City of Dover, New Hampshire

Greenhouse Gas and Nitrogen Inventory Report for Municipal and School Operations

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Executive Summary

The City of Dover recognizes the many challenges that a changing climate presents and acknowledges that municipalities have a responsibility to lead adaptation and greenhouse gas reduction efforts at the local level. Through a University of New Hampshire Sustainability Fellowship undertaken by UNH doctoral student Jackson Kaspari, the City of Dover has become the first municipality in North America to complete a baseline footprint for both greenhouse gas (GHG) and nitrogen impacts of local government operations. This inventory informs Dover's policymakers, residents, property owners, and business owners on how to best introduce mitigation measures, helping Dover contribute to a global effort.

Conducting a GHG and nitrogen inventory serves the following purposes:

- Allows for the development of a baseline to which further GHG and nitrogen analyses can be compared.
- Leads to the identification of opportunities to improve energy efficiency.
- Leads to the identification of opportunities to reduce nitrogen releases to the environment.
- Demonstrates climate change leadership through the development of reduction targets.
- Increases the general transparency and consistency of GHG and nitrogen accounting and reporting among institutions.

This carbon and nitrogen footprint baseline was compiled through the utilization of two online tools: the Environmental Protection Agency's Portfolio Manager and the University of New Hampshire's Sustainability Indicator Management and Analysis Platform (SIMAP). The inventory is organized into categories, or sectors, which represent the major sources of carbon and nitrogen emissions. Most sectors contribute to both types of emissions. The sectors analyzed in this report include: stationary fuels, purchased electricity, the municipal fleet, employee commuting, employee travel, fertilizer and animals, school cafeteria food, solid waste, paper use, transmission and distribution losses, and wastewater treatment. In addition to analyzing the energy use and GHG impacts for each sector, the City's energy costs have also been calculated for both 2016 and 2017.

Overall, municipal operations generated 9,896 metric tons of carbon dioxide equivalent (MT of $C0_{2e}$) in 2016 and 9,560 MT of $C0_{2e}$ in 2017, representing a 3.4% reduction from year to year. Reactive nitrogen released to the environment was 40 MT and 42.3 MT in 2016 and 2017, respectively, a 5.4% increase. Figures for each sector and each year are included, and the likely causes of increases or reductions are presented.

This inventory concludes with models of the impact of projects that are already underway as well as reduction scenarios that the City and schools may opt to pursue. It also includes recommendations for improving upon data collection in future years and appendices detailing energy use at each facility.

Introduction

Dover is the first city to establish a combined greenhouse gas (GHG) and nitrogen inventory for its local government operations.

The City of Dover is located in Strafford County, New Hampshire. Settled in 1623 by William and Edward Hilton, Dover is the earliest permanent settlement in New Hampshire and seventh in the United States. The City covers an area of approximately 29 square miles including land and water. Dover is known for its iconic brick mill buildings, in which a successful textile industry flourished for decades throughout the early 1900s. Today, Dover is thriving more than ever and is growing quickly. The current population is estimated to be 31,153 and is predicted to grow to 34,915 by 2040, making Dover one of the fastest growing cities in New Hampshire.[1]

The City of Dover recognizes the many challenges that climate change presents and acknowledges that cities should lead the way in the implementation of efforts to protect our environment for present and future generations. This is exemplified by the award-winning Climate Adaptation Chapter of Dover's Master Plan titled "Planning Today for a Resilient Tomorrow". The chapter covers in depth the risks Dover faces in the coming years, predictions regarding how the southern New Hampshire climate will change, local impacts that the community will face, and resiliency and reduction efforts the City has taken. The following examples show Dover's commitment to addressing climate change:

- November 2017 retrofit of 1,781 streetlights to LED fixtures.
- 2016 wastewater facility upgrade which improved nitrogen removal efficiency.
- Power purchase agreements with Revision Energy involving the installation of solar panels on the new Dover High School, the Children's Museum of NH, and the Indoor Pool.
- Purchase of the first electric vehicle in the City fleet by the Information Technology Department.

Conducting this greenhouse gas (GHG) and nitrogen inventory benchmark analysis aligns with Dover's 2023 Vision, established in 2012 Visioning Chapter of the Master Plan. "When Dover celebrates its 400th anniversary in 2023, it will be a dynamic community with an outstanding quality of life because it has achieved the following interconnected characteristics:

- Residents celebrate safe, family friendly neighborhoods, a strong sense of community and an excellent school system.
- The historic downtown is alive with a wide variety of retail, dining, entertainment, cultural opportunities and a mix of hosing choices that make it the vibrant focal point of the community.
- **Municipal government and schools are run effectively and efficiently with full transparency, resulting in high quality services, well maintained buildings and infrastructure, a great recreation system and a competitive property tax burden.**
- The community is fully served by public transportation and is very accessible for walking, bicycling, and persons with disabilities.
- Vehicular traffic volumes and speeds are well managed.

- Dover attracts and retains well-paying employers because it is business friendly and has a high quality of life.
- Rural character is preserved and well-designed development is encouraged in and around the downtown core and waterfront.
- **Enhanced environmental quality and sustainability are actively pursued and inherent in all the city's activities."**

Definitions

The following is a list of definitions for important terms included in this inventory report.

- **Carbon footprint:** Total amount of greenhouse gases produced to directly and indirectly support human activities. Values are normalized using equivalent tons of carbon dioxide (CO_2e).[1]
- **Nitrogen footprint:** The amount of reactive nitrogen released to the environment as a result of an organization's resource consumption. Reactive nitrogen refers to compounds such as nitrous oxide, nitrite, ammonia, and ammonium. The two main sectors releasing reactive nitrogen are the consumption and production of food and the combustion of fossil fuels.[2]
- **Footprint baseline:** Selected time period to which future footprints are compared. Essential for setting reduction goals and evaluating emission sources.[3]
- **Radiative forcing:** The difference between the sunlight absorbed by the Earth and the energy radiated back to space.[4]
- **Anthropogenic:** Of, relating to, or resulting from the influence of human beings on nature.

Effects of Anthropogenic GHGs

Today, many people understand that the human species has significantly contributed to climate change through a variety of pathways. However, the scale of this impact is not as readily known. The following information regarding the scale of humanity's contribution to climate change as a result of GHG emissions comes from the Intergovernmental Panel on Climate Change's (IPCC) "Climate Change 2014 Synthesis Report Summary for Policymakers".[5] According to the IPC:

> **"Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever. This has led to atmospheric concentrations of carbon dioxide, methane, and nitrous oxide that are unprecedented in at least the last 800,000 years. Their effects, together with those of other anthropogenic drivers, have been detected throughout the climate system and are extremely likely to have been the dominant cause of observed warming since the mid-20th century."**

Total anthropogenic GHG emissions have increased from 1970 to 2010, with greater increases occurring between 2000 and 2010. The total amount of anthropogenic GHG emissions in 2010 reached 49 ± 4.5 gigaton of CO2-equivalent per year (GtCO_2-eq/yr) (Figure 1). Carbon dioxide emissions stemming from industrial processes and fossil fuel combustion made up approximately 78% of the total GHG emission increase from 1970 to 2010. From 1750 to 2011, cumulative anthropogenic CO_2 emissions to the atmosphere were 2040 ± 319 GtCO_2. It is estimated that around 40% of these emissions have remained in the atmosphere, with the rest removed and stored in plants, soils and the ocean.

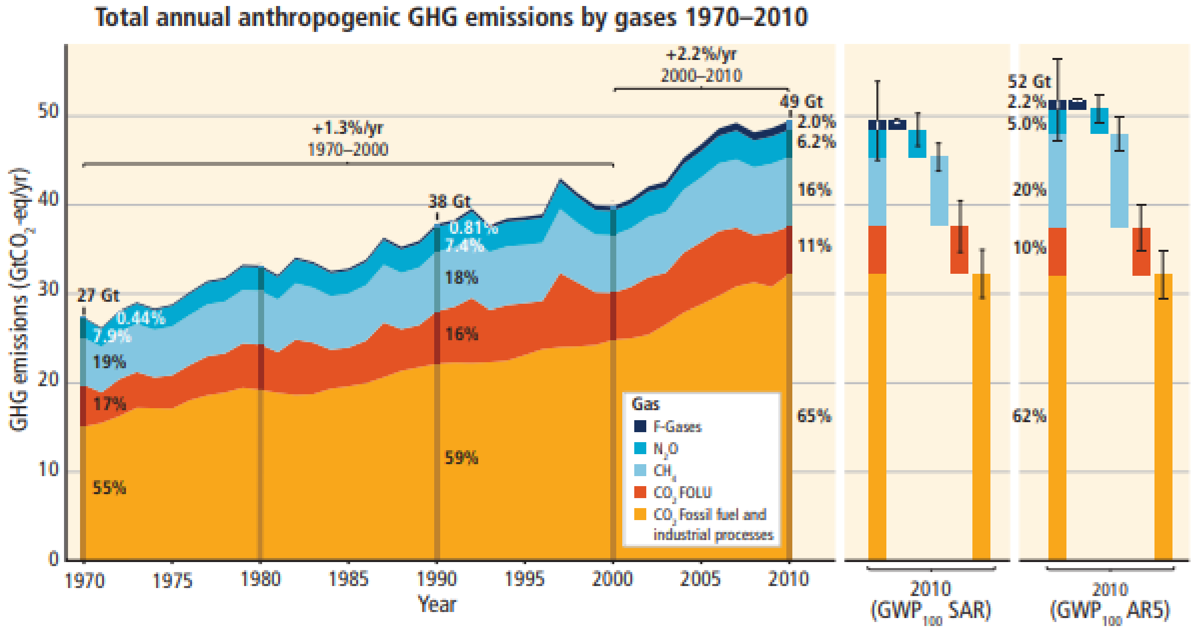


Figure 1. Total annual anthropogenic greenhouse gas (GHG) emissions (gigaton of CO2-equivalent per year, $GtCO_2$-eq/yr) for the period 1970 to 2010 by gasses: CO_2 from industrial processes; CO_2 from Forestry and other Land Use (FOLU); methane (CH_4); nitrous oxide (N_2O; fluorinated gases covered under the Kyoto Protocol (F-gases). Right hand side shows 2010 emissions, using alternatively CO_2-equivalent emissions weightings based on the IPCC Second Assessment Report (SAR) and AR5 values. Unless otherwise stated, CO_2-equivalent emissions in this report include the basket of Kyoto gasses (CO_2, CH_4, N_2O as well as F-gases) calculated based on 100-year Global Warming Potential (GWP_{100}) values from SAR. Using the most recent GWP_{100} values from the AR5 (right hand bars) would result in higher annual total GHG emissions (52 $GtCO_2$-eq/yr) from an increased contribution of methane, but does not change the long-term trend significantly. [5]

The IPCC uses the phrases likely, very likely, and extremely likely to describe anthropogenic climate impacts in relation to the uncertainties in the data which informed its statements. The following list outlines these impacts:

- **Extremely likely** that more than half of the observed increase in global average surface temperature from 1951 to 2010 was caused by anthropogenic increase in GHG concentrations and other forcings (Figure 2).
- Anthropogenic forcings have **likely** made a substantial contribution to the surface temperature increases since the mid-20th century over every continental region except Antarctica.
- Anthropogenic influences have **likely** affected the global water cycle since 1960 and contributed to the retreat of glaciers since the 1960s and to the increased surface melting of the Greenland ice sheet since 1993.
- Anthropogenic influences have **very likely** contributed to Artic sea-ice loss since 1979.
- Anthropogenic influences have **very likely** made a substantial contribution to increases in global upper ocean heat content and to global mean sea level rise since the 1970s.

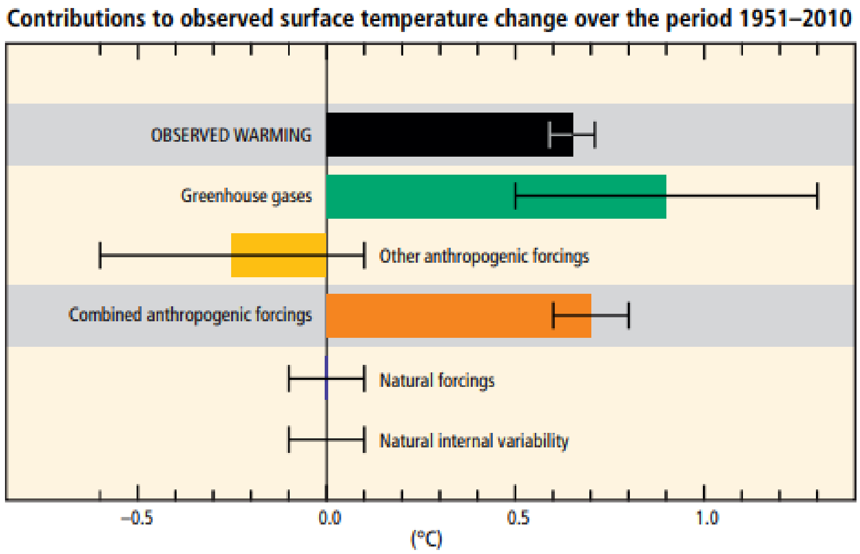


Figure 2. Assessed likely ranges and their mid-points (bars) for warming trends over the 1951-2010 period from well-mixed greenhouse gases, other anthropogenic forcings (including the cooling effect of aerosols and land use change), combined anthropogenic forcings, natural forcings and natural internal climate variability (which is an element of climate variability that arises spontaneously within the climate system even in the absence of forcings). The observed surface temperature change is shown in black, with the 5 to 95% uncertainty range due to observational uncertainty. The attributed warming ranges (colors) are based on observations combined with climate model simulations, in order to estimate the contribution of an individual forcings to the observed warming. The contribution from the combined anthropogenic forcings can be estimated with less uncertainty than the contribution from greenhouse gases and from other anthropogenic forcings separately. This is because these two contributions partially compensate, resulting in a combined signal that is better than constrained by observations.[5]

As a result of past anthropogenic emissions, future emissions and natural climate variability, the IPCC states the following with regards to projected changes in the climate system:

> **"Surface temperature is projected to rise over the 21st century under all assessed emission scenarios. It is very likely that heat waves will occur more often and last longer, and that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify, and global mean sea level to rise."**

These findings make clear the utmost importance of introducing large-scale mitigation and adaptation efforts in the near future:

> **"Without additional mitigation efforts beyond those in place today, and even with adaptation, warming by the end of the 21st century will lead to high to very high risk of severe, wide-spread and irreversible impacts globally. Mitigation involves some level of co-benefits and of risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as a risk from climate change, increasing the benefits from near-term mitigation efforts."**

This inventory will help inform Dover's policymakers on how to best introduce mitigation procedures helping Dover contribute to a much needed global effort. For much more detailed information on the topics summarized in this section, please review the IPCCs full report.

The Nitrogen Dilemma

Unlike the effects of anthropogenic-derived GHGs, the impacts of nitrogen and its effects on environmental and human health have only recently been brought to the public spotlight through resources such as the web based N-print tool.[6] Nitrogen in its pure form, which makes up 78% of the atmosphere, is inert. It is not this nitrogen, but reactive nitrogen (Nr), that is of concern. Pure nitrogen is converted to reactive forms through a variety of pathways (Figure 3).

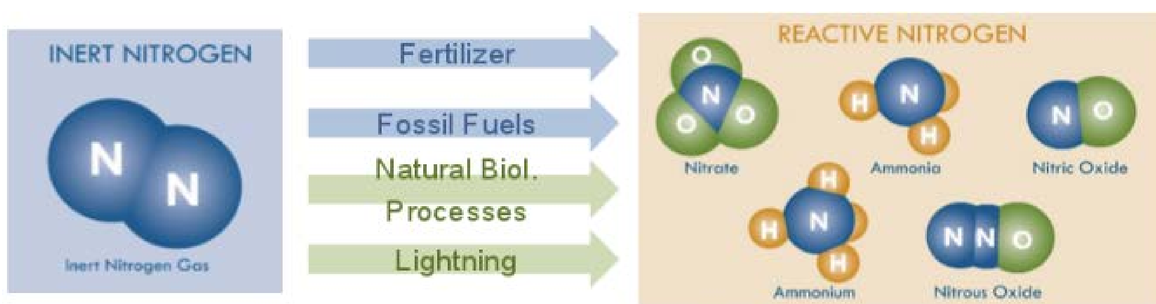


Figure 3. The anthropogenic (blue) and natural (green) pathways that convert pure inert nitrogen into its reactive forms.[6]

Anthropogenic Nr comes from activities such as the creation of synthetic fertilizer via the Haber-Bosch process as well as through the combustion of fossil fuels.[6] The largest natural process that generates Nr is through microbe fixation. The extreme heat of lightning strikes may also form Nr by splitting the bonds of the diatomic form. Humans have significantly altered the global Nr cycle.[6] It is estimated that human Nr releases are 7 times greater than those from natural sources.[6]

There are a host of implications associated with anthropogenic reactive nitrogen releases (Table 1).

Table 1. Impacts associated with reactive nitrogen releases and their descriptions.

