

Carlisle's Greenhouse Gas Emissions, Past and Future

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Introduction

The Borough of Carlisle is one of twenty municipalities planning for climate change as part of the *Local Government Climate Action Assistance Program* of the Pennsylvania Department of Environmental Protection (DEP). Carlisle is receiving assistance from DEP, ICLEI Local Governments for Sustainability, and Dickinson College to develop a local climate action plan to benefit the Carlisle community and help advance goals of Pennsylvania's Climate Action Plan (PA Department of Environmental Protection, 2019).

In the first phase of the program, greenhouse gas emissions produced by activities of Carlisle residents, businesses, government offices and other entities were estimated for 2005 and 2017 and a scenario of potential future emissions was constructed. Results of the analyses from the first phase, summarized in this report, provide information intended for use in a subsequent phase of local climate action planning.

Greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) are emitted by burning fossil fuels and other activities. The gases accumulate in the atmosphere where they amplify the capacity of the atmosphere to absorb and retain thermal energy and cause the climate to warm and change in other ways.

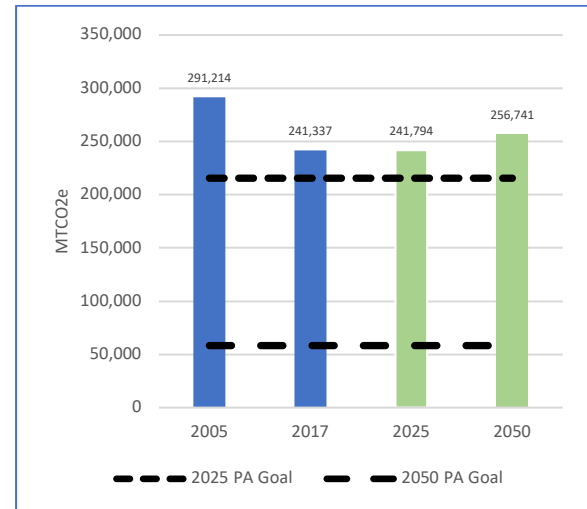
Carlisle's emissions of greenhouse gases are estimated from activity data for Carlisle (e.g. electricity and other energy use, travel by car and truck, and disposal of municipal solid waste) and average rates of emissions from the activities that were input to ClearPath, an online greenhouse gas inventory tool (ICLEI, 2014). Emissions of each type of greenhouse gas are converted into metric tons of carbon dioxide equivalent (MTCO₂e) to provide a standard

measurement of their contributions to climate change. The methodology and data sources for estimating Carlisle's emissions are described in the appendix.

Total Emissions

Carlisle's total greenhouse gas emissions in 2005 are estimated to be equivalent to just over 291,000 metric tons of carbon dioxide (MTCO₂e), or 16.1 metric tons per resident (Figure 1). From 2005 to 2017, the most recent year for which complete data are available, estimated emissions declined 17.1 percent to roughly 241,000 MTCO₂e, or 12.7 metric tons per resident. The decrease resulted primarily from a reduction in the share of electricity generated with coal, which produces high emissions per kilowatt hour (kWh) of electricity, and an increase in the share generated with natural gas, which produces less emissions per kWh.

Figure 1. Total greenhouse gas emissions, past and future



To put these numbers in perspective, emissions in 2017 are equivalent to every Carlisle resident

* Numerous collaborators provided technical support, data, and other assistance to estimate Carlisle's greenhouse gas emissions. Borough Council members Sean Shultz and Joel Hicks oversaw the project and Heidi Kunka, PA Department of Environmental Protection, and Jesse Carpentier and Calyn Hart of ICLEI Local Governments for Sustainability provided technical support. Susan Armstrong, Borough of Carlisle, Kathryn Frazier, PPL Electric Utilities, Dusty Hilbert, Advanced Disposal, Mark Malarich, Borough of Carlisle, Brian Meilinger, UGI Utilities, Justin Miller, Cumberland County Recycling and Waste Authority, Sean Shultz, Borough of Carlisle, Jeff Smith, Carlisle Airport, and Dan Szekeres, Michael Baker International provided data for the project. Funding was provided by the Borough of Carlisle and by the PA Department of Environmental Protection.

