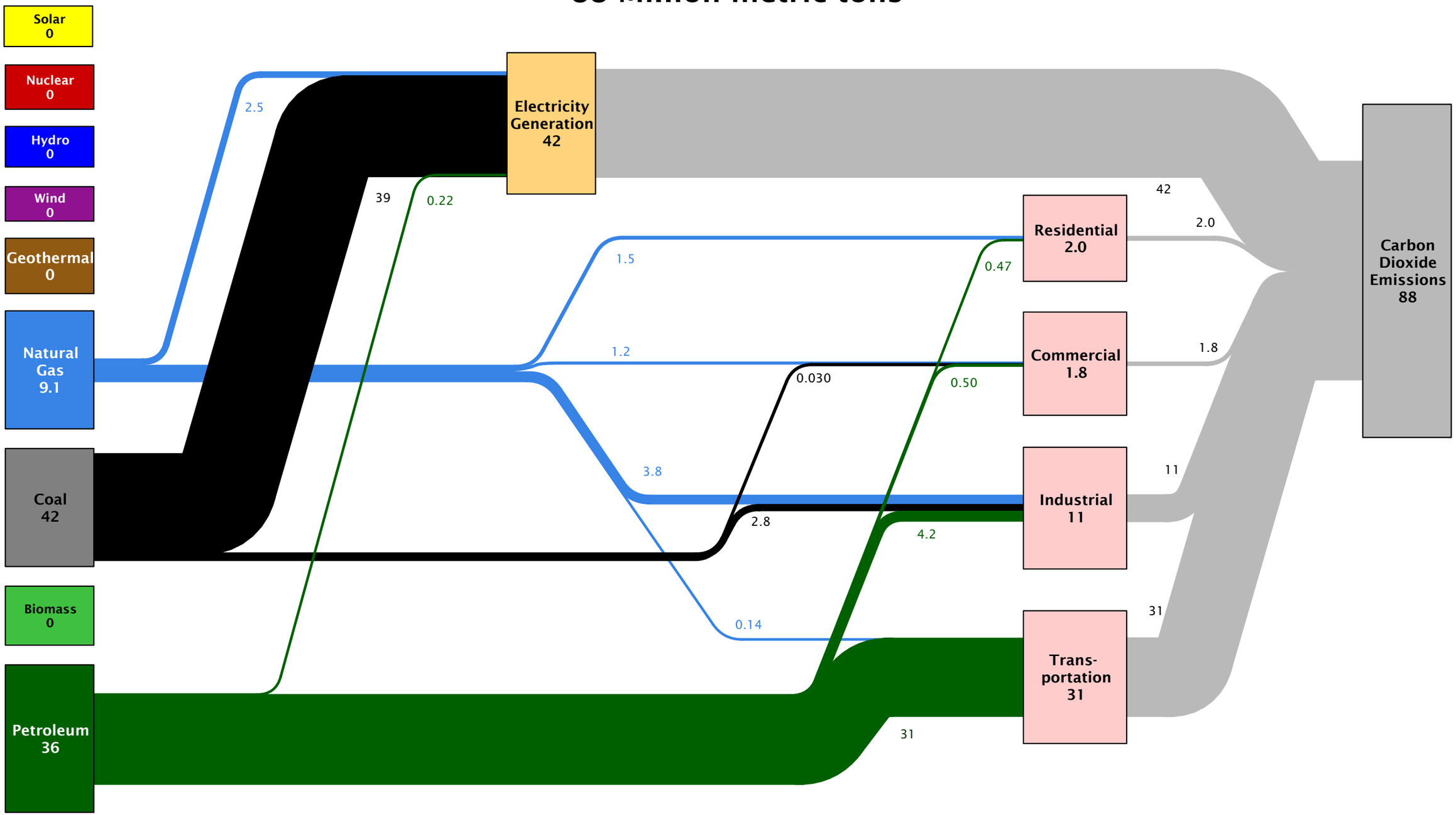
Estimated South Carolina Carbon Dioxide Emissions in 2008: ~88 Million metric tons

Lawrence Livermore National Laboratory



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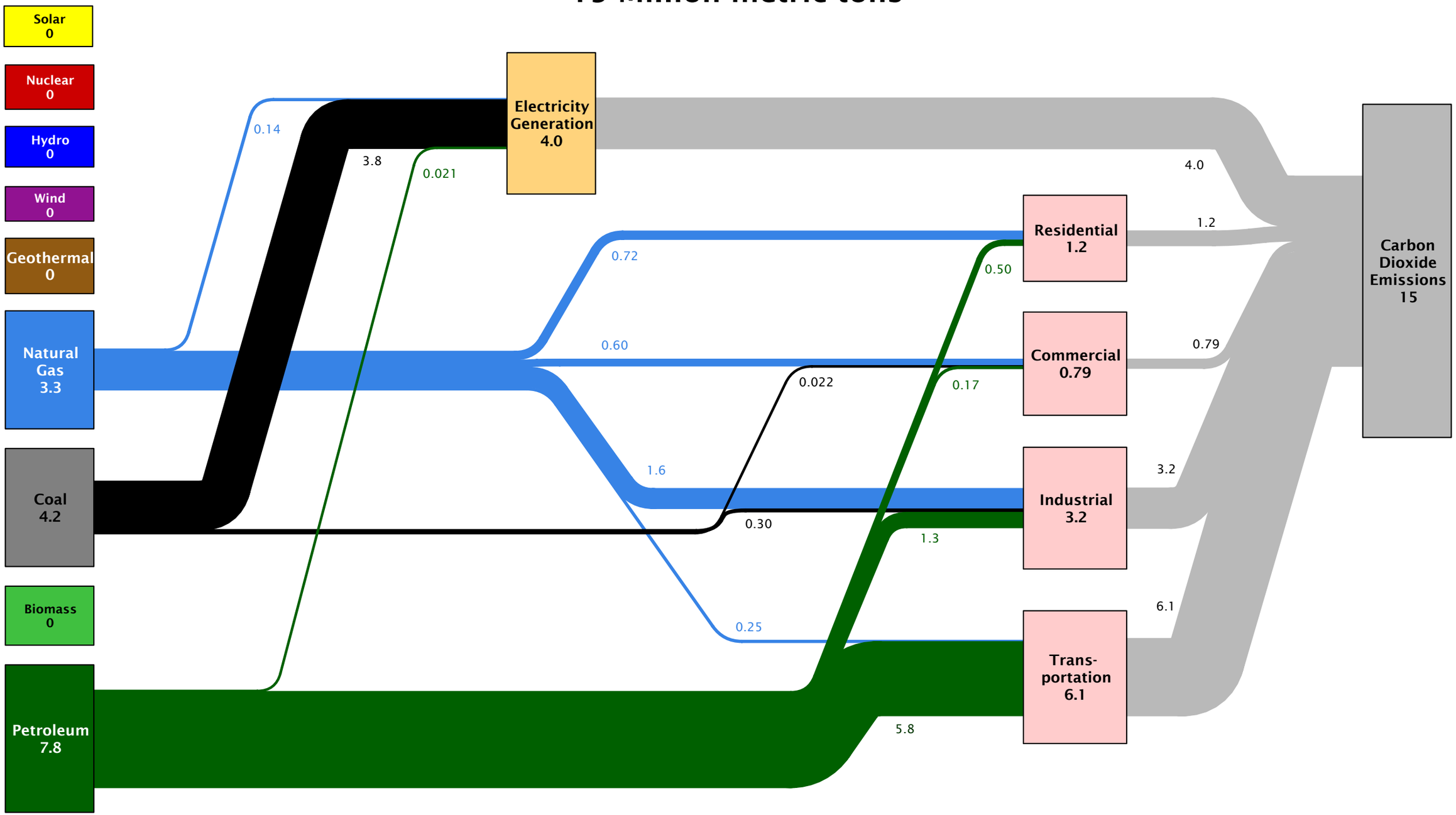
Estimated South Dakota Carbon Dioxide Emissions in 2008: ~15 Million metric tons