Impact [6]	Description
Smog and Haze	Nitrogen oxides react with sunlight near earth's surface, which creates smog. Ozone is beneficial in the stratosphere but detrimental to human health when it in the tropospheric zone.
Forest Die-Back	Excess Nr in the atmosphere leads to acid rain which can change the chemical composition of soil damaging root systems.
Acidification	When nitrogen runoff enters lakes and streams, it can increase their acidity. This is detrimental to some aquatic organisms and thus reduces the biodiversity of the freshwater ecosystems.
Ozone Hole	Nitrous oxide (N_2O) in the stratosphere leads to ozone depletion, increasing the size of the current ozone layer hole.
Climate Change	N_2O is also a potent GHG with 300 times the global warming potential of CO_2. Reactive nitrogen on the ground level decreases the ability of peat to sequester carbon. It is estimated that the CO_2 stored in peatlands is around 500 billion tones, which is more than what is stored in all of the Earth's rainforests combined. Furthermore, NO_x emissions increase ozone concentrations in the tropospheric region of the atmosphere.
Eutrophication	Excessive nitrogen in coastal ecosystems also causes algal blooms, which deplete oxygen levels. This kills life in these ecosystems, while also making freshwater sources unsuitable for human consumption.

There is also very significant economic strain that stems from dealing with nitrogen pollution and its sources. An analysis was done which estimated and broke down the costs to the European Union as a result of Nr impacts as well as the sources that contribute to each pollutant (Figure 4).

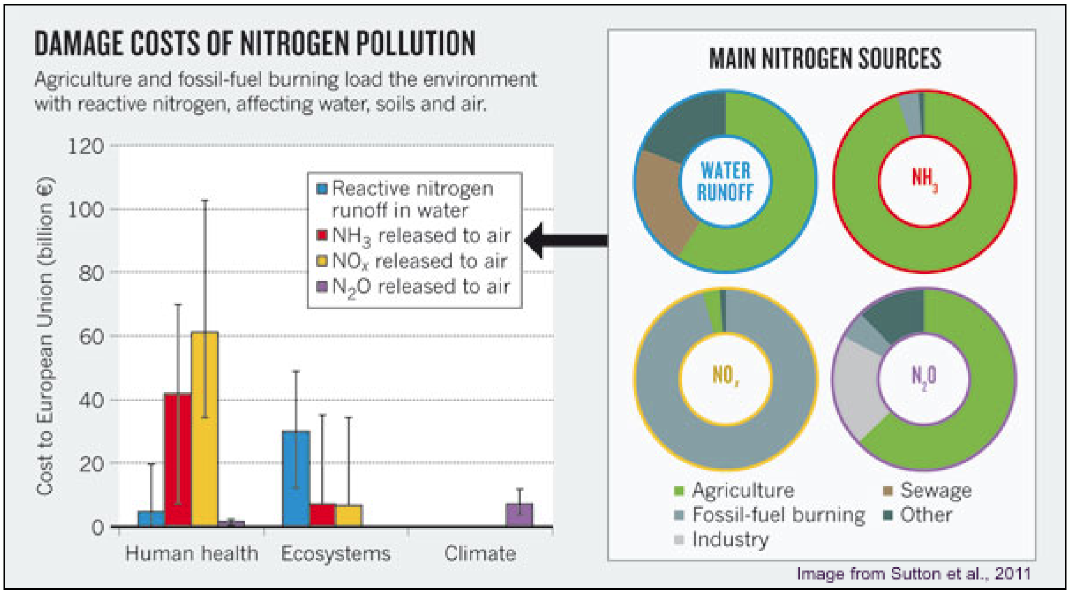


Figure 4. Costs to the European Union categorized by type of reactive nitrogen as well as impact sector. Contributions from sources which result in the four reactive nitrogen forms are also shown.[6]

The nitrogen dilemma stems from the human population needing Nr sources such as synthetic fertilizer to sustain food production. As a result of releasing Nr to the environment, there are many consequences as previously discussed. Therefore, the challenge we face as a species is to optimize Nr use while minimizing its negative effects. As a result of this study, Dover, New Hampshire is only the second municipality to quantify and report its nitrogen impact. The hope is that this combined inventory will serve as an example for other communities, which should also quantify and work toward reducing their nitrogen footprints.

Purpose of Municipal Emissions Inventories

Conducting a GHG and nitrogen inventory serves the following purposes:

- Allows for the development of a baseline to which further GHG and nitrogen developments can be compared.
- Leads to the identification of opportunities to improve energy efficiency in municipal buildings, school buildings, or the water supply.
- Leads to the identification of opportunities to reduce nitrogen releases to the environment.
- Demonstrates climate change leadership through the establishment of reduction targets.
- Increases the general transparency and consistency of GHG and nitrogen accounting and reporting among institutions.

Methodology

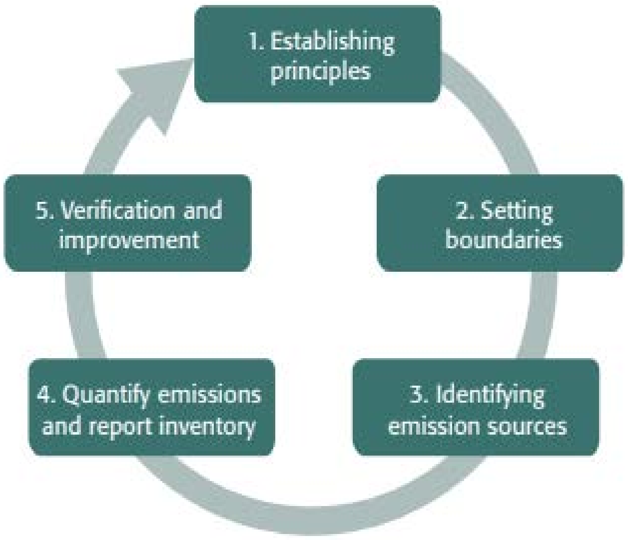


Figure 5. GHG Protocol's five major steps for conducting a local government operations inventory.[7]

This combined inventory aligns with the guidance provided by Appendix B of the Greenhouse Gas Protocol: Inventories for local government operations. Thus, the procedure for conducting Dover's inventory requires the implementation of five overarching steps (Figure 5).[7] Upon the completion of this report:

1. Principles have been established as are presented in the Climate Adaptation Chapter of Dover's Master Plan.
2. Boundaries have been selected so that the resulting inventory will include both municipal and school operations.
3. Emissions sources have been identified that align with the selected boundaries.
4. Emissions are quantified and presented in this report.
5. Future improvements to LGO can be made in terms of energy efficiency, cost, and emissions reductions.

This carbon and nitrogen footprint baseline was compiled through the utilization of two online tools, EPA's Portfolio Manager and the University of New Hampshire's Sustainability Indicator Management and Analysis Platform (SIMAP).[8,9] Portfolio Manager allowed for energy, water use, and the resulting GHG emissions to be tracked for individual properties and utilities. SIMAP, which is currently designed for campus based analysis, allowed for the quantification of a carbon and nitrogen footprint baseline. Dover is the first municipality to use the SIMAP tool for a carbon and nitrogen footprint analysis. As a result of this beta testing process, the developers of SIMAP plan to alter the platform based on Dover's user feedback so that municipalities throughout North America can utilize it with greater clarity.

Emissions Sectors

This inventory is organized into categories, or sectors, which represent the major sources of carbon and nitrogen emissions. The majority of these sectors contribute to both types of emissions. Emissions for all sectors were quantified using the built in emissions factors contained in the SIMAP platform.

Stationary Fuels

The stationary fuels sector represents the fuel consumption of all municipal and school buildings and facilities. The type of fuels in this sector include natural gas, diesel, No. 2 oil, and propane. Data was aggregated for calendar years 2016 and 2017 using bill records retrieved from the City and School Finance Departments.

Purchased Electricity

The purchased electricity sector includes all electrical use by municipal and school buildings and facilities. Examples range from City Hall to the water supply pump stations. Street and traffic light electrical use also falls into this category. Data was aggregated for calendar years 2016 and 2017 using bill records retrieved from the City and School Finance Departments.

Municipal Fleet

The municipal fleet sector represents the fuel consumption (diesel and unleaded) and resulting emissions produced by the four most prominent consumers. These are the Fire, Police, Community Services and Recreation Departments. Data was aggregated for calendar years 2016 and 2017 using bill records retrieved from the City Finance Department. As school transportation is provided by an outside contractor, it did not fall within the defined emissions scopes and was not included in this analysis.

Employee Commuting

The employee commuting sector includes the emissions that are a result of the commuting distances, and thus fuel consumption, of municipal and school employees. Data was aggregated for calendar years 2016 and 2017 using an anonymous list of addresses retrieved from the City and School Human Resources Departments.

Employee Travel

The employee travel sector includes the emissions that are a result of employees traveling by car, bus, train, or plane to conferences or other work-related events. Data was aggregated for calendar years 2016 and 2017 using travel reimbursement records from the City's Finance Department.

Fertilizer and Animals

The fertilizer and animals sector represents the emissions that are caused by fertilizer applications on city and school properties as well as the waste generated from Dover's two Police horses. Information on fertilizer applications were received from the three fertilizer companies used over the last two calendar years: Boston Co., Green Grass Landscape Co., and LANDMARK Landscaping.

School Food

The school food sector represents the cumulative emissions associated with the transportation, waste, and production of food supplied to the Dover Schools (Dover High School and Alternative School, Dover Middle School, and the Horne Street, Garrison, and Woodman Park Elementary Schools.) Data was provided by the School's food services contractor, Fresh Picks Café and from NH Surplus, which handles the distribution of federally provided food.

Solid Waste

The solid waste sector contains the emissions produced from the disposal of the City's and Schools' solid waste. Information on solid waste disposal was received from the City's Solid Waste Coordinator.

Paper

The paper sector expresses the impact associated with the harvesting and production of paper products. Information on paper disposal was received from the Dover School District Facilities Director.

Transmission and Distribution (T and D) Losses

The transmission and distribution losses sector contains the GHG emissions associated with losses that occur when energy is supplied to a building or facility. In the case of electricity these losses are partly due to the energy which dissipates into conductors and transformers during transmission as well as energy which is lost in the form of heat. SIMAP estimates these emissions based on the quantity of the energy source entered.

Wastewater

The wastewater sector includes the impact of the level of nitrogen contained in the effluent stream of the wastewater treatment plant (WWTP). A custom emissions factor was used in SIMAP to reflect the removal efficiency of Dover's WWTP. Information on removal and the treatment procedures came from WTTP Facility Supervisor.

Emissions Scopes

The emissions sectors previously discussed can further be organized by emissions scope according to the defining limits of each (Table 2).[7]

Table 2. Definitions for scope 1, 2, and 3 emissions categories.[7]

Scope	Description
1	Emissions from sources that are directly owned or controlled by the organization.
2	Emissions from the consumption of purchased electricity.
3	Emissions that are a consequence of the organization's operations.

Based on these definitions, the emissions sectors fall into their respective scopes as follows (Table 3).

Table 3. Emissions sectors contained in this analysis categorized by scope.

Sectors	Scope 1 Direct Emission	Scope 2 Indirect Emission	Scope 3 Indirect Emission
Stationary Fuels	X		
Municipal Fleet	X		
Fertilizer and Animals	X		
Wastewater	X		
Purchased Electricity		X	
T & D Losses			X
Employee Commuting			X
Employee Travel			X
Solid Waste			X
School Food			X
Paper			X

Weather

Energy use and resulting emissions are influenced by weather variability. For example, colder winters require a greater amount of energy consumption to heat buildings. Therefore, to provide a direct comparison between energy use and the resulting emissions, data sets must be normalized using heating and cooling degree days (HDD and CDD). A HDD represents the difference between the normal interior building temperature (65º F for this analysis) and the average outdoor temperature for a particular day. Therefore, an annual HDD value is the sum of all HDD values for each day of the year. As a result, larger HDD totals reflect colder winters, while larger CDD values reflect hotter summers. The following Table 4 displays the changes in HDDs, CDDs and total degree days (TDD), the annual sum of HDDs and CDDs, between calendar years 2016 and 2017 for Dover, New Hampshire.[10] Weather data was collected at Pease International Tradeport located in Newington, New Hampshire.

Table 4. Changes in heating degree days (HDD), cooling degree days (CDD) and total degree days (TDD) between 2016 and 2017 for Dover, New Hampshire.[10]

	2016	2017	% Change
HDD	5,976	6,147	3
CDD	685	623	-9
TDD	6,661	6,770	2

The Dover Community Services Department is responsible for plowing, salting, and sanding the City's public roads and sidewalks and the portions of State-owned roads located within the urban compact area. As a result, comparing snowfall trends between 2016 and 2017 provides insight into changes in fleet fuel consumption between 2016 and 2017 (Figure 6).[11] The cumulative snow fall in 2016 was 54.1 inches, compared to that of 70.1 in 2017, equating to a 26% difference.

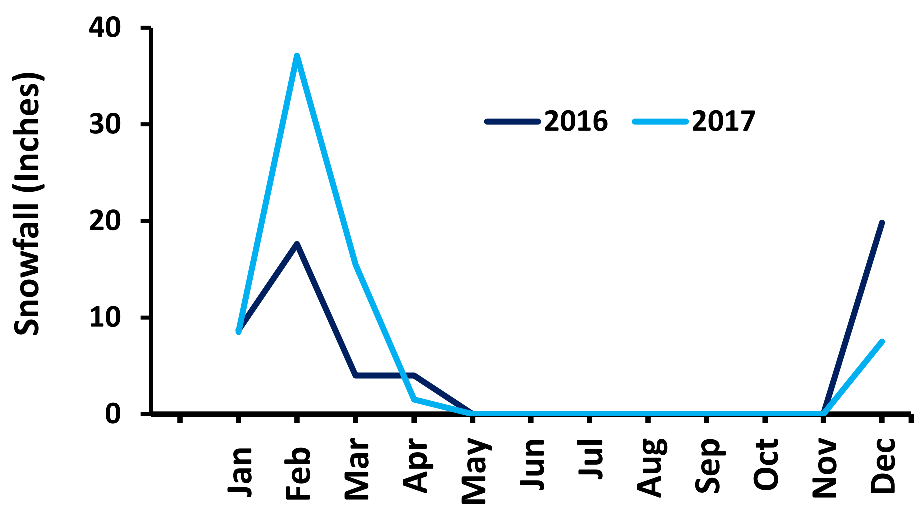


Figure 6. Snowfall trends for Dover, New Hampshire between 2016 and 2017.

Energy Consumption and Cost

Quantifying energy use is an essential step in establishing a footprint baseline. Here the contributions of each energy source are made apparent, via normalization by converting to million British Thermal Units (MMBTU). For reference, one BTU is the amount of energy it takes to raise a pound of water one degree Fahrenheit. Total raw energy usage was 104,800 MMBtu in 2016 and 102,670 MMBtu in 2017. To provide a more direct comparison between the two years, weather was incorporated into the data set through the use of TDD (Table 4). The normalized values yielded a 3.7% reduction between 2016 and 2017. Electricity and natural gas account for approximately 47% and 46% of the total usage, respectively. The remaining 7% is distributed almost evenly between diesel, No. 2 oil, and propane for 2016 and 2017. The overall 3.7% reduction can be contributed to a decrease in electric, natural gas, No. 2 oil and propane use (Table 5). See Appendix A-1 for a full breakdown of energy use by property or property type.

Energy cost is a useful metric to track, as it allows for the identification of sources which result in the highest contributions. Furthermore, including cost in a baseline analysis allows for future LGO projects to be compared in terms either increased savings or spending. The total raw energy cost in 2016 was $2.36M, and in 2017 was $2.59M. Again, weather normalization was incorporated to result in a non-weather variant comparison. The normalized values yielded a 7.7% increase between 2016 and 2017. Electricity is by far the highest contributor to energy cost, making up 74% in 2016 and 75% in 2017. Natural gas remained constant at 21% between the two years. The remaining 4-5% is distributed almost evenly between diesel, No. 2 fuel oil, and propane, with diesel moving from 1% to 2% and vice versa for No. 2 fuel oil. The increased spending between 2016 and 2017 can be contributed to a spike in electric, natural gas, and diesel costs (Table 6). Electricity is the only source which saw a decrease in usage, but an increase in resulting cost. This is a result of continually climbing electricity supply rates. See Appendix A-1 for a full breakdown of energy cost by property or property type.