disposing 13 Borough Bags of carbon dioxide into the atmosphere *every week*. Adding this over the year for all residents, we are collectively putting 13.3 million Borough Bags of greenhouse gases into the atmosphere each year.[†]

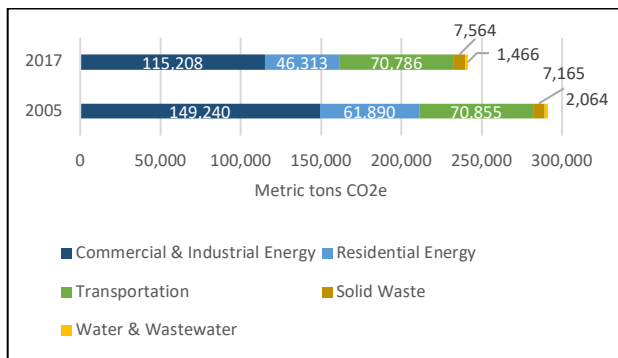
While recognizing that the future is uncertain, a scenario of future emissions was constructed for 2020 – 2050, assuming that no new policies or actions would be implemented to limit emissions. Under this and other assumptions, Carlisle’s emissions are projected to grow slowly to almost 242,000 MTCO₂e by 2025 and 257,000 MTCO₂e by 2050.

Past and projected future emissions are shown in Figure 1. For comparison, the figure also displays emission levels that correspond to statewide goals of the Pennsylvania Climate Action Plan: 26 percent reduction from 2005 by 2025 and 80 percent reduction by 2050. Estimates of past emissions, the projection of future emissions for a “No Action” scenario, and the state-level goals provide benchmarks that can be used to evaluate strategies for reducing Carlisle’s greenhouse gas emissions.

Emissions by Sector

Emissions were estimated for five sectors for the years 2005 and 2017: commercial and industrial energy, residential energy, transportation, municipal solid waste, and water and wastewater. 2017 is the most recent year for which complete data is available to estimate emissions for Carlisle. Emissions were also estimated for 2005 because 2005 is the year used in the Pennsylvania Climate Action Plan as a benchmark against which emission reductions are measured for the state.

Figure 2. Emissions by sector, 2005 and 2017



[†] This calculation assumes that the carbon dioxide gas is compressed to a density equal to that of municipal solid waste and each Borough Bag is filled to its maximum allowed 40 pounds.

Commercial and industrial energy use produced the largest share of Carlisle’s emissions in both 2005 and 2017, followed by transportation, residential energy, solid waste, and water and wastewater (Figure 2). In 2017, commercial and industrial energy accounted for 47.7% of total emissions, transportation for 29.3%, and residential energy for 19.2%. Solid waste, water, and wastewater combined account for less than 4% of emissions.

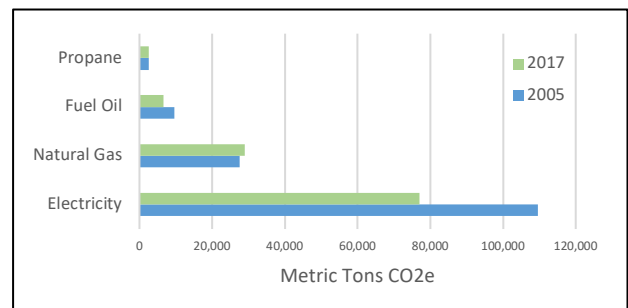
Commercial and Industrial Energy

Carlisle’s commercial and industrial establishments use over 1,400 billion British thermal units (Btus) of energy per year. Use of this energy generated nearly 150,000 MTCO₂e of greenhouse gas emissions in 2005 and roughly 115,000 MTCO₂e in 2017 (Table 1; Figure 3). Electricity use is the biggest contributor to these emissions. 223 million kWh of electricity was used by Carlisle’s commercial and industrial establishments in 2017, up 5.6% from 2005. Despite the rise in commercial and industrial electricity use in Carlisle, emissions produced by electric utilities to supply this electric power decreased from about 110,000 MTCO₂e to 77,000 MTCO₂e. The decline in emissions is attributable to natural gas displacing coal in generating electric power.