Lawrence Livermore National Laboratory



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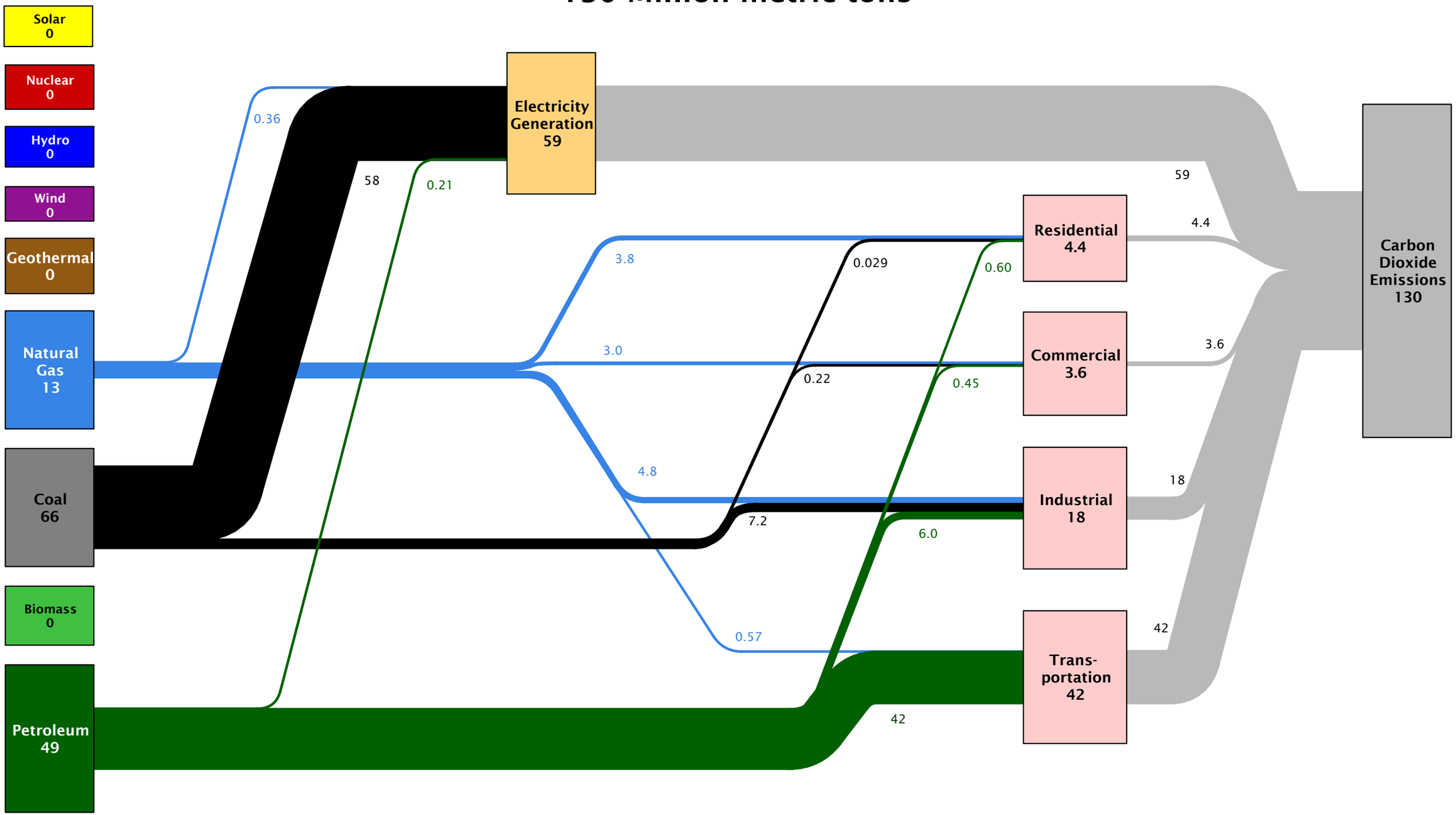
Estimated Tennessee Carbon Dioxide Emissions in 2008: ~130 Million metric tons

Lawrence Livermore National Laboratory



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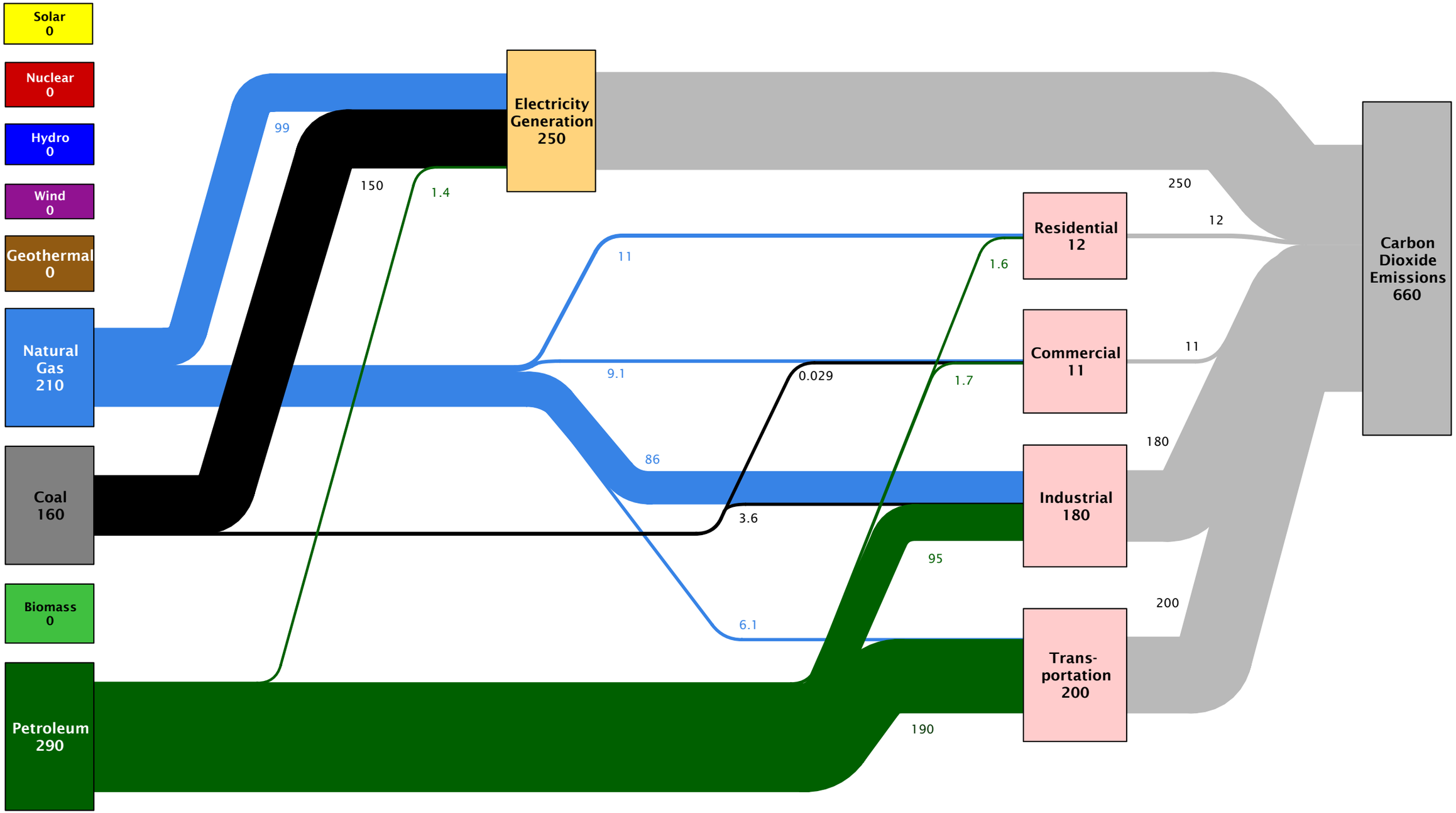
Estimated Texas Carbon Dioxide Emissions in 2008: ~660 Million metric tons

