Interim report: energy use and greenhouse gas emissions from industry and agriculture in the Genesee/Finger Lakes Region *

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In support of the State of New York's Climate Leadership and Community Protection Act (CLCPA) and its own mission, The Climate Solutions Accelerator of the Genesee-Finger Lakes Region is contributing to preparation of a regional climate action plan for the nine-county Genesee/Finger Lakes (GFL) Region. A key element of this action plan will be a Greenhouse Gas Inventory, which will provide rigorously-derived estimates of the current levels of greenhouse gas (GHG) emissions in the region to serve as a basis for goal-setting and advancing the region's renewable energy transition. This paper reports progress in preparation of a Greenhouse Gas Inventory for the industrial and agricultural sectors of the regional economy, which are probably responsible for about 15 to 25% of the region's total greenhouse gase emissions. A dataset from the US National Renewable Energy Laboratory (NREL) provides detailed breakdowns of US energy use by county and industry sector, which are analyzed to generate energy use profiles for the region. The US Environmental Protection Agency has published a set of emission factors for estimating greenhouse gas emissions from energy use; these are used to estimate and analyze greenhouse gas emissions from industry and agriculture across the region.

1 Introduction[1]

The Climate Solutions Accelerator of the Genesee-Finger Lakes Region [3], a nonprofit coalition of organizations committed to climate action in the region, is planning to champion and contribute to the development of a Regional Climate Action Plan for the Genesee/Finger lakes region: Genesee, Livingston, Monroe, Ontario, Orleans, Seneca, Wayne, Wyoming, and Yates Counties. A key element of this effort will be preparation of a Greenhouse Gas Inventory [21][13] providing reliable estimates of annual anthropogenic (human-caused) greenhouse gas emissions for the region. This inventory will serve several key roles in the preparation and implementation of the action plan:

- Providing a defined starting point or baseline for the effort: What are the region's current anthropogenic greenhouse gas emissions? What is their impact on the global climate crisis?
- Solution identification and prioritization: What economic sectors and activities are responsible for significant amounts of greenhouse gas emissions? What candidate solutions are potentially applicable and will have the greatest favorable impact?
- Target-setting: What reduced levels of net greenhouse gas emissions do we want to achieve, and over what time frame?
- Progress tracking (in due course): n years into the plan, what are the region's annual GHG emissions? How successful have actions under the plan been in reducing them? If other changes in GHG emissions have occurred, what were the causes? Does the plan need to be revised as a result?
- Public education and advocacy: What actions at an individual or community level have the greatest potential to reduce GHG emissions? How can individuals take action to further these reductions?

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[1] **commit:** e0df3a08 2021-09-12 UC!

These objectives can be more effectively realized to the extent that the prepared inventory has several important attributes: it needs to be

- credible, using sound methods based on authoritative research to measure and estimate emissions;
- transparent, using clearly-defined, surveyable algorithms and techniques to obtain emissions estimates;
- open, lending itself to being publicly reviewed, analyzed, and defended;
- fine-grained, permitting emissions sources to be unambiguously identified and made objects of targeted actions;
- versatile, facilitating the preparation of made-to-order analyses and visualizations in support of the diverse tasks and challenges of the transition to a sustainable economy;
- extendable, facilitating incorporation of new data as the effort proceeds.

The analyses described in this paper have been performed in order to

- explore possible approaches to development of a Greenhouse Gas Inventory that could meet these essential requirements;
- gain insight into the level of effort, skills, tools, and methods required to effectively estimate GHG emissions for the region; and
- make early progress on inventorying GHG emissions for the region in support of the broader planned effort.

2 Data sources

The industrial and agricultural economic sectors have been recognized as being especially challenging to address in climate change mitigation activities due to the diversity of activities and processes involved [15]. Recognizing these challenges, a research group at the US National Renewable Energy Laboratory has sought to develop efficient and reliable techniques for estimating energy use in these sectors through the development of the NREL Industrial Emissions Tool (IET) [19]. In addition, they have used the IET to develop and publish a dataset of industrial and agricultural GHG energy use statistics broken down to the level of individual counties, NAICS activity codes [23], and fuel types used for energy generation for the entire United States, the NREL Industrial Energy Data Book (IEDB) [18], published through the NREL data catalogue. The analyses presented here use the IEDB in conjunction with publicly-available tables of County FIPS codes [20] and 2017 NAICS codes [23].

The energy use statistics in [18] are drawn from a variety of sources. Facilities with large amounts of greenhouse gas emissions are required to report their emissions under the US EPA's Greenhouse Gas Reporting Program (GHGRP) [27]. These reported quantities are used directly. To obtain emissions estimates for the far more numerous smaller emitters in the manufacturing, agricultural, mining, and construction sectors, data are combined from

- the EPA's Manufacturing Energy Consumption Survey (MECS) [9]
- the US Energy Information Administration's EIA Form-923 data on electricity use [6]
- the US Department of Agriculture's Agriculture Survey [30][31] and Census of Agriculture [29]
- the US Census Bureau's Economic Census [2] and County Business Patterns (CBP) dataset [28]

in order to first estimate the relationship between facility size and emissions for each economic sector; these estimates are combined with the numbers and sizes (employment, fuel and lubricant cost data, etc.) of emissions-generating facilities to obtain GHG emissions estimates [19].

Because of its reliance on census data available only after a time-lag of about three years, the NREL IEDB provides energy use data only through calendar year 2016. It is likely that any Greenhouse Gas

Inventory would be similarly limited for similar reasons; for instance, New York State's Greenhouse Gas Inventory for years 1990-2016 [21] was not published until July 2019.

3 Tools and methods

The analyses and illustrations presented in this report were prepared using the R programming language [24] and the powerful associated collection of tools for data analysis and visualization [32][33]. The report itself is prepared using an R facility known as Rmarkdown [1], in which a single file or collection of files contains both the text of a document such as this one and the code (which needn't only be R code) used to generate the analysis it presents. Management of the document and code as a single unit permits the use of the rich, capable version control tools available to software developers and ensures that the document in its final form is reproducible. In use of Rmarkdown, the code used to generate elements such as figures and tables can be presented interleaved with the document text as desired, in the form of 'code chunks' such as the example below. A companion document to this one presents all of the code used in preparing the document in this form, along with text describing the data processing and interpretation. Interestingly, little of the code used in preparing this document would need to change in order to prepare similar analyses for any other region in New York State.

```
# I had been using countyNames.Rmd as a child document here, but ran into an Rstudio deficiency that
# makes debugging the document harder: the "Run All Chunks Above" and "Run Current Chunk" icons
# shown in the upper right corner of the chunk don't work when the chunk is a child document. This
# is a longstanding issue: see https://community.rstudio.com/t/making-child-code-chunks-execute-
# by-clicking-run-current-chunk/12907
# and https://stackoverflow.com/questions/48764918/rmarkdown-running-child-chunks-from-inside-
# rstudio/48777264.

# The NREL dataset identifies counties only by FIPS code. We get the corresponding county-names
# and add them to the dataset along with the NAICS sector names and descriptions. Then we filter
# to just the nine counties of the Genesee/Finger Lakes Region.

County_FIPS_codes <- read_delim("County FIPS codes.txt",
    "\t", escape_double = FALSE, col_names = FALSE,
    trim_ws = TRUE) %>%
  transmute(COUNTY_FIPS = X1, County = X2, State = X3)

NYcountyEnergyEsts <- Updated_county_energy_estimates %>%
  filter(STATE == "NEW YORK") %>%                      # Keep only the NEW YORK rows
  left_join(County_FIPS_codes, by = "COUNTY_FIPS") %>%  # Add county names
  left_join(NAICS_Descriptions_2017, by = "NAICS")      # Add NAICS code names and
                                                       # descriptions

GFLcounties <- c("Monroe", "Orleans", "Genesee", "Wyoming", "Livingston",
                 "Ontario", "Yates",  "Wayne",   "Seneca")
GFLcountyEnergyEsts <- NYcountyEnergyEsts %>%
  filter(County %in% GFLcounties)

# The NREL dataset contains some rows with missing MMBTU_TOTAL values; these result in NAs.
# Replace the NAs with 0s.
GFLcountyEnergyEsts[["MMBTU_TOTAL"]][
    which(is.na(GFLcountyEnergyEsts[["MMBTU_TOTAL"]]))] <- 0
```

4 Energy use

One of the benefits of using the NREL IEDB is the insight it provides into changes in energy use patterns that have occurred in recent years. As Figure 4.1 illustrates, Monroe County's energy use in 2016 is about 40% of industrial and agricultural energy use for the region as a whole. However, the decline in Monroe County energy use over the period 2010-2016 is quite remarkable — roughly a 40% decline. Table 4.1 presents the same data in numerical form.

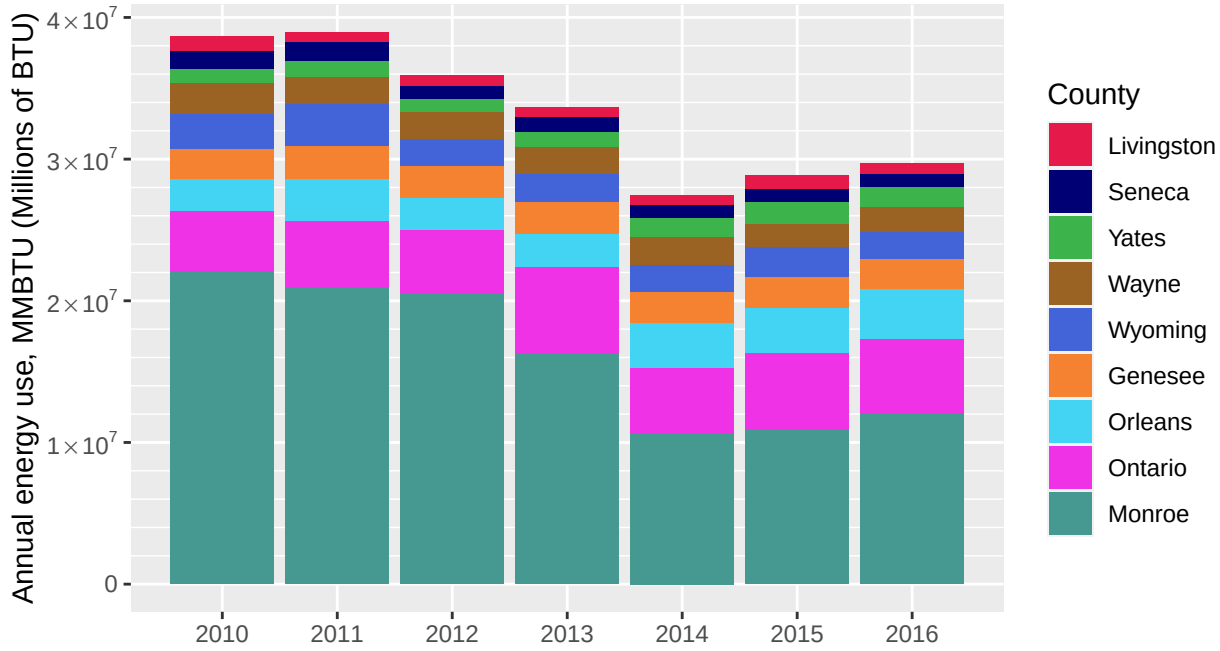

Figure 4.1: Energy use summary, industrial and agricultural

Table 4.1: Annual industrial and agricultural energy use (millions of BTU) by county

County	2010	2011	2012	2013	2014	2015	2016
Livingston	1,076,345	712,392	711,880	761,146	714,366	964,391	757,098
Seneca	1,259,022	1,337,604	950,480	1,080,584	917,285	921,373	904,099
Yates	941,916	1,066,878	884,669	1,000,306	1,277,644	1,548,254	1,396,637
Wayne	2,274,171	1,983,065	1,938,428	1,917,883	2,055,859	1,661,157	1,808,375
Wyoming	2,431,902	2,956,963	1,875,397	1,939,111	1,878,797	2,069,706	1,883,152
Genesee	2,149,425	2,341,810	2,300,367	2,336,406	2,190,285	2,200,564	2,128,657
Orleans	2,198,114	2,895,656	2,240,140	2,282,325	3,144,063	3,171,847	3,495,222
Ontario	4,289,109	4,660,516	4,478,274	6,087,898	4,666,991	5,381,593	5,352,130
Monroe	22,077,510	21,002,892	20,494,910	16,300,085	10,602,359	10,926,289	11,984,305
Totals	38,697,515	38,957,776	35,874,544	33,705,743	27,447,649	28,845,172	29,709,677

Figure 4.2 presents the same total energy use shown above, but this time broken down by fuel type. The decline in the use of coal is especially striking. Since there is only a modest increase at most in the use of other fuels, the coal decline seems likely to be a result of changes in economic activity rather than of fuel-switching. Use of natural gas increases from 32% in 2010 to 38% in 2016; use of other fuels changes only modestly.

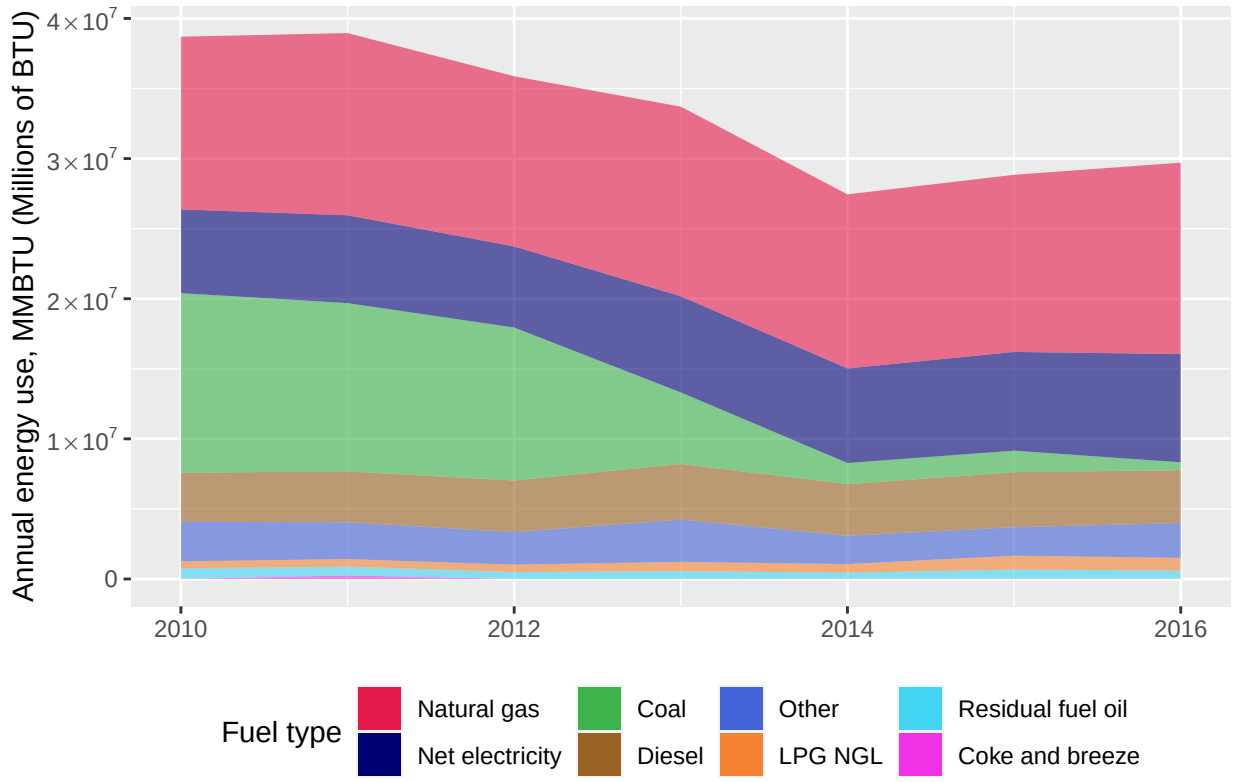

Figure 4.2: Energy use summary, industrial and agricultural by fuel type

Table 4.2: Annual industrial and agricultural energy use (millions of BTU) by fuel type