Table 1. Commercial and industrial energy use and emissions

	Usage Units	2005		2017	
		Usage	GHG Emissions (MTCO ₂ e)	Usage	GHG Emissions (MTCO ₂ e)
Electricity	Million kWh	211.2	109,650	223.0	77,066
Natural Gas	Billion Btu	516.7	27,483	545.7	29,022
Fuel Oil	Billion Btu	128.2	9,547	88.3	6,572
Propane	Billion Btu	41.3	2,561	41.1	2,549
Total	Billion Btu	1,406.7	149,241	1,435.8	115,209

Figure 3. Emissions from commercial and industrial energy use by energy type



Natural gas is the second largest energy source for Carlisle’s commercial and industrial establishments and is also the second largest source of greenhouse emissions for the sector. Relatively small amounts of fuel oil and propane are used by Carlisle’s commercial and industrial sector and account for small shares of emissions.

Residential Energy

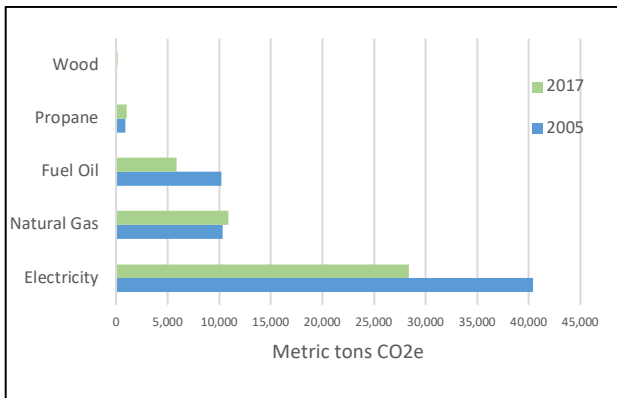
Carlisle residents used 617 billion Btus of energy in 2005 and 594 billion Btus in 2017 to heat and cool their homes, power appliances, and for other purposes. Of Carlisle’s 7,475 occupied households, 45% used natural gas as their primary heating fuel in 2017, 38% used electricity, 12% used distillate fuel oil, nearly 3% used propane, and 1% used wood.

Energy use by Carlisle’s residential sector emitted close to 62,000 MTCO₂e of greenhouse gases in 2005 and 46,000 MTCO₂e in 2017, a decrease of 25% (Table 2; Figure 4). Electricity use is the largest source of emissions for Carlisle’s residences, 61.3% in 2017, followed by natural gas, 23.5%, and fuel oil, 12.6%. The decrease in emissions from residential energy use is largely due to lower emissions per kWh of electricity generation.

Table 2. Residential energy use and emissions

	Usage Units	2005		2017	
		Usage	GHG Emissions (MTCO ₂ e)	Usage	GHG Emissions (MTCO ₂ e)
Electricity	Million kWh	77.8	40,395	82.2	28,391
Natural Gas	Billion Btu	193.7	10,301	204.5	10,877
Fuel Oil	Billion Btu	134.9	10,212	77.2	5,846
Propane	Billion Btu	14.5	903	17.0	1,054
Wood	Billion Btu	8.0	79	14.5	145
Total	Billion Btu	616.5	61,890	593.5	46,313

Figure 4. Emissions from residential energy use by energy type



Transportation

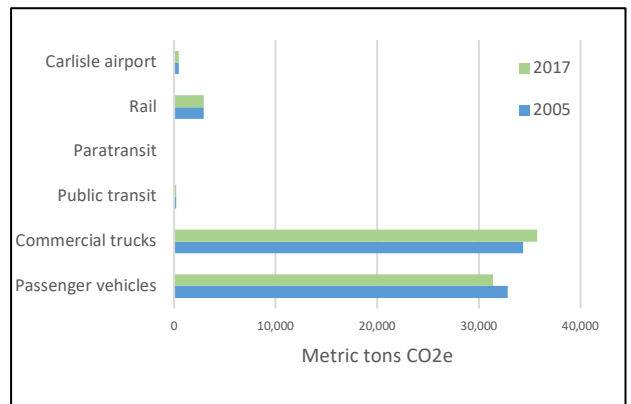
Roughly 100 million miles are driven annually for trips that begin or end in Carlisle. This includes nearly 84 million miles driven in passenger vehicles and light trucks and 21.7 million miles driven in commercial trucks in 2017. Road and other transportation resulted in emissions of nearly 71,000 MTCO₂e in both years (Table 3; Figure 5). Excluded from these estimates are trips that just pass through Carlisle.