Lawrence Livermore National Laboratory



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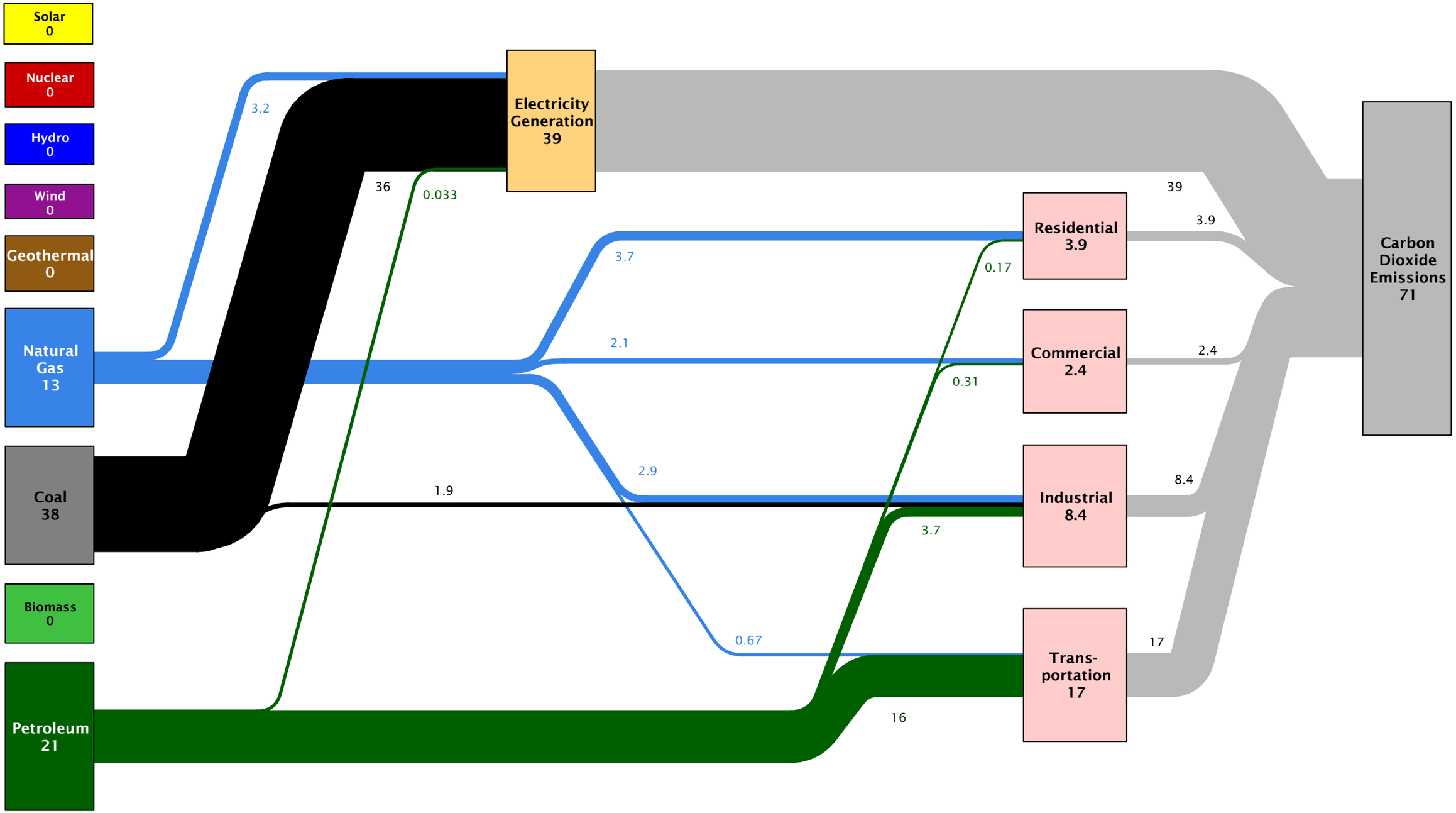
Estimated Utah Carbon Dioxide Emissions in 2008: ~71 Million metric tons

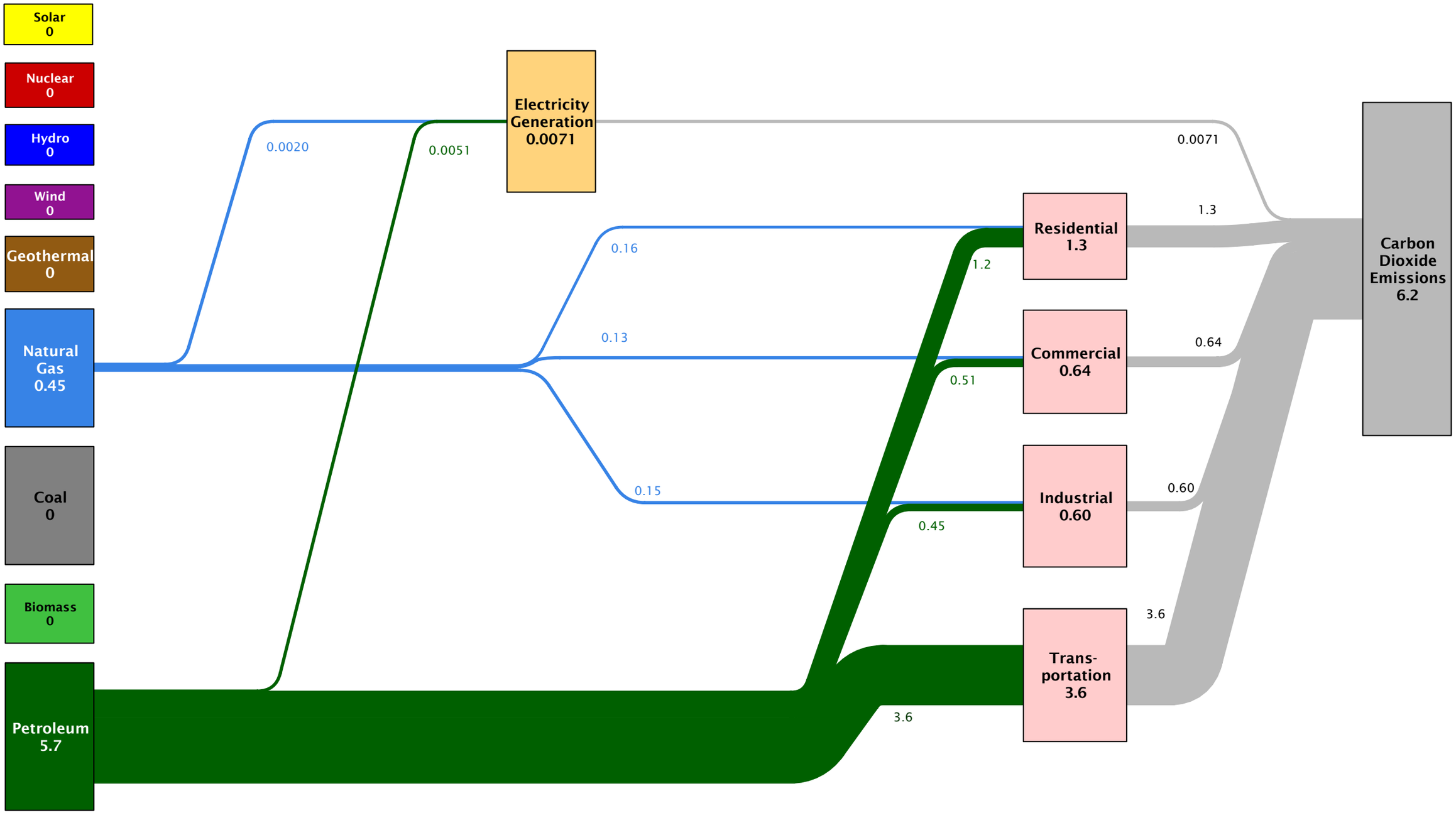
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Vermont Carbon Dioxide Emissions in 2008: ~6.2 Million metric tons