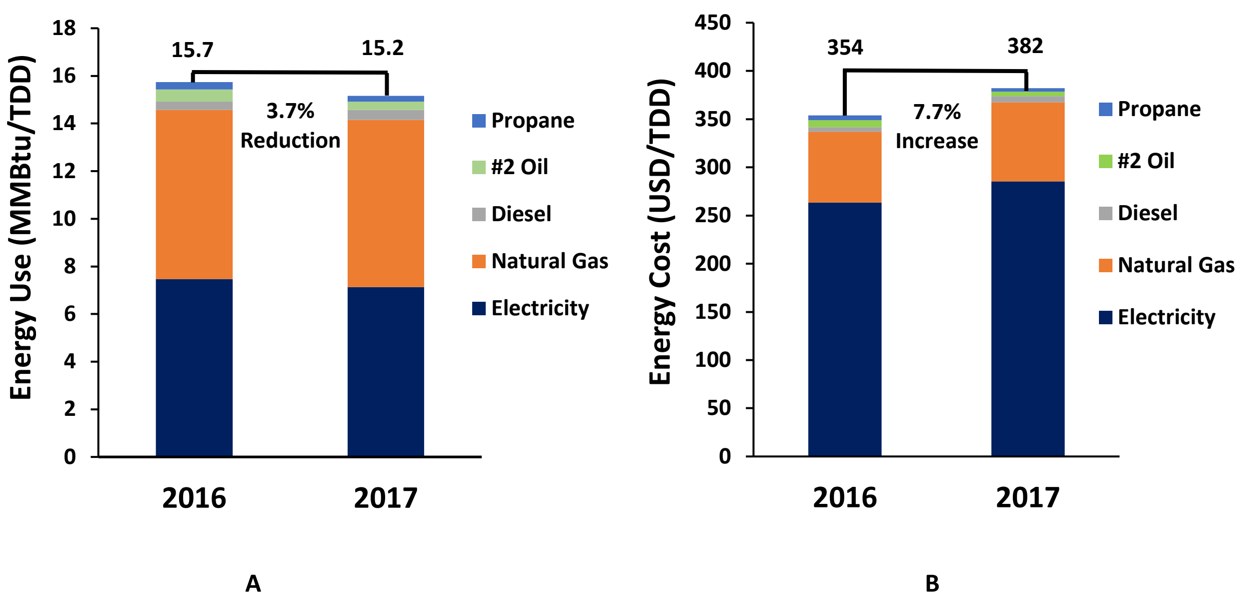


Figure 7. A comparison of Dover's energy use by source (A) and energy cost by source (B) between 2017 and 2017. Energy use values were normalized through conversion to million British Thermal Units (MMBTU). Changes in weather between the two years was accounted for by normalizing values by the total degree days (TDD) that occurred.

Table 5. Breakdown of Dover's LGO raw and weather-normalized energy use as well as the normalized percent changes between 2016 and 2017.

Energy Source	Energy Use (MMBtu)		Norm. Energy Use (MMBtu/TDD)		Percent Change
	2016	2017	2016	2017	
Electricity	49,760	48,329	7.5	7.1	-4.5
Natural Gas	47,310	47,523	7.1	7.0	-1.2
Diesel	2,327	2,804	0.3	0.4	17.0
#2 Oil	3,375	2,373	0.5	0.4	-36.4
Propane	2,028	1,641	0.3	0.2	-22.7
Cumulative	104,800	102,670	15.7	15.2	-3.7

Table 6. Breakdown of Dover's LGO raw and normalized energy cost as well as the normalized percent changes between 2016 and 2017.

Energy Source	Energy Cost (USD)		Norm. Energy Cost (USD/TDD)		Percent Change
	2016	2017	2016	2017	
Electricity	1,754,003	1,931,308	263.3	285.3	8.0
Natural Gas	490,727	556,055	73.7	82.1	10.9
Diesel	30,576	43,368	4.6	6.4	33.0
#2 Oil	49,385	30,375	7.4	4.5	-49.2
Propane	32,837	26,580	4.9	3.9	-22.7
Cumulative	2,357,527	2,587,686	353.9	382.2	7.7

GHG emissions in this inventory have been analyzed to show contributions within each sector. Overall results containing the impact of all sectors are available in the Comprehensive Footprints section. A raw total of 7,075 MTs of CO_2e and 6,539 MTs of CO_2e were released in 2016 and 2017, respectively, as a result of Dover's LGO energy consumption. TDD normalization yielded a 9.5% reduction in emissions between the two years (Figure 8). This is largely a result of decreases in electrical use and much more substantial reductions, respective to 2016 values, in No. 2 oil and propane (Table 7). Electricity made up approximately 57% of the emissions produced in 2016, and 54% in 2017. Natural gas was the second-highest contributor at about 36% in 2016 and 39% in 2017. The remaining sources contributed a combined 7% in 2016 and 2017.

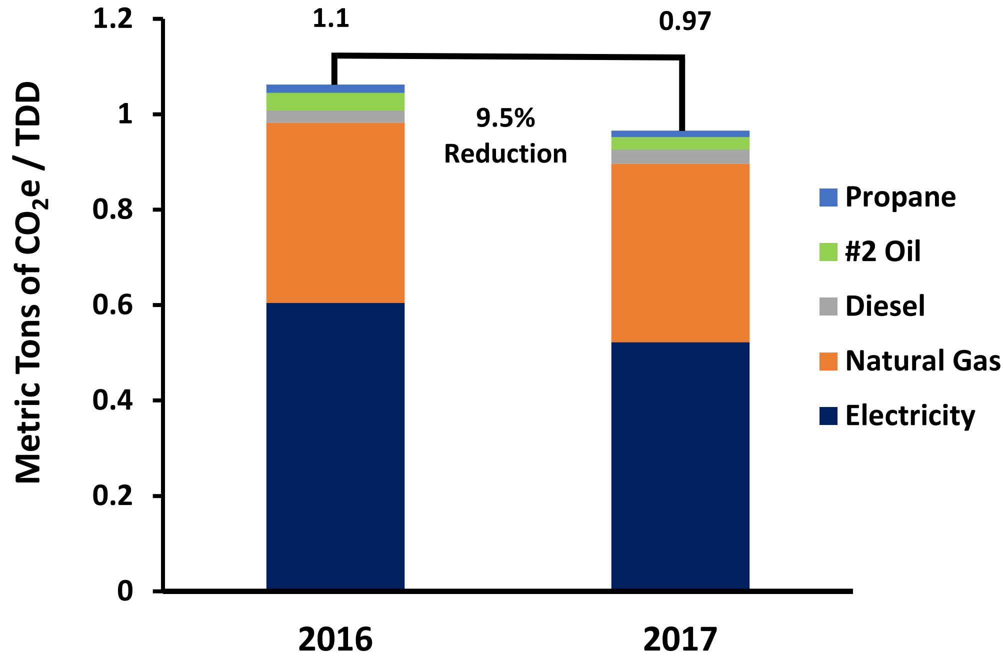


Figure 8. A comparison of the weather-normalized GHG emissions between 2016 and 2017 produced from Dover's LGO stationary fuel and electricity consumption.

Table 7. Breakdown between Dover's LGO raw and weather-normalized GHG emissions as well as the normalized percent changes between 2016 and 2017.

Energy Source	MT of CO_2e		MT of CO_2e / TDD		Percent Change
	2016	2017	2016	2017	
Electricity	4,027	3,538	0.605	0.523	-14.6
Natural Gas	2,516	2,527	0.378	0.373	-1.2
Diesel	171	206	0.026	0.030	17.0
#2 Oil	245	174	0.037	0.026	-35.6
Propane	115	94	0.017	0.014	-22.0
Cumulative	7,075	6,539	1.062	0.966	-9.5

Municipal Fleet

To ensure a comprehensive footprint baseline, fleet usage (a scope one emissions source) must be included. Fleet vehicles are most prominently used by the Fire, Police, Community Services and Recreation Departments. Fuel consumption for these departments can be separated into diesel and unleaded gas. The total diesel usage in 2016 was 37,010 gallons and in 2017 was 36,522 gallons, yielding a 1.3% reduction (Figure 9). The total unleaded gasoline usage in 2016 was 57,414 gallons and in 2017 was 62,619 gallons, resulting in an 8.7% increase.

The Community Services Department consumed over half of the diesel used in 2016 and 2017, equating to approximately 60% and 57% of total fleet fuel use. The Fire Department was the second-highest consumer, making up approximately 40% in 2016 and 41% in 2017. The combined usage between the Police and Recreation Departments was under 1% in 2016 and about 2% in 2017.

The Police Department consumed about 54% of the unleaded gasoline used in 2016, which fell to 48% in 2017. The Community Services Department used about 33% in 2016, which rose to 40% in 2017. Fire usage remained constant at 12% between both years and the Recreation Department made up 1% in 2016 which dropped to a fraction of a percent in 2017.

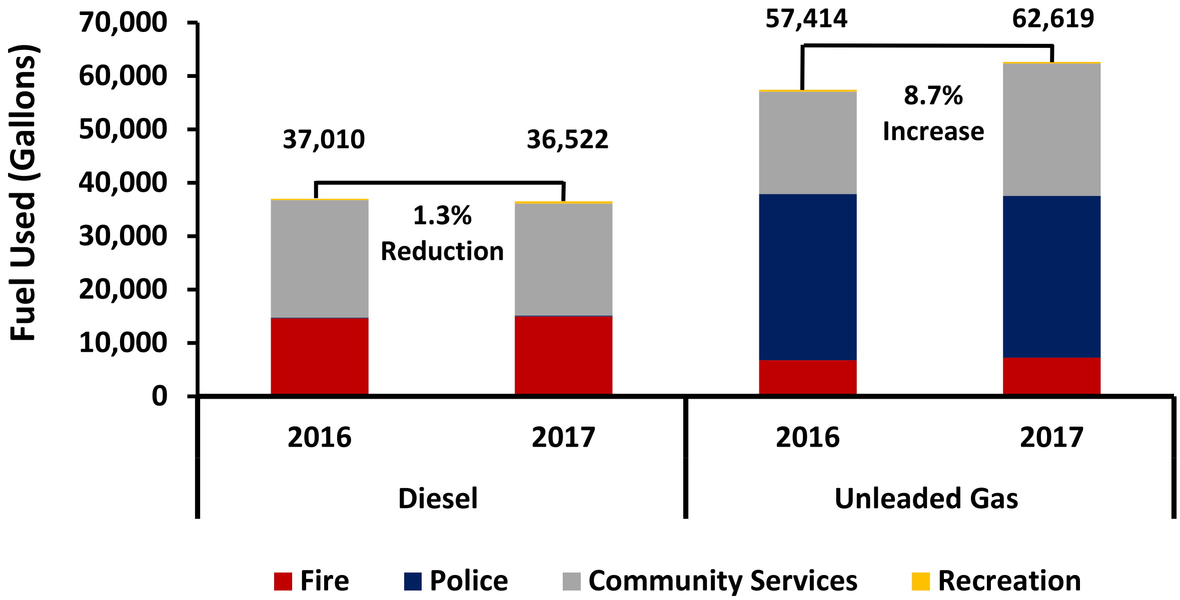


Figure 9.A comparison of Dover's LGO fleet fuel consumption between 2016 and 2017.

The 1.3% decrease between diesel use in 2016 and 2017 is a result of a 4.9% reduction in diesel usage by the Community Services Department, which is the primary consumer (Table 8). The reason for this reduction stems from a decision made by the Community Services Fleet Supervisor to stop buying diesel vehicles and switch to those that use unleaded gasoline. This change was made based upon reliability issues associated with the diesel vehicles in the fleet

Table 8. Breakdown of Dover's LGO fleet diesel use and the percent changes between 2016 and 2017.

Department	Diesel Use Totals (Gallons)		Percent Change
	2016	2017	
Fire	14,601	14,949	2.4
Police	148	203	31.5
Community Services	22,036	20,975	-4.9
Recreation	226	394	54.3
Cumulative	37,010	36,522	-1.3

The 8.7% increase in unleaded gasoline use between 2016 and 2017 is largely a result of the almost 26% jump in consumption by the Community Service Department (Table 9). The previously mentioned decision to switch to unleaded gas vehicles partly accounts for this, but the most likely contributing factor was the 16-inch increase in cumulative snowfall between 2016 and 2017. This is because the Community Services Department plows the main Dover roadways and the majority of these plow trucks consume unleaded gasoline.

Table 9. Breakdown of Dover's LGO fleet unleaded gasoline use and the percent changes between 2016 and 2017.

Department	Unleaded Gas Use Totals (Gallons)		Percent Change
	2016	2017	
Fire	6,779	7,255	6.8
Police	31,148	30,297	-2.8
Community Services	19,135	24,773	25.7
Recreation	352	294	-18
Cumulative	57,414	62,619	8.7

The total fleet fuel consumption cost for 2016, including contributions from diesel and unleaded gasoline, was $196,142, which saw a 20% increase to $239,787 in 2017 (Figure 10). This increase is a result of the 8.7% overall spike in unleaded gasoline consumption between the two years. The Community Services Department was the highest contributor to fleet fuel costs, accounting for 46% in both 2016 and 2017, due to the large number of diesel and unleaded gasoline vehicles in service. The second-largest contributor to fuel cost was the Police Department, followed by the Fire and Recreation Departments (Table 10). This aligns with the previously displayed usage trends.

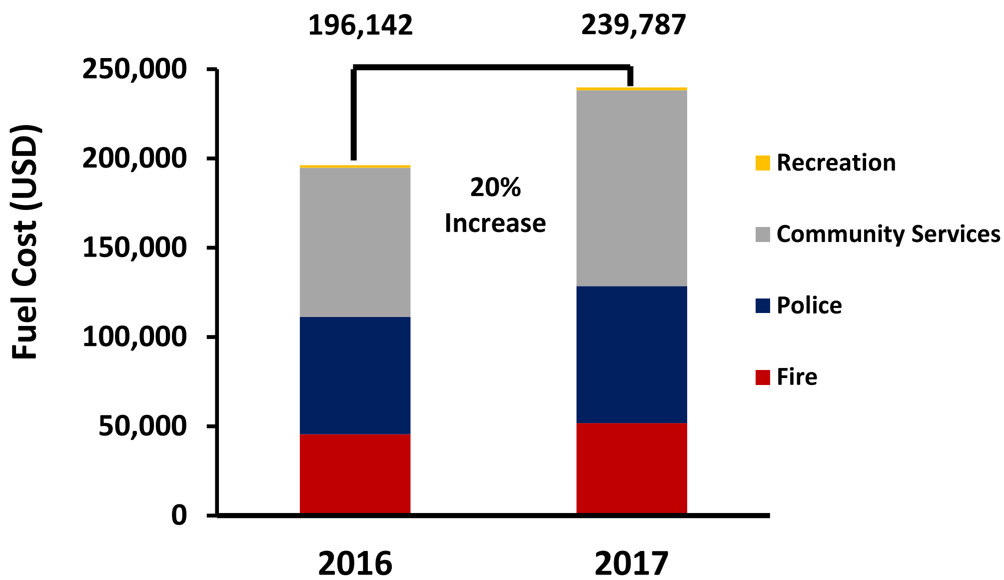


Figure 10. A comparison of Dover's total LGO fleet fuel cost between 2016 and 2017.

Table 10. Breakdown of Dover's LGO total fleet fuel cost and the percent changes between 2016 and 2017.

Department	Fuel Costs (USD)		Percent Change
	2016	2017	
Fire	45,562	51,815	12.8
Police	65,668	76,678	15.5
Community Services	83,598	109,592	26.9
Recreation	1,314	1,702	25.7
Cumulative	196,142	239,787	20.0

The total amount of GHG emissions released in 2016 as a result of diesel consumption from the municipal fleet equated to 379 MTs of CO_2e (Figure 11). Comparatively, in 2017, there was a total of 378 MTs of CO_2e released, resulting in a 0.4% reduction. This is a result of relatively consistent fleet diesel use between the two years. The quantity of GHGs released as a result of fleet consumption of unleaded gasoline, on the other hand, shifted more dramatically between 2016 and 2017. In 2016 there was a total of 507 MTs of CO_2e released to the atmosphere versus 570 MTs of CO_2e in 2017. This 11.7% increase in emissions can be mostly attributed to the approximately 26% increase in unleaded gasoline consumption by the Community Services Department between 2016 and 2017.

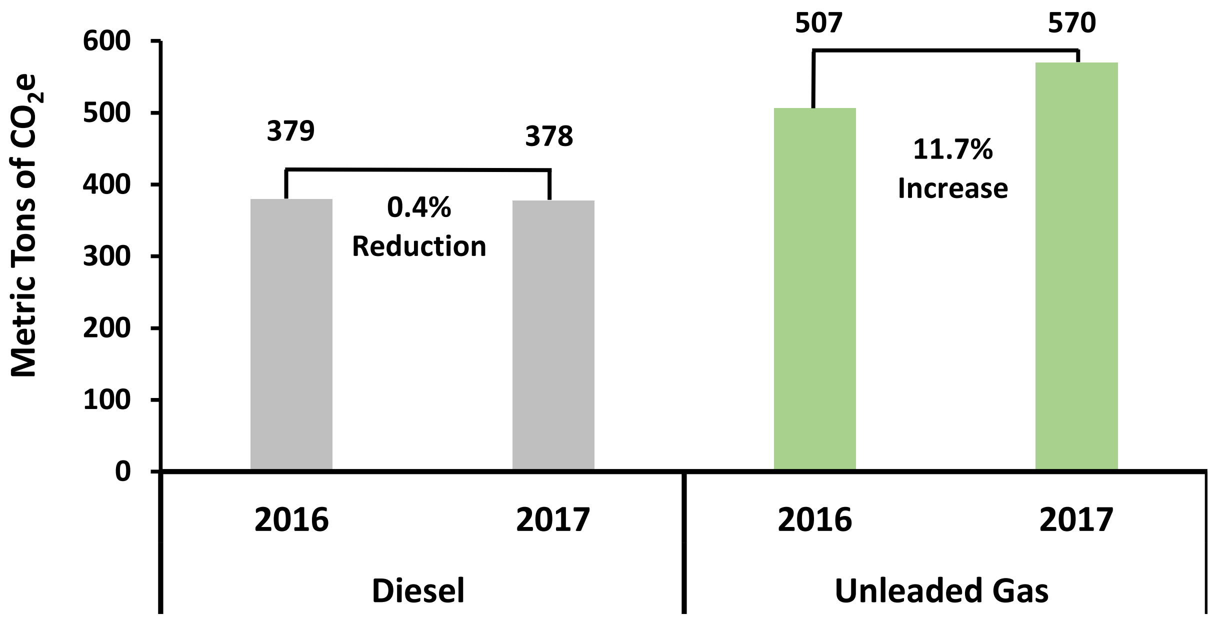


Figure 11. A comparison of the GHG emissions emitted from Dover's diesel and unleaded gasoline fleet vehicles between 2016 and 2017.