While vehicle miles traveled in passenger vehicles and light trucks are nearly four-times greater than miles traveled by commercial trucks, commercial trucks are a larger source of greenhouse gas emissions. This is because commercial trucks have much lower fuel economy and consequently burn more fuel than passenger vehicles. Commercial trucks emitted nearly 36,000 MTCO₂e in 2017 and passenger vehicles emitted slightly more than 31,000 MTCO₂e that year.

Table 3. Transportation emissions

	2005		2017	
	Vehicle Miles Traveled	GHG Emissions (MTCO ₂ e)	Vehicle Miles Traveled	GHG Emissions (MTCO ₂ e)
Passenger vehicles	79,536,980	32,852	83,988,726	31,380
Commercial trucks	20,593,429	34,366	21,746,059	35,753
Public transit	64,910	184	68,543	194
Paratransit	49,485	87	52,255	92
Rail	NA	2,919	NA	2,919
Carlisle Airport	NA	448	NA	448
Total	100,244,804	70,856	105,855,583	70,786

Figure 5. Emissions from transportation



Public transit and paratransit bus revenue miles are much smaller in comparison to passenger and commercial vehicle travel. They contributed less than 300 MTCO₂e to emissions. Rail added a bit less than 3,000 MTCO₂e and fuel use at the Carlisle Airport added close to 450 MTCO₂e.

Municipal Solid Waste, Water, and Wastewater

Landfilling municipal solid waste, distributing drinking water, and treating wastewater contribute emissions of greenhouse gases that are small in comparison to emissions from energy use and transportation (Table 4). Municipal solid waste generated by Carlisle residents, businesses and other establishments is taken to the Cumberland County Landfill where organic components decompose and produce methane, a greenhouse gas that is 25 times more powerful than carbon dioxide. Some of the landfill gas is captured and either combusted to generate electricity or flared, which converts the methane to the less powerful greenhouse gas carbon dioxide.

In 2017, nearly 13,000 tons of solid waste was generated by Carlisle and landfilled. Emissions of methane from the landfilled waste are estimated at roughly 7,500 MTCO₂e, slightly more than in 2005. Combustion and flaring of landfill gas contribute an additional 20 MTCO₂e.

Table 4. Solid waste, water, and wastewater emissions

	2005	2017
Municipal Solid Waste		
Landfilled waste (short tons)	12,095	12,772
GHG emissions - fugitive (MTCO ₂ e)	7,145	7,545
GHG emissions - combustion & flaring (MTCO ₂ e)	20	20
Total MSW emissions (MTCO ₂ e)	7,165	7,565
Drinking water		
Water use (millions gals)	493	521
Electricity use (kWh)	1,647,038	1,739,224
GHG emissions - electricity (MTCO ₂ e)	855	601
Wastewater		
Electricity use (kWh)	2,248,320	2,374,160
GHG emissions - electricity (MTCO ₂ e)	1,167	821
GHG emissions - fugitive (MTCO ₂ e)	42	44
Total wastewater emissions (MTCO ₂ e)	2,064	1,466

Carlisle residents and establishments used an estimated 493 million gallons of drinking water in 2005 and 521 million gallons in 2017. 1.7 million kWh of electricity was used to pump and treat the water in 2017, the generation of which produced 601 MTCO₂e of emissions, which was down from 855 MTCO₂e in 2005.

The treatment of Carlisle’s wastewater consumed an estimated 2.25 million kWh of electricity in 2005 and 2.37 million kWh in 2017. Generation of this electricity produced 1,167 MTCO₂e of emissions in 2005 and 821 MTCO₂e in 2017. In addition, the nitrification/denitrification process used to treat the

wastewater emitted nitrous oxide equivalent to 42 and 44 MTCO₂e in 2005 and 2017, respectively.