Year	Natural gas	Net electricity	Coal	Diesel	Other	LPG NGL	Residual fuel oil	Coke and breeze	Annual totals
2010	12,322,425	5,973,777	12,821,083	3,497,654	2,826,787	489,975	763,750	2,065	38,697,515
2011	13,000,376	6,268,203	12,011,018	3,629,709	2,627,298	535,800	632,209	253,165	38,957,776
2012	12,145,319	5,782,518	10,918,589	3,680,316	2,324,554	526,106	495,754	1,388	35,874,544
2013	13,526,770	6,864,422	5,107,783	3,970,744	3,013,689	661,663	559,260	1,412	33,705,743
2014	12,425,098	6,745,854	1,511,964	3,682,369	2,018,555	614,875	444,612	4,323	27,447,649
2015	12,641,042	7,043,588	1,537,364	3,926,365	2,032,216	996,177	664,099	4,321	28,845,172
2016	13,661,714	7,722,315	562,797	3,768,765	2,487,670	899,827	602,266	4,324	29,709,677
Totals	89,722,742	46,400,676	44,470,598	26,155,922	17,330,769	4,724,424	4,161,950	270,998	233,238,077

Table 4.3: Standard fuel types

Fuel type	Definition
Coal	Coal: A readily combustible black or brownish-black rock whose composition, including inherent moisture, consists of more than 50 percent by weight and more than 70 percent by volume of carbonaceous material. It is formed from plant remains that have been compacted, hardened, chemically altered, and metamorphosed by heat and pressure over geologic time. Includes Anthracite, Bituminous, and Lignite varieties, which have different levels of heat content.
Coke and Breeze	Coal Coke: A hard, porous product made from baking bituminous coal in ovens at temperatures as high as 2,000 degrees Fahrenheit. It is used both as a fuel and as a reducing agent in smelting iron ore in a blast furnace. Breeze: The fine screenings from crushed coke. Usually breeze will pass through a $\frac{1}{2}$-inch or $\frac{3}{4}$-inch screen opening. It is most often used as a fuel source in the process of agglomerating iron ore.
Diesel	Diesel fuel: A fuel composed of distillates obtained in petroleum refining operation or blends of such distillates with residual oil used in motor vehicles. The boiling point and specific gravity are higher for diesel fuels than for gasoline.
LPG-NGL	Liquefied Petroleum Gases (LPG): Ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutane produced at refineries or natural gas processing plants, including plants that fractionate raw natural gas plant liquids. Natural Gas Liquids (NGL): Those portions of reservoir gas that are liquefied at the surface in field facility or gas processing plants. Some examples are ethane, propane, butanes, pentanes, natural gasoline, and condensate.
Natural gas	A mixture of hydrocarbon compounds and small quantities of various nonhydrocarbons existing in the gaseous phase or in solution with crude oil in natural underground reservoirs at reservoir conditions.
Net electricity	Net Electricity: Net electricity is estimated for each manufacturing establishment as the sum of purchased electricity, transfers in, and generation from noncombustible renewable resources minus the quantities of electricity sold and transferred offsite. Thus net electricity excludes the quantities of electricity generated or cogenerated onsite from combustible energy sources.
Other	Energy source not falling into any of the other categories. Includes wood-derived and other biomass fuels, but can also include miscellany such as used vehicle tires.
Residual fuel oil	A general classification for the heavier oils, known as No. 5 and No. 6 fuel oils, that remain after the distillate fuel oils and lighter hydrocarbons are distilled away in refinery operations. It conforms to ASTM Specifications D396 and D975 and Federal Specification VV-F-815C. No. 5, a residual fuel oil of medium viscosity, is also known as Navy Special and is defined in Military Specification MIL-F-859E, including Amendment 2 (NATO Symbol F-770). It is used in steam-powered vessels in government service and inshore powerplants. No. 6 fuel oil includes Bunker C fuel oil and is used for the production of electric power, space heating, vessel bunkering, and various industrial purposes.

Source: The EIA Glossary

Table 4.3 provides definitions of the fuel types used in the NREL IEDB and in this document, based on definitions provided by the US Energy Information Agency [7][11]. *Net electricity* in most cases refers to energy purchased from grid suppliers, but could refer increasingly to on-site renewable electricity generation in future years.

Figure 4.3 shows the trend in industrial/agricultural energy and fuel use over the period 2010-2016; note that vertical scales differ from one panel to another to allow detail to be shown legibly. Here it is clear that the former use of coal was mostly limited to Monroe and Wyoming counties, and had nearly disappeared by 2016 in both cases. Differences in fuel type composition from one county to another are very striking, probably resulting from the presence of diverse kinds of industrial and agricultural

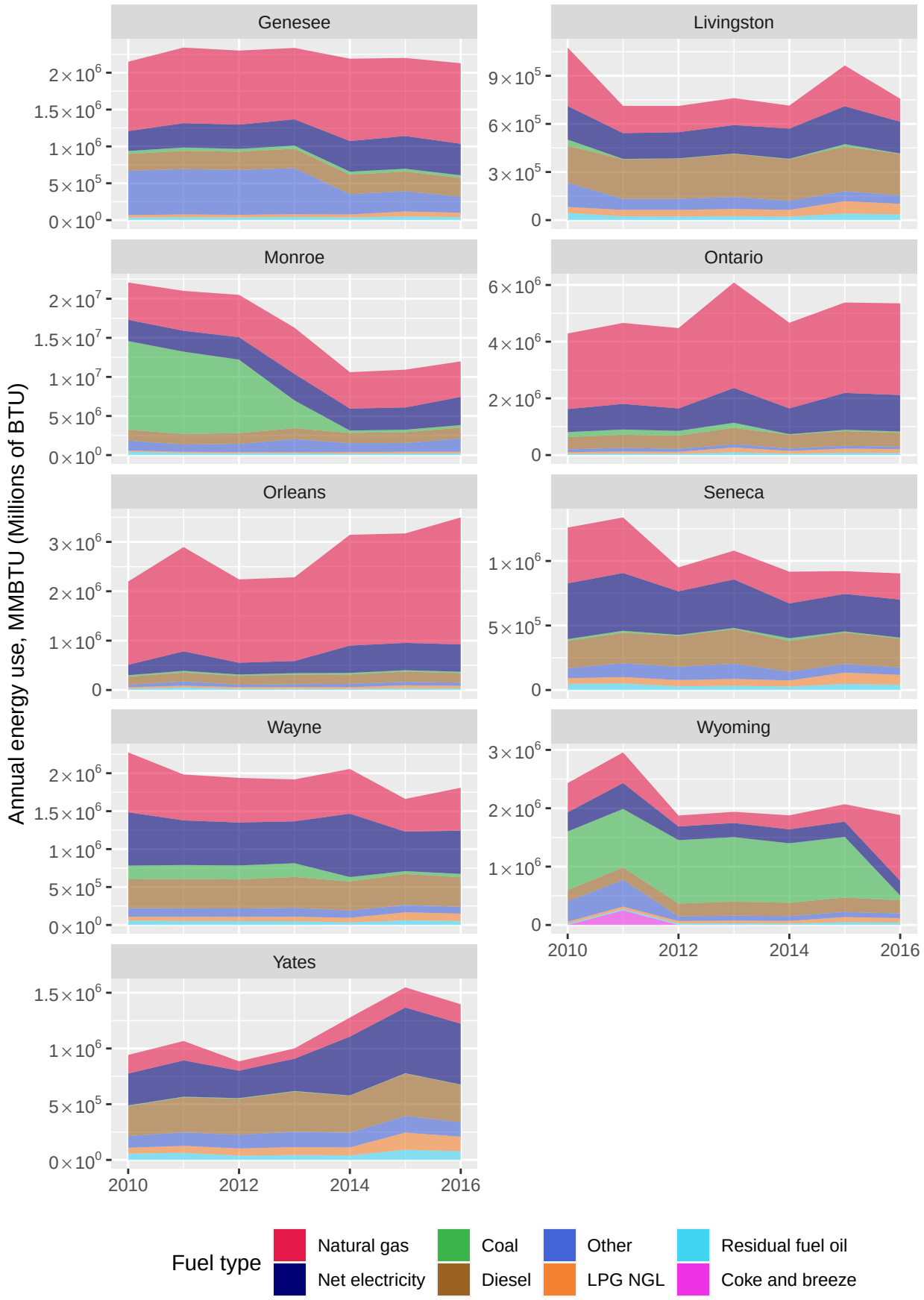

Figure 4.3: Annual industrial and agricultural energy use by county and fuel type

activity in the counties of the region.

Figures 4.4, 4.5, and 4.6 show energy use by fuel type for each economic sector represented by a 3-digit NAICS code. (Here again, different panels have different vertical scales.) Use of coal in the early time period is clearly identified as being primarily for chemical manufacturing, roughly coinciding with Eastman Kodak Corporation's 2011 bankruptcy filing and the sale of its photographic film business [17]. The contrasts in energy use from one economic sector to another are striking, suggesting that the challenges in making the transition to renewable energy will also be very diverse.

Table 4.4 provides numerical breakdowns of energy use by economic sector and fuel type, with the sectors having highest total energy use at the top and most-used fuels on the left. Table 4.5 provides the analogous breakdowns by sector and county. Comparing the two tables makes it a straightforward process to identify the sectors and approximate locations of the industrial and agricultural activities having the greatest energy use and likely greenhouse gas emissions, which should help focus climate actions where they can have the greatest beneficial impact.

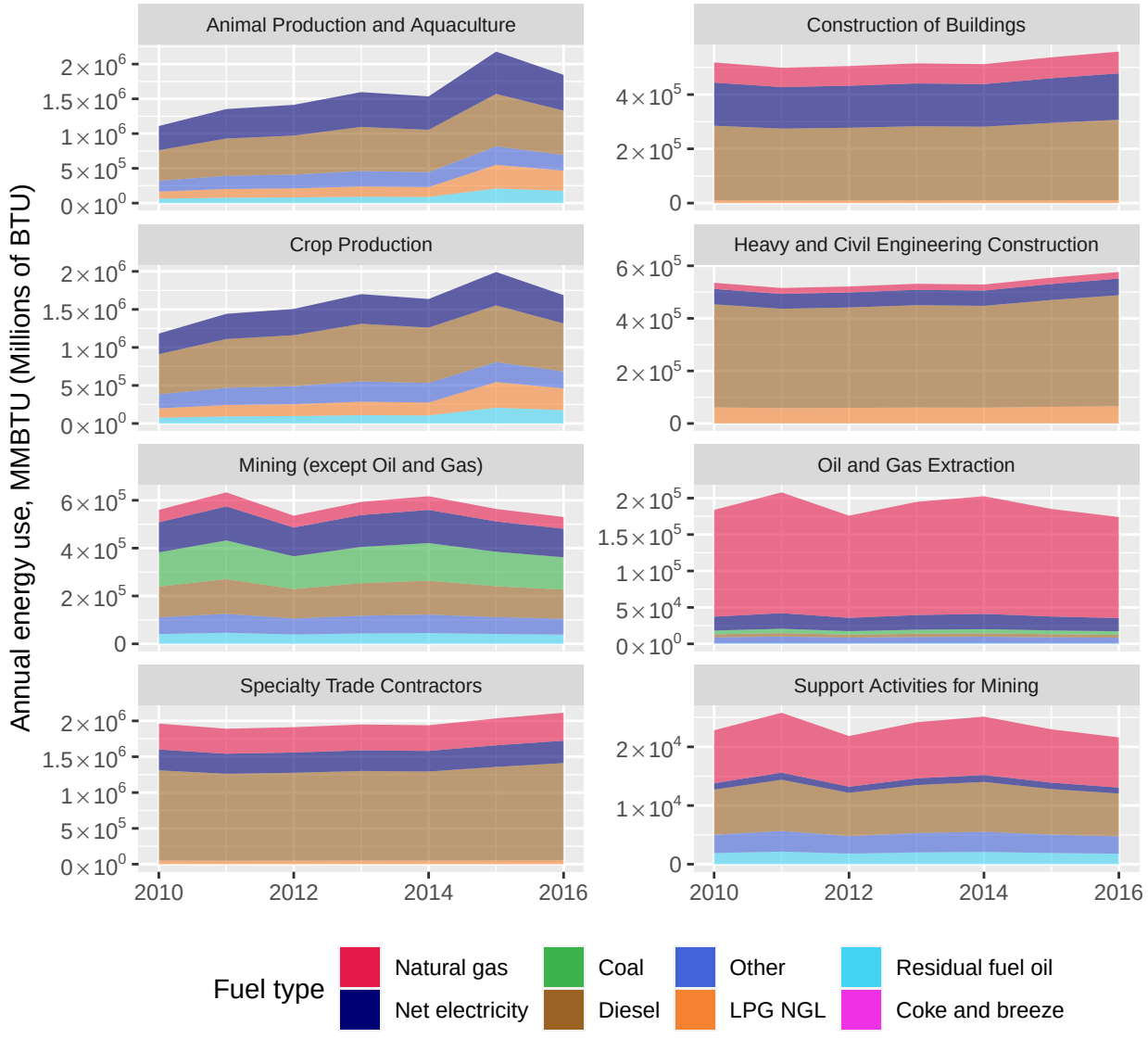

Figure 4.4: Annual energy use by *non-manufacturing* sector and fuel type, entire region

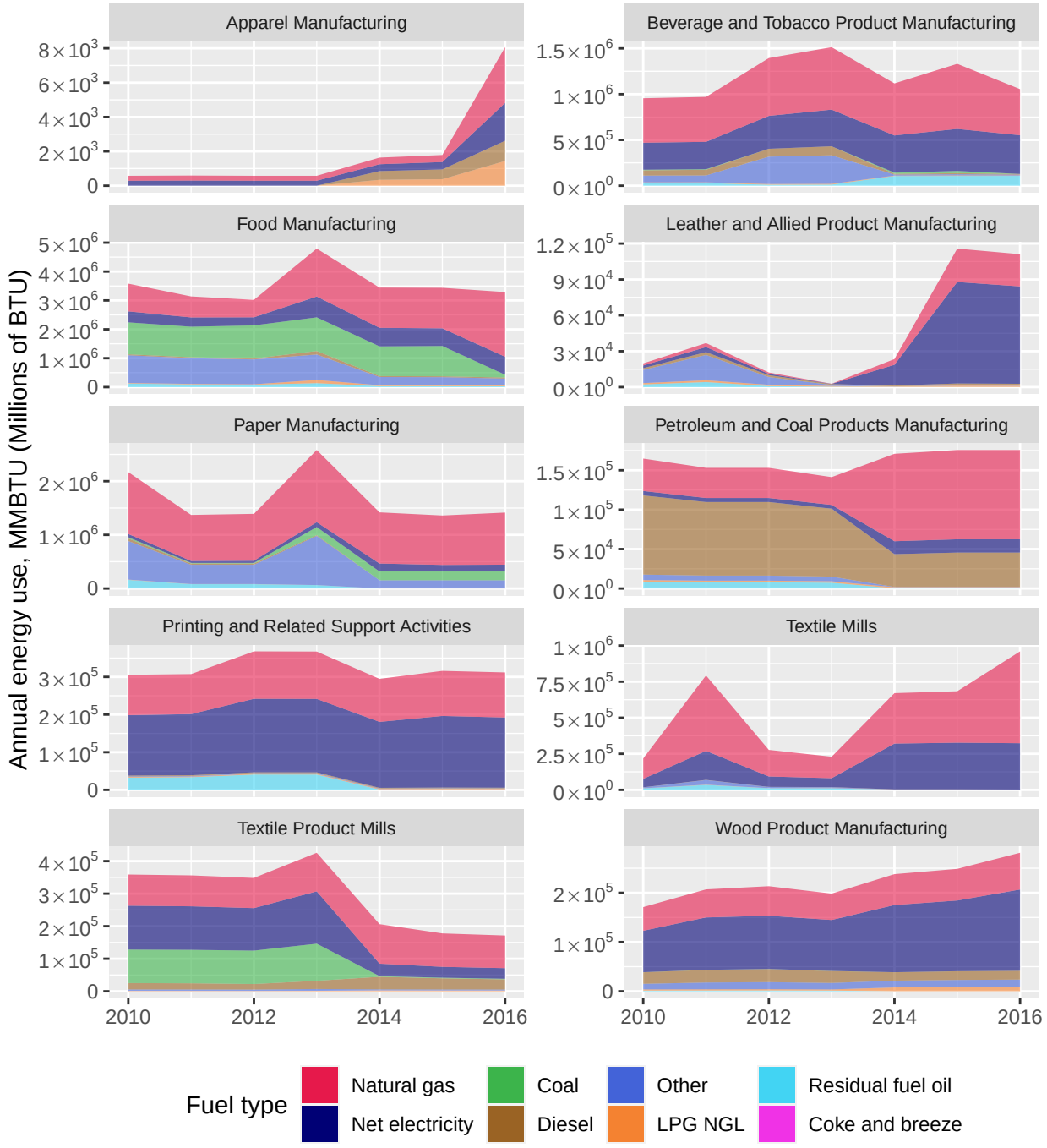

Figure 4.5: Annual energy use by *manufacturing* sector and fuel type, entire region (NAICS codes 311-324)