Employee Commuting and Travel

Commuting:

A substantial source of GHG emissions for LGO, which falls into the scope three category, stems from the commuting distances of municipal and school employees. This analysis only includes the contribution from full-time employees. Employees who live within one mile of their workplace were assumed to walk and thus excluded from the data set. Municipal and school employee commuting distances were compared by determining the average miles traveled per one way trip (Table 11). Municipal employees have a shorter commuting distance, averaging 9.7 miles per trip, versus the 10.5 miles for school employees, yielding an 8% difference. With a greater number of full-time employees and a longer average commute, the total annual impact of school employees was 1,028 MTs of CO_2e versus the approximately 407 MTs of CO_2e emitted from municipal employees' commutes. To provide a direct comparison, the GHG emissions emitted from each sector the totals were normalized by the MTs of CO_2e generated from each commuter annually. The average for municipal employees is 1.77 MTs of CO_2e compared to the 1.91 MTs of CO_2e for school employees. Again, there is an 8% difference, which is expected based upon the calculation method.

Table 11. Full time municipal and school employee commuting statistics as well as the total and normalized GHG emissions produced from the two sectors.

Metric	Municipal Employees	School Employees	Percent Difference
Total One Way Miles	**2,229**	**5,640**	
No. of Car Commuters	**230**	**537**	
Avg. Miles / Trip	**9.7**	**10.5**	**8**
Total MTs of CO_2e	**407.2**	**1,028**	
MTs of CO_2e / Commuter	**1.77**	**1.91**	**8**

Travel:

Employee business travel, much like commuting, is a scope three emissions source which also significantly contributes to the total GHG emissions released as a result of Dover's LGO. This metric is one that is not frequently analyzed in LGO GHG inventories. There were a total of 71 MTs of CO_2e released in 2016 and 59 MTs of CO_2e released in 2017, yielding a 19% overall reduction (Figure 12). Air travel resulted in the majority of GHG emissions, making up 73% in 2016 and 66% in 2017. Travel by car was the second-highest contributor equating to 24% and 29% respectively, followed by bus travel, which made up approximately 3% and 5% in each year. Travel by train was only a fraction of a percent in each case. Out of these modes of transportation, buses are the most efficient. This is due to the ration of their fuel consumption to passenger carrying capacity. It is estimated that buses get an average of 240 passenger miles per gallon of fuel.

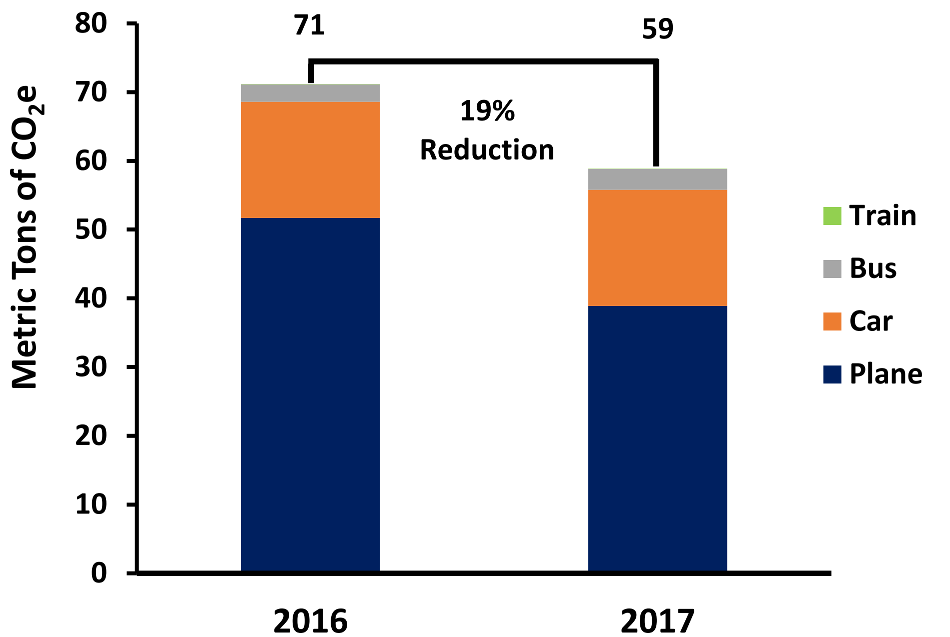


Figure 12. A comparison of the GHG emissions emitted from municipal and school employee travel broken down by the mode of transportation used.

As displayed in Table 12, the 19% reduction in travel emissions between 2016 and 2017 can be attributed to a substantial decrease in air miles traveled in 2017. Air travel has by far the largest GHG emission impact out of all modes of transportation currently available. This is because not only do aircraft release a substantial amount of CO_2 from the combustion of fuel, they also release NO_x and form contrails in the lower stratosphere. The IPCC has estimated that the climate impact of aircraft is 2-4 times greater than the effect of their CO_2 emissions. This is because when NO_x is released in this part of the atmosphere, it depletes ozone more readily than when releases occur on or near Earth's surface. Contrails, which are anthropogenic cloud formations, cause the most harm at night. This is because at night these contrails trap solar energy that would otherwise escape the atmosphere.

Table 12. A breakdown of the miles traveled and GHG emissions produced from municipal and school employee travel between 2016 and 2017.

Mode of Transport	Total Distance Traveled (mi)		Percent Change	MTs of CO_2e		Percent Change
	2016	2017		2016	2017	
Train	198	89	-76	0.03	0.01	-100
Bus	672	808	18	2.53	3.04	18
Car	46,230	44,880	-3	16.9	16.9	0
Plane	259,799	195,477	-28	51.7	38.9	-28
Cumulative	306,899	241,254	-24	71.16	58.85	-19

Fertilizer and Animals

Fertilizer:

The use of fertilizer is key for keeping plots of land, such as athletic fields and parks, lush with green grass in the rocky New Hampshire soil. All fertilizer contains some amount of nitrogen, which generally makes up anywhere between 2-50% of the total content. Therefore, tracking fertilizer use as a result of Dover's LGO is necessary for a complete nitrogen footprint analysis. In 2016, a total of 19,103 lbs. of fertilizer were applied to City and School Properties (Figure 13). Comparatively, 22,019 lbs. were applied in 2017, representing a 14.2% increase over 2016. The reason for the spike in use is a result of Green Grass Landscaping (GGL), the main landscaper for the City, applying fertilizer on four occasions in 2017 versus three in 2016. Nitrogen made up approximately 14% of the total quantity applied in 2016, which rose to 17% in 2017. This is because two of the applications by GGL in 2017 used higher nitrogen contents equating to 46% and 25%, which are substantially more than the consistent 18% nitrogen content used in 2016. It is important to note that the impact of the nitrogen contained within the fertilizer only applies to the reactive nitrogen that is not taken up by the plant matter or soil. An estimated 0.66 MTs and 0.93 MTs of reactive nitrogen were released in the environment in 2016 and 2017 respectively. See Appendix A-2 for data validation.

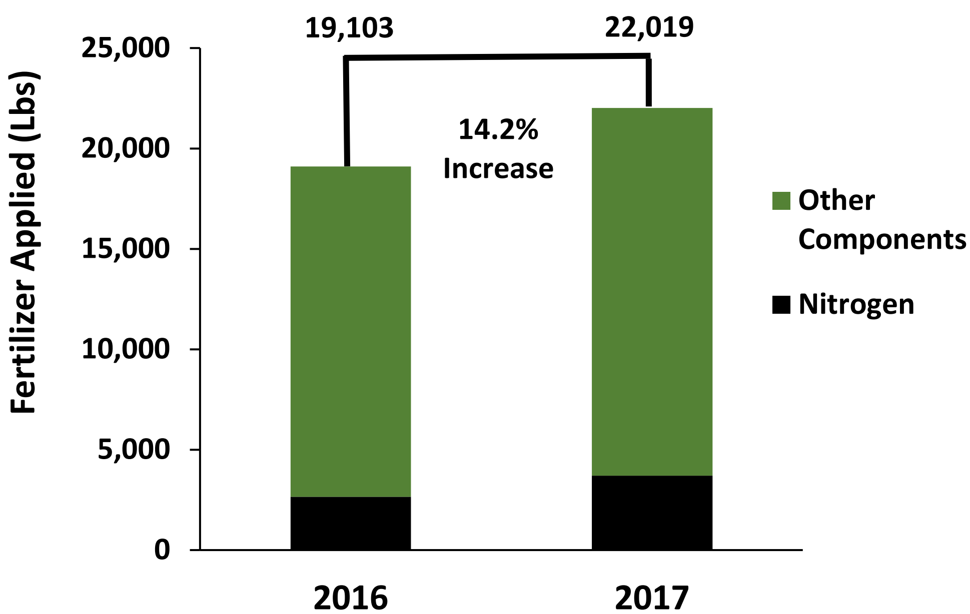


Figure 13. Comparison of the total quantity of nitrogen applied between 2016 and 2017.

Animals:

The Dover Police Department currently implements the use of two police horses, CJ and Rasa, who are used for mounted patrol operations. In Dover, the main benefit of using police horses is to help the community connect with the officers as well as providing localized neighborhood patrols. CJ and Rasa do contribute a small amount to Dover's LGO GHG emissions producing approximately 1.24 MTs of CO_2e a year.

School Food

All school food distributed to the Dover Schools from both private vendors and the federal government was analyzed for calendar year 2017. The provided 2016 data set was deemed incomplete and thus an accurate annual comparison could not be performed. The total quantity of food provided to the Dover Schools in 2017, equating to 72,191 kg, was categorized by food type (Figure 14.A). The three largest categories provided were starches (potatoes, grains, and beans) which made up 27%, followed by fruits and vegetables at 22% and meat at 18%. These quantities provide the most insight when they are compared to their nitrogen impacts (Figure 14.B). Even though meat only made up 18% of the food supplied in 2017 by weight, it accounted for 67% of the total 3,453 kg of nitrogen released. Out of the meat served, the impact of beef was the most substantial. This is due to the size of the animals. With larger animals comes more nitrogen required to feed them, as well as more waste. On the other hand, fruits and vegetables made up 22% of the food provided but only contributed to 3% of the nitrogen released. The nitrogen impact includes estimates for the reactive nitrogen lost during growing, transportation from source to consumer, and in the animals' waste. The impact associated with human consumption is factored into the wastewater sector.

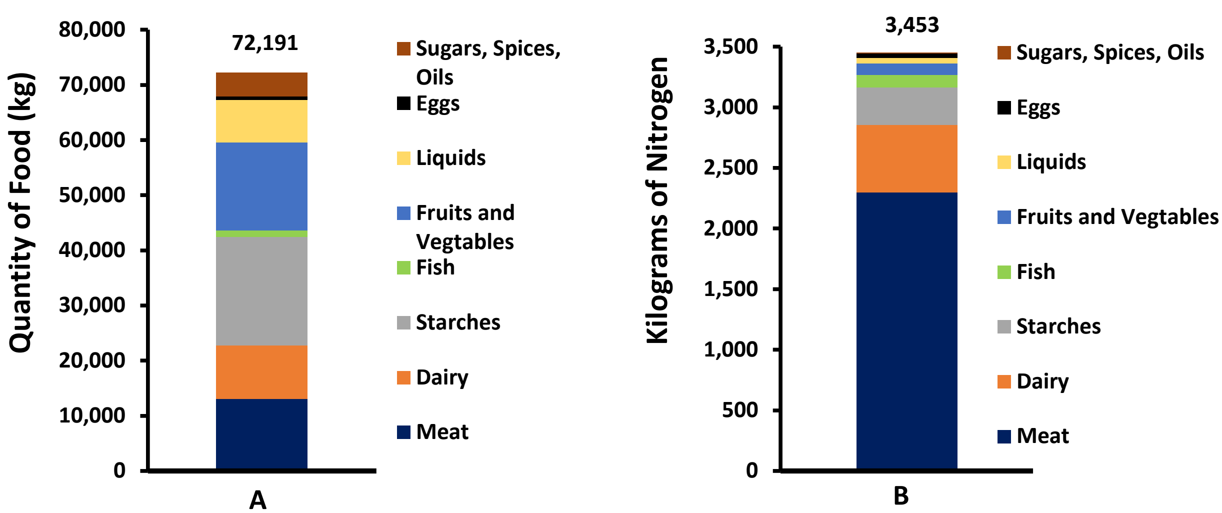


Figure 14. The quantity of food by category, delivered to Dover schools in 2017 (A) and the nitrogen impact associated with those categories (B).

Solid Waste and Paper

Solid Waste:

Municipal waste is disposed in a total of 28 dumpsters spread throughout the City. The total volume of these dumpsters equates to approximately 200 $yrds^3$. Only the volume of the dumpsters, and not the weight of garbage they generally contained, was provided. Therefore, a fill scenario analysis was performed to estimate the amount of municipal solid waste generated in a year using an assumed density of 264.6 lbs/yrd^3 (Table 13). Two pickups are performed per week, resulting in 104 pickups annually. This metric was used to convert weight per pickup to the annual weight values.

Table 13. Municipal waste dumpster fill scenario analysis.

Fill Scenario	Low	Med	High	GHG Reduction (MTs)
Volume Filled ($yrds^3$)	100	150	200	62
Weight Per Pickup (Lbs)	26,459	39,689	52,918	
Annual Weight (Lbs)	2,751,736	4,127,604	5,503,472	

The medium fill scenario was entered into SIMAP to estimate the emissions impact. Dover's municipal waste is processed at the ecomaine facility located in Portland, Maine. This facility has a state of the art waste-to-energy plant which combusts the waste, reducing it by 90% of its initial volume while generating power using a steam driven turbine (Figure 15).[12] Since Dover's municipal waste is used to generate power in a system that also cleans the flue gasses and controls for pollution, the solid waste acts to reduce Dover's total LGO carbon footprint. The reduction for the medium fill scenario was 62 MTs of CO_2e (Table 13).

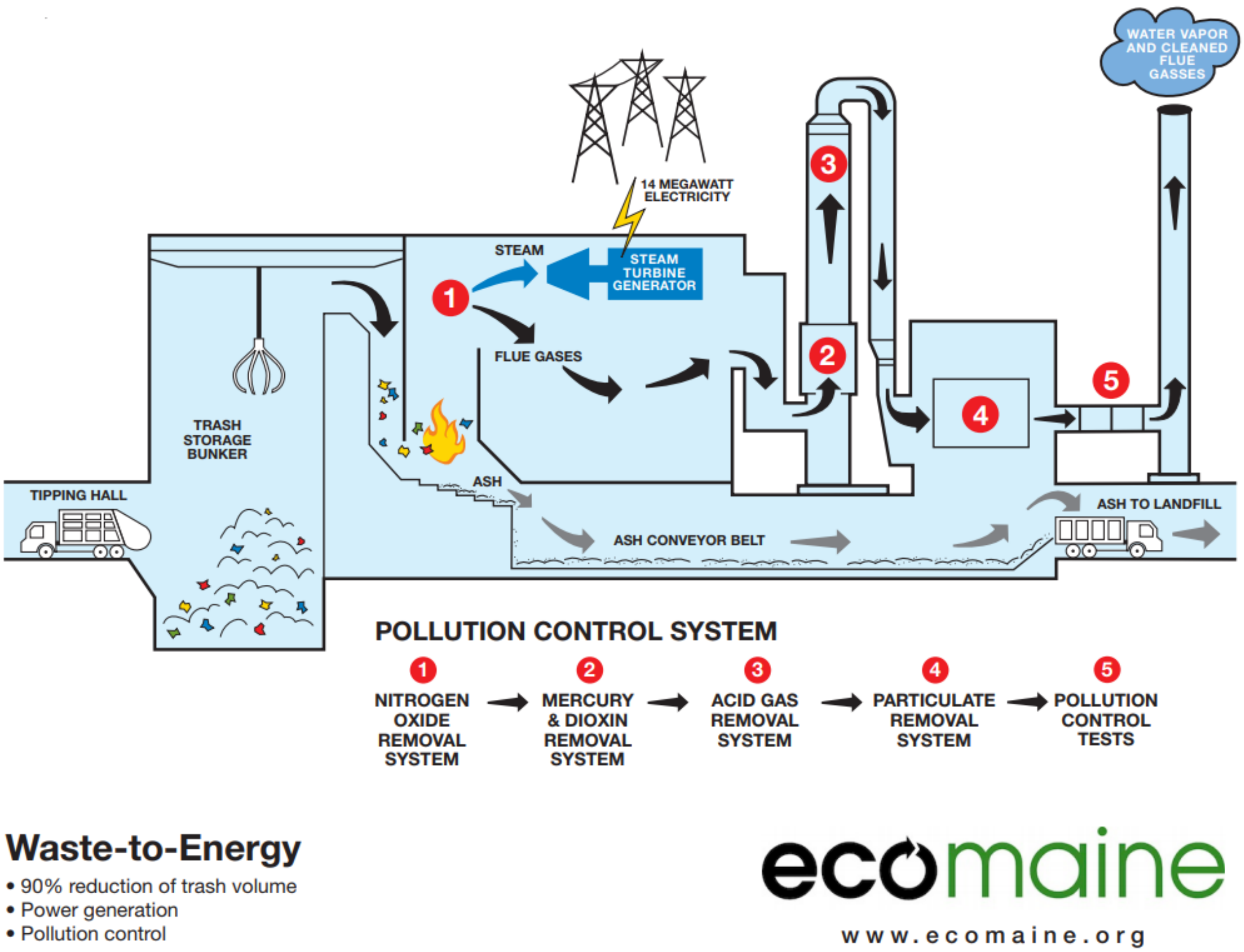


Figure 15. The ecomaine Waste-to-Energy plant.[12]

Paper:

The Dover Schools have a total of ten 96 gallon totes which are recycled with mostly paper. These totes are emptied at a removal frequency of once a week and thus there are 52 pickups assumed annually. A similar fill scenario analysis, as was done for solid waste, was performed for these totes using an assumed density of 1.31 lbs/gal (Table 14).