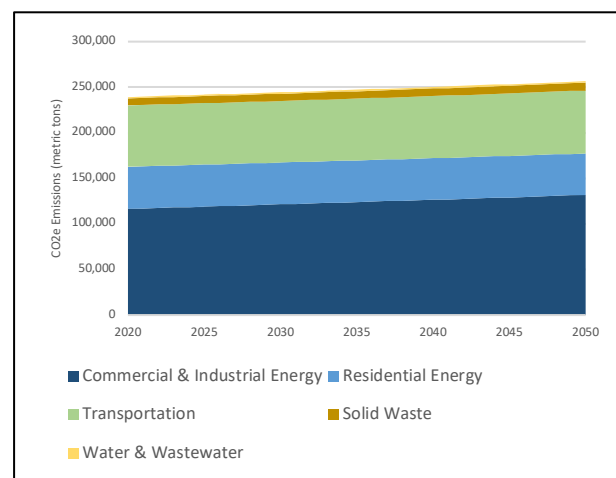
Future Emissions

A scenario of Carlisle’s future emissions was constructed for 2020 – 2050 to provide a comparison case for evaluating emission reduction strategies. To construct the scenario, it was assumed that no new policies or actions would be implemented to limit emissions. Additionally, it was assumed that changes in energy use and other variables in Carlisle would track closely with changes at the state level as projected for the Pennsylvania Climate Action Plan.

Future emissions are uncertain, and the “No Action” scenario represents one possible future for Carlisle. The methodology used to construct Carlisle’s “No Action” scenario is described in the appendix.

For the “No Action” scenario, Carlisle’s total greenhouse gas emissions grow at a compound annual rate of 0.002, increasing from 239,000 metric tons of carbon dioxide (MTCO₂e) in 2020 to 257,000 MTCO₂e in 2050 (Figure 7). The cumulative increase is 7.3%. The shares of emissions contributed by each sector remain close to current levels, with commercial and industrial energy as the largest source of emissions throughout the forecast period, followed by transportation, residential energy, solid waste, and water and wastewater.

Figure 6. Future emissions: No Action Scenario



Appendix: Methodology and Data Sources

2017 and 2005 Emission Inventories

Greenhouse gas emissions were estimated for Carlisle by collecting activity data and average emission rates for the activities and entering them into ClearPath, an online tool developed by ICLEI for calculating greenhouse gas emission inventories (ICLEI, 2014). The calculations performed by ClearPath are consistent with the U.S. Community Protocol for greenhouse gas inventories (ICLEI, 2012).

Emissions were initially estimated for 2017, the most recent year for which complete data are available for Carlisle's. Emissions were also estimated for 2005 using activity data that is available for that year and by scaling other activity data from 2017 using population and other measures from 2005. Estimates for both years provide rough approximations of Carlisle's greenhouse gas emissions that are more accurate for 2017 than for 2005.

The estimates capture most of the emissions for which Carlisle residents, businesses and institutions are responsible, but not all. Not included, to give one example, are emissions that are generated by producing goods and services outside of Carlisle that are transported to Carlisle for our consumption. Another example are emissions generated by Carlisle residents' air travel to and from airports other than the Carlisle airport.

Commercial and Industrial Energy

Electricity use in 2017 by commercial and industrial users in the 17013 zip code service area was provided by PPL Utilities. The percentage of employees in the 17013 service area who worked in Carlisle in 2012, the most recent year for which data is available, was 59.6 percent and was used to estimate commercial and industrial electricity use that is attributable to Carlisle.

Natural gas use for commercial and industrial users in Carlisle for 2017 was provided by UGI. Use of fuel oil and propane by commercial and industrial users in Carlisle was estimated using state level data from the U.S. Energy Information Agency. A portion of the consumption of fuel oil and propane in Pennsylvania was allocated to Carlisle using Carlisle's percentage of the value of sales, shipments, receipts, revenue and business in Pennsylvania from the U.S. Census Bureau, which was 0.15 percent in 2012, the most recent year for which data is available.

Energy use for the sector in 2005 was estimated using Carlisle population data and assuming per capita use of each type of energy was the same in 2005 as in 2017.

Emissions per kWh of electricity used depend on the mix of energy sources used to generate electricity, which vary by region of the country. Carlisle is located in the RFC East utility region. Emission factors for the RFC East region for 2005 and 2017 were obtained from the USEPA's eGrid data set and input to ClearPath. Default emission factors for other energy sources are provided by the ClearPath tool.