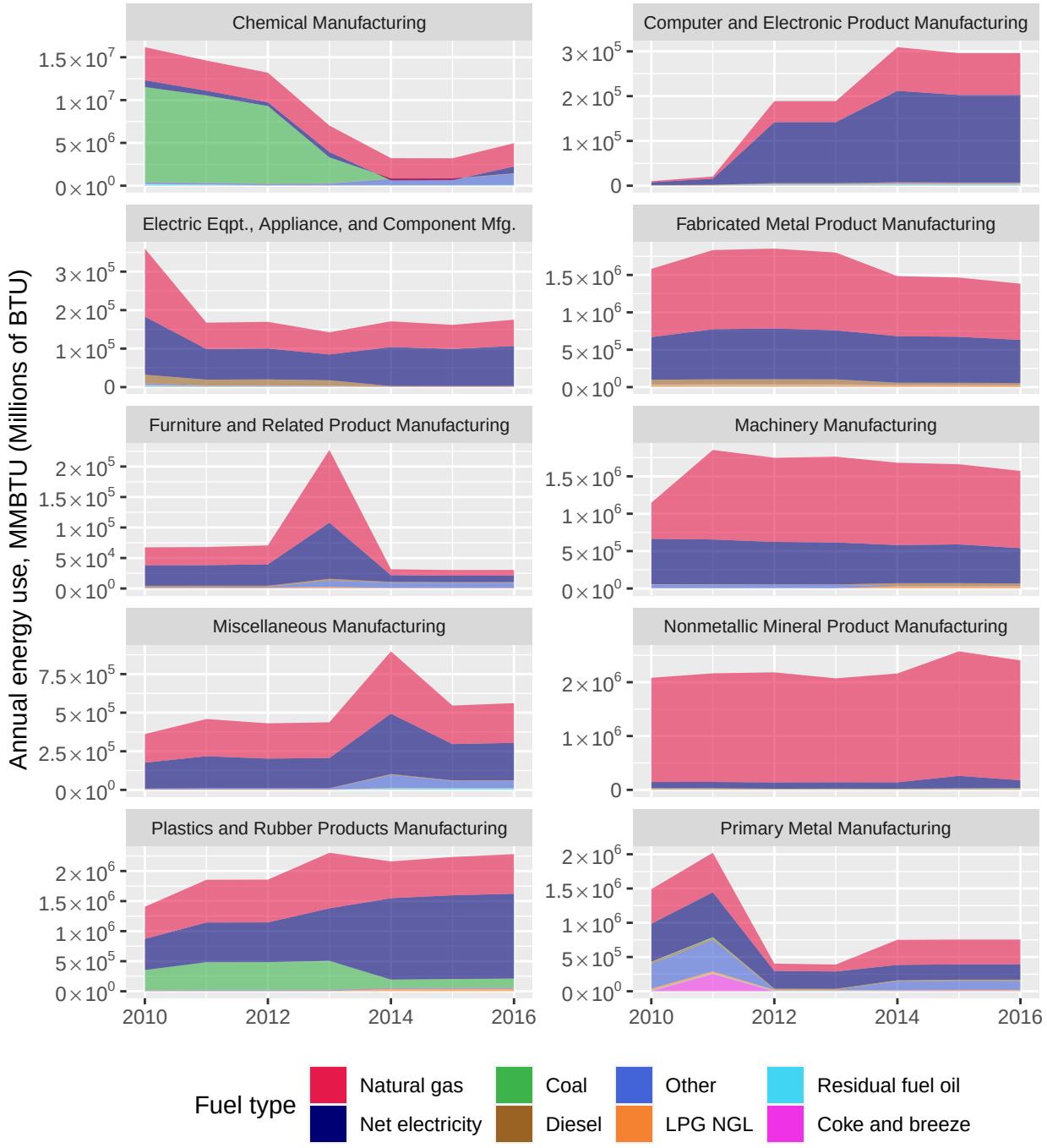

Figure 4.6: Annual energy use by *manufacturing* sector and fuel type, entire region (NAICS codes 325-339)

Table 4.4: 2016 energy use (millions of BTU) by industry sector and fuel type

Sector (NAICS)	Fuel types								Sector totals
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze	
325. Chemical Manufacturing	2,720,769	789,354	47,801	1,325,722	23,815	56,931	0	0	4,964,393
311. Food Manufacturing	2,240,185	623,498	36,032	239,030	27,841	28,647	94,099	0	3,289,333
327. Nonmetallic Mineral Product Manufacturing	2,225,137	145,410	8,665	6,334	7,314	0	11,370	0	2,404,232
326. Plastics and Rubber Products Manufacturing	659,313	1,410,356	6,080	13,626	40,836	0	150,624	0	2,280,835
238. Specialty Trade Contractors	390,040	312,716	1,354,605	0	56,287	0	0	0	2,113,649
112. Animal Production and Aquaculture	0	515,008	638,511	225,414	288,731	177,921	0	0	1,845,584
111. Crop Production	0	371,785	631,097	222,796	285,378	175,855	0	0	1,686,912
333. Machinery Manufacturing	1,032,283	473,303	34,598	3,460	28,671	0	0	0	1,572,315
322. Paper Manufacturing	971,334	126,948	1,117	151,958	909	0	162,933	0	1,415,199
332. Fabricated Metal Product Manufacturing	751,063	576,940	29,078	3,386	22,392	0	0	0	1,382,859
312. Beverage and Tobacco Product Manufacturing	503,789	423,107	7,720	9,381	3,536	107,473	0	0	1,055,005
313. Textile Mills	636,493	321,005	899	153	1,060	157	0	0	959,765
331. Primary Metal Manufacturing	363,508	223,378	17,184	131,181	14,427	672	1,771	4,298	756,420
237. Heavy and Civil Engineering Construction	25,033	63,171	422,384	0	65,830	0	0	0	576,417
339. Miscellaneous Manufacturing	257,062	242,532	3,360	47,958	1,210	9,630	0	0	561,753
236. Construction of Buildings	80,191	170,853	296,227	0	10,959	0	0	0	558,230
212. Mining (except Oil and Gas)	49,122	119,086	121,480	66,349	0	38,785	135,257	0	530,078
323. Printing and Related Support Activities	119,645	186,420	1,870	1,236	1,715	972	0	0	311,858
334. Computer and Electronic Product Manufacturing	93,425	195,568	1,300	1,687	1,807	2,268	0	0	296,055
321. Wood Product Manufacturing	74,644	165,112	17,837	14,696	8,953	105	53	0	281,399
324. Petroleum and Coal Products Manufacturing	113,353	16,849	43,498	325	1,455	279	0	0	175,759
335. Electrical Equipment, Appliance, and Component Manufacturing	68,175	104,027	1,236	579	1,027	0	0	26	175,068
211. Oil and Gas Extraction	138,770	17,990	3,986	7,726	0	677	4,927	0	174,076
314. Textile Product Mills	100,305	32,578	31,266	3,031	2,336	0	1,762	0	171,278
316. Leather and Allied Product Manufacturing	26,933	81,400	1,416	212	1,044	96	0	0	111,102
337. Furniture and Related Product Manufacturing	9,351	10,695	1,040	8,482	852	0	0	0	30,419
213. Support Activities for Mining	8,549	1,020	7,302	2,950	0	1,799	0	0	21,619
315. Apparel Manufacturing	3,243	2,205	1,176	0	1,441	0	0	0	8,064
Totals	13,661,714	7,722,315	3,768,765	2,487,670	899,827	602,266	562,797	4,324	29,709,677

Table 4.5: 2016 energy use (millions of BTU) by industry sector and county

Sector (NAICS)	Counties									Sector totals
	Monroe	Ontario	Orleans	Genesee	Wyoming	Wayne	Yates	Seneca	Livingston	
325. Chemical Manufacturing	2,506,459	11,197	1,950,064	74,971	0	24,861	334,843	0	61,997	4,964,393
311. Food Manufacturing	638,244	839,556	0	447,602	1,071,369	221,001	10,366	22,134	39,060	3,289,333
327. Nonmetallic Mineral Product Manufacturing	135,738	2,055,271	0	10,317	0	202,905	0	0	0	2,404,232
326. Plastics and Rubber Products Manufacturing	1,376,215	709,761	15,142	7,650	2,550	128,632	35,785	0	5,100	2,280,835
238. Specialty Trade Contractors	1,200,505	243,426	64,122	122,307	66,497	214,927	60,560	48,685	92,621	2,113,649
112. Animal Production and Aquaculture	52,533	237,466	78,843	120,948	287,086	153,310	554,344	222,962	138,090	1,845,584
111. Crop Production	205,197	249,876	143,358	141,091	116,147	288,754	220,579	144,578	177,332	1,686,912
333. Machinery Manufacturing	1,211,046	46,529	9,918	95,063	25,076	32,416	0	112,837	39,430	1,572,315
322. Paper Manufacturing	870,635	0	0	544,564	0	0	0	0	0	1,415,199
332. Fabricated Metal Product Manufacturing	690,020	437,137	13,013	103,533	37,670	67,533	2,324	3,486	28,142	1,382,859
312. Beverage and Tobacco Product Manufacturing	647,138	110,899	6,429	4,286	0	4,286	87,637	190,044	4,286	1,055,005
313. Textile Mills	52,159	0	907,606	0	0	0	0	0	0	959,765
331. Primary Metal Manufacturing	521,115	29,846	0	5,752	151,527	0	0	48,180	0	756,420
237. Heavy and Civil Engineering Construction	270,033	72,701	36,351	25,965	20,772	46,737	5,193	31,158	67,508	576,417
339. Miscellaneous Manufacturing	220,361	1,357	132,693	2,036	339	175,216	339	29,072	339	561,753
236. Construction of Buildings	309,192	61,959	21,655	31,280	21,655	43,311	20,452	16,242	32,483	558,230
212. Mining (except Oil and Gas)	143,407	66,580	84,636	113,000	0	74,785	0	28,761	18,909	530,078
323. Printing and Related Support Activities	274,203	3,099	775	1,937	10,486	1,162	775	775	18,647	311,858
334. Computer and Electronic Product Manufacturing	296,055	0	0	0	0	0	0	0	0	296,055
321. Wood Product Manufacturing	44,298	15,635	2,606	2,606	71,505	66,293	60,793	0	17,664	281,399
324. Petroleum and Coal Products Manufacturing	29,223	127,054	0	0	0	14,611	0	4,870	0	175,759
335. Electrical Equipment, Appliance, and Component Manufacturing	104,751	19,669	0	2,102	0	44,341	0	0	4,204	175,068
211. Oil and Gas Extraction	0	0	0	174,076	0	0	0	0	0	174,076
314. Textile Product Mills	164,759	4,346	0	0	0	0	2,173	0	0	171,278
316. Leather and Allied Product Manufacturing	9,370	4,685	0	97,046	0	0	0	0	0	111,102
337. Furniture and Related Product Manufacturing	3,633	4,082	17,201	474	474	3,292	474	316	474	30,419
213. Support Activities for Mining	0	0	10,809	0	0	0	0	0	10,809	21,619
315. Apparel Manufacturing	8,014	0	0	50	0	0	0	0	0	8,064
Totals	11,984,305	5,352,130	3,495,222	2,128,657	1,883,152	1,808,375	1,396,637	904,099	757,098	29,709,677

5 Greenhouse gas emissions

5.1 Assumptions

With the energy use information in hand, it remains only to estimate greenhouse gas emissions using the conversion factors provided by the EPA, considering in turn the various fuel types and industry sectors. Since the energy use quantities are all provided in units of millions of BTU (mmBTU) and quantities of CO_2, CH_4, and N_2O generated are provided per mmBTU for each fuel type, the calculations are quite straightforward, although the assumptions underlying them warrant a degree of scrutiny.[2]

- Coal: The coal used in the US is of various types. For the year 2016, coal production by weight was 44.6% bituminous, 45.3% sub-bituminous, 9.8% lignite, and less than 0.3% anthracite by weight; or 55% bituminous, 38% sub-bituminous, 6.8% lignite, and less than 0.3% anthracite by heat content. The EPA emission factors include a set of emission values for a coal fuel type of "Mixed (Industrial Sector)" which are used below in computing GHG emissions from coal. This is clearly a weighted average of the emission values for the four coal types, based on the relative amounts of these coal grades used by the industrial sector [5].
- Coke and breeze: In addition to coke derived from coal, US petroleum refineries synthesize significant amounts of petroleum coke; however, nearly all of this 'petcoke' is exported rather than being used domestically [8]. The EPA emission factors provide values only for Coke (not Breeze), so these are used in the analysis below; breeze apparently differs from coke only in chunk size and not in composition to any significant degree.
- Diesel: Most diesel fuel used in the US is what is known as "Grade No.2-D diesel fuel", where the "No.2" refers to the fuel's level of density and viscosity. Grade No.2-D diesel fuel is very similar in composition to what the industry classifies as No.2 fuel oil [16]. The EPA emission factors don't specify values for diesel fuel specifically, so the values for No.2 fuel oil are used below.
- LPG and NGL: The fuel type "LPG-NGL" would appear from its name to apply to two categories of fuels: "Liquefied Petroleum Gases" and "Natural Gas Liquids". However, the EIA definitions don't seem to clearly distinguish the two categories; both are composed primarily of liquefied propane and butane [12]. Accordingly, the analysis below uses the EPA's emission factors for "Liquefied Petroleum Gases (LPG)" for this fuel type; EPA provides no separate factors for natural gas liquids.
- Natural gas: The natural gas fuel type is clearly delineated and has specified emission factors; these are used in the analysis below.
- Net electricity: For net electricity, the emission factors used are those provided by the EPA in [26] for the Northeast Power Coordinating Council's Upstate NY region, which contains the entire GFL region. Note that the EPA table gives emissions for all three GHGs in kg/MWh; these are converted to kg or g per mmBTU.
- Other: Other fuels for the region are almost entirely wood-based biomass fuels, based on statistics for New York State as a whole [10]. Modest quantities of wind and hydrolelectric power are also generated for on-site industrial use. Like the latter, biomass is considered for this analysis to have no greenhouse gas emissions, since emitted carbon was earlier absorbed from the atmosphere through photosynthesis (recognizing that this may be an oversimplification; see for instance Costanza et al [4]). Changes in carbon sequestration capacity due to the conversion from wild forest to harvested commercial forest should be accounted for under land use change.

[2] The EPA tables give differing quantities of greenhouse gas emissions per unit fuel consumption (gallons) for gasoline-fueled vs. diesel-fueled agricultural equipment and for gasoline- vs. diesel-fueled construction equipment. However, the NREL dataset gives us no way to distinguish between gasoline-fueled and diesel-fueled equipment; the assumption appears to be that diesel fuel is used in most cases.

- Residual fuel oil: The term "residual fuel oil" as defined applies to both of what are classified as No.5 and No.6 residual fuel oils. No.5 residual fuel oil is evidently used mostly as a fuel for naval and commercial ships [12]. Accordingly, only the emission factors for No.6 residual fuel oil (which has a variety of onshore uses) are used in the analysis below.