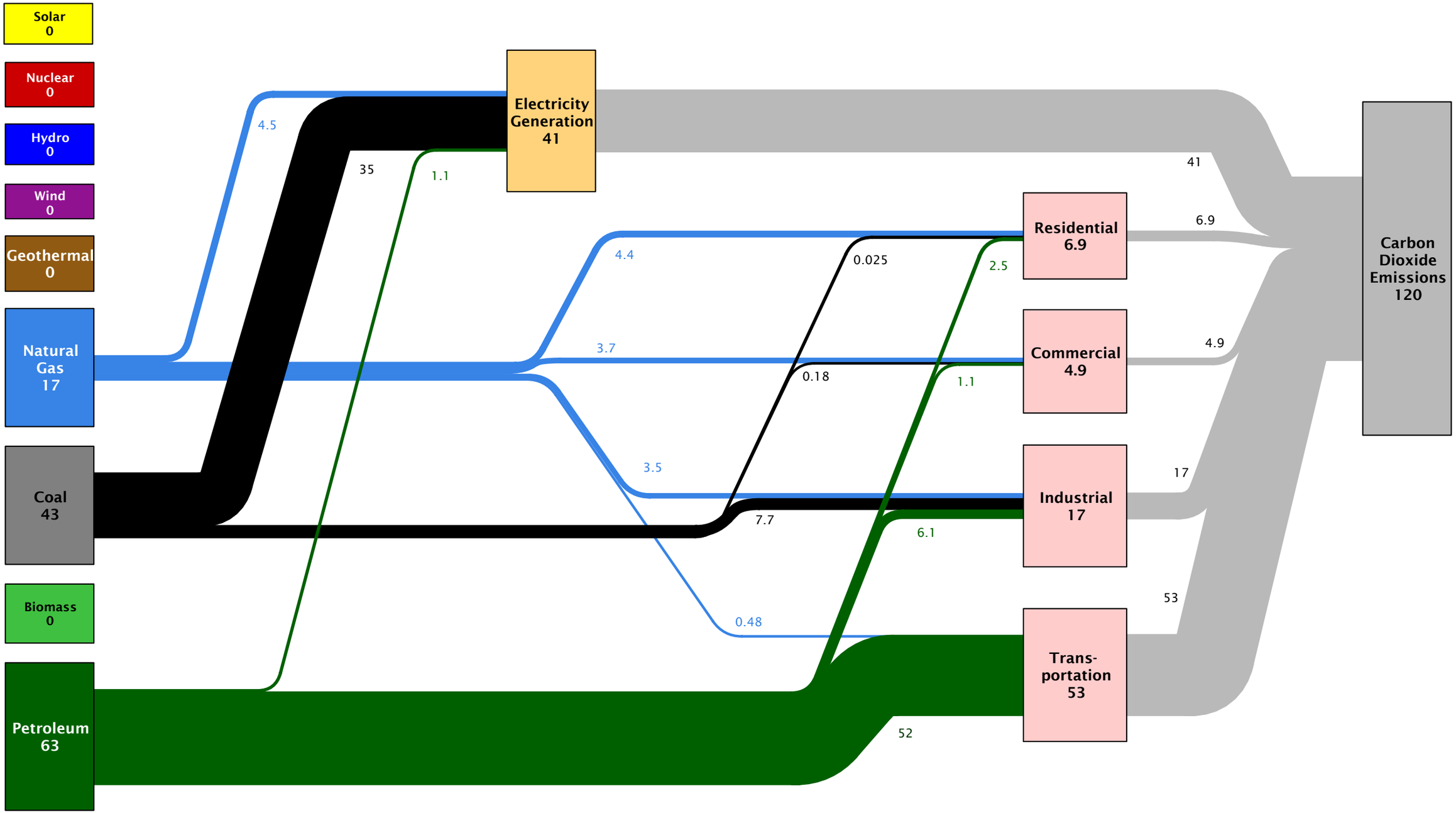
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Virginia Carbon Dioxide Emissions in 2008: ~120 Million metric tons

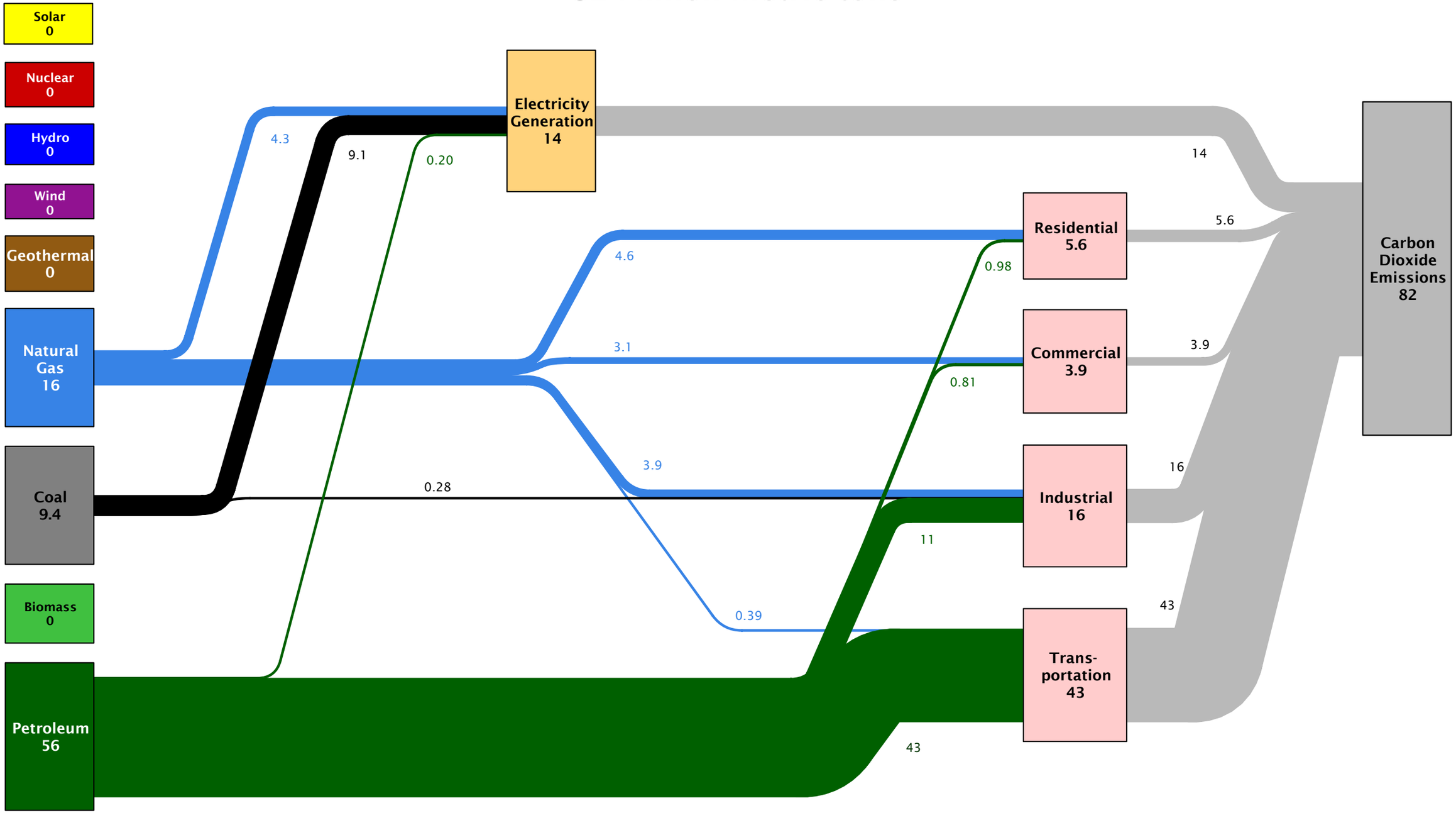
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Washington Carbon Dioxide Emissions in 2008: ~82 Million metric tons