Residential Energy

Electricity use in 2017 by residential users in the 17013 zip code service area was provided by PPL Utilities. The percentage of population in the 17013 service area who lived in Carlisle in 2017, 53.4 percent, is used to estimate Carlisle's residential electricity use.

UGI provided natural gas use for residential users in Carlisle. Data for use of fuel oil, propane, and wood by Carlisle residences are not directly available and had to be estimated. Estimates were calculated from data on total residential energy use in Pennsylvania by fuel type, the number of households in Pennsylvania using each fuel as a primary heating source, their average use of these fuels, and the number of households in Carlisle using each fuel as a heating source.

Residential use of electricity and natural gas in 2005 was estimated using Carlisle population data and assuming per capita use of each was the same in 2005 as in 2017. For fuel oil, propane, and wood, it was assumed that Carlisle used the same percentages of statewide consumption in 2005 as in 2017. Emission factors for residential energy are the same as for the commercial and industrial sector.

Transportation

Emissions of greenhouse gases for on-road transportation are calculated from estimates of vehicle miles traveled within Carlisle for different vehicle and fuel types, vehicle fuel efficiencies, and average emissions per gallon of fuel or per mile traveled. Estimates of vehicle miles traveled (VMT) for passenger and commercial freight vehicles by fuel

type were provided by Michael Baker International, a contractor for the Harrisburg Metropolitan Planning Organization. They estimate VMT for Carlisle using data available from PennDOT and information about trip origins and destinations derived from the South-Central Travel Demand Model. Estimates of VMT for Carlisle include 100 percent of miles for trips that start and end in Carlisle and 50 percent of miles for trips that either start or end in Carlisle but not both.

Vehicles traveling on I-81 and other throughways that neither start or stop in Carlisle are excluded.

Capital Area Transit and Rabbitransit provide bus service to the region, including Carlisle. Data on vehicle revenue miles and fuel use for their entire service areas were obtained from the 2017 Annual Agency Profile of the Cumberland Dauphin-Harrisburg Transit Authority. Miles and fuel use attributable to Carlisle were estimated using Carlisle's population as a percentage of the total population served by Transit Authority, 3.73 percent.

National data for average fuel economy and emission factors for methane and nitrous oxide for passenger cars, light trucks, heavy trucks, transit buses, and paratransit buses are input to ClearPath to calculate emissions from these transportation modes. Emissions per mile traveled declined from 2005 to 2017 as average fuel economy increased.

Norfolk Southern Railway, which owns and operates the freight rail line that passes through Carlisle, reports that 15.8 million MTCO_{2e} of greenhouse gases were emitted by their national rail operations in 2017. Emissions attributable to Carlisle are estimated using the percentage of Norfolk Southern's route miles that lie within Carlisle, 0.02 percent. Emissions produced by flights in and out of the Carlisle airport are estimated using volumes of aviation gasoline and jet fuel that are loaded on planes at the airport.

Transportation emissions in 2005 were estimated assuming that they are proportional to population.

Solid Waste, Water, and Wastewater

Waste generation is not measured directly for Carlisle but is estimated using the average weight per county resident of municipal solid waste received at the county landfill. Organic wastes decompose in the landfill, a process the emits methane, a powerful greenhouse gas. Different types of waste emit methane at different rates. The percentage of waste by type (e.g. corrugated cardboard, newspaper, office paper, food and yard waste) were derived from a 2003 DEP study of waste composition in Pennsylvania.

A portion of the landfill gas, typically ranging from 40 to 60 percent, is captured and either combusted to generate electricity or flared. This reduces the amount of methane that reaches the atmosphere but produces emissions of the less powerful greenhouse gas carbon dioxide. Quantities of landfill gas flared and combusted were provided by Advanced Disposal, the operator of the landfill.

Distribution and treatment of drinking water and wastewater uses electricity, the generation of which produces greenhouse gases. In addition, Carlisle's wastewater treatment plant uses a process that produces nitrous oxide, a greenhouse gas that is 298 times more powerful than carbon dioxide. Data for electricity consumption and treatment processes for Carlisle's water and wastewater treatment plants were provided by the Carlisle Borough Office.