Table 5.1: Summary: emission factors for NREL fuel types

Fuel type	CO_2, kg per mmBTU	CH_4, g per mmBTU	N_2O, g per mmBTU	CO_2-equivalent emissions, $kgCO_2$ per mmBTU
Coal	94.67	11.00	1.6	95.42
Coke and breeze	113.67	11.00	1.6	114.42
Diesel	73.96	3.00	0.6	74.21
LPG-NGL	61.71	3.00	0.6	61.96
Natural gas	53.06	1.00	0.1	53.11
Net electricity	39.21	2.79	0.4	39.39
Other	0.00	0.00	0.0	0.00
Residual fuel oil	75.10	3.00	0.6	75.35

Table 5.1 summarizes the emission factors used for these fuel types.

The greenhouse gas emission quantities in this report are presented in terms of "CO_2-equivalent emissions," weighting emissions of other greenhouse gases based on their marginal impact on radiative forcing compared to that of an equivalent incremental concentration of CO_2 [14]. As can be seen in Table A.5, the global warming potentials of both methane and nitrous oxide are substantially larger than that of carbon dioxide; it is only because CO_2 is emitted in far greater quantities that it has a greater total impact on the global climate. Based on the NREL dataset and the EPA emission factors, CO_2 itself accounts for about 99.6% of the CO_2-equivalent agricultural and industrial greenhouse gas emissions of the Genesee/Finger Lakes Region; methane and nitrous oxide constitute an almost negligible fraction of these emissions.[3]

5.2 Results and analysis

Figure 5.1 provides a summary view of estimated annual greenhouse gase emissions for the region, stratified by county; the same data appear in Table 5.2. Monroe County has the greatest quantity of total emissions, but the decline in its emissions over this period is very striking. As can be seen in Figure 5.2, Monroe County's *per capita* industrial and agricultural emissions are almost the lowest in the nine-county region by 2016. No value judgment should be drawn from this comparison: the relatively high per capita emissions of the sparsely-populated rural counties in the region are possibly a result of the prevalence of highly-mechanized agricultural operations in these counties. 2016 emissions per capita for New York State as a whole were found to be about 10 metric tons CO2-equivalent per person, with the largest fractions resulting from transportation (37%) and from commercial (18%) and residential (21%) combustion primarly for heating [21], so this estimate of industrial and agricultural emissions for the region is roughly in line with the pattern of emissions for the state as a whole. Natural gas is the largest remaining source of greenhouse gas emissions as of 2016, with diesel fuel and net electricity also being significant contributors.

[3] This will not necessarily be true when use of nitrogen-based fertilizers and other agricultural chemicals is considered in a companion report.

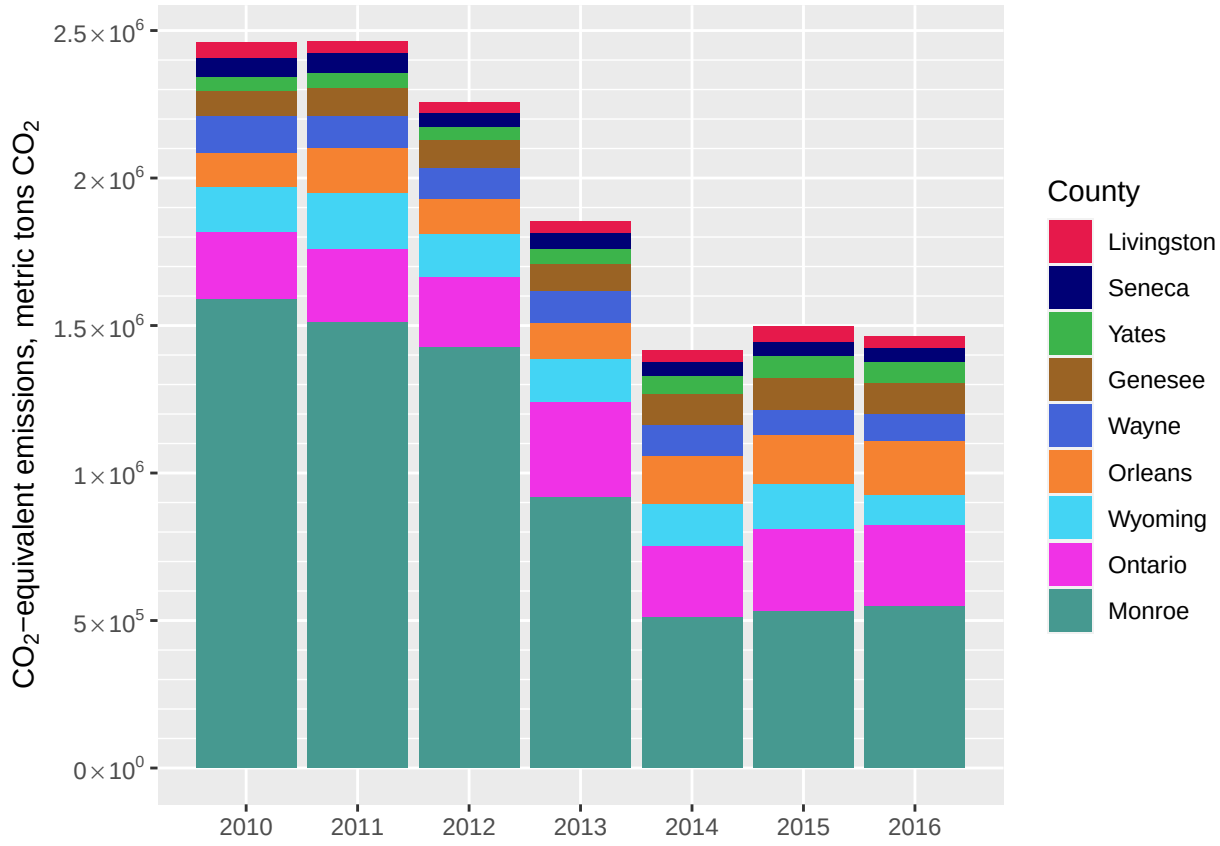

Figure 5.1: Annual CO_2-equivalent agricultural/industrial emissions, metric tons

Table 5.2: Annual agricultural/industrial CO_2-equivalent emissions (metric tons) by county

County	2010	2011	2012	2013	2014	2015	2016
Livingston	54,126	38,183	38,166	40,749	38,787	52,771	41,662
Seneca	63,300	66,407	46,854	53,175	48,351	48,753	47,519
Yates	48,123	54,533	45,539	51,282	62,225	77,890	69,848
Genesee	86,227	95,479	93,337	94,516	104,439	105,148	103,809
Wayne	122,502	108,810	106,722	105,988	104,474	88,488	95,490
Orleans	116,869	150,545	118,969	121,163	162,086	164,059	181,002
Wyoming	153,326	189,910	143,776	147,945	140,954	152,659	102,017
Ontario	229,504	247,601	239,752	323,982	243,986	278,753	277,214
Monroe	1,586,997	1,511,275	1,424,901	915,475	510,062	530,738	546,331
Totals	2,460,973	2,462,742	2,258,015	1,854,276	1,415,363	1,499,260	1,464,891

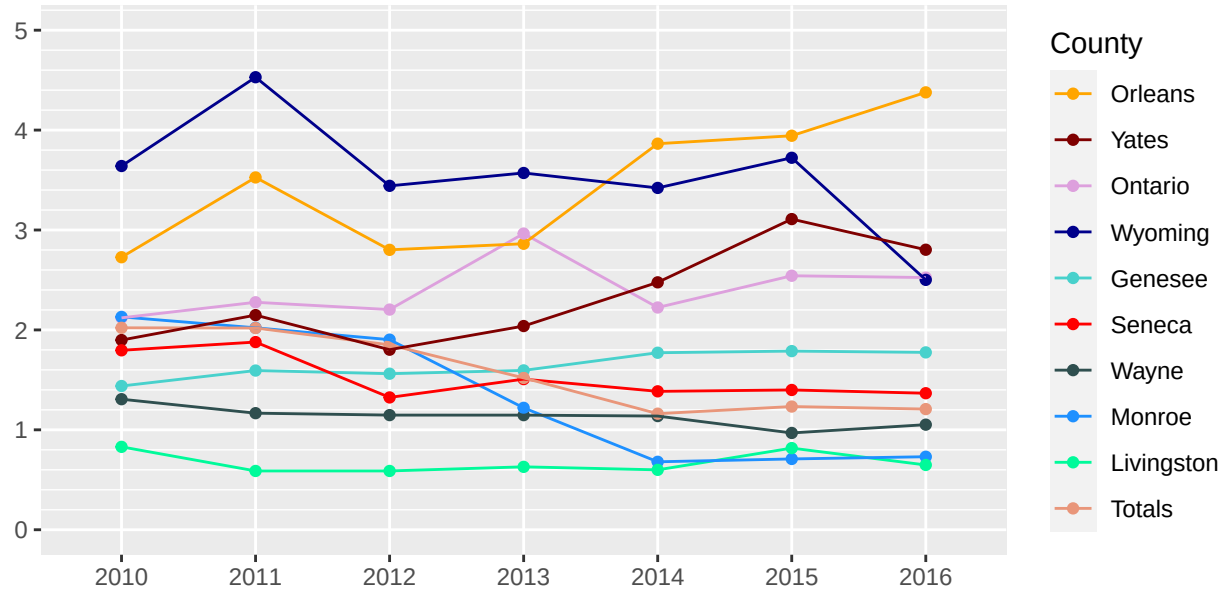

Figure 5.2: CO_2-equivalent agricultural/industrial emissions per capita, metric tons

Table 5.3: CO_2-equivalent agricultural/industrial GHG emissions per capita, metric tons

County	2010	2011	2012	2013	2014	2015	2016
Orleans	2.73	3.53	2.80	2.86	3.86	3.94	4.38
Yates	1.90	2.15	1.80	2.04	2.48	3.11	2.80
Ontario	2.12	2.28	2.20	2.96	2.22	2.54	2.52
Wyoming	3.64	4.53	3.44	3.57	3.42	3.72	2.50
Genesee	1.44	1.59	1.56	1.59	1.77	1.79	1.78
Seneca	1.80	1.88	1.32	1.51	1.39	1.40	1.37
Wayne	1.31	1.17	1.15	1.15	1.14	0.97	1.05
Monroe	2.13	2.02	1.90	1.22	0.68	0.71	0.73
Livingston	0.83	0.59	0.59	0.63	0.60	0.82	0.65
Totals	2.02	2.02	1.85	1.52	1.16	1.23	1.21

As Figure 5.3 makes clear, emissions from coal were nearly half of the region's total industrial and agricultural greenhouse gas emissions in 2010, but had fallen almost to zero by 2016. In fact, four large boilers at Eastman Kodak Corporation's Kodak Park facility accounted for the majority of this coal use in 2010, but had been shut down by 2013 [18].

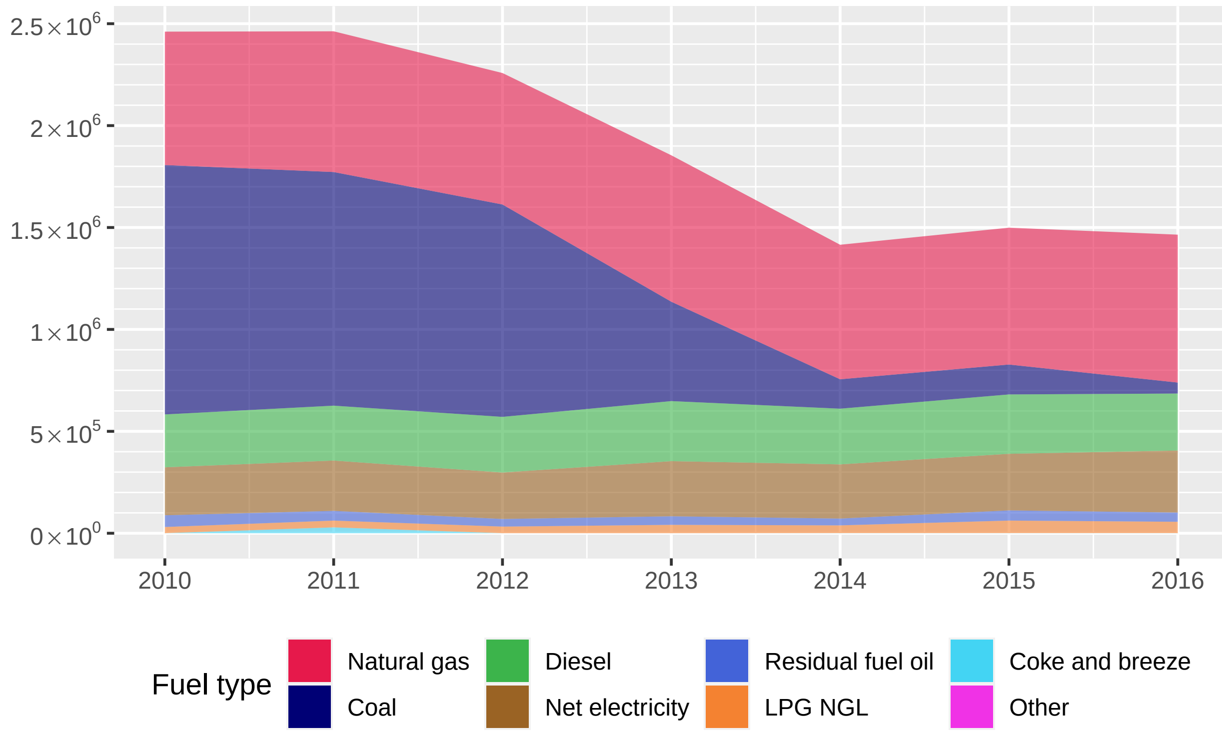

Figure 5.3: CO_2-equivalent agricultural/industrial emissions per fuel type, metric tons

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5.3 *Sector analysis*

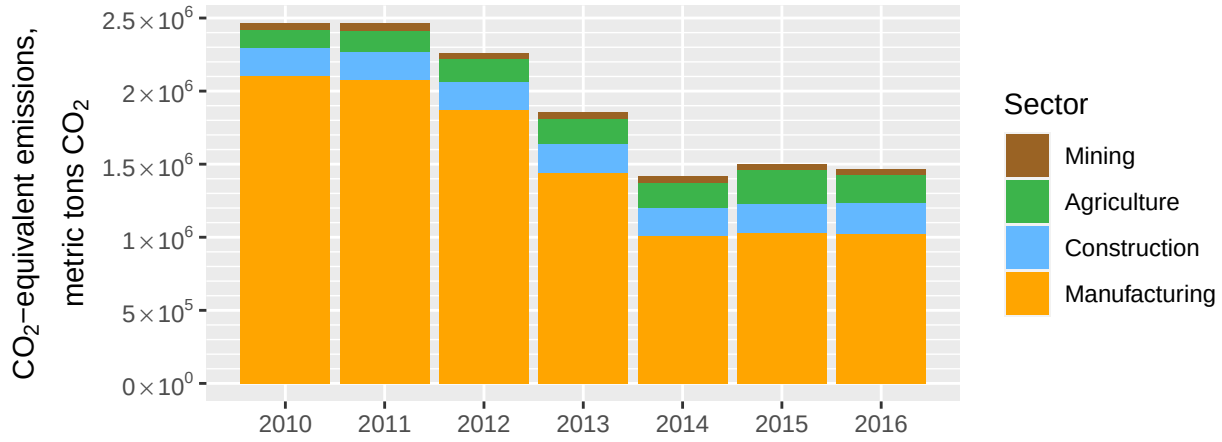

Figure 5.4: CO_2-equivalent agricultural/industrial emissions per sector, metric tons

Figure 5.4 provides an overview of GHG emissions by economic sector for the region. Manufacturing is responsible for by far the largest fraction of emissions, but its contribution has declined by nearly half over the period from 2010 to 2016. Table 5.4 breaks down each sector's 2016 emissions by county[4]; we see that Monroe County has the largest fraction of the manufacturing emissions, with Ontario and Orleans Counties also significant contributors. Monroe County has by far the largest portion of construction-related emissions, while emissions from agriculture are rather widely distributed and mining constitutes a very small fraction of the total.