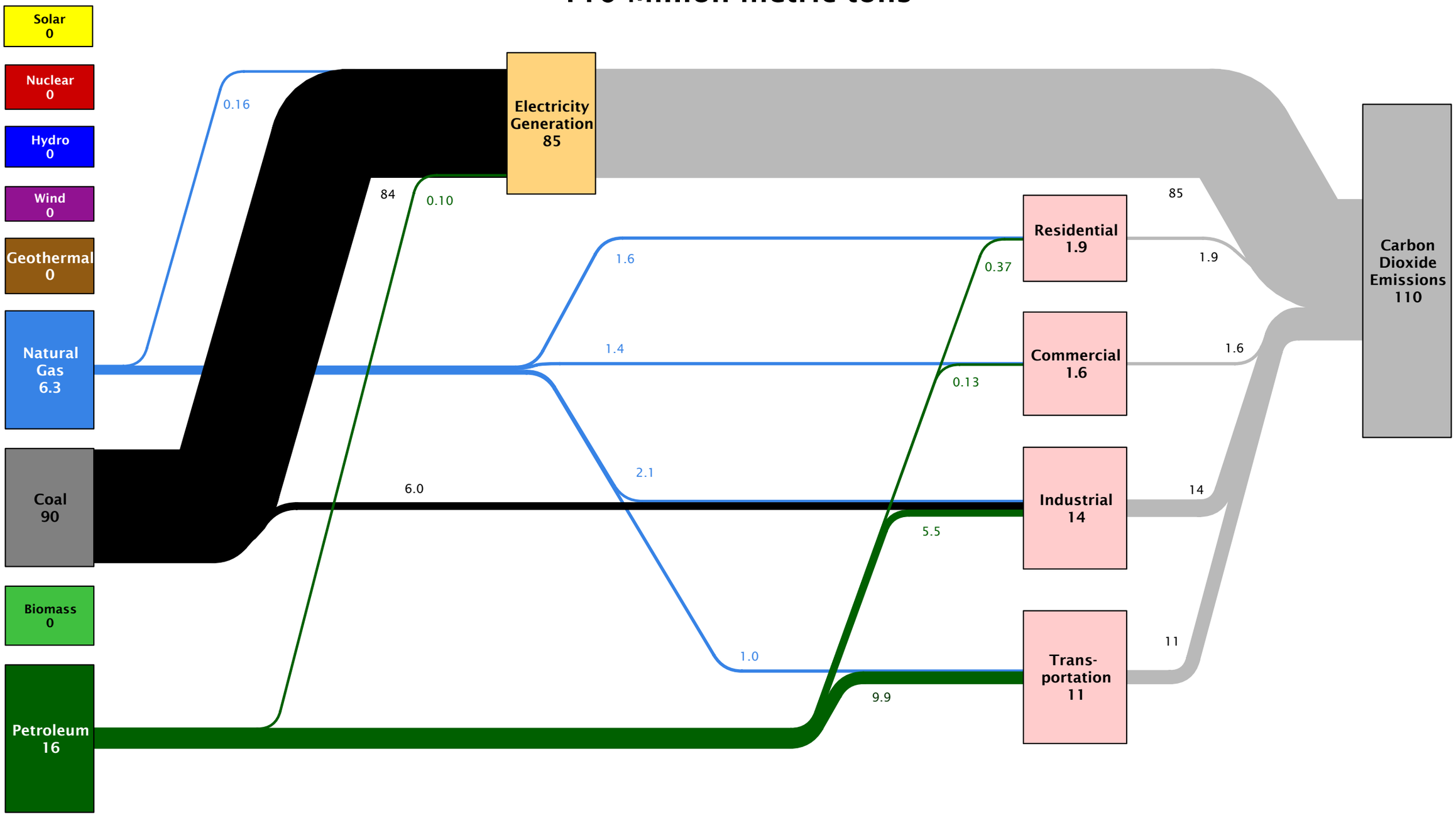
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated West Virginia Carbon Dioxide Emissions in 2008: ~110 Million metric tons

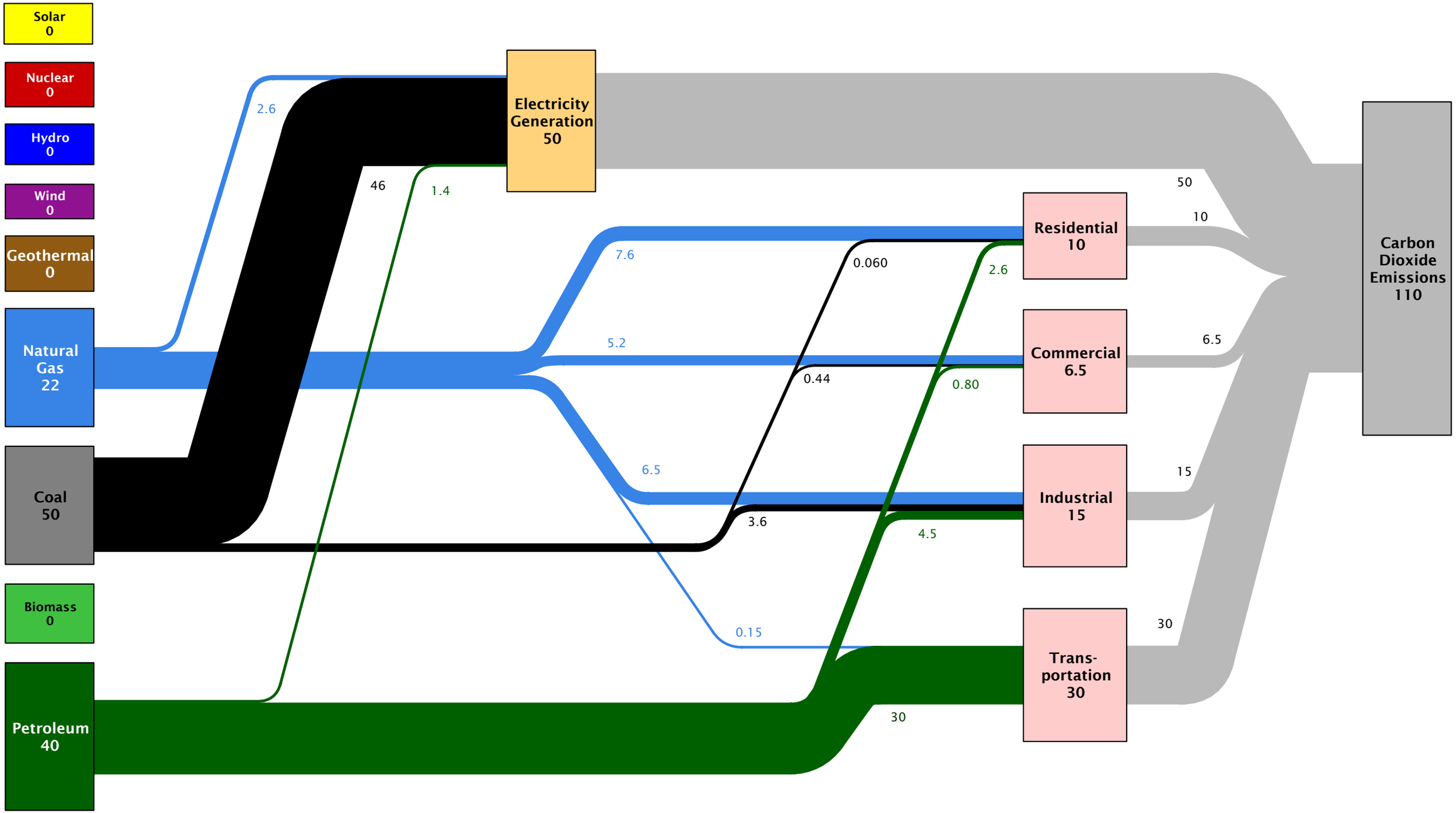
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Wisconsin Carbon Dioxide Emissions in 2008: ~110 Million metric tons

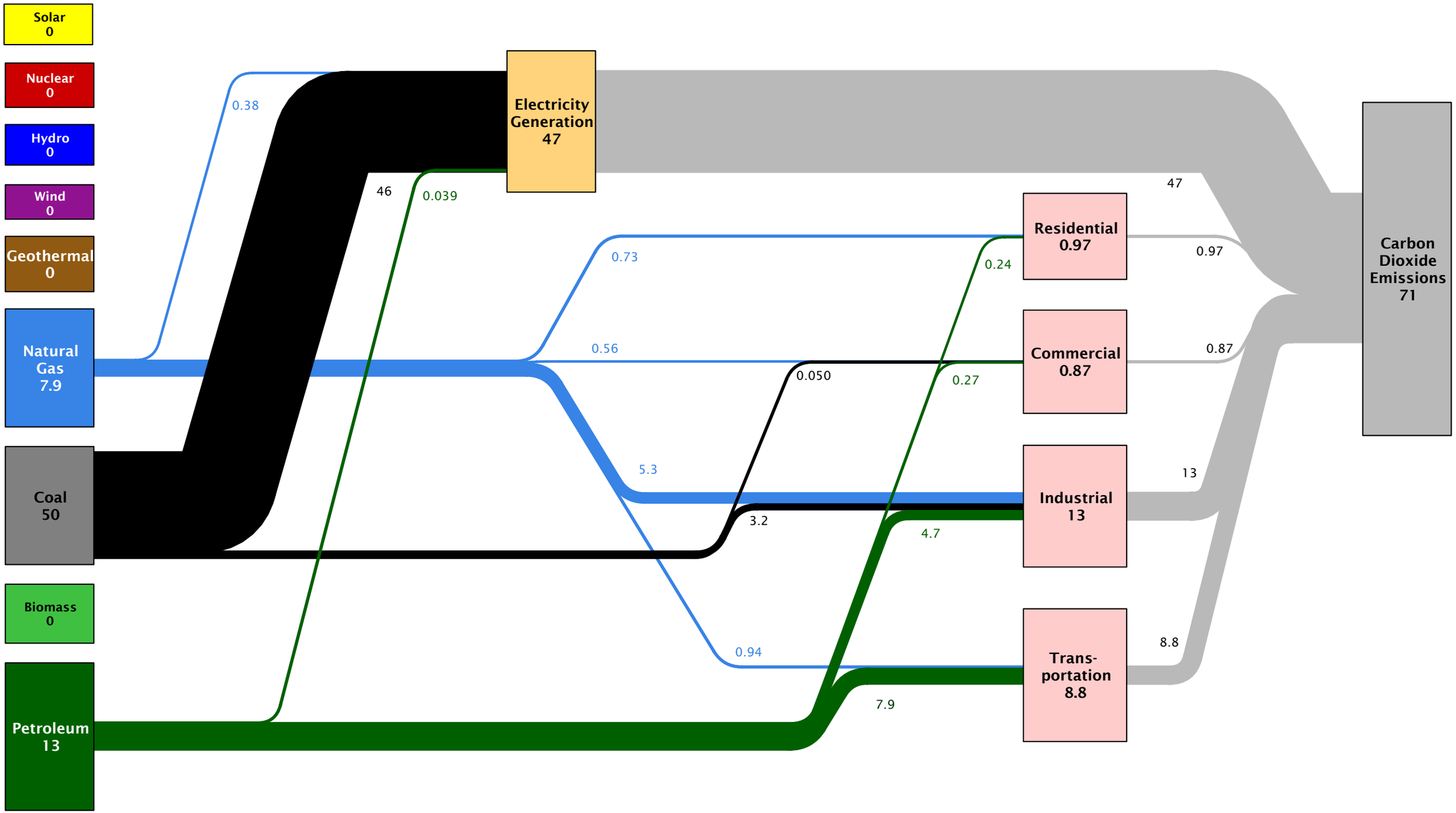
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated Wyoming Carbon Dioxide Emissions in 2008: ~71 Million metric tons