Table 14. School waste tote fill scenario analysis.

Fill Scenario	Low	Med	High	GHG Emissions (MTs)
Volume Filled (gal)	480	720	960	97.6
Weight Per Pickup (Lbs)	907	1361	1814	
Annual Weight (Lbs)	47,174	70,762	94,349	

The medium fill scenario was entered into SIMAP to estimate the emissions impact. The emissions impact from paper comes from the GHG emissions produced during paper production, printing and distribution. Because that paper also comes from trees, a carbon sequestration source is also reduced. The impact of the estimated paper produced from the Dover School systems was determined to be 97.6 MTs of CO_2e (Table 14). The Schools also have a 10 cu. yrd. cardboard-only dumpster. SIMAP unfortunately does not currently have the capability to estimate the impact of cardboard. Paper produced from municipal operations was also not included in the study due to data processing time constraints, but it is recommended that future impact assessments include this metric.

Wastewater

The nitrogen contained in the water that leaves a wastewater facility, known as the effluent stream, is a major contributor to the nitrogen footprint of LGO. Therefore, maintaining high nitrogen removal efficiencies is of the utmost importance in reducing the impact. As a result of the massive facility upgrade completed in 2016, Dover's wastewater treatment plant (WTTP) located at 484 Middle Road exhibits top-notch performance regarding its nitrogen removal efficiency during standard operations. One an average day the facility handles approximately 2.5 million gallons (MG) of wastewater, but it is designed to process up to 4.7 MG per day. The nitrogen content in the influent stream is generally 40 milligrams per L (mg/L). After a series of nitrogen removal steps, the content in the effluent stream discharged to the Piscataqua River is 8 mg/L or less. This equates to an 80% removal efficiency (Table 15). The national average in the United States is around 50%, and the limit of current technology does not allow for efficiencies above 90%.[13] However, when storm surges take place, the volume of the influent stream can reach approximately 10 MG per day due to the present of illicit connections to and undetected infiltration into the sewer system. During these events, the plant cannot maintain the levels of nitrogen removal present during normal operations. This highlights the importance of improving the City's storm water management and sewer infrastructure.

Figure 16. Aerial photo of Dover's WWTP.

Table 15. Nitrogen content generally found in the influent and effluent streams of Dover's WWTP as well as Dover's removal efficiency compared to the US national average.[13]

Stream	Nitrogen Content (mg/L)	Dover's Removal Efficiency	US National Average Removal Efficiency	Annual Nitrogen Released to the Environment (MTs)
Influent	~40	~80%	~50%	34.5
Effluent	~8			

The influent stream for the plant comes from the whole community that is served by public sewer (approximately 5,600 customers), and thus the resulting nitrogen impact is not just a product of municipal and school water use. However, since the City controls the operations of the plant and the nitrogen removal procedures in place, the nitrogen contained in the effluent stream is part of Dover's LGO nitrogen footprint. There is an estimated annual total of 34.5 MTs of nitrogen released in the effluent stream, making it the largest contributor out of the sectors (Table 15). This effluent stream is released into the Piscataqua River. The GHG's released from the facility have been included in the overall energy breakdown for Dover's LGO (Figure 8).

Comprehensive Footprints

Carbon:

The comprehensive carbon footprints represent the total annual amount of GHGs released to environment as a result of Dover's LGO in 2016 and 2017. In 2016 there were 9,896 MTs of CO_2e emitted, versus the 9,560 MTs of CO_2e in 2017, yielding a 3.4% reduction (Figure 17). Not surprisingly, the two sectors resulting in the highest contributions in both years were purchased electricity and stationary fuel consumption. Together these sectors accounted for 71% of the GHG emissions in 2016 and 68% in 2017. The next two largest contributors in both years were employee commuting and the municipal fleet.

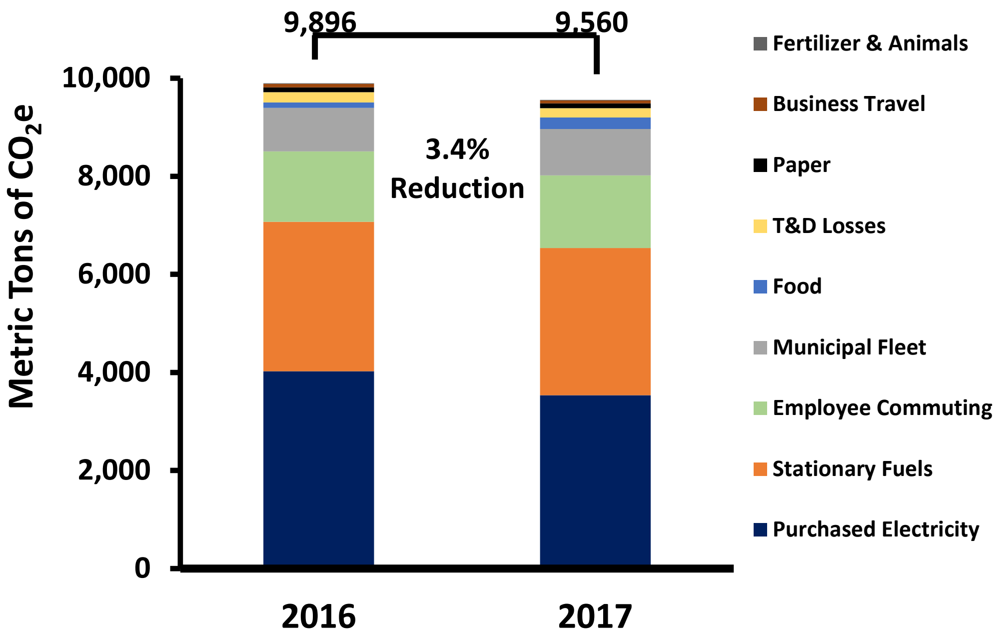


Figure 17. A comparison of the total carbon footprints as a result of LGO between 2016 and 2017. Based on the sectors leading to the largest contributions to GHG emissions, Dover can have the greatest impact on lowering its LGO carbon footprint in the following ways:

- Reduce the purchased electricity sector through the installment of more solar arrays.
- Provide incentives for employees to carpool or take public transportation to work.
- Increase the number of electric vehicles (EVs) in the municipal fleet.
- Upgrade older facilities to improve insulation and install remotely monitored HVAC systems.

The Reductions Scenario section of this report covers the level of impact some of these changes could have on lowering the LGO carbon footprint. Table 16 displays a breakdown of the MTs of CO_2e emitted from each sector as well as the percent changes between 2016 and 2017.

Table 16. A breakdown of the carbon footprint contributions by emissions category between 2016 and 2017 as well as the percent changes.

Category	MTs of CO_2e		Percent Change
	2016	2017	
Purchased Electricity	4,027	3,538	-12.9
Stationary Fuel Consumption	3,047	3,001	-1.5
Municipal Fleet	886	948	6.8
Employee Commuting	1,435	1,479	3.1
Food	109	235	73.9
T&D Losses	211	185	-12.9
Paper	97.6	97.6	0
Business Travel	71.1	58.8	-18.9
Fertilizer & Animals	12.2	16.6	30.5
Cumulative	9,896	9,560	-3.4

In terms of the contributions by emissions scope, both scope one and two emissions sources accounted for approximately 40% each, thus equating to around 80% of the amount of GHGs emitted in 2016 and 2017 (Figure 18). Again, scope one emissions are produced on-site by the organization and scope two emissions are those indirectly produced as a result of electricity consumption. The included scope three sources were cumulatively the least impactful in both years, contributing about 20%. Scope three emissions are those which are a consequence of the organization's operations.

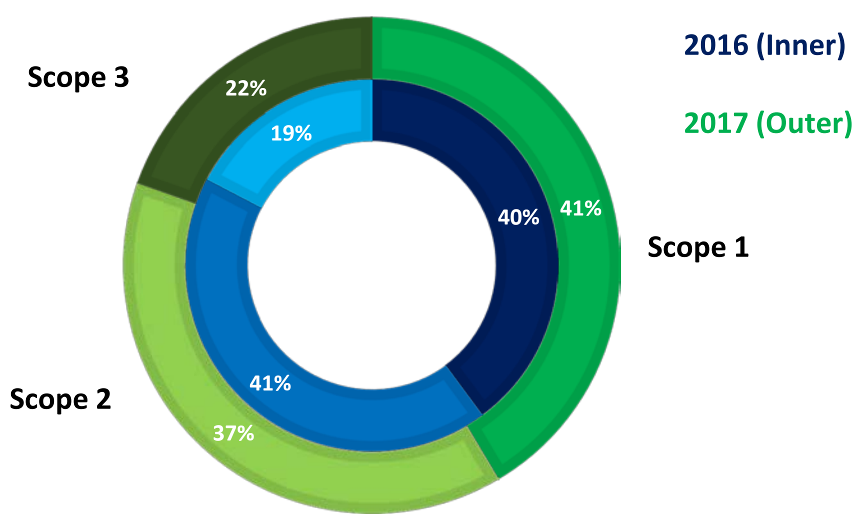


Figure 18. Scope contributions to the 2016 and 2017 LGO carbon footprints.

Nitrogen:

Much like comprehensive carbon footprints, nitrogen footprints represent the total annual amount of reactive nitrogen released to the environment as a result of Dover's LGO in 2016 and 2017. In 2016. 40 MTs of nitrogen were emitted, versus 42.3 MTs of nitrogen in 2017, a 5.4% increase (Figure 19). It is very likely that the increase was actually less than what is presented. This is due to evidence which shows that the food data provided for 2016 is incomplete. However, since 2017 serves as the baseline year, this uncertainty will not affect future comparisons. Wastewater was the largest contributor in both years, making up 86% of the reactive nitrogen released in 2016 and 82% in 2017. Food was the second greatest contributor in each year, making up 4% in 2016 and 8% in 2017.

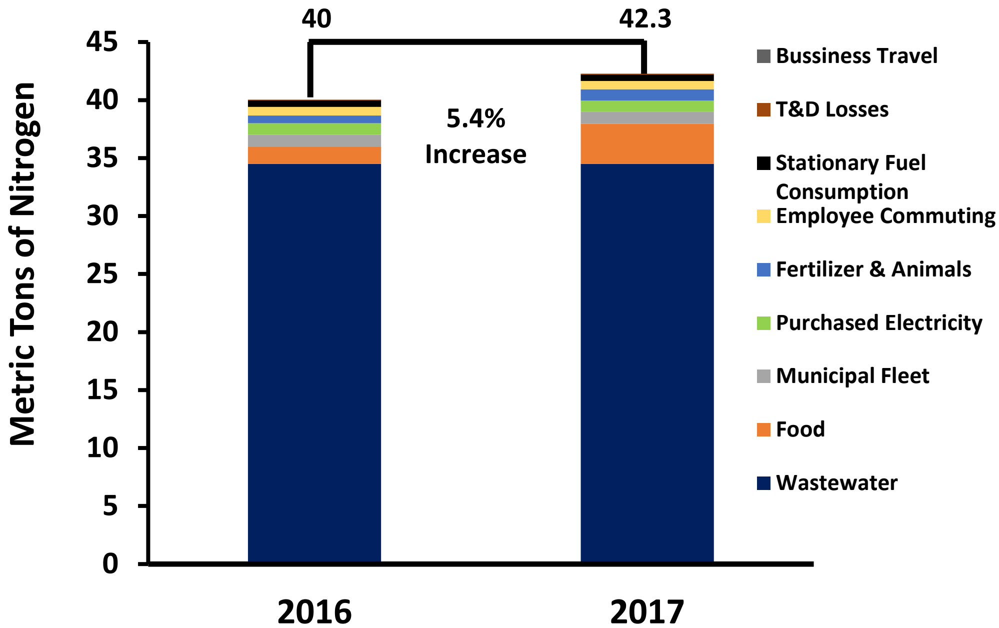


Figure 19. A comparison of the total nitrogen footprints as a result of LGO between 2016 and 2017.

Recognizing that a handful of sectors lead to the largest nitrogen contributions, it is suggested that Dover can have the greatest impact on reducing its LGO nitrogen footprint in the following ways:

- Continue to separate stormwater drainage from the sewer system so that the wastewater facility can more consistently maintain its 80% nitrogen removal efficiency throughout the year.
- Consider changing the school lunch menu so that it includes more alternative sources of protein such as beans or nuts, reducing the impact of serving meat.
- Reduce the number of diesel vehicles in the fleet, as diesel engines operate at higher temperatures and pressures than unleaded gas engines, favoring the formation of nitrous oxides.
- Once again, reduce the purchased electricity sector through more solar array installations.

The Reductions Scenario section of this report covers the level of impact that school lunch menu changes could have on reducing Dover's LGO nitrogen footprint. Table 17 displays a breakdown of the MTs of reactive nitrogen emitted from each sector, as well as the percent changes between 2016 and 2017. Since some calculations included estimates that applied to both years, the resulting percent changes were null.

Table 17. A breakdown of nitrogen footprint contributions by emissions category between 2016 and 2017 as well as the percent changes.

Category	MTs of N		Percent Change
	2016	2017	
Wastewater	34.5	34.5	0.0
Food	1.51	3.45	78.2
Municipal Fleet	1	1.06	5.8
Purchased Electricity	0.99	0.96	-3.1
Fertilizer & Animals	0.68	0.96	34.1
Employee Commuting	0.73	0.73	0.0
Stationary Fuel Consumption	0.56	0.54	-3.6
T&D Losses	0.05	0.05	0.0
Business Travel	0.02	0.02	0.0
Cumulative	40.0	42.3	5.4

Scope one emissions sources accounted for 92% and 88% of total nitrogen emissions in 2016 and 2017 respectively. This is due to the large contribution of wastewater. Wastewater is defined as a scope one source, even though the influent stream comes from the entire community, because the wastewater is treated within city limits. The contribution from purchased electricity, the only scope two source, accounted for only 2% in both years. Scope three made up 6% in 2016 and 10% in 2017, due mostly to the fairly sizable nitrogen impact associated with school food.