Table 5.4: CO_2-equivalent GHG emissions per sector and county, metric tons CO_2

Sector	County distribution	Monroe	Ontario	Wyoming	Orleans	Wayne	Genesee	Yates	Seneca	Livingston
Manufacturing		408,869	222,483	73,166	155,026	47,162	62,144	22,540	19,586	10,355
Construction		114,868	24,469	7,031	7,938	19,729	11,584	5,513	6,257	12,560
Agriculture		14,002	26,472	21,818	12,040	23,947	14,258	41,793	19,906	17,150
Mining		8,591	3,788	0	5,996	4,651	15,821	0	1,769	1,595

The more detailed breakdowns by NAICS category in the following sub-sections yield greater insight into the sources of these emissions. For each of the four sectors, the following pages provide a plot showing the relative emissions quantities for sub-categories of each sector, and the distribution of these emissions across the nine-county region. For manufacturing, the top three categories (chemical, glass, and plastic product manufacturing) are responsible for more than a third of all manufacturing emissions. Interestingly, these emissions are not at all confined to Monroe County. The breakdown to this level of detail makes it possible in some cases to identify specific manufacturing operations responsible for large quantities of emissions; for instance

[4]The County distribution column employs a variant of the sparklines popularized by Edward Tufte [25] to graphically display the approximate geographic breakdown of emissions; the order of the bars corresponds to the order of the county columns to the right.

- the large quantity of chemical manufacturing emissions in Orleans County is probably due to Western New York Energy LLC's manufacturing facility in Medina, New York, which processes corn to produce biofuels (ethanol) and livestock feed components. Eastman Kodak in Rochester was the dominant contributor in this category as of 2010, but had largely shut down the responsible operations by 2016.
- the glass manufacturing emissions in Ontario County are probably due to Guardian Industries' glass manufacturing operation in Geneva, NY.
- the food manufacturing emissions in Wyoming County are probably due to Morton Salt's production facility in Silver Springs, NY, which until 2015 was producing approximately one million mmBTU per year from bituminous coal; they seem to have largely replaced coal with natural gas in 2016.

These operations were easily identified because they appear in a *large energy users* dataset accompanying the *county energy estimates* dataset used primarily in this analysis [18]. Unfortunately, only a handful of manufacturing operations in the region count as large energy users by the criteria of the EPA's Greenhouse Gas Reporting Program, so further research will be necessary to identify the next tier of significant GHG emitters. Fortunately, additional detail to the level of the entire NAICS six-digit classification is available for analysis, and is not presented in this report only due to time and space limitations.

5.3.1 *Manufacturing*

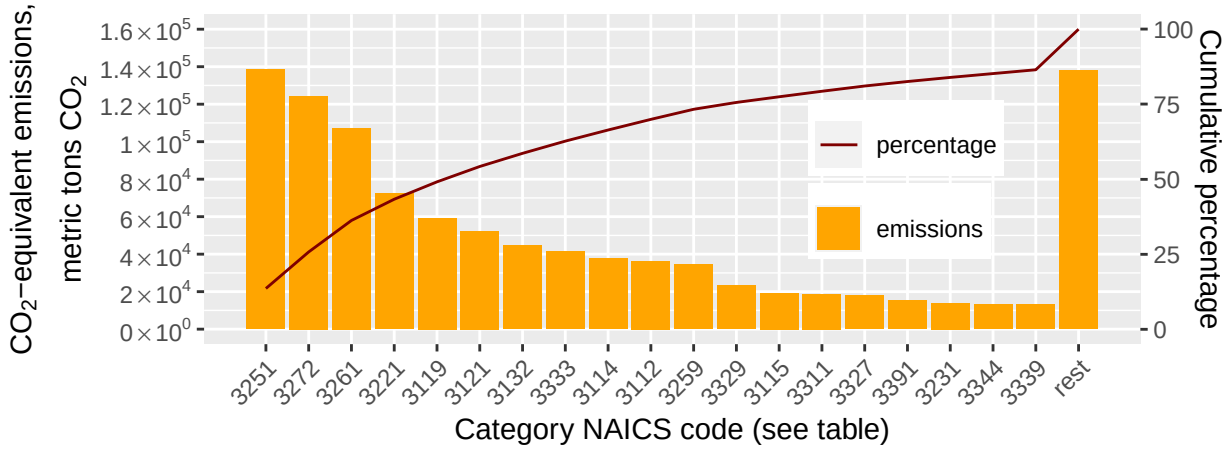

Figure 5.5: GFL manufacturing categories with highest CO_2-equivalent GHG emissions

Table 5.5: GFL manufacturing categories with highest CO_2-equivalent GHG emissions

NAICS	Manufacturing category	CO_2-equivalent emissions, tonnes	County distribution	Principal counties
3251	Basic Chemical Manufacturing	138,493		Orleans, Monroe
3272	Glass and Glass Product Manufacturing	124,373		Ontario
3261	Plastics Product Manufacturing	107,243		Monroe, Ontario
3221	Pulp, Paper, and Paperboard Mills	72,279		Monroe, Genesee
3119	Other Food Manufacturing	59,251		Wyoming
3121	Beverage Manufacturing	52,317		Monroe, Seneca, Ontario
3132	Fabric Mills	44,766		Orleans
3333	Commercial and Service Industry Machinery Manufacturing	41,532		Monroe
3114	Fruit and Vegetable Preserving and Specialty Food Manufacturing	37,856		Monroe, Wayne, Ontario
3112	Grain and Oilseed Milling	36,281		Ontario
3259	Other Chemical Product and Preparation Manufacturing	34,336		Monroe
3329	Other Fabricated Metal Product Manufacturing	23,280		Ontario, Monroe
3115	Dairy Product Manufacturing	19,281		Genesee, Monroe
3311	Iron and Steel Mills and Ferroalloy Manufacturing	18,774		Monroe
3327	Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	17,934		Monroe, Ontario
3391	Medical Equipment and Supplies Manufacturing	15,198		Monroe, Orleans
3231	Printing and Related Support Activities	14,017		Monroe
3344	Semiconductor and Other Electronic Component Manufacturing	13,045		Monroe
3339	Other General Purpose Machinery Manufacturing	13,037		Seneca, Monroe, Ontario
0	Remaining manufacturing categories	138,033		Monroe, Wayne, Genesee

5.3.2 *Agriculture*

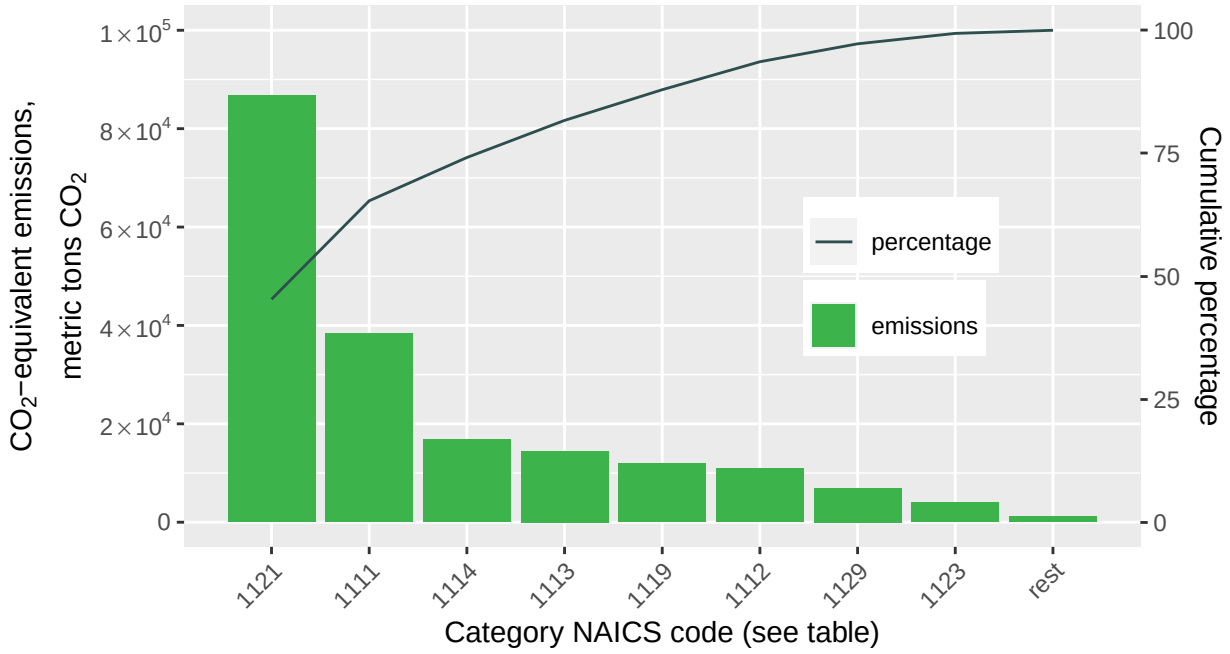

Figure 5.6: GFL agriculture categories with highest CO_2-equivalent GHG emissions

Table 5.6: GFL agricultural categories with highest CO_2-equivalent GHG emissions

NAICS	Agriculture category	CO_2-equivalent emissions, tonnes	County distribution	Principal counties
1121	Cattle Ranching and Farming	86,733		Yates, Wyoming, Ontario, Seneca
1111	Oilseed and Grain Farming	38,314		Ontario, Wayne, Livingston, Seneca, Genesee
1114	Greenhouse, Nursery, and Floriculture Production	16,838		Monroe, Wayne, Ontario, Yates, Livingston
1113	Fruit and Tree Nut Farming	14,439		Wayne, Yates, Seneca
1119	Other Crop Farming	11,945		Ontario, Livingston, Wyoming, Genesee, Wayne
1112	Vegetable and Melon Farming	10,879		Monroe, Ontario, Orleans, Wayne, Yates, Genesee
1129	Other Animal Production	6,977		Livingston, Monroe, Ontario, Orleans, Wayne, Wyoming
1123	Poultry and Egg Production	4,053		Yates, Seneca, Wayne
0	Remaining agriculture categories	1,208		Wyoming, Wayne, Livingston, Yates, Ontario

5.3.3 *Construction*

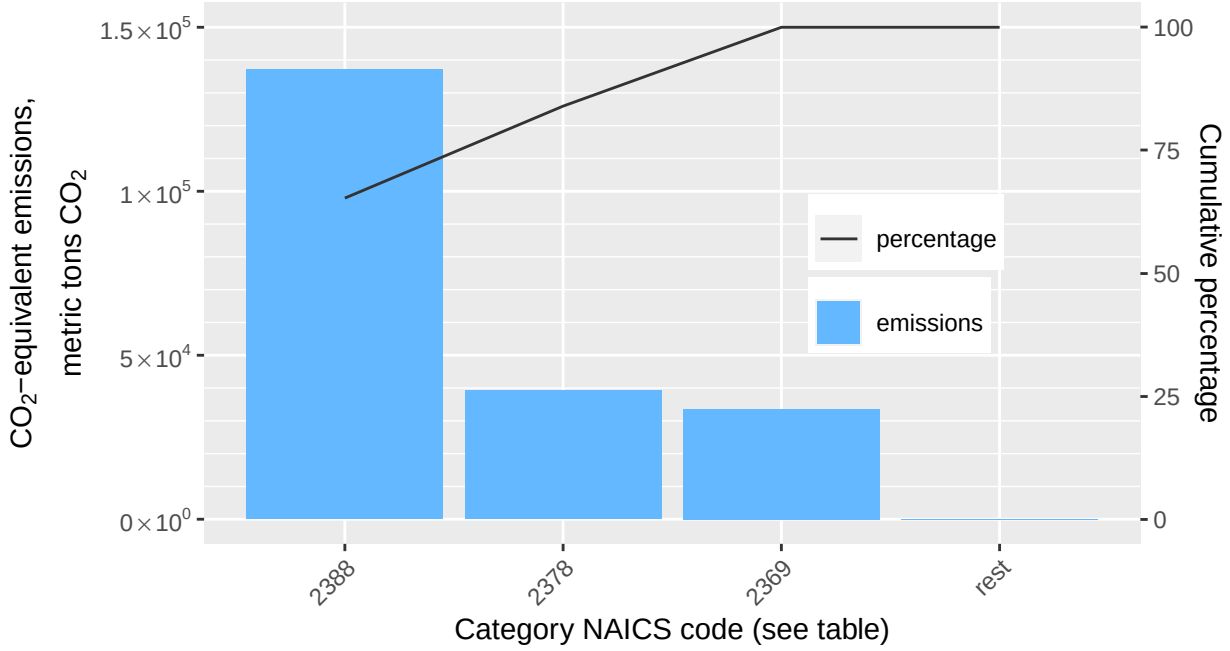

Figure 5.7: GFL Construction categories with CO_2-equivalent GHG emissions

Table 5.7: GFL construction categories with CO_2-equivalent GHG emissions

NAICS	Construction category	CO_2-equivalent emissions, tonnes	County distribution	Principal counties
2388	Specialty Trade Contractors (unclassified)	137,054		Monroe, Ontario, Wayne
2378	Heavy and Civil Engineering Construction (unclassified)	39,243		Monroe, Ontario, Livingston
2369	Building Construction (unclassified)	33,653		Monroe, Ontario
0	Remaining construction categories	0		

5.3.4 *Mining*

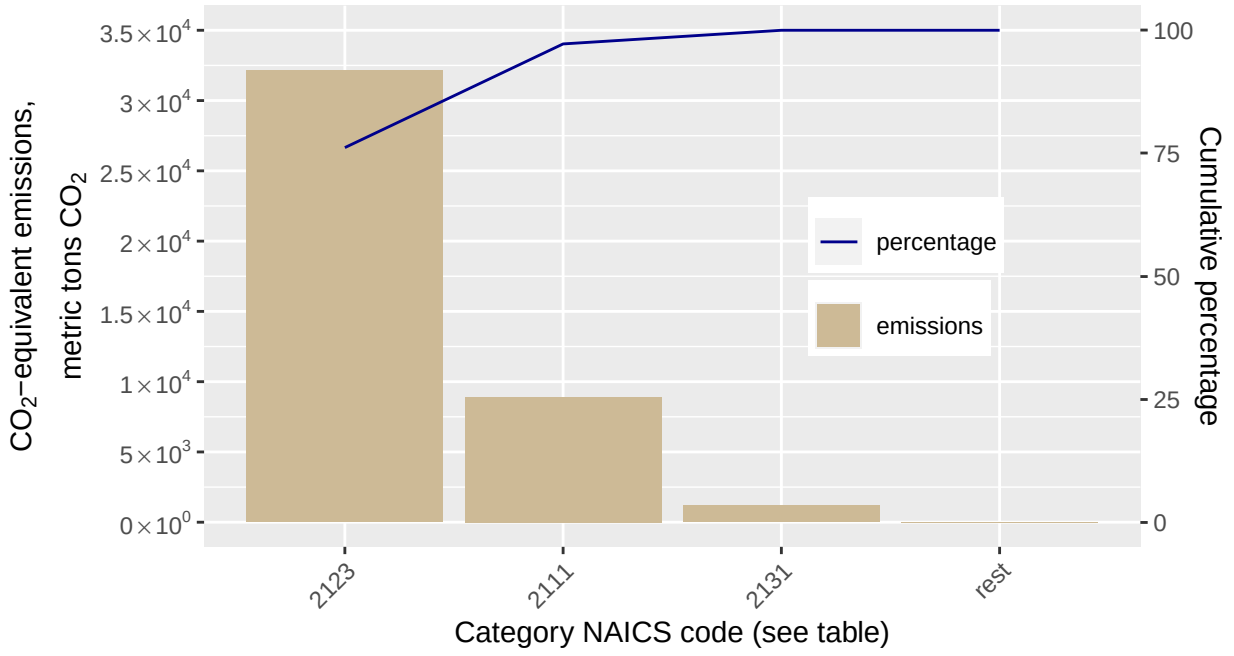

Figure 5.8: GFL mining categories with CO_2-equivalent GHG emissions

Table 5.8: GFL mining categories with CO_2-equivalent GHG emissions

NAICS	Mining category	CO_2-equivalent emissions, tonnes	County distribution	Principal counties
2123	Nonmetallic Mineral Mining and Quarrying	32,144		Monroe, Genesee, Orleans, Wayne, Ontario
2111	Oil and Gas Extraction	8,896		Genesee
2131	Support Activities for Mining	1,171		Livingston, Orleans
0	Remaining mining categories	0		

6 Limitations and caveats

1. The NREL dataset and the heuristic methods used to generate the estimates it contains deserve scrutiny – ideally, by comparison with independent sources of information. This may be difficult as the NREL dataset is apparently the most detailed data source available in the areas it covers.
2. The presentation of agricultural GHG emissions provided in this report is substantially incomplete as it includes no information about GHG emissions due to use (or overuse) of agricultural chemicals including nitrate fertilizers. This information can be obtained; it just requires more work.
3. The GHG emissions profiled in this report are those resulting from fuel combustion for generation of heat, kinetic energy, or electricity. Halocarbon emissions as a byproduct of industrial processes are potentially a significant contributor to global warming because of their very high global warming potentials. The EPA requires reporting of emissions of many of these chemicals as toxic pollutants rather than as greenhouse gases; the relevant reports may provide information useful in analyzing greenhouse gas emissions as well.
4. Unfortunately omitted from the NREL dataset is data on GHG emissions from waste management operations such as landfills. This information is also readily obtained and will be included in any full inventory of GHG emissions across the region.