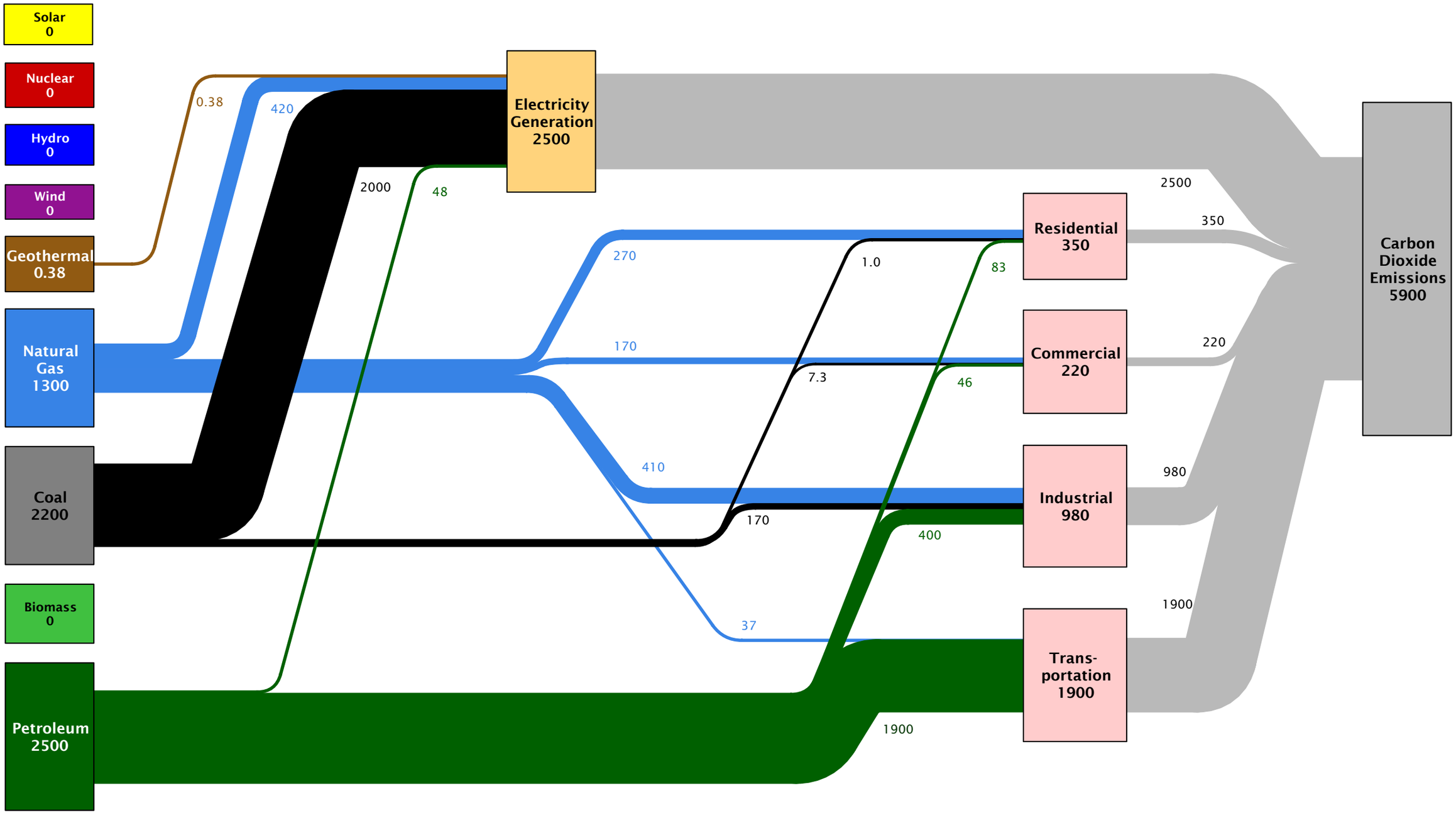
Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Estimated United State Carbon Dioxide Emissions in 2008: ~5900 Million metric tons

Lawrence Livermore National Laboratory



Source: LLNL 2011. Data is based on DOE/EIA-0214(2008), June 2010. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions - lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Emissions from U.S. Territories and international aviation and marine bunkers are not included. All quantities are rounded to 2 significant digits and annual flows of less than 0.01 MMmT are not included. Totals may not equal sum of components due to independent rounding. LLNL-TR-480261.

Analysis

Fundamental to this analysis is the assumption that carbon dioxide emissions can be accurately estimated from energy usage. All carbon dioxide emissions are calculated from energy usage as depicted and explained in the 2008 State-Level Energy Flow Charts for the United States.

Carbon dioxide emissions depicted in the flow charts were calculated as follows:

<u>Sources:</u>

Solar:
Carbon dioxide emissions associated with solar energy are assumed to be zero.

Nuclear:
Carbon dioxide emissions associated with nuclear energy are assumed to be zero.

Hydro:
Carbon dioxide emissions associated with hydroelectricity are assumed to be zero.

Wind:
Carbon dioxide emissions associated with wind energy are assumed to be zero.

Natural Gas:
Carbon dioxide emissions are calculated as the sum of carbon dioxide emissions from electricity generation, residential, commercial, industrial, and transportation activities using natural gas as a fuel source.

Coal:
Carbon dioxide emissions are calculated as the sum of carbon dioxide emissions from electricity generation, residential, commercial, and industrial activities using coal as a fuel source.

Biomass:
Net carbon dioxide emissions associated with biomass energy are assumed to be zero. Fossil energy inputs into the production of biomass feedstocks and fuels are accounted for in the industrial sector.

Petroleum:
Carbon dioxide emissions are calculated as the sum of carbon dioxide emissions from electricity generation, residential, commercial, industrial, and transportation activities using petroleum as a fuel source.

Flows:

Geothermal-> Electricity Generation:

Carbon dioxide emissions from electricity generation using geothermal methods for individual states (CO2_G-eGen(state)) are estimated by multiplying the energy associated with geothermal power plants for each state (E_G-eGen(state)) and the ratio of reported carbon dioxide emissions for the United States from geothermal power plants (CO2_G-eGen(US)) in 2008 (0.384 million metric tons) to the reported quantity of energy associated with geothermal power plants (E_G-eGen(US)) in 2008 (314 trillion BTU). This flow is appreciable only for California and Nevada.

```
CO2_G-eGen(state) = E_G-eGen(state) * CO2_G-eGen(US) / E_G-eGen(US)
```

Natural Gas-> Electricity Generation:

Carbon dioxide emissions from electricity generation using natural gas as a fuel source for individual states in 2008 are used as reported in the 1990-2009 U.S. Electric Power Industry Estimated Emissions by State (U.S. EIA, 2011). The emissions reported from electricity generation using natural gas for each individual state are shown in Table 1.