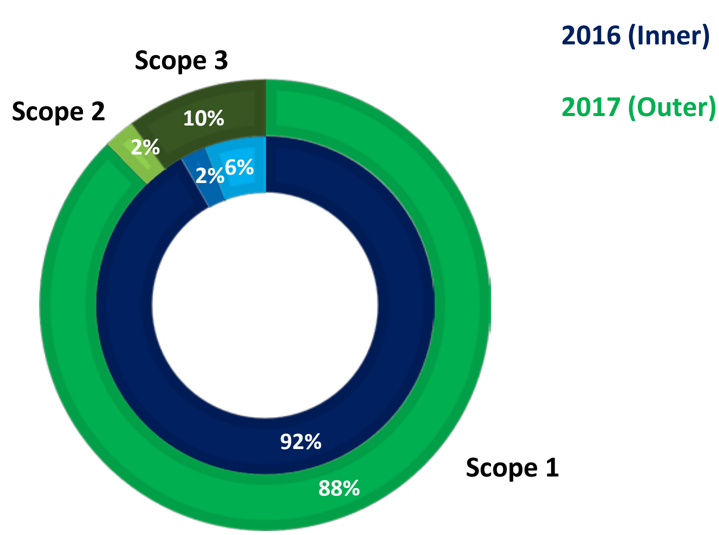
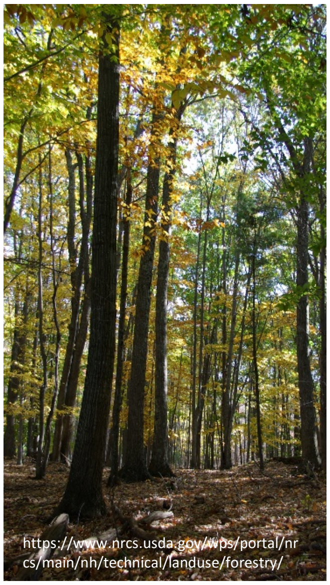


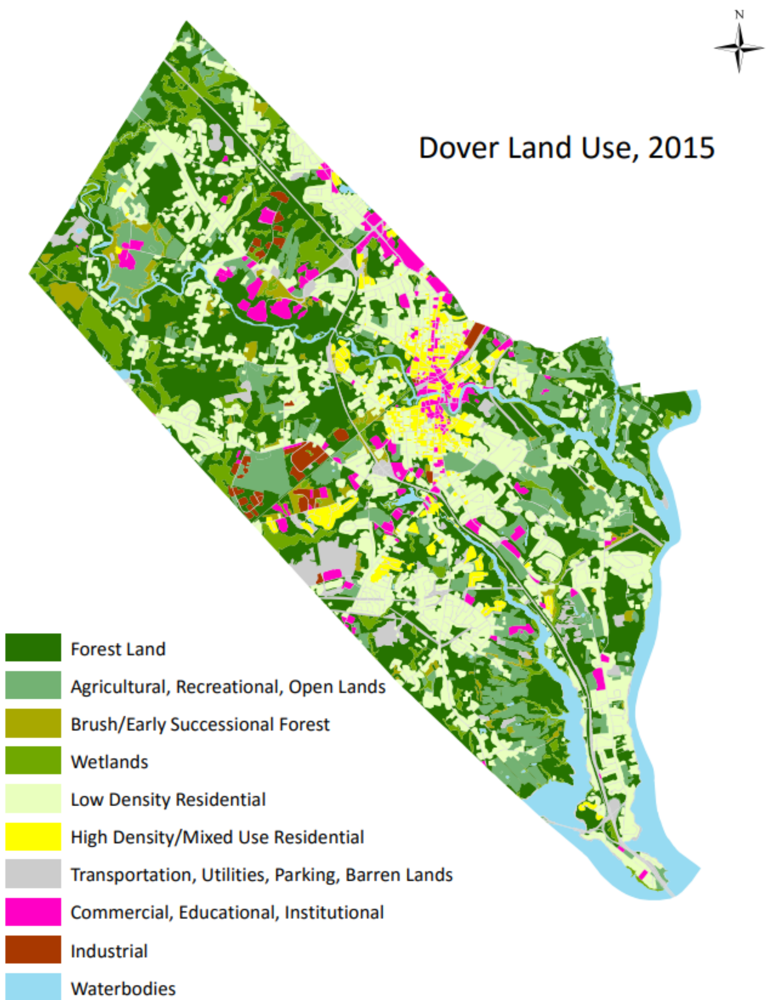
Figure 20. Scope contributions to the 2016 and 2017 LGO nitrogen footprints.

Equivalencies



It can be difficult to grasp the scale of GHG or nitrogen emissions when they are presented in terms of carbon dioxide equivalencies or MTs of nitrogen. The following conversions help to make MTs of CO_2 and N more relatable:

- A single MT of CO_2 is enough to fill the volume of an average two-story home, approximately 1400 ft^2.[14]
- A total of 11,260 acres of fully developed forest would be required to sequester Dover's emissions in one year, 2017.[15]
- 11,260 acres of forest is equivalent to approximately 66% of Dover's total land area.[16]
- The amount of nitrogen emitted by Dover's 2017 LGO equates to the impact from enough food to feed approximately 8,600 people for one year.[17]
- 8,600 people is equivalent to around 28% of Dover's population. [16]



This map shows Dover's land use as of 2015. 37% of Dover's available land is forested. These forested areas act as carbon sinks for emissions in that they sequester both natural and anthropogenic carbon dioxide. Therefore, keeping these forested areas preserved is of importance.

Initiatives

Streetlights to LED:

In November of 2017, the City completed the retrofitting of 1,781 streetlights with LED fixtures. These lights are outfitted with smart controls, which allow the lights to be remotely monitored and adjusted. The results of the retrofit become very apparent when comparing the block of time from November 2016 to April 2017 with November 2017 to April 2018 (Figure 21). The cumulative usage during this period decreased by approximately 199,150 kWh, resulting in almost $39,400 in savings over the previous six-month period. Furthermore, the GHG emissions declined by approximately 52.2 MT CO_2e.

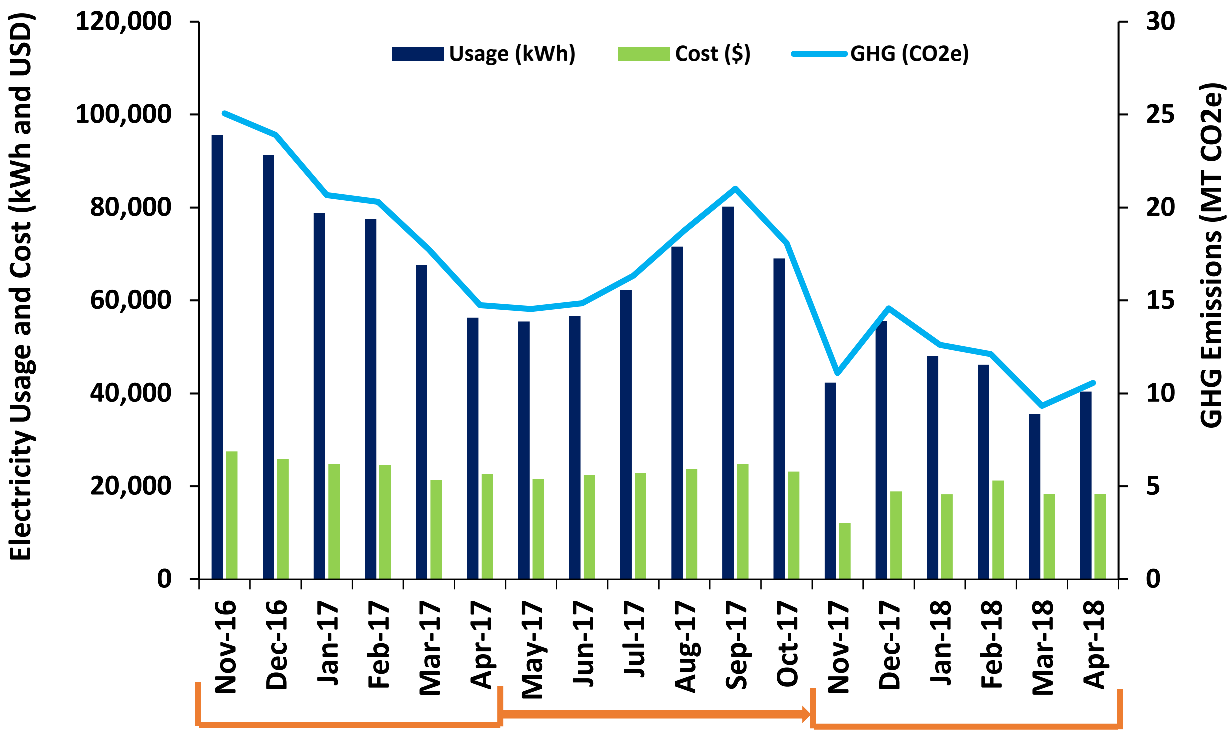


Figure 21. Impact of streetlight LED retrofit.

Solar Projects:

As the result of a power purchase agreement with Revision Energy, the newly constructed Dover High School will support a 912 kW roof-mounted solar array. This array will produce an estimated 1,055,330 kWh of electricity per year, covering 40% of the new building's projected annual electrical usage (Figure 22). The old Dover High School consumed 1,871,365 kWh of purchased electricity in 2017. With the contributions of solar on the new Dover High School, the quantity of electricity purchased annually for the High School is predicted to fall to 1,582,995 kWh, despite the increased electricity needs of the new facility. This will result in an overall GHG reduction of approximately 75.5 MTs of CO_2e, which equates to a 0.8% overall reduction of Dover's LGO carbon footprint.

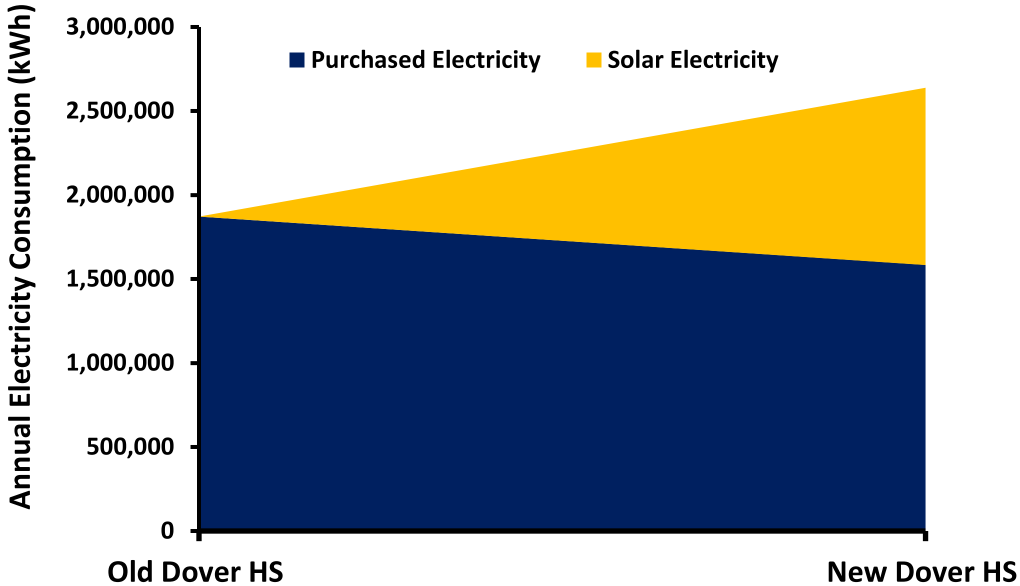


Figure 22. A comparison of the old Dover High School's purchased electricity consumption with that of the new High School's with the implementation of solar.

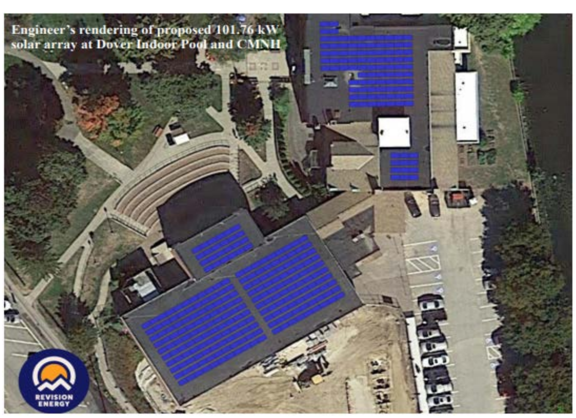


Figure 23. Revision Energy's rendering of the solar layout for the Children's Museum of New Hampshire and the Dover Indoor Pool.

The other site receiving rooftop solar panels is the Children's Museum of New Hampshire along with Dover's Indoor Pool (Figure 23). The installed array will be 101.76 kW. This array is estimated to produce 119,823 kWh annually, reducing GHG emissions by an approximately 31.4 MTs of CO_2e a year. Therefore, with the combination of the two solar sites the overall GHG reduction will be an estimated 1.1% of the total LGO carbon footprint.

The City has also signed an agreement with the solar company Gaia Energy, LLC to exclusively develop proposals to finance, construct, own, and operate solar facilities via a feasibility study. To date there have been four sites identified as potential candidates: the Dover Ice Arena, the wastewater treatment facility, the Varney Brook Pump Station and the Transportation Center. Based upon both the available land areas, roof top spaces, and in the case of the Transportation Center, carport potential, the combination of these sites could generate a total of over 5,500,000 kWh annually. See Appendix A-3 for the current electrical data for these sites.

Reduction Scenarios

Solar Based:

A series of three GHG reduction scenarios were analyzed, using SIMAP's Reduction Scenario Calculator, based upon the impact of planned and potential solar projects (Table 18). The implementation of solar decreases the purchased electricity requirement for Dover's LGO and in doing so reduces the associated GHG emissions from that source. Scenario one is the existing GHG emissions baseline for 2017. The second scenario is the predicted reduction as a result of the planned solar array installations for the New Dover High School, The Children's Museum of New Hampshire and the Indoor Pool. The third scenario contains the reductions as a result of scenario two as well as those predicted for the four potential sites previously discussed. This scenario takes into account the 1 MW cap on net metering that currently exists in New Hampshire. The fourth scenario is the same as the third except it does not take into account the 1 MW cap and instead is based upon the maximum solar potential for each site.

Table 18. Descriptions of the reduction scenarios which correspond to the data seen in Figure 24.

Reduction Scenario	Description
1	**2017 GHG LGO Emissions Baseline**
2	**Solar for New Dover HS, Children's Museum and Indoor Pool**
3	**Scenario 2 + Solar at WWTP, Varney Brook, Ice Arena and Transportation Center (1 MW Array Cap)**
4	**Scenario 2 + Solar at WWTP, Varney Brook, Ice Arena and Transportation Center (Max)**

Scenario two will reduce Dover's LGO carbon footprint by 107 MTs of CO_2e, resulting in a 1.1% reduction (Figure 24). Scenario three, when combined with the impact from scenario two, is estimated to reduce the total carbon footprint by 1044 MTs of CO_2e, yielding a 12% overall reduction. Finally if the 1 MW net metering cap is removed and these sites are allowed to achieve their full potential, then the footprint could be reduced by 404 MTs of CO_2e, leading to a very sizable 16% decrease in GHG emission.

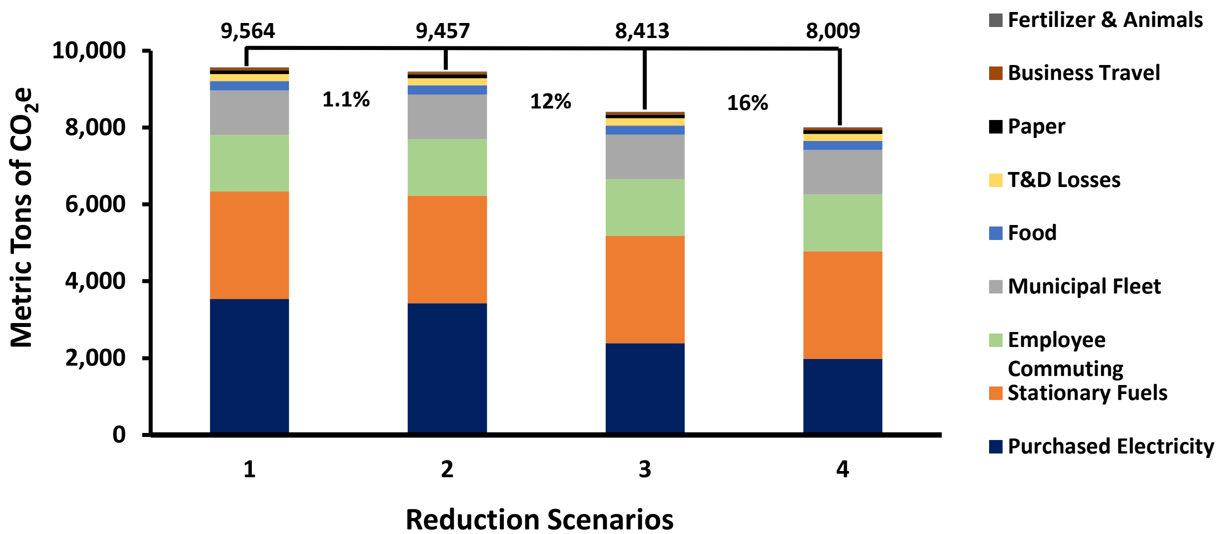


Figure 24. GHG emission reduction scenarios considering planned and potential solar projects for City-operated properties.

Food Based:

A series of food-based nitrogen reduction scenarios were performed using the SIMAP Food Scenarios Template (Figure 25). The first, which may be the most realistic to implement, projects the reduction associated with introducing a composting program where 90% of compostable food is diverted. The Dover schools do not currently have a composting system in place; if one were implemented, nitrogen would be reduced by a projected 5.8%. Beef has the largest nitrogen impact among meats served. Therefore, the second scenario predicts the reduction that would result from changing 50% of the beef served to chicken. This yielded an approximately 10% overall reduction to the food-associated nitrogen impact. The third scenario is similar to the second, except that instead of replacing half of the beef with chicken, beef is replaced with beans, a viable alternative protein source. This change would result in a predicted 15% reduction. The last scenario would be much more difficult to implement but would also result in the most drastic footprint reduction. By removing meat from school lunches and switching to a vegetarian menu, the nitrogen impact associated with Dover's school food would be reduced by 61%. The overall nitrogen footprint, containing contributions from all sectors, would be reduced by a sizable 5% under the vegetarian case.