7 Next steps

1. Investigate alternative methods and data sources that could be used to validate energy use and GHG emissions for industry and agriculture based on the NREL IEDB. Useful data sources for this purpose have already been identified, and include agricultural census information from the US Department of Agriculture [29][30], US Census Bureau information[28][2], and information from the New York State government including NYSERDA's *Patterns and Trends* report [22] and from the data.ny.gov portal.
2. Populate Appendix C with data tables providing further details of greenhouse gas emissions, up to and including the full six-digit NAICS categorization.
3. Conduct and report similar analyses for other sources of greenhouse gas emissions: residential and commercial buildings, transportation, agricultural emissions unrelated to energy use, etc.

Appendices

A EPA emission factors

Source: [26]. The EPA publication includes additional tables; the ones shown here are those directly bearing on the agricultural and industrial sectors' greenhouse gas emissions.

Table A.1: Emission factors, liquid fuels

Fuel Type	Heat Content (HHV), mmBtu per gallon	CO_2 Factor, kg CO_2 per mmBtu	CH_4 Factor, g CH_4 per mmBtu	N_2O Factor, g N_2O per mmBtu	CO_2 Factor, kg CO_2 per gallon	CH_4 Factor, g CH_4 per gallon	N_2O Factor, g N_2O per gallon
Asphalt and Road Oil	0.158	75.36	3.0	0.60	11.91	0.47	0.09
Aviation Gasoline	0.120	69.25	3.0	0.60	8.31	0.36	0.07
Butane	0.103	64.77	3.0	0.60	6.67	0.31	0.06
Butylene	0.105	68.72	3.0	0.60	7.22	0.32	0.06
Crude Oil	0.138	74.54	3.0	0.60	10.29	0.41	0.08
Distillate Fuel Oil No. 1	0.139	73.25	3.0	0.60	10.18	0.42	0.08
Distillate Fuel Oil No. 2	0.138	73.96	3.0	0.60	10.21	0.41	0.08
Distillate Fuel Oil No. 4	0.146	75.04	3.0	0.60	10.96	0.44	0.09
Ethane	0.068	59.60	3.0	0.60	4.05	0.20	0.04
Ethylene	0.058	65.96	3.0	0.60	3.83	0.17	0.03
Heavy Gas Oils	0.148	74.92	3.0	0.60	11.09	0.44	0.09
Isobutane	0.099	64.94	3.0	0.60	6.43	0.30	0.06
Isobutylene	0.103	68.86	3.0	0.60	7.09	0.31	0.06
Kerosene	0.135	75.20	3.0	0.60	10.15	0.41	0.08
Kerosene-Type Jet Fuel	0.135	72.22	3.0	0.60	9.75	0.41	0.08
Liquefied Petroleum Gases (LPG)	0.092	61.71	3.0	0.60	5.68	0.28	0.06
Lubricants	0.144	74.27	3.0	0.60	10.69	0.43	0.09
Motor Gasoline	0.125	70.22	3.0	0.60	8.78	0.38	0.08
Naphtha (<401 deg F)	0.125	68.02	3.0	0.60	8.50	0.38	0.08
Natural Gasoline	0.110	66.88	3.0	0.60	7.36	0.33	0.07
Other Oil (>401 deg F)	0.139	76.22	3.0	0.60	10.59	0.42	0.08
Pentanes Plus	0.110	70.02	3.0	0.60	7.70	0.33	0.07
Petrochemical Feedstocks	0.125	71.02	3.0	0.60	8.88	0.38	0.08
Petroleum Coke	0.143	102.41	3.0	0.60	14.64	0.43	0.09
Propane	0.091	62.87	3.0	0.60	5.72	0.27	0.05
Propylene	0.091	67.77	3.0	0.60	6.17	0.27	0.05
Residual Fuel Oil No. 5	0.140	72.93	3.0	0.60	10.21	0.42	0.08
Residual Fuel Oil No. 6	0.150	75.10	3.0	0.60	11.27	0.45	0.09
Special Naphtha	0.125	72.34	3.0	0.60	9.04	0.38	0.08
Unfinished Oils	0.139	74.54	3.0	0.60	10.36	0.42	0.08
Used Oil	0.138	74.00	3.0	0.60	10.21	0.41	0.08
Biodiesel (100%)	0.128	73.84	1.1	0.11	9.45	0.14	0.01
Ethanol (100%)	0.084	68.44	1.1	0.11	5.75	0.09	0.01
Rendered Animal Fat	0.125	71.06	1.1	0.11	8.88	0.14	0.01
Vegetable Oil	0.120	81.55	1.1	0.11	9.79	0.13	0.01
North American Softwood	NA	94.40	1.9	0.42	NA	NA	NA
North American Hardwood	NA	93.70	1.9	0.42	NA	NA	NA
Bagasse	NA	95.50	1.9	0.42	NA	NA	NA
Bamboo	NA	93.70	1.9	0.42	NA	NA	NA
Straw	NA	95.10	1.9	0.42	NA	NA	NA

Table A.2: Emission factors, solid fuels

Fuel Type	Heat Content (HHV), mmBtu per short ton	CO_2 Factor, kg CO_2 per mmBtu	CH_4 Factor, g CH_4 per mmBtu	N_2O Factor, g N_2O per mmBtu	CO_2 Factor, kg CO_2 per short ton	CH_4 Factor, g CH_4 per short ton	N_2O Factor, g N_2O per short ton
Anthracite Coal	25.09	103.69	11.0	1.6	2602	276	40
Bituminous Coal	24.93	93.28	11.0	1.6	2325	274	40
Sub-bituminous Coal	17.25	97.17	11.0	1.6	1676	190	28
Lignite Coal	14.21	97.72	11.0	1.6	1389	156	23
Mixed (Commercial Sector)	21.39	94.27	11.0	1.6	2016	235	34
Mixed (Electric Power Sector)	19.73	95.52	11.0	1.6	1885	217	32
Mixed (Industrial Coking)	26.28	93.90	11.0	1.6	2468	289	42
Mixed (Industrial Sector)	22.35	94.67	11.0	1.6	2116	246	36
Coal Coke	24.80	113.67	11.0	1.6	2819	273	40
Municipal Solid Waste	9.95	90.70	32.0	4.2	902	318	42
Petroleum Coke (Solid)	30.00	102.41	32.0	4.2	3072	960	126
Plastics	38.00	75.00	32.0	4.2	2850	1216	160
Tires	28.00	85.97	32.0	4.2	2407	896	118
Agricultural Byproducts	8.25	118.17	32.0	4.2	975	264	35
Peat	8.00	111.84	32.0	4.2	895	256	34
Solid Byproducts	10.39	105.51	32.0	4.2	1096	332	44
Wood and Wood Residuals	17.48	93.80	7.2	3.6	1640	126	63

Table A.3: Emission factors, gaseous fuels

Fuel Type	Heat Content (HHV), mmBtu per scf	CO_2 Factor, kg CO_2 per mmBtu	CH_4 Factor, g CH_4 per mmBtu	N_2O Factor, g N_2O per mmBtu	CO_2 Factor, kg CO_2 per scf	CH_4 Factor, g CH_4 per scf	N_2O Factor, g N_2O per scf
Natural Gas	0.001026	53.06	1.000	0.10	0.054440	0.001030	0.000100
Blast Furnace Gas	0.000092	274.32	0.022	0.10	0.025240	0.000002	0.000009
Coke Oven Gas	0.000599	46.85	0.480	0.10	0.028060	0.000288	0.000060
Fuel Gas	0.001388	59.00	3.000	0.60	0.081890	0.004164	0.000833
Propane Gas	0.002516	61.46	3.000	0.60	0.154630	0.007548	0.001510
Landfill Gas	0.000485	52.07	3.200	0.63	0.025254	0.001552	0.000306
Other Biomass Gases	0.000655	52.07	3.200	0.63	0.034106	0.002096	0.000413

Table A.4: Emission factors, grid electricity

eGRID Subregion	Total Output			Non-Baseload		
	CO_2 Factor, (kg / MWh)	CH_4 Factor, (g / MWh)	N_2O Factor, (g / MWh)	CO_2 Factor, (kg / MWh)	CH_4 Factor, (g / MWh)	N_2O Factor, (g / MWh)
AKGD (ASCC Alaska Grid)	486.39	34.93	4.99	620.42	49.90	7.26
AKMS (ASCC Miscellaneous)	228.20	10.43	1.81	695.72	30.84	5.44
AZNM (WECC Southwest)	473.37	35.83	5.44	628.13	44.00	6.35
CAMX (WECC California)	239.45	14.97	1.81	427.69	20.41	2.72
ERCT (ERCOT All)	457.77	34.47	4.99	636.30	48.99	6.80
FRCC (FRCC All)	458.90	34.02	4.54	539.09	35.38	4.99
HIMS (HICC Miscellaneous)	522.54	43.09	6.80	694.00	66.68	10.43
HIOA (HICC Oahu)	754.28	82.10	12.70	742.76	69.40	10.89
MROE (MRO East)	756.68	70.76	11.79	789.30	70.76	11.34
MROW (MRO West)	561.91	52.16	9.07	826.45	69.85	13.15
NEWE (NPCC New England)	253.20	40.82	5.44	442.30	39.01	4.99
NWPP (WECC Northwest)	295.38	27.67	4.08	691.68	56.25	9.07
NYCW (NPCC NYC/Westchester)	288.39	9.98	1.36	481.58	9.98	0.91
NYLI (NPCC Long Island)	534.47	57.15	7.26	607.27	16.33	1.81
NYUP (NPCC Upstate NY)	133.67	9.53	1.36	461.85	27.67	3.63
RFCE (RFC East)	343.91	22.68	4.08	650.63	35.83	7.71
RFCM (RFC Michigan)	576.97	30.39	8.16	819.23	45.81	11.34
RFCW (RFC West)	564.00	48.99	8.62	877.43	78.02	13.15
RMPA (WECC Rockies)	620.42	62.14	9.07	765.80	66.68	9.53
SPNO (SPP North)	640.65	67.59	9.98	903.01	91.63	13.15
SPSO (SPP South)	566.22	43.09	6.80	754.10	54.88	8.62
SRMV (SERC Mississippi Valley)	380.52	22.68	3.18	537.96	32.21	4.54
SRMW (SERC Midwest)	731.46	37.19	11.79	886.86	38.10	14.06
SRSO (SERC South)	494.14	39.46	5.90	659.30	52.16	7.71
SRTV (SERC Tennessee Valley)	537.69	42.18	7.71	797.14	61.23	11.34
SRVC (SERC Virginia/Carolina)	365.28	30.39	4.99	645.10	50.35	8.62
US Average	452.87	36.29	5.90	680.84	50.35	8.16

Table A.5: Global warming potentials (IPCC AR4)

Gas	100-Year GWP	Gas	100-Year GWP
CO_2	1	HFC-236ea	1370
CH_4	25	HFC-236fa	9810
N_2O	298	HFC-245ca	693
HFC-23	14800	HFC-245fa	1030
HFC-32	675	HFC-365mfc	794
HFC-41	92	HFC-43-10mee	1640
HFC-125	3500	SF_6	22800
HFC-134	1100	NF_3	17200
HFC-134a	1430	CF_4	7390
HFC-143	353	C_2F_6	12200
HFC-143a	4470	C_3F_8	8830
HFC-152	53	c-C_4F_8	10300
HFC-152a	124	C_4F_{10}	8860
HFC-161	12	C_5F_{12}	9160
HFC-227ea	3220	C_6F_{14}	9300
HFC-236cb	1340	$C_{10}F_{18}$	>7,500

Table A.6: Global warming potentials for blended refrigerants (IPCC AR4)

ASHRAE #	100-year GWP	Blend Composition
R-401A	16	53% HCFC-22 , 34% HCFC-124 , 13% HFC-152a
R-401B	14	61% HCFC-22 , 28% HCFC-124 , 11% HFC-152a
R-401C	19	33% HCFC-22 , 52% HCFC-124 , 15% HFC-152a
R-402A	2100	38% HCFC-22 , 6% HFC-125 , 2% propane
R-402B	1330	6% HCFC-22 , 38% HFC-125 , 2% propane
R-403B	3444	56% HCFC-22 , 39% PFC-218 , 5% propane
R-404A	3922	44% HFC-125 , 4% HFC-134a , 52% HFC 143a
R-406A	0	55% HCFC-22 , 41% HCFC-142b , 4% isobutane
R-407A	2107	20% HFC-32 , 40% HFC-125 , 40% HFC-134a
R-407B	2804	10% HFC-32 , 70% HFC-125 , 20% HFC-134a
R-407C	1774	23% HFC-32 , 25% HFC-125 , 52% HFC-134a
R-407D	1627	15% HFC-32 , 15% HFC-125 , 70% HFC-134a
R-407E	1552	25% HFC-32 , 15% HFC-125 , 60% HFC-134a
R-408A	2301	47% HCFC-22 , 7% HFC-125 , 46% HFC 143a
R-409A	0	60% HCFC-22 , 25% HCFC-124 , 15% HCFC-142b
R-410A	2088	50% HFC-32 , 50% HFC-125
R-410B	2229	45% HFC-32 , 55% HFC-125
R-411A	14	87.5% HCFC-22 , 11 HFC-152a , 1.5% propylene
R-411B	4	94% HCFC-22 , 3% HFC-152a , 3% propylene
R-413A	2053	88% HFC-134a , 9% PFC-218 , 3% isobutane
R-414A	0	51% HCFC-22 , 28.5% HCFC-124 , 16.5% HCFC-142b
R-414B	0	5% HCFC-22 , 39% HCFC-124 , 9.5% HCFC-142b
R-417A	2346	46.6% HFC-125 , 5% HFC-134a , 3.4% butane
R-422A	3143	85.1% HFC-125 , 11.5% HFC-134a , 3.4% isobutane
R-422D	2729	65.1% HFC-125 , 31.5% HFC-134a , 3.4% isobutane
R-423A	2280	47.5% HFC-227ea , 52.5% HFC-134a ,
R-424A	2440	50.5% HFC-125, 47% HFC-134a, 2.5% butane/pentane
R-426A	1508	5.1% HFC-125, 93% HFC-134a, 1.9% butane/pentane
R-428A	3607	77.5% HFC-125 , 2% HFC-143a , 1.9% isobutane
R-434A	3245	63.2% HFC-125, 16% HFC-134a, 18% HFC-143a, 2.8% isobutane
R-500	32	73.8% CFC-12 , 26.2% HFC-152a , 48.8% HCFC-22
R-502	0	48.8% HCFC-22 , 51.2% CFC-115
R-504	325	48.2% HFC-32 , 51.8% CFC-115
R-507	3985	5% HFC-125 , 5% HFC143a
R-508A	13214	39% HFC-23 , 61% PFC-116
R-508B	13396	46% HFC-23 , 54% PFC-116