Coal-> Electricity Generation:

Carbon dioxide emissions from electricity generation using coal as a fuel source for individual states in 2008 are used as reported in the 1990-2009 U.S. Electric Power Industry Estimated Emissions by State (U.S. EIA, 2011). The emissions reported from electricity generation using coal for each individual state are shown in Table 1.

Petroleum-> Electricity Generation:

Carbon dioxide emissions from electricity generation using petroleum as a fuel source for individual states in 2008 are used as reported in the 1990-2009 U.S. Electric Power Industry Estimated Emissions by State (U.S. EIA, 2011). The emissions reported from electricity generation using petroleum for each individual state are shown in Table 1.

Natural Gas-> Residential:

Carbon dioxide emissions from residential activities using natural gas as a fuel source for individual states (CO2_NG-Res(state)) are estimated by multiplying the energy associated with natural gas use in residential activities for each state (E_NG-Res(state)) and the ratio of reported carbon dioxide emissions for the United States from residential activities using natural gas (CO2_NG-Res(US)) in 2008 (265 million metric tons) to the reported quantity of energy associated with natural gas use in residential activities (E_NG-Res(US)) in 2008 (4,989 trillion BTU).

```
CO2_NG-Res(state) = E_NG-Res(state) * CO2_NG-Res(US) / E_NG-Res(US)
```

Table 1: Estimated CO_2 Emissions (million metric tons) from the U.S. Electric Power Industry by State in 2008

State	Coal	Natural Gas	Petroleum
AK	1.35	2.35	0.67
AL	73.03	9.83	0.26
AR	26.55	3.97	0.07
AZ	43.30	15.54	0.04
CA	3.77	55.91	2.17
CO	35.72	5.92	0.02
CT	4.33	3.48	0.50
DC	0.00	0.00	0.07
DE	5.67	0.71	0.21
FL	63.06	44.47	11.12
GA	82.61	5.68	1.31
HI	1.66	0.00	7.14
IA	44.98	0.96	0.19
ID	0.26	0.76	0.00
IL	103.43	2.80	0.12
IN	121.40	2.75	0.16
KS	35.72	1.44	0.16
KY	90.05	0.73	3.24
LA	25.40	26.49	2.65
MA	9.98	9.11	1.85
MD	26.97	1.22	0.38
ME	0.56	3.32	0.92
MI	70.82	5.28	0.79
MN	34.40	1.63	0.27
MO	75.23	2.33	0.06
MS	16.45	9.36	0.08

State	Coal	Natural Gas	Petroleum
MT	19.57	0.08	0.71
NC	72.74	1.97	0.54
ND	32.82	0.00	0.07
NE	22.04	0.39	0.03
NH	3.75	2.73	0.18
NJ	9.20	9.86	0.30
NM	27.02	3.83	0.04
NV	7.94	10.15	0.01
NY	19.75	22.23	3.38
OH	125.47	1.38	2.18
OK	37.52	15.84	0.03
OR	3.86	6.87	0.02
PA	113.19	8.19	1.16
RI	0.00	2.96	0.03
SC	39.46	2.55	0.22
SD	3.85	0.14	0.02
TN	58.10	0.36	0.21
TX	152.42	98.91	1.38
UT	36.11	3.18	0.03
VA	34.96	4.52	1.08
VT	0.00	0.00	0.01
WA	9.08	4.29	0.20
WI	45.52	2.57	1.44
WV	84.34	0.16	0.10
WY	46.42	0.38	0.04
US	2001.81	419.60	47.86

Coal-> Residential:
Carbon dioxide emissions from residential activities using coal as a fuel source for individual states (CO2_C-Res(state)) are estimated by multiplying the energy associated with coal from residential activities for each state (E_C-Res(state)) and the ratio of reported carbon dioxide emissions for the United States from residential activities using coal (CO2_C-Res(US)) in 2008 (1 million metric tons) to the reported quantity of energy associated with coal use in residential activities (E_C-Res(US)) in 2008 (8 trillion BTU).

```
CO2_C-Res(state) = E_C-Res(state) * CO2_C-Res(US) / E_C-Res(US)
```

Petroleum-> Residential:
Carbon dioxide emissions from residential activities using petroleum as a fuel source for individual states (CO2_P-Res(state)) are estimated by multiplying the energy associated with petroleum use in residential activities for each state (E_P-Res(state)) and the ratio of reported carbon dioxide emissions for the United States from residential activities using petroleum (CO2_P-Res(US)) in 2008 (83 million metric tons) to the reported quantity of energy associated with petroleum use in residential activities (E_P-Res(US) in 2008 (1,204 trillion BTU).

```
CO2_P-Res(state) = E_P-Res(state) * CO2_P-Res(US) / E_P-Res(US)
```

Natural Gas-> Commercial:
Carbon dioxide emissions from commercial activities using natural gas as a fuel source for individual states (CO2_NG-Com(state)) are estimated by multiplying the energy associated with natural gas use in commercial activities for each state (E_NG-Com(state)) and the ratio of reported carbon dioxide emissions for the United States from commercial activities using natural gas (CO2_NG-Com(US)) in 2008 (170 million metric tons) to the reported quantity of energy associated with natural gas use in commercial activities (E_NG-Com(US)) in 2008 (3,211 trillion BTU).

```
CO2_NG-Com(state) = E_NG-Com(state) * CO2_NG-Com(US) / E_NG-Com(US)
```

Coal-> Commercial:
Carbon dioxide emissions from commercial activities using coal as a fuel source for individual states (CO2_C-Com(state)) are estimated by multiplying the energy associated with coal use in commercial activities for each state (E_C-Com(state)) and the ratio of reported carbon dioxide emissions for the United States from commercial activities using coal (CO2_C-Com(US)) in 2008 (7 million metric tons) to the reported quantity of energy associated with coal use in commercial activities (E_C-Com(US)) in 2008 (69 trillion BTU).

```
CO2_C-Com(state) = E_C-Com(state) * CO2_C-Com(US) / E_C-Com(US)
```

Petroleum-> Commercial:
Carbon dioxide emissions from commercial activities using petroleum as a fuel source for individual states (CO2_P-Com(state) are estimated by multiplying the energy associated with petroleum use in commercial activities in each state (E_P-Com(state)) and the ratio of reported carbon dioxide emissions for the United States from commercial activities using petroleum (CO2_P-Com(US)) in 2008 (46 million metric tons) to the reported quantity of energy associated with petroleum use in commercial activities (E_P-Com(US)) in 2008 (638 trillion BTU).

```
CO2_P-Com(state) = E_P-Com(state) * CO2_P-Com(US) / E_P-Com(US)
```

Natural Gas-> Industrial:
Carbon dioxide emissions from industrial activities using natural gas as a fuel source for individual states (CO2_NG-Ind(state)) are estimated by multiplying the energy associated with natural gas use in industrial activities for each state (E_NG-Ind(state)) and the ratio of reported carbon dioxide emissions for the United States from industrial activities using natural gas (CO2_NG-Ind(US)) in 2008 (407 million metric tons) to the reported quantity of energy associated with natural gas use in industrial activities (E_NG-Ind(US)) in 2008 (8,067 trillion BTU).

```
CO2_NG-Ind(state) = E_NG-Ind(state) * CO2_NG-Ind(US) / E_NG-Ind(US)
```

Coal-> Industrial:
Carbon dioxide emissions from industrial activities using coal as a fuel source for individual states (CO2_C-Ind(state)) are estimated by multiplying the energy associated with coal use in industrial activities in each state (E_C-Ind(state)) and the ratio of reported carbon dioxide emissions for the United States from industrial activities using coal (CO2_C-Ind(US)) in 2008 (172 million metric tons) to the reported quantity of energy associated with coal use in industrial activities (E_C-Ind(US)) in 2008 (1,796 trillion BTU).

```
CO2_C-Ind(state) = E_C-Ind(state) * CO2_C-Ind(US) / E_C-Ind(US)
```

Petroleum-> Industrial:
Carbon dioxide emissions from industrial activities using petroleum as a fuel source for individual states (CO2_P-Ind(state)) are estimated by multiplying the energy associated with petroleum use in industrial activities in each state (E_P-Ind(state)), the ratio of reported carbon dioxide emissions for the United States from industrial activities using petroleum (CO2_P-Ind(US)) in 2008 (378 million metric tons) to the reported quantity of energy associated with petroleum use in industrial activities (E_P-Ind(US)) in 2008 (8,547 trillion BTU from both nonfuel and fuel activities then subtracting 4,610 trillion BTU from nonfuel activities), and the fraction of petroleum used as a fuel (1-θ(state)).

```
CO2_P-Ind(state) = E_P-Ind(state) * CO2_P-Ind(US) / E_P-Ind(US) *
                   (1 - θ(state))
```