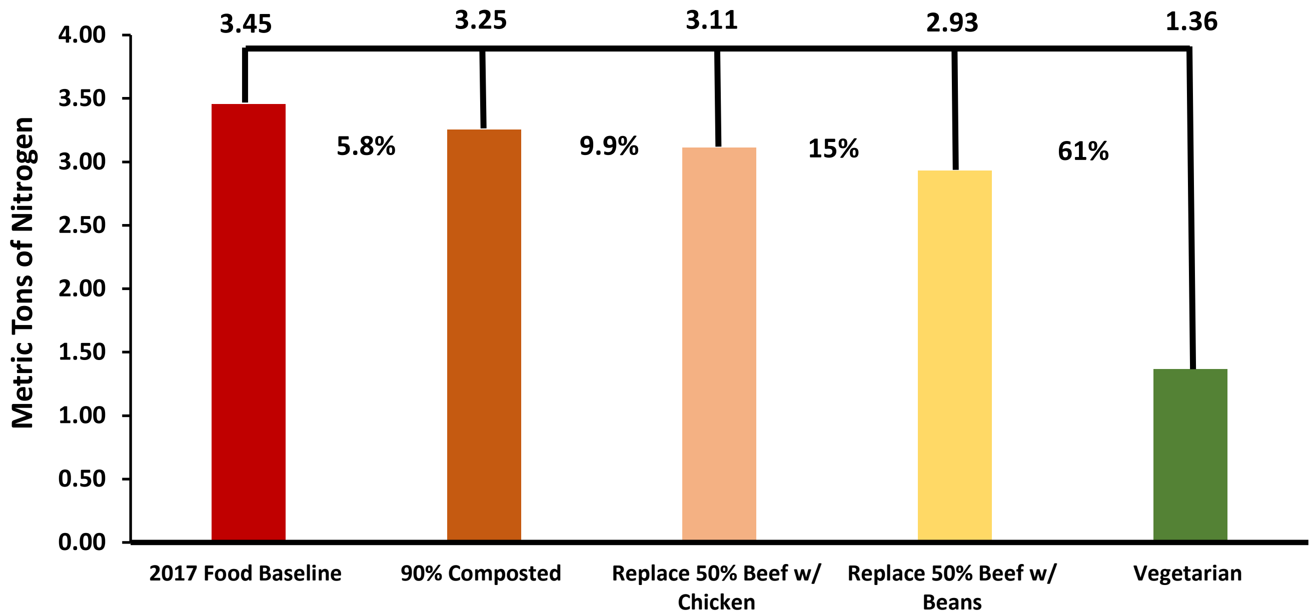


Figure 25. Nitrogen reduction scenarios as a result of hypothetical changes to the Dover School food program.

Conclusions and Recommendations

Conclusions:

Conclusions are provided by section and are intended to relay the most critical information.

Introduction:

- Dover recognizes the challenges climate change presents, exemplified by the Climate Adaptation Chapter of Dover's Master Plan "Planning Today for a Resilient Tomorrow".
- A portion of Dover's 2023 vision states "When Dover celebrates its 400th anniversary in 2023 it will be a dynamic community with an outstanding quality of life because it has achieved the following interconnected characteristics….Enhanced environmental quality and sustainability are actively pursued and in all the city's activities."

Effects of Anthropogenic GHGs:

- Human activity has led to atmospheric concentrations of carbon dioxide, methane, and nitrous oxide that are unprecedented in at least the last 80,000 years.
- It is very likely that heat waves will occur and last longer. It is also very likely that extreme precipitation events will become more intense and frequent in many regions. The ocean will continue to warm and acidify and the global mean sea level will continue to rise.

- Mitigation efforts involve both benefits and risks due to adverse side effects, but these risks do not involve the same possibility of severe, widespread and irreversible impacts as a risk from climate change.
- This inventory will help inform Dover's policymakers on how to best introduce mitigation procedures, helping Dover contribute to a much-needed global effort.

The Nitrogen Dilemma:

- Reactive nitrogen, including compounds such as ammonia, ammonium, and nitrous oxide, causes negative impacts to environmental and human health.
- Pure nitrogen is converted to reactive nitrogen through a variety of anthropogenic and natural pathways.
- Negative impacts associated with excess reactive nitrogen releases include the production of smog and haze, forest die-back, acidification, ozone depletion, climate change, and eutrophication.
- The nitrogen dilemma stems from mankind relying on nitrogen to feed our population.

Methodology:

- This inventory aligns with the GHG Protocol's five major steps for conducting a local government operations (LGO) inventory.
- The carbon and nitrogen footprint baseline were established using two web-based tools, EPA's Portfolio Manager and the University of New Hampshire's Sustainability Indicator Management and Analysis Platform (SIMAP).
- Dover is the first municipality to use the SIMAP tool and as a result, the developers plan to alter the tool to better suit municipal use upon receiving recommendations generated from this analysis.

Emissions Sectors:

- The majority of sectors contribute to Dover's LGO carbon and nitrogen footprints.

Emissions Scopes:

- Scope 1 emissions are from sources directly owned or controlled by the organization. Sectors include stationary fuels, the municipal fleet, and fertilizer and animals.
- Scope 2 emissions are indirect emissions and only include emissions produced from purchased electricity.
- Scope 3 emissions are a consequence of the organization's operations. Sectors include transmission & distribution losses, employee commuting, employee travel, solid waste, school food, paper, and wastewater.

Weather:

- There were 5,976 HDDs in 2016 and 6,147 HDDs in 2017, yielding a 3% increase.
- There were 685 CDDs in 2016 and 623 CDDs in 2017, resulting in a 9% decrease.
- Over all there was a 2% increase in TDDs between the two years.
- Dover received 16 more inches of snow in 2017 than in 2016.

Energy Consumption and Cost:

- The total raw usage was 104,800 MMBtu in 2016 and 102,670 MMBtu in 2017.
- A TDD-normalized comparison yielded a 3.7% reduction between the two years.
- Total raw energy cost was $2.36M in 2016 and $2.59M in 2017.
- A TDD-normalized comparison yielded a 7.7% increase between the two years.
- 7,075 MTs of CO_2e were released in 2016 and 6,539 MTs of CO_2e were released in 2017.
- The TDD normalized comparison yielded a 9.5% reduction between the two years.

Municipal Fleet:

- The total diesel usage in 2016 was 37,010 gallons and in 2017 was 36,522 gallons, yielding a 1.3% reduction.
- The total unleaded gasoline usage in 2016 was 57,414 gallons and in 2017 was 62,619 gallons, resulting in an 8.7% increase.
- The total fleet fuel consumption cost for 2016, including contributions from diesel and unleaded gasoline, was $196,142 which saw a 20% increase to $239,786 in 2017.
- The total amount of GHG emissions released from diesel consumption in 2016 equated to 379 MTs of CO_2e and 378 MTs of CO_2e, resulting in a 0.4% reduction.
- In 2016 there was a total of 507 MTs of CO_2e released to the atmosphere versus 570 MTs of CO_2e in 2017, resulting in an 11.7% increase.

Commuting:

- Municipal employees commuted to work an average of 9.7 miles one way, compared to 10.5 miles for school employees.
- Annually, it is estimated that municipal employee commuting contributed 407.2 MTs of CO_2e and school 1,028 MTs of CO_2e to Dover's LGO carbon footprint.
- When normalized by GHG emissions per commuter the result was 1.77 MTs CO_2e for municipal employees and 1.91 MTs CO_2e for school employees annually.

Travel:

- There were a total of 71 MTs of CO_2e released in 2016 and 59 MTs of CO_2e released in 2017, yielding a 19% overall reduction.
- Air travel resulted in the majority of GHG emissions, making up 73% in 2016 and 66% in 2017.
- The IPCC has estimated that the climate impact of aircraft is 2-4 times greater than the effect of their CO_2 emissions due to the location of the emission in the atmosphere.

Fertilizer:

- In 2016, a total of 19,103 lbs. of fertilizer were applied to City and School Properties.
- Comparatively, 22,019 lbs. were applied in 2017, representing a 14.2% increase over 2016.
- It's important to note that the impact of the nitrogen contained within fertilizer only applies to the reactive nitrogen that is not taken up by the plant matter or soil.
- An estimated 0.66 MTs and 0.93 MTs of reactive nitrogen were released in the environment in 2016 and 2017 respectively.

Animals:

- The Dover Police Department currently implements the use of two police horses, CJ and Rasa, who are used for mounted patrol operations.
- CJ and Rasa do contribute a small amount to Dover's LGO GHG emissions producing approximately 1.24 MTs of CO_2e a year.

School Food:

- All school food distributed to the Dover Schools from both private vendors and the federal government was analyzed for calendar year 2017.
- The total quantity of food provided to the Dover Schools, equating to 72,191 kg, was categorized by food type.
- Even though meat only made up 18% of the supplied food in 2017, it accounted for 67% of the total 3,453 kg of nitrogen released.
- On the other hand, fruits and vegetables made up 22% of the food provided but only contributed to 3% of the nitrogen released.

Solid Waste:

- Municipal waste is disposed in a total of 28 dumpsters spread throughout the City. The total volume of these dumpsters equates to approximately 200 $yrds^3$.
- A fill scenario analysis was performed to estimate the amount of municipal solid waste generated in a year using an assumed density of 264.6 lbs/yrd^3.
- Dover's municipal waste is processed at the ecomaine facility located in Portland, Maine.
- The reduction for the medium fill scenario was 62 MTs of CO_2e.

Paper:

- The Dover schools have a total of ten, 96-gallon totes which are recycled with mostly paper.
- A similar fill scenario analysis, as was done for the solid waste, was performed for these totes using an assumed density of 1.31 lbs/gal.
- The impact of the estimated paper produced from the Dover school system was determined to be 97.6 MTs of CO_2e.

Wastewater:

- On an average day the facility handles approximately 2.5 million gallons (MG), but it is designed to process up to 4.7 MG per day.
- The plant maintains an 80% nitrogen removal efficiency, which is much better than the national average of 50%.
- During storm water events, the plant cannot maintain the levels of nitrogen removal present during normal operations.
- There is an estimated annual total of 34.5 MTs of nitrogen released into the effluent stream, making it the largest contributor out of all sectors.

Comprehensive Carbon Footprints:

- In 2016, 9,896 MTs of CO_2e were emitted, versus 9,560 MTs of CO_2e in 2017, yielding a 3.4% reduction.
- Together, purchased electricity and stationary fuels accounted for 71% of the GHG emissions in 2016 and 68% in 2017.
- Scope one and two emissions sources accounted for approximately 40% each, equating to around 80% of the amount of GHGs emitted in 2016 and 2017
- The included scope 3 sources were cumulatively the least impactful in both years, contributing about 20%.

Comprehensive Nitrogen Footprints:

- In 2016, 40 MTs of nitrogen were emitted, versus the 42.3 MTs of nitrogen in 2017, resulting in 5.4% increase.
- It is very likely that the increase was actually less than what is presented, due to evidence which shows that the food data provided for 2016 is incomplete.
- Wastewater was the largest contributor in both years, making up 86% of the reactive nitrogen released in 2016 and 82% in 2017.
- Scope one emissions sources accounted for 92% and 88% of the total nitrogen emission in 2016 and 2017 respectively. This is due to the large contribution of wastewater, a scope one source.
- The contribution from purchased electricity, the only scope two source, accounted for only 2% in both years. Scope three made up 6% in 2016 and 10% in 2017 due mostly to the fairly sizable nitrogen impact associated with school food.

Streetlights to LED:

- In November of 2017, the City completed the retrofitting of 1,781 streetlights with LED fixtures.
- The results of the retrofit become very apparent when comparing the block of time from November 2016 to April 2017 with November 2017 to April 2018.
- The cumulative usage during this period decreased by approximately 199,150 kWh, resulting in almost $39,400 in savings over the previous six-month period. Furthermore, the GHG emissions declined by approximately 52.2 MT CO_2e.

Solar Projects:

- As the result of a power purchase agreement with Revision Energy, the newly constructed Dover High School will contain a 912 kW solar array. This array will produce an estimated 1,055,330 kWh of electricity a year covering 40% of the projected electrical usage.
- This will result in an overall GHG reduction of approximately 75.5 MTs of CO_2e, which equates to a 0.8% overall reduction of Dover’s LGO carbon footprint.
- The other site receiving solar panels is the Children’s Museum of New Hampshire along with Dover’s Indoor Pool. This array is estimated to produce 119,823 kWh annually and will reduce GHG emissions by an estimated 31.4 MTs of CO_2e a year.
- With the combination of the two solar sites, the overall GHG reduction will be an estimated 1.1% of the total LGO carbon footprint.
- The City has also signed an agreement with the solar company Gaia Energy, LLC to exclusively develop proposals to finance, construct, own, and operate solar facilities via a feasibility study.

Based upon available land areas, roof top spaces, and in the case of the transportation center, a potential carport, the combination of these sites could generate a total of over 5,500,000 kWh annually.

Solar Based Reduction Scenarios:

- The implementation of solar decreases the purchased electricity requirement for Dover's LGO and in doing so reduces the associated GHG emissions from that source.
- Scenario two will reduce Dover's LGO carbon footprint by 107 MTs of CO_2e resulting in a 1.1% reduction.
- Scenario three when combined with the impact from scenario two is estimated to reduce the total carbon footprint by 1044 MTs of CO_2e yielding a 12% overall reduction.
- If the 1 MW net metering cap is lifted by the legislature and these sites are allowed to achieve their full potential, the footprint could be reduced by 404 MTs of CO_2e, a very sizable 16% decrease in GHG emission.

Food-Based Reduction Scenarios:

- The first, which may be the most realistic to implement, projects the reduction associated with the introduction of a composting program where 90% of compostable food is diverted from the solid waste stream. If one were to be implemented, the nitrogen released would be reduced by a projected 5.8%.
- The second scenario predicts the reduction that would be the result of changing 50% of the supplied beef to chicken. This yielded an approximately 10% overall reduction to the food associated nitrogen impact.
- The third scenario is similar to the second except that instead of replacing half of the beef with chicken, beans were chosen, as they are a viable alternative protein source. This change would result in a predicted 15% reduction.
- By removing meat from school lunches and switching to a vegetarian menu, the nitrogen impact associated with Dover's school food would be reduced by 61%. The overall nitrogen footprint, containing contributions from all sectors, would be reduced by a sizable 5% under the vegetarian case.

Recommendations:

The following is a review of recommendations that would help Dover to lower its LGO carbon footprint:

- Reduce purchased electricity through the installation of more solar arrays.
- Provide incentives for employees to carpool or take public transportation to work.
- Increase the number of electric vehicles (EVs) in the municipal fleet.
- Upgrade older facilities to improve insulation and install remotely monitored HVAC systems.

The following is a review of recommended actions that would help Dover to lower its LGO nitrogen footprint:

- Improve stormwater management infrastructure so that the wastewater facility can more consistently maintain its 80% nitrogen removal efficiency throughout the year.
- Consider changing the school lunch menu so that it includes more alternative sources of protein such as beans or nuts, thus reducing the impact of meat.
- Reduce the number of diesel vehicles in the fleet, as diesel engines operate at higher temperatures and pressures than unleaded gas engines, favoring the formation of nitrous oxides.
- Once again, reduce the purchased electricity sector through more solar array installations.

The following list contains emissions sources that were not included in this study due to both time constraints and unavailability of data, as well as methods that would improve the accuracy of the results.

- Include analysis of refrigerants and chemicals which release fugitive emissions. These include HCFC-22, HCFE-235da2, HFC-134a, and other fluoric compounds.
- Municipal paper waste should be estimated to increase the comprehensiveness of the LGO carbon footprint.
- Conduct a survey to improve the accuracy of the employee commuting estimations, as employees may ride their bikes or take public transportation to work.
- Use a truck weigh station or some other method to increase the accuracy of the municipal waste and school waste estimations.

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Appendix

A-1) Annual Totals for Municipally Operated Properties

Table 19. Propane usage as well as cost for all applicable properties for 2016 and 2017.

	2016 Propane			2017 Propane		
Property	Usage (Gallons)	Usage (MMBtu)	Cost (USD)	Usage (Gallons)	Usage (MMBtu)	Cost (USD)
South End Fire Station	4,871	448	7,257	2,622	241	3,906
Public Works Facility/Recycling Center	118	11	176	137	13	203
Ice Arena	2,273	209	3,386	1,894	174	2,823
Mt. Pleasant Pump Station	140	13	208	182	17	271
Watson Rd Pump Station	646	59	962	609	56	907
Leighton Way Pump Station	9	1	13	0	0	0
Boston Harbor Pump Station	7	1	10	0	0	0
Brickyard Estates Pump Station	230	21	343	139	13	206
Country Farm Rd Pump Station	411	38	613	358	33	533
Crosby Road Pump Station	401	37	598	518	48	771
Campbell Well	507	47	756	943	87	1,405
Cummings Well	149	14	222	1	0	2
Isinglass Recharge	153	14	228	257	24	383
Calderwood Well	513	47	764	1,064	98	1,586
Hughes Well	604	56	899	406	37	605
NE Water Tower	413	38	616	0	0	0
Bouchard WTP	2,945	271	4,388	1,986	183	2,958
Smith Well	534	49	795	429	40	640
Ireland Well	532	49	792	408	38	608
Recreation Garage	1,616	149	2,408	1,528	141	2,277
Griffin Well	4,968	457	7,402	4,359	401	6,495

Table 20. No. 2 Oil usage as well as cost for all applicable properties for 2016 and 2017.

	2016 No. 2 Oil			2017 No. 2 Oil		
Property	Usage (Gallons)	Usage (MMBtu)	Cost (USD)	Usage (Gallons)	Usage (MMBtu)	Cost (USD)
City Hall	11,562	1,630	23,128	9,545	1,346	17,430
Cemetery Chapel	1,417	200	2,846	1,178	166	2,132
Cemetery Barn	1,183	167	2,393	793	112	1,457
Bellamy Park Admin.	474	67	967	179	25.3	332
Middle Rd. WWTP	9,298	1,311	20,050	5,135	724	9,024

Table 21. Diesel usage as well as cost for all applicable properties for 2016 and 2017.