B Additional energy use tables

Table B.1: 2016 energy use (millions of BTU) by county and industry sector

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
Genesee								
1111. Oilseed and Grain Farming	0	10,516	27,991	9,882	12,657	7,800	0	0
1112. Vegetable and Melon Farming	0	5,780	7,421	2,620	3,356	2,068	0	0
1113. Fruit and Tree Nut Farming	0	1,528	1,593	562	720	444	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	5,076	7,910	2,793	3,577	2,204	0	0
1119. Other Crop Farming	0	5,998	8,923	3,150	4,035	2,486	0	0
1121. Cattle Ranching and Farming	0	27,353	36,698	12,956	16,595	10,226	0	0
1122. Hog and Pig Farming	0	365	418	148	189	117	0	0
1123. Poultry and Egg Production	0	1,715	1,165	411	527	325	0	0
1124. Sheep and Goat Farming	0	203	193	68	87	54	0	0
1129. Other Animal Production	0	4,137	3,358	1,185	1,518	936	0	0
2111. Oil and Gas Extraction	138,770	17,990	3,986	7,726	0	677	4,927	0
2123. Nonmetallic Mineral Mining and Quarrying	11,381	24,985	25,088	13,487	0	7,840	30,220	0
2369. Building Construction (unclassified)	4,493	9,574	16,599	0	614	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	1,128	2,846	19,026	0	2,965	0	0	0
2388. Specialty Trade Contractors (unclassified)	22,570	18,095	78,384	0	3,257	0	0	0
3114. Fruit and Vegetable Preserving and Specialty Food Manufacturing	7,802	4,755	275	41	149	66	33	0
3115. Dairy Product Manufacturing	180,938	78,171	8,180	161,167	1,006	5,019	0	0
3121. Beverage Manufacturing	1,986	2,010	80	12	43	154	0	0
3152. Cut and Sew Apparel Manufacturing	8	9	22	0	12	0	0	0
3162. Footwear Manufacturing	24,053	70,999	1,016	152	826	0	0	0
3219. Other Wood Product Manufacturing	552	1,519	219	197	119	0	0	0
3221. Pulp, Paper, and Paperboard Mills	534,764	9,800	0	0	0	0	0	0
3231. Printing and Related Support Activities	638	1,230	36	5	19	9	0	0
3252. Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing	48,107	23,666	508	2,277	413	0	0	0
3261. Plastics Product Manufacturing	1,906	5,163	66	10	360	0	145	0
3272. Glass and Glass Product Manufacturing	6,548	3,153	364	54	198	0	0	0
3315. Foundries	4,381	527	0	182	661	0	0	0
3321. Forging and Stamping	268	255	37	1	20	0	0	0
3323. Architectural and Structural Metals Manufacturing	536	510	75	1	40	0	0	0
3324. Boiler, Tank, and Shipping Container Manufacturing	60,315	30,507	829	209	1,214	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	2,681	2,548	373	6	202	0	0	0
3328. Coating, Engraving, Heat Treating, and Allied Activities	804	764	112	2	61	0	0	0
3329. Other Fabricated Metal Product Manufacturing	536	510	75	1	40	0	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
3331. Agriculture, Construction, and Mining Machinery Manufacturing	18,872	28,215	1,182	171	1,712	0	0	0
3333. Commercial and Service Industry Machinery Manufacturing	294	442	97	2	53	0	0	0
3335. Metalworking Machinery Manufacturing	4,476	5,909	787	12	509	0	0	0
3336. Engine, Turbine, and Power Transmission Equipment Manufacturing	3,301	4,140	399	6	298	0	0	0
3339. Other General Purpose Machinery Manufacturing	9,142	13,665	494	84	803	0	0	0
3353. Electrical Equipment Manufacturing	783	1,257	36	5	20	0	0	0
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	93	112	26	70	14	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	47	56	13	35	7	0	0	0
3391. Medical Equipment and Supplies Manufacturing	291	350	13	14	7	3	0	0
3399. Other Miscellaneous Manufacturing	581	700	27	28	15	6	0	0
Livingston								
1111. Oilseed and Grain Farming	0	13,019	34,656	12,235	15,671	9,657	0	0
1112. Vegetable and Melon Farming	0	3,902	5,009	1,768	2,265	1,396	0	0
1113. Fruit and Tree Nut Farming	0	3,363	3,504	1,237	1,584	976	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	7,977	12,430	4,388	5,621	3,464	0	0
1119. Other Crop Farming	0	8,100	12,049	4,254	5,449	3,358	0	0
1121. Cattle Ranching and Farming	0	28,255	38,030	13,426	17,197	10,597	0	0
1122. Hog and Pig Farming	0	438	502	177	227	140	0	0
1123. Poultry and Egg Production	0	2,744	1,864	658	843	519	0	0
1124. Sheep and Goat Farming	0	610	580	205	262	162	0	0
1129. Other Animal Production	0	7,673	6,228	2,199	2,816	1,736	0	0
2123. Nonmetallic Mineral Mining and Quarrying	1,618	4,230	6,184	3,463	0	1,376	2,039	0
2131. Support Activities for Mining	4,274	510	3,651	1,475	0	900	0	0
2369. Building Construction (unclassified)	4,666	9,942	17,237	0	638	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	2,932	7,398	49,468	0	7,710	0	0	0
2388. Specialty Trade Contractors (unclassified)	17,092	13,703	59,359	0	2,467	0	0	0
3114. Fruit and Vegetable Preserving and Specialty Food Manufacturing	3,901	2,378	137	21	75	33	17	0
3115. Dairy Product Manufacturing	4,479	2,696	1,246	2,980	68	300	0	0
3116. Animal Slaughtering and Processing	8,606	7,890	1,842	1,404	100	443	448	0
3121. Beverage Manufacturing	1,986	2,010	80	12	43	154	0	0
3211. Sawmills and Wood Preservation	3,643	3,759	1,448	866	79	35	18	0
3219. Other Wood Product Manufacturing	1,656	4,556	658	590	357	0	0	0
3231. Printing and Related Support Activities	7,110	11,283	130	19	102	3	0	0
3251. Basic Chemical Manufacturing	49,610	10,847	466	696	379	0	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
3261. Plastics Product Manufacturing	635	1,721	22	3	120	0	48	0
3262. Rubber Product Manufacturing	635	1,721	22	3	120	0	48	0
3323. Architectural and Structural Metals Manufacturing	13,128	12,395	330	50	496	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	804	764	112	2	61	0	0	0
3331. Agriculture, Construction, and Mining Machinery Manufacturing	294	442	97	2	53	0	0	0
3332. Industrial Machinery Manufacturing	294	442	97	2	53	0	0	0
3333. Commercial and Service Industry Machinery Manufacturing	882	1,327	291	5	158	0	0	0
3335. Metalworking Machinery Manufacturing	9,142	13,665	494	84	803	0	0	0
3339. Other General Purpose Machinery Manufacturing	4,182	5,467	690	11	456	0	0	0
3353. Electrical Equipment Manufacturing	783	1,257	36	5	20	0	0	0
3359. Other Electrical Equipment and Component Manufacturing	783	1,257	36	5	20	0	0	0
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	93	112	26	70	14	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	47	56	13	35	7	0	0	0
3399. Other Miscellaneous Manufacturing	145	175	7	7	4	2	0	0
Monroe								
1111. Oilseed and Grain Farming	0	8,513	22,659	7,999	10,246	6,314	0	0
1112. Vegetable and Melon Farming	0	10,115	12,987	4,585	5,873	3,619	0	0
1113. Fruit and Tree Nut Farming	0	4,891	5,096	1,799	2,305	1,420	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	18,855	29,380	10,372	13,286	8,187	0	0
1119. Other Crop Farming	0	4,072	6,057	2,138	2,739	1,688	0	0
1121. Cattle Ranching and Farming	0	7,550	10,289	3,632	4,653	2,867	0	0
1122. Hog and Pig Farming	0	0	0	0	0	0	0	0
1123. Poultry and Egg Production	0	686	466	165	211	130	0	0
1124. Sheep and Goat Farming	0	534	507	179	229	141	0	0
1129. Other Animal Production	0	7,540	6,120	2,161	2,767	1,705	0	0
2123. Nonmetallic Mineral Mining and Quarrying	11,174	33,189	33,882	18,980	0	11,525	34,659	0
2369. Building Construction (unclassified)	44,416	94,632	164,074	0	6,070	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	11,727	29,594	197,873	0	30,839	0	0	0
2388. Specialty Trade Contractors (unclassified)	221,534	177,616	769,385	0	31,970	0	0	0
3114. Fruit and Vegetable Preserving and Specialty Food Manufacturing	296,831	119,359	1,666	2,247	1,975	804	4,491	0
3115. Dairy Product Manufacturing	47,248	28,250	2,149	55,662	350	4,653	0	0
3116. Animal Slaughtering and Processing	30,120	27,614	6,446	4,913	350	1,551	1,567	0
3121. Beverage Manufacturing	298,857	236,441	3,835	8,435	792	98,778	0	0
3132. Fabric Mills	6,749	6,166	70	1	38	17	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
3133. Textile and Fabric Finishing and Fabric Coating Mills	20,247	18,497	209	3	113	50	0	0
3141. Textile Furnishings Mills	1,631	533	2,075	29	70	0	8	0
3149. Other Textile Product Mills	96,226	31,246	26,079	2,958	2,160	0	1,743	0
3152. Cut and Sew Apparel Manufacturing	3,227	2,186	1,132	0	1,418	0	0	0
3159. Apparel Accessories and Other Apparel Manufacturing	8	9	22	0	12	0	0	0
3169. Other Leather and Allied Product Manufacturing	1,920	6,934	267	40	145	64	0	0
3219. Other Wood Product Manufacturing	9,383	25,819	3,729	3,344	2,023	0	0	0
3221. Pulp, Paper, and Paperboard Mills	436,570	117,148	1,117	151,958	909	0	162,933	0
3231. Printing and Related Support Activities	105,788	163,348	1,497	1,180	1,466	924	0	0
3241. Petroleum and Coal Products Manufacturing	14,583	2,508	11,592	87	314	139	0	0
3251. Basic Chemical Manufacturing	270,287	99,700	2,639	23,153	2,778	0	0	0
3252. Resin, Synthetic Rubber, and Artificial and Synthetic Fibers and Filaments Manufacturing	54,709	27,640	737	3,306	538	55	0	0
3254. Pharmaceutical and Medicine Manufacturing	56,846	23,898	6,162	718	592	0	0	0
3259. Other Chemical Product and Preparation Manufacturing	300,832	286,460	23,228	1,255,037	10,478	56,664	0	0
3261. Plastics Product Manufacturing	389,164	840,926	3,676	8,254	31,645	0	102,550	0
3271. Clay Product and Refractory Manufacturing	15,647	3,767	871	130	472	0	0	0
3272. Glass and Glass Product Manufacturing	68,656	36,856	3,287	1,355	2,547	0	2,149	0
3311. Iron and Steel Mills and Ferroalloy Manufacturing	230,487	145,041	1,457	104,548	791	0	1,771	4,298
3313. Alumina and Aluminum Production and Processing	15,060	12,087	1,397	209	758	336	0	0
3315. Foundries	2,191	264	0	91	331	0	0	0
3321. Forging and Stamping	35,902	32,610	1,249	110	1,401	0	0	0
3322. Cutlery and Handtool Manufacturing	2,413	2,293	336	5	182	0	0	0
3323. Architectural and Structural Metals Manufacturing	39,120	35,668	1,696	117	1,643	0	0	0
3324. Boiler, Tank, and Shipping Container Manufacturing	12,860	12,141	292	50	476	0	0	0
3325. Hardware Manufacturing	64,736	34,035	1,068	212	1,388	0	0	0
3326. Spring and Wire Product Manufacturing	1,072	1,019	149	2	81	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	140,006	123,886	7,101	338	6,016	0	0	0
3328. Coating, Engraving, Heat Treating, and Allied Activities	5,899	5,606	821	13	445	0	0	0
3329. Other Fabricated Metal Product Manufacturing	58,409	52,570	2,130	169	2,285	0	0	0
3331. Agriculture, Construction, and Mining Machinery Manufacturing	882	1,327	291	5	158	0	0	0
3332. Industrial Machinery Manufacturing	64,219	75,317	4,052	505	4,798	0	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
3333. Commercial and Service Industry Machinery Manufacturing	708,055	76,969	4,338	297	4,287	0	0	0
3335. Metalworking Machinery Manufacturing	90,957	94,690	8,353	632	7,053	0	0	0
3336. Engine, Turbine, and Power Transmission Equipment Manufacturing	588	884	194	3	105	0	0	0
3339. Other General Purpose Machinery Manufacturing	24,107	32,879	2,671	118	2,311	0	0	0
3344. Semiconductor and Other Electronic Component Manufacturing	93,425	195,568	1,300	1,687	1,807	2,268	0	0
3351. Electric Lighting Equipment Manufacturing	7,277	10,006	153	23	105	0	0	4
3353. Electrical Equipment Manufacturing	15,709	25,089	271	172	244	0	0	5
3359. Other Electrical Equipment and Component Manufacturing	17,275	27,603	344	183	283	0	0	6
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	747	900	208	559	113	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	234	281	65	175	35	0	0	0
3379. Other Furniture Related Product Manufacturing	93	112	26	70	14	0	0	0
3391. Medical Equipment and Supplies Manufacturing	90,950	80,090	1,131	16,312	400	3,095	0	0
3399. Other Miscellaneous Manufacturing	13,129	14,196	373	390	230	65	0	0
Ontario								
1111. Oilseed and Grain Farming	0	17,276	45,985	16,234	20,794	12,814	0	0
1112. Vegetable and Melon Farming	0	9,826	12,616	4,454	5,705	3,515	0	0
1113. Fruit and Tree Nut Farming	0	6,878	7,167	2,530	3,241	1,997	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	10,153	15,820	5,585	7,154	4,408	0	0
1119. Other Crop Farming	0	8,713	12,961	4,576	5,861	3,612	0	0
1121. Cattle Ranching and Farming	0	54,944	73,453	25,931	33,215	20,468	0	0
1122. Hog and Pig Farming	0	256	293	103	132	82	0	0
1123. Poultry and Egg Production	0	2,744	1,864	658	843	519	0	0
1124. Sheep and Goat Farming	0	559	532	188	240	148	0	0
1129. Other Animal Production	0	7,540	6,120	2,161	2,767	1,705	0	0
2123. Nonmetallic Mineral Mining and Quarrying	5,422	15,171	18,519	10,372	0	5,118	11,978	0
2369. Building Construction (unclassified)	8,900	18,963	32,879	0	1,216	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	3,157	7,968	53,274	0	8,303	0	0	0
2388. Specialty Trade Contractors (unclassified)	44,920	36,015	156,008	0	6,483	0	0	0
3112. Grain and Oilseed Milling	457,831	232,065	6,704	0	21,818	12,903	0	0
3114. Fruit and Vegetable Preserving and Specialty Food Manufacturing	58,879	35,682	569	517	628	703	891	0
3116. Animal Slaughtering and Processing	4,303	3,945	921	702	50	222	224	0
3121. Beverage Manufacturing	51,577	51,938	809	486	708	5,380	0	0
3149. Other Textile Product Mills	1,631	533	2,075	29	70	0	8	0
3162. Footwear Manufacturing	960	3,467	134	20	72	32	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
3219. Other Wood Product Manufacturing	3,312	9,113	1,316	1,180	714	0	0	0
3231. Printing and Related Support Activities	1,021	1,967	57	8	31	14	0	0
3241. Petroleum and Coal Products Manufacturing	89,048	12,669	24,179	181	931	46	0	0
3259. Other Chemical Product and Preparation Manufacturing	3,171	3,817	882	2,637	478	212	0	0
3261. Plastics Product Manufacturing	211,853	451,091	1,899	4,923	4,335	0	33,110	0
3262. Rubber Product Manufacturing	635	1,721	22	3	120	0	48	0
3272. Glass and Glass Product Manufacturing	1,988,409	51,965	830	124	583	0	339	0
3279. Other Nonmetallic Mineral Product Manufacturing	7,087	4,266	986	147	535	0	0	0
3313. Alumina and Aluminum Production and Processing	15,060	12,087	1,397	209	758	336	0	0
3321. Forging and Stamping	268	255	37	1	20	0	0	0
3323. Architectural and Structural Metals Manufacturing	1,341	1,274	186	3	101	0	0	0
3324. Boiler, Tank, and Shipping Container Manufacturing	4,421	3,527	239	4	174	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	28,268	24,761	1,307	66	1,160	0	0	0
3328. Coating, Engraving, Heat Treating, and Allied Activities	536	510	75	1	40	0	0	0
3329. Other Fabricated Metal Product Manufacturing	215,370	143,070	6,412	1,869	1,840	0	0	0
3331. Agriculture, Construction, and Mining Machinery Manufacturing	588	884	194	3	105	0	0	0
3332. Industrial Machinery Manufacturing	588	884	194	3	105	0	0	0
3333. Commercial and Service Industry Machinery Manufacturing	588	884	194	3	105	0	0	0
3334. Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing	882	1,327	291	5	158	0	0	0
3335. Metalworking Machinery Manufacturing	882	1,327	291	5	158	0	0	0
3339. Other General Purpose Machinery Manufacturing	13,618	19,574	1,281	97	1,312	0	0	0
3353. Electrical Equipment Manufacturing	1,566	2,514	73	11	39	0	0	1
3359. Other Electrical Equipment and Component Manufacturing	6,494	8,749	117	17	85	0	0	3
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	234	281	65	175	35	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	1,332	1,341	140	376	103	0	0	0
3391. Medical Equipment and Supplies Manufacturing	145	175	7	7	4	2	0	0
3399. Other Miscellaneous Manufacturing	436	525	20	21	11	5	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
Orleans								
1111. Oilseed and Grain Farming	0	8,388	22,326	7,882	10,096	6,221	0	0
1112. Vegetable and Melon Farming	0	7,370	9,462	3,340	4,279	2,637	0	0
1113. Fruit and Tree Nut Farming	0	7,642	7,963	2,811	3,601	2,219	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	3,626	5,650	1,995	2,555	1,574	0	0
1119. Other Crop Farming	0	5,298	7,881	2,782	3,564	2,196	0	0
1121. Cattle Ranching and Farming	0	14,561	19,748	6,972	8,930	5,503	0	0
1123. Poultry and Egg Production	0	2,058	1,398	494	632	390	0	0
1124. Sheep and Goat Farming	0	127	121	43	55	34	0	0
1129. Other Animal Production	0	6,606	5,362	1,893	2,425	1,494	0	0
2123. Nonmetallic Mineral Mining and Quarrying	8,955	18,640	15,812	8,293	0	5,775	27,162	0
2131. Support Activities for Mining	4,274	510	3,651	1,475	0	900	0	0
2369. Building Construction (unclassified)	3,111	6,628	11,492	0	425	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	1,579	3,984	26,637	0	4,151	0	0	0
2388. Specialty Trade Contractors (unclassified)	11,833	9,487	41,095	0	1,708	0	0	0
3121. Beverage Manufacturing	2,980	3,015	120	18	65	231	0	0
3132. Fabric Mills	609,497	296,342	621	148	909	90	0	0
3219. Other Wood Product Manufacturing	552	1,519	219	197	119	0	0	0
3231. Printing and Related Support Activities	255	492	14	2	8	3	0	0
3251. Basic Chemical Manufacturing	1,849,133	76,239	11,818	6,463	6,410	0	0	0
3261. Plastics Product Manufacturing	4,285	9,800	61	9	433	0	554	0
3323. Architectural and Structural Metals Manufacturing	804	764	112	2	61	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	1,341	1,274	186	3	101	0	0	0
3328. Coating, Engraving, Heat Treating, and Allied Activities	4,421	3,527	239	4	174	0	0	0
3332. Industrial Machinery Manufacturing	3,301	4,140	399	6	298	0	0	0
3334. Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing	294	442	97	2	53	0	0	0
3339. Other General Purpose Machinery Manufacturing	294	442	97	2	53	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	4,725	5,650	215	6,262	350	0	0	0
3391. Medical Equipment and Supplies Manufacturing	59,355	54,390	698	14,490	57	3,024	0	0
3399. Other Miscellaneous Manufacturing	291	350	13	14	7	3	0	0
Seneca								
1111. Oilseed and Grain Farming	0	12,394	32,990	11,646	14,918	9,193	0	0
1112. Vegetable and Melon Farming	0	1,879	2,412	851	1,091	672	0	0
1113. Fruit and Tree Nut Farming	0	10,699	11,149	3,936	5,041	3,107	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	2,659	4,143	1,463	1,874	1,155	0	0
1119. Other Crop Farming	0	2,758	4,103	1,449	1,856	1,143	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
1121. Cattle Ranching and Farming	0	52,330	69,809	24,645	31,567	19,452	0	0
1122. Hog and Pig Farming	0	183	209	74	95	58	0	0
1123. Poultry and Egg Production	0	6,174	4,195	1,481	1,897	1,169	0	0
1124. Sheep and Goat Farming	0	458	435	154	197	121	0	0
1129. Other Animal Production	0	3,069	2,491	880	1,127	694	0	0
2123. Nonmetallic Mineral Mining and Quarrying	2,187	6,711	6,151	3,446	0	2,365	7,900	0
2369. Building Construction (unclassified)	2,333	4,971	8,619	0	319	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	1,353	3,415	22,832	0	3,558	0	0	0
2388. Specialty Trade Contractors (unclassified)	8,984	7,203	31,202	0	1,297	0	0	0
3115. Dairy Product Manufacturing	4,479	2,696	1,246	2,980	68	300	0	0
3116. Animal Slaughtering and Processing	4,303	3,945	921	702	50	222	224	0
3121. Beverage Manufacturing	99,869	85,718	1,697	254	1,196	1,310	0	0
3231. Printing and Related Support Activities	255	492	14	2	8	3	0	0
3241. Petroleum and Coal Products Manufacturing	2,430	418	1,932	14	52	23	0	0
3313. Alumina and Aluminum Production and Processing	13,229	13,016	11,173	1,670	9,091	0	0	0
3322. Cutlery and Handtool Manufacturing	268	255	37	1	20	0	0	0
3323. Architectural and Structural Metals Manufacturing	268	255	37	1	20	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	804	764	112	2	61	0	0	0
3328. Coating, Engraving, Heat Treating, and Allied Activities	268	255	37	1	20	0	0	0
3332. Industrial Machinery Manufacturing	588	884	194	3	105	0	0	0
3339. Other General Purpose Machinery Manufacturing	48,995	56,227	4,180	1,275	385	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	93	112	26	70	14	0	0	0
3391. Medical Equipment and Supplies Manufacturing	12,098	14,472	114	1,018	157	195	0	0
3399. Other Miscellaneous Manufacturing	436	525	20	21	11	5	0	0
Wayne								
1111. Oilseed and Grain Farming	0	16,775	44,652	15,764	20,192	12,442	0	0
1112. Vegetable and Melon Farming	0	7,225	9,277	3,275	4,195	2,585	0	0
1113. Fruit and Tree Nut Farming	0	26,289	27,394	9,671	12,387	7,633	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	10,878	16,950	5,984	7,665	4,723	0	0
1119. Other Crop Farming	0	5,561	8,272	2,920	3,740	2,305	0	0
1121. Cattle Ranching and Farming	0	31,156	41,959	14,813	18,974	11,692	0	0
1122. Hog and Pig Farming	0	511	586	207	265	163	0	0
1123. Poultry and Egg Production	0	5,831	3,961	1,399	1,791	1,104	0	0
1124. Sheep and Goat Farming	0	737	701	247	317	195	0	0
1129. Other Animal Production	0	6,205	5,037	1,778	2,278	1,404	0	0
2123. Nonmetallic Mineral Mining and Quarrying	8,386	16,159	15,844	8,309	0	4,786	21,300	0
2369. Building Construction (unclassified)	6,222	13,256	22,983	0	850	0	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
2378. Heavy and Civil Engineering Construction (unclassified)	2,030	5,122	34,247	0	5,338	0	0	0
2388. Specialty Trade Contractors (unclassified)	39,661	31,799	137,744	0	5,724	0	0	0
3114. Fruit and Vegetable Preserving and Specialty Food Manufacturing	151,390	63,468	643	1,311	990	687	2,512	0
3121. Beverage Manufacturing	1,986	2,010	80	12	43	154	0	0
3211. Sawmills and Wood Preservation	1,822	1,880	724	433	39	17	9	0
3219. Other Wood Product Manufacturing	16,455	38,116	2,596	2,328	1,875	0	0	0
3231. Printing and Related Support Activities	383	738	21	3	12	5	0	0
3241. Petroleum and Coal Products Manufacturing	7,291	1,254	5,796	43	157	70	0	0
3251. Basic Chemical Manufacturing	6,179	16,735	430	1,285	233	0	0	0
3261. Plastics Product Manufacturing	38,922	67,824	173	327	2,416	0	11,320	0
3262. Rubber Product Manufacturing	1,906	5,163	66	10	360	0	145	0
3272. Glass and Glass Product Manufacturing	138,790	45,403	2,328	4,523	2,980	0	8,882	0
3323. Architectural and Structural Metals Manufacturing	6,298	5,311	500	8	316	0	0	0
3324. Boiler, Tank, and Shipping Container Manufacturing	16,745	15,158	456	52	609	0	0	0
3325. Hardware Manufacturing	268	255	37	1	20	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	8,043	7,644	1,119	18	607	0	0	0
3328. Coating, Engraving, Heat Treating, and Allied Activities	1,072	1,019	149	2	81	0	0	0
3329. Other Fabricated Metal Product Manufacturing	804	764	112	2	61	0	0	0
3331. Agriculture, Construction, and Mining Machinery Manufacturing	294	442	97	2	53	0	0	0
3332. Industrial Machinery Manufacturing	3,594	4,582	496	8	351	0	0	0
3333. Commercial and Service Industry Machinery Manufacturing	294	442	97	2	53	0	0	0
3334. Ventilation, Heating, Air-Conditioning, and Commercial Refrigeration Equipment Manufacturing	3,007	3,698	302	5	245	0	0	0
3335. Metalworking Machinery Manufacturing	1,175	1,769	388	6	211	0	0	0
3339. Other General Purpose Machinery Manufacturing	4,182	5,467	690	11	456	0	0	0
3359. Other Electrical Equipment and Component Manufacturing	17,504	26,295	170	157	211	0	0	6
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	1,192	1,173	101	271	82	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	140	169	39	105	21	0	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
3399. Other Miscellaneous Manufacturing	78,914	76,235	922	15,622	301	3,221	0	0
Wyoming								
1111. Oilseed and Grain Farming	0	7,010	18,661	6,588	8,438	5,200	0	0
1112. Vegetable and Melon Farming	0	2,746	3,525	1,244	1,594	982	0	0
1113. Fruit and Tree Nut Farming	0	1,376	1,433	506	648	399	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	5,318	8,287	2,925	3,747	2,309	0	0
1119. Other Crop Farming	0	8,100	12,049	4,254	5,449	3,358	0	0
1121. Cattle Ranching and Farming	0	69,237	93,040	32,846	42,072	25,925	0	0
1122. Hog and Pig Farming	0	402	460	162	208	128	0	0
1123. Poultry and Egg Production	0	2,058	1,398	494	632	390	0	0
1124. Sheep and Goat Farming	0	915	870	307	393	242	0	0
1129. Other Animal Production	0	5,538	4,495	1,587	2,033	1,253	0	0
2123. Nonmetallic Mineral Mining and Quarrying	0	0	0	0	0	0	0	0
2369. Building Construction (unclassified)	3,111	6,628	11,492	0	425	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	902	2,276	15,221	0	2,372	0	0	0
2388. Specialty Trade Contractors (unclassified)	12,271	9,838	42,617	0	1,771	0	0	0
3115. Dairy Product Manufacturing	4,479	2,696	1,246	2,980	68	300	0	0
3116. Animal Slaughtering and Processing	4,303	3,945	921	702	50	222	224	0
3119. Other Food Manufacturing	965,991	0	0	0	0	0	83,245	0
3211. Sawmills and Wood Preservation	1,822	1,880	724	433	39	17	9	0
3219. Other Wood Product Manufacturing	17,559	41,153	3,035	2,722	2,113	0	0	0
3231. Printing and Related Support Activities	3,938	6,379	86	13	63	7	0	0
3262. Rubber Product Manufacturing	635	1,721	22	3	120	0	48	0
3312. Steel Product Manufacturing from Purchased Steel	81,896	39,173	745	24,120	1,212	0	0	0
3315. Foundries	1,203	1,183	1,016	152	826	0	0	0
3323. Architectural and Structural Metals Manufacturing	268	255	37	1	20	0	0	0
3324. Boiler, Tank, and Shipping Container Manufacturing	12,860	12,141	292	50	476	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	5,762	4,801	425	7	275	0	0	0
3335. Metalworking Machinery Manufacturing	294	442	97	2	53	0	0	0
3339. Other General Purpose Machinery Manufacturing	9,142	13,665	494	84	803	0	0	0
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	47	56	13	35	7	0	0	0
3372. Office Furniture (including Fixtures) Manufacturing	93	112	26	70	14	0	0	0
3399. Other Miscellaneous Manufacturing	145	175	7	7	4	2	0	0
Yates								
1111. Oilseed and Grain Farming	0	10,391	27,658	9,764	12,507	7,707	0	0
1112. Vegetable and Melon Farming	0	6,214	7,978	2,816	3,608	2,223	0	0