Future Emissions

A scenario of future greenhouse gas emissions is constructed for Carlisle for the period 2020 through 2050. The scenario incorporates existing policies but assumes that no new policies are implemented at local, state, or federal levels that would influence the borough's future emissions of GHGs. The effects of state level measures envisioned in Pennsylvania's Climate Action Plan are excluded, as are the effects of recent rollbacks in federal regulations for vehicle fuel economy.

The No Action Scenario is constructed using the forecasting module of ICLEI's ClearPath tool. Inputs to the analysis include Carlisle's 2017 greenhouse gas inventory, population forecasts for Carlisle from the *Cumberland County Comprehensive Plan* (Cumberland County Planning Commission, 2017), projections of future state-level energy consumption from the *Energy Assessment Report for the Commonwealth of Pennsylvania* (Pennsylvania Department of Environmental Protection, 2019), and national-level transportation forecasts from the *Annual Energy Outlook 2020* (U.S. Energy Information Administration, 2020).

Energy Consumption

The *Energy Assessment Report for the Commonwealth of Pennsylvania* projects future energy consumption for the period 2015 to 2050 for a 'business as usual' scenario. Growth rates from the report are applied to extrapolate energy consumption in Carlisle to the year 250. This imposes an assumption that energy consumption by Carlisle's residents, businesses and

other institutions will grow at the same rate as a projected for the state.

The mix of energy sources used to generate electricity in Pennsylvania is also projected to change. The share of electricity generated with natural gas is projected to grow substantially, nuclear to decline by half, renewables to increase marginally, and coal to be flat. The projected changes would increase emissions of greenhouse gases per kWh of electricity in Pennsylvania by 6.8% from 2015 to 2050.

Transportation

Projections of vehicle miles traveled and energy consumed per mile are not contained in the *Energy Assessment Report for the Commonwealth of Pennsylvania*. But national level forecasts are available from the *Annual Energy Outlook 2020* (USEIA, 2020). Growth rates from the national forecasts are applied to extrapolate vehicle miles traveled and carbon intensity of travel for Carlisle. Vehicle miles traveled in the U.S. are projected to grow for light duty vehicles, heavy trucks, and transit buses, while energy intensity is projected to decline. The declining energy intensity incorporates projected changes in fuel economy based on implementation of the national clean car standards that the USEPA now plans to roll back. If the rollback is maintained, future emissions from transportation would likely be greater than projected for the Carlisle No Action Scenario forecast.

Solid Waste, Water and Wastewater

For Carlisle's No Action Scenario, GHG emissions from solid waste, water, and wastewater are assumed to grow at the same rate as Carlisle's population. The 2017 Cumberland County Comprehensive Plan includes projections of populations to the year 2040 for Carlisle and other municipalities in the county. The population forecast for 2040 is extrapolated to 2050 by applying the compound annual growth rate for the period 2020 to 2040.

Data Sources

Demographic Data

Population, number of households, household heating fuel, and number of employees: US Census Bureau, American FactFinder, accessed December 21, 2019. <https://factfinder.census.gov/faces/nav/jsf/pages/index.xhtml>.

Residential and Non-Residential Energy

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Rail transportation emissions: Norfolk Southern Railway, 2018 Corporate Social Responsibility Report, accessed January 20, 2020. <http://www.nscorp.com/content/dam/nscorp/get-to-know-ns/about-ns/environment/ns-2018-social-responsibility-report.pdf>

Carlisle Airport fuel use: Carlisle Airport, personal communication by email from Jeff Smith, Airport Manager.

Municipal Solid Waste

Municipal solid waste generation, Cumberland County and Carlisle: Cumberland County Recycling and Waste Authority, personal communication by email from Justin Miller, Recycling Coordinator.

Municipal waste composition: Pennsylvania Department of Environmental Protection, *Final Report, Statewide Waste Composition Study*, April, 2003. <http://files.dep.state.pa.us/Waste/Recycling/RecyclingPortalFiles/Documents/wastecompositionstudy.pdf>

Landfill gas flaring and combustion: Advanced Disposal, personal communication by email from Dusty Hilbert, General Manager.

Water and Wastewater

Water and wastewater volumes, service populations and electricity use: Borough of Carlisle, personal email communications from Susan Armstrong, Borough Manager; Mark Malarich, Director of Public Works; and Sean Shultz, Council Member.

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