	2016 Diesel			2017 Diesel		
Property	Usage (Gallons)	Usage (MMBtu)	Cost (USD)	Usage (Gallons)	Usage (MMBtu)	Cost (USD)
City Hall (generators)	0	0	0	576	80	1,335
Middle Rd. WWTP	393	54	619	553	76	1,354
North End Fire Station	0	0	0	153	21	322
River Street Sewer	2,500	345	5,400	2,002	276	4,797
Varney Brook Sewer	661	92	1,119	1,610	222	3,217
Piscataqua Sewer	361	50	952	622	86	1,332
Fleet Services/277 Mast. Rd	12,944	1,786	22,486	14,640	2,020	30,577
PD Station & Garage	0	0	0	162	23	434

Table 22. Natural gas usage as well as cost for all applicable properties for 2016 and 2017.

	2016 Natural Gas			2017 Natural Gas		
Property	Usage (Therms)	Usage (MMBtu)	Cost (USD)	Usage (Gallons)	Usage (MMBtu)	Cost (USD)
Veteran's Building	765	76.5	1,562	595	59.5	1,538
McConnell Center	39,630	3,963	43,076	36,625	3,663	50,271
South End Fire Station	16	1.6	694	50	5	868
Central Fire Station	3,243	324	4,116	3,313	331	4,964
Public Works Facility	15,998	1,600	19,134	15,251	1,525	21,981
Butterfield Gym/Indoor Pool	42,709	4,271	43,229	35,893	3,589	44,999
Guppey Park/Jenny Thompson Pool	10,867	1,087	12,592	8,744	874	10,801
Train Station	386	38.6	1,212	399	40	1,332
Library	8,148	815	10,727	6,704	670	11,456
Ice Arena	51,518	5,152	50,391	41,146	4,115	53,697
Mast Rd. Pump Station	72	7.2	837	405	41	1,196
Charles St. Pump Station	531	53.1	1,353	460	46	1,406
NEPZ Booster Station	234	23.4	1,055	305	31	1,215
North End Fire Station	8,179	818	10,802	6,747	675	10,476
PD Station & Garage	3,567	357	7,953	1,484	148	4,007
Lowell Ave. Water	2,509	251	2,979	224	22	530
Pump House #1	420	42	1,214	357	36	1,228
Stone Wall Dr. Pump Station	6.4	0.6	57	89	9	975
Woodman Park School	43,472	4,347	41,797	52,533	5,253	54,272
Horne Street School	25,570	2,557	25,355	27,757	2,776	29,628
Garrison School	36,130	3,613	34,352	35,116	3,512	36,656
Dover High School	91,919	9,191	93,326	97,551	9,755	110,659
Dover Middle School	44,534	4,453	48,777	54,172	5,417	55,809
Alternative School	3,243	324	2,022	5,369	537	9,920
School Storage Building	2,660	266	3,108	3,385	339	3,995
Vocational School	36,776	3,678	29,008	40,556	4,056	36,979

Table 23. Electricity usage as well as cost for all applicable properties for 2016 and 2017. Here properties are grouped due to the extremely large number of properties that consume electricity.

	2016 Electricity			2017 Electricity		
Property Group	Usage (kWh)	Usage (MMBtu)	Cost (USD)	Usage (kWh)	Usage (MMBtu)	Cost (USD)
Cemeteries	11,301	39	2,897	12,632	42	2,923
City Buildings	3,112,581	10,620	395,522	2,937,186	10,022	362,401
Parking	380,497	1,298	50,487	215,869	737	30,724
Parks and Rec	370,405	1,263	50,606	352,083	1,201	46,583
Police and Fire	548,625	1,872	65,621	698,871	2,385	81,888
Pump Stations	1,235,891	4,217	175,930	1,078,835	3,681	155,927
Schools	4,440,374	15,151	267,853	4,578,105	15,620	594,461
Sewer and WTP	2,308,798	7,878	274,921	2,550,991	8,704	286,435
Street Lights	874,003	2,982	296,196	726,663	2,479	230,400
Traffic and Misc. Lights	66,645	227	16,132	60,081	205	14,551
Wells	1,232,538	4,206	157,321	950,933	3,245	125,138
Holiday Lights	2,225	7.6	516	2,328	7.9	503

A-2) Fertilizer Data Validation

In an effort to validate the provided fertilizer application data from GGL the following statistical analysis was performed. The quantity of nitrogen applied was plotted as a function of land area which yielded regression (R^2) values of 0.98 for both 2016 and 2017 (Figure 26). This proves an expected linear relationship between the quantity of nitrogen applied and the total area of the land which it is being applied to. Further validation was provided through the use of a statistical t-test with a 95% confidence interval which yielded alpha values of 0.004 for both 2016 and 2017. Alpha values under the 0.05 threshold provide evidence that the null hypothesis can be rejected and thus the linear relationship previously discussed is significant.

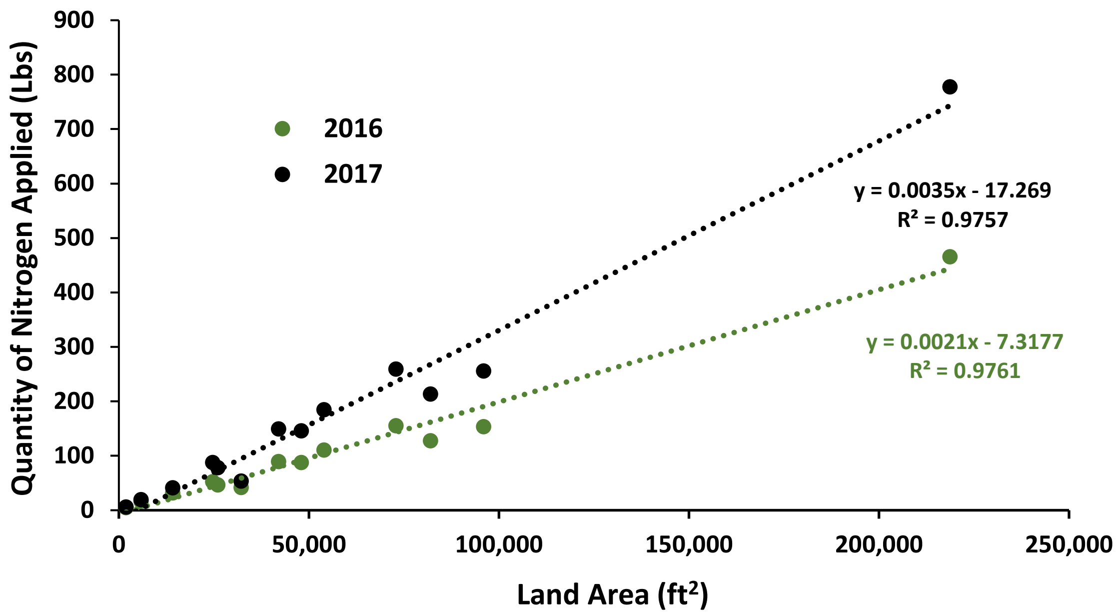

Figure 26. The linear relationship between the quantity of nitrogen applied and the area of the land to which the application occurred. The R^2 values of 0.98 proves the linearity of the relationship while the alpha values show that the relationship is one of significance.

A-3) Electrical Data for Four Potential Solar Sites

Dover Ice Arena

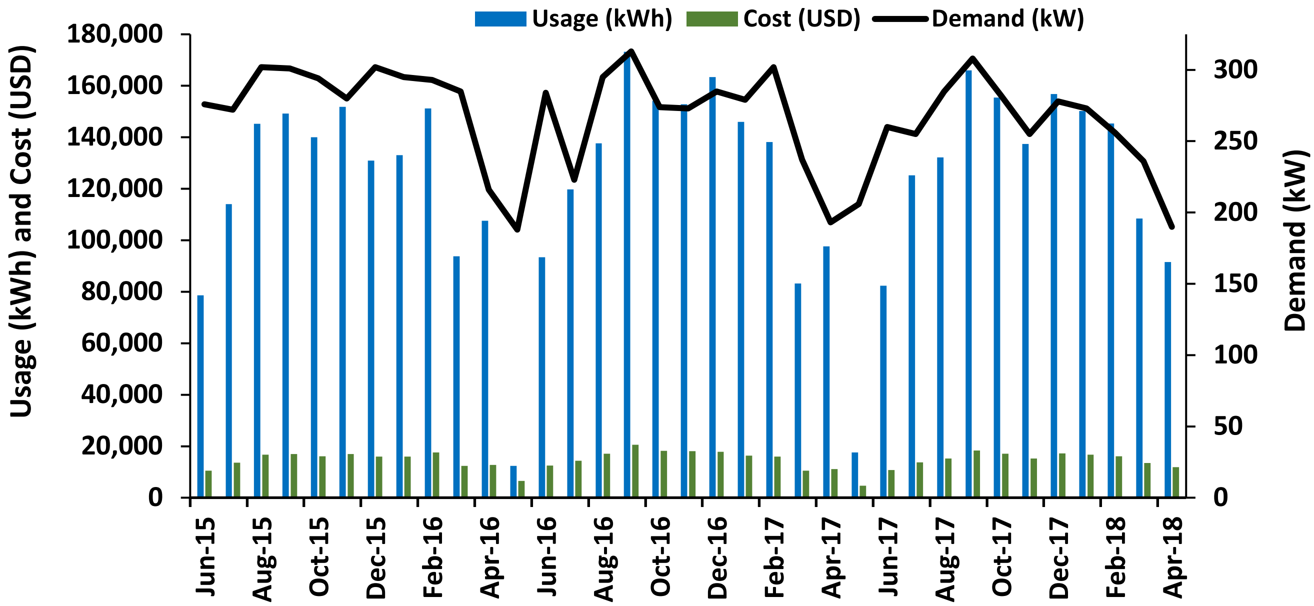

Figure 27. Historical electrical usage, cost and demand for the Dover Ice Arena. Large drops in May are associated with the removal of the older of the two ice sheets. This highlights the need for a facility upgrade.

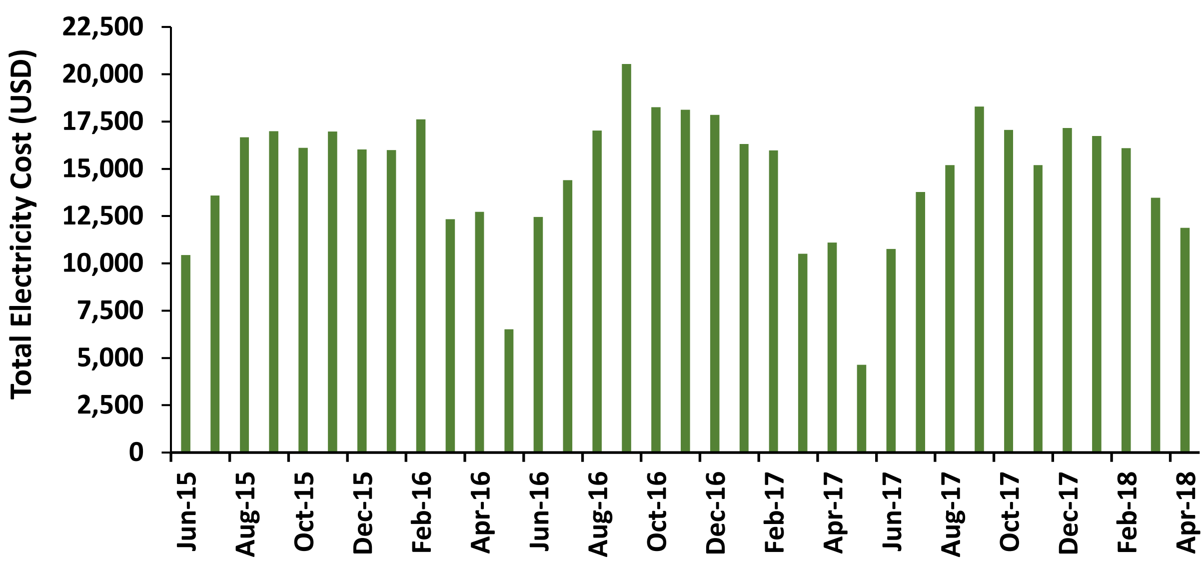

Figure 28. Historical costing data for the Dover Ice Arena separated out so the trends are more apparent than what is visible in Figure 27.

Varney Brook Pump Station

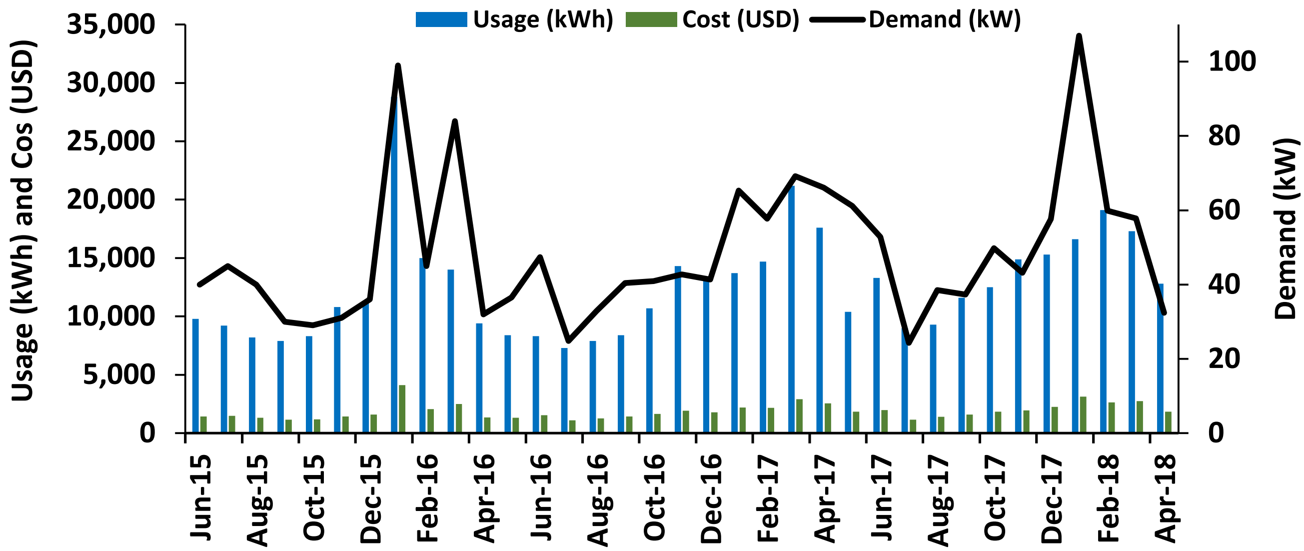

Figure 29. Historical electrical usage, cost and demand for the Varney Brook Pump Station.

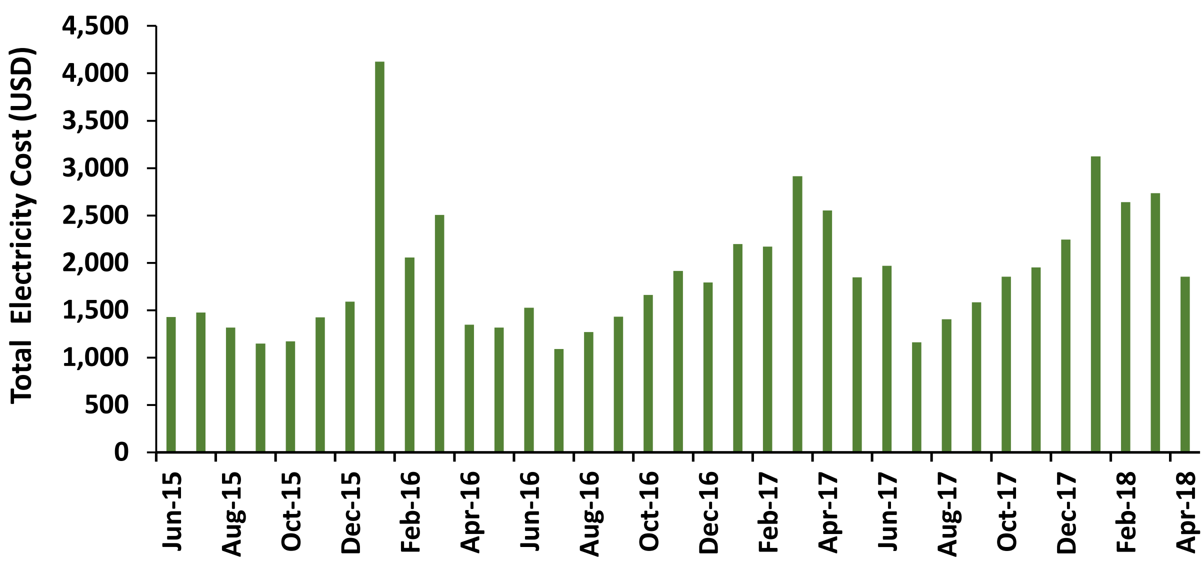

Figure 30. Historical costing data for the Varney Brook Pump Station separated out so the trends are more apparent than what is visible in Figure 29.

Middle Rd. Wastewater Treatment Plant