Petroleum-> Industrial (con't):

θ(state) is calculated for each state by summing the energy content of petroleum used for non-fuel (ie. plastics, lubricants, etc) purposes (ARICB, LGICB, PPICB, LUICB, FNICB, FOICB, FSICB, PCICB, SNICB, WXICB, MSICB, and NAICB) and dividing by the total amount of energy potential of petroleum used in industrial activities (PAICB). A portion of liquefied petroleum gases (LPG) and petroleum coke is used for nonfuel purposes, while the other quantities are assumed to be wholly used in nonfuel industrial activities. θ values are shown for each state in Table 2.

$$\theta = \{ARICB + LGICB * C_1 + PPICB + LUICB + FNICB + FOICB + FSICB + PCICB * C_2 + SNICB + WXICB + MSICB + NAICB\} / PAICB$$

The portion of LPG used for nonfuel activities is represented by multiplying the energy associated with all LPG by C_1 (0.775), the ratio of total LPG used for nonfuel purposes in the United States (1,450 trillion BTU) to total LPG used for all industrial purposes in the United States (1,870 trillion BTU). Similarly, the portion of petroleum coke used for nonfuel activities is estimated by multiplying the energy associated with all petroleum coke by C_2 (0.276), the ratio of total petroleum coke used for nonfuel purposes in the United States (240 trillion BTU) to total petroleum coke used for all industrial purposes in the United States (870 trillion BTU).

Natural Gas-> Transportation:

Carbon dioxide emissions from the transportation sector using natural gas as a fuel source for individual states (CO2_NG-Tran(state)) are estimated by multiplying the energy associated with natural gas use in the transportation sector in each state (E_NG-Tran(state)) and the ratio of reported carbon dioxide emissions for the United States from the transportation sector using natural gas (CO2_NG-Tran(US)) in 2008 (37 million metric tons) to the reported quantity of energy associated with natural gas use in the transportation sector (E_NG-Tran(US)) in 2008 (694 trillion BTU).

```
CO2_NG-Tran(state) = E_NG-Tran(state) * CO2_NG-Tran(US) / E_NG-Tran(US)
```

Petroleum->Transportation:

Carbon dioxide emissions from the transportation sector using petroleum as a fuel source for individual states (CO2_P-Tran(state)) are estimated by multiplying the energy associated with petroleum use in the transportation sector for each state (E_P-Tran(state)) and the ratio of reported carbon dioxide emissions for the United States from the transportation sector using petroleum (CO2_P-Tran(US)) in 2008 (1,889 million metric tons) to the reported quantity of energy associated with petroleum use in the transportation sector (E_P-Tran(US)) in 2008 (26,423 trillion BTU).

```
CO2_P-Tran(state) = E_P-Tran(state) * CO2_P-Tran(US) / E_P-Tran(US)
```

Table 2: Ratio of petroleum used in non-energy activities in the industrial sector to the total petroleum used in the industrial sector for each state

STATE	θ
AK	0.015
AL	0.552
AR	0.343
AZ	0.411
CA	0.356
CO	0.343
CT	0.469
DC	0.266
DE	0.408
FL	0.512
GA	0.598
HI	0.031
IA	0.557
ID	0.472
IL	0.510
IN	0.352
KS	0.412
KY	0.465
LA	0.512
MA	0.480
MD	0.652
ME	0.035
MI	0.599
MN	0.393
MO	0.445
MS	0.364

STATE	θ
MT	0.179
NC	0.652
ND	0.138
NE	0.212
NH	0.518
NJ	0.611
NM	0.444
NV	0.321
NY	0.575
OH	0.492
OK	0.254
OR	0.553
PA	0.458
RI	0.822
SC	0.564
SD	0.419
TN	0.561
TX	0.632
UT	0.215
VA	0.461
VT	0.145
WA	0.275
WI	0.532
WV	0.527
WY	0.189
US	0.511

Sector:

Electricity Generation

Carbon dioxide emissions from electricity generation (CO2_eGen(state)) are estimated as the sum of carbon dioxide emissions from electricity generation using natural gas (CO2_NG-eGen(state)), coal (CO2_C-eGen(state)), and petroleum(CO2_P-eGen(state)).

```
CO2_eGen(state) = CO2_G-eGen(state) + CO2_NG-eGen(state) +
                  CO2_C-eGen(state) + CO2_P-eGen(state)
```

Residential

Carbon dioxide emissions from the residential sector (CO2_Res(state)) are estimated as the sum of carbon dioxide emissions from residential sector using natural gas (CO2_NG-Res(state)), coal (CO2_C-Res(state)), and petroleum (CO2_P-Res(state)).

```
CO2_Res(state) = CO2_NG-Res(state) + CO2_C-Res(state) + CO2_P-Res(state)
```

Commercial

Carbon dioxide emissions from the commercial sector (CO2_Com(state)) are estimated as the sum of carbon dioxide emissions from commercial sector using natural gas (CO2_NG-Com(state)), coal (CO2_C-Com(state)), and petroleum (CO2_P-Com(state)).

```
CO2_Com(state) = CO2_NG-Com(state) + CO2_C-Com(state) + CO2_P-Com(state)
```

Industrial

Carbon dioxide emissions from the industrial sector (CO2_Ind(state)) are estimated as the sum of carbon dioxide emissions from industrial sector using natural gas (CO2_NG-Ind(state)), coal (CO2_C-Ind(state)), and petroleum (CO2_P-Ind(state)).

```
CO2_Ind(state) = CO2_NG-Ind(state) + CO2_C-Ind(state) + CO2_P-Ind(state)
```

Transportation

Carbon dioxide emissions from the transportation sector (CO2_Tran(state)) are estimated as the sum of carbon dioxide emissions from transportation sector using natural gas (CO2_NG-Tran(state)) and petroleum (CO2_P-Tran(state)).

```
CO2_Tran(state) = CO2_NG-Tran(state) + CO2_P-Tran(state)
```

Conclusion

The flow charts described in this report are compact depictions of the national carbon dioxide emissions calculated from state-level energy use in 2008. These diagrams are available at: http://flowcharts.llnl.gov

References

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Appendix

SEDS reports many of the energy flows used to calculate carbon dioxide emissions on the state-level charts.

```
CLEIB  Coal consumed by the electric power sector.
CLRCB  Coal consumed by the residential sector.
CLCCB  Coal consumed by the commercial sector.
CLICB  Coal consumed by the industrial sector.

NGEIB  Natural gas consumed by the electric power sector.
NGRCB  Natural gas consumed by the residential sector.
NGCCB  Natural gas consumed by the commercial sector.
NGICB  Natural gas consumed by the industrial sector.
NGACB  Natural gas consumed by the transportation sector.

PAEIB  All petroleum products consumed by the electric power sector.
PARCB  All petroleum products consumed by the residential sector.
```

Those that are not reported directly are calculated from the following data:

```
PACCB  All petroleum products consumed by the commercial sector.
PAICB  All petroleum products consumed by the industrial sector.
PAACB  All petroleum products consumed by the transportation sector.
```

Certain other flows are computed as functions of directly reported energy use in SEDS:

SEDS reports petroleum consumption in certain sectors as the total of consumption petroleum products including blended ethanol. Therefore, petroleum consumption is computed for the following sectors as:

```
PACCB – ENCCB (Commercial)
PAICB – ENICB (Industrial)
PAACB – ENACB (Transportation)
```

Energy flows used to calculate θ are reported in SEDS from the following data:

```
ARICB  Asphalt and road oil consumed by the industrial sector.
LGICB  LPG consumed by the industrial sector
PPICB  Pentanes plus.
LUICB  Lubricants consumed by the industrial sector.
FNICB  Petrochemical feedstocks, naphtha less than 401°F.
FOICB  Petrochemical feedstocks, other oils equal to or greater than 401°F.
FSICB  Petrochemical feedstocks, still gas, consumed by the industrial sector.
PCICB  Petroleum coke consumed in the industrial sector.
SNICB  Special naphthas.
WXICB  Waxes.
MSICB  Miscellaneous petroleum products.
NAICB  Natural gasoline (including isopentane).
```