Table B.1: 2016 energy use (millions of BTU) by county and industry sector *(continued)*

County / Sector (NAICS)	Fuel types							
	Natural gas	Net electricity	Diesel	Other	LPG NGL	Residual fuel oil	Coal	Coke and breeze
1113. Fruit and Tree Nut Farming	0	23,385	24,368	8,602	11,019	6,790	0	0
1114. Greenhouse, Nursery, and Floriculture Production	0	8,219	12,807	4,521	5,791	3,569	0	0
1119. Other Crop Farming	0	5,035	7,490	2,644	3,387	2,087	0	0
1121. Cattle Ranching and Farming	0	139,328	185,029	65,321	83,669	51,558	0	0
1122. Hog and Pig Farming	0	438	502	177	227	140	0	0
1123. Poultry and Egg Production	0	8,918	6,059	2,139	2,740	1,688	0	0
1124. Sheep and Goat Farming	0	585	556	196	251	155	0	0
1129. Other Animal Production	0	1,735	1,408	497	637	392	0	0
2369. Building Construction (unclassified)	2,938	6,260	10,853	0	402	0	0	0
2378. Heavy and Civil Engineering Construction (unclassified)	226	569	3,805	0	593	0	0	0
2388. Specialty Trade Contractors (unclassified)	11,175	8,960	38,812	0	1,613	0	0	0
3116. Animal Slaughtering and Processing	4,303	3,945	921	702	50	222	224	0
3121. Beverage Manufacturing	44,546	39,963	1,019	152	645	1,310	0	0
3141. Textile Furnishings Mills	816	267	1,037	15	35	0	4	0
3211. Sawmills and Wood Preservation	3,643	3,759	1,448	866	79	35	18	0
3219. Other Wood Product Manufacturing	14,247	32,041	1,719	1,541	1,399	0	0	0
3231. Printing and Related Support Activities	255	492	14	2	8	3	0	0
3251. Basic Chemical Manufacturing	81,896	220,350	931	30,150	1,515	0	0	0
3261. Plastics Product Manufacturing	8,736	23,504	50	80	808	0	2,607	0
3323. Architectural and Structural Metals Manufacturing	268	255	37	1	20	0	0	0
3327. Machine Shops; Turned Product; and Screw, Nut, and Bolt Manufacturing	804	764	112	2	61	0	0	0
3371. Household and Institutional Furniture and Kitchen Cabinet Manufacturing	140	169	39	105	21	0	0	0
3399. Other Miscellaneous Manufacturing	145	175	7	7	4	2	0	0

C Additional emissions tables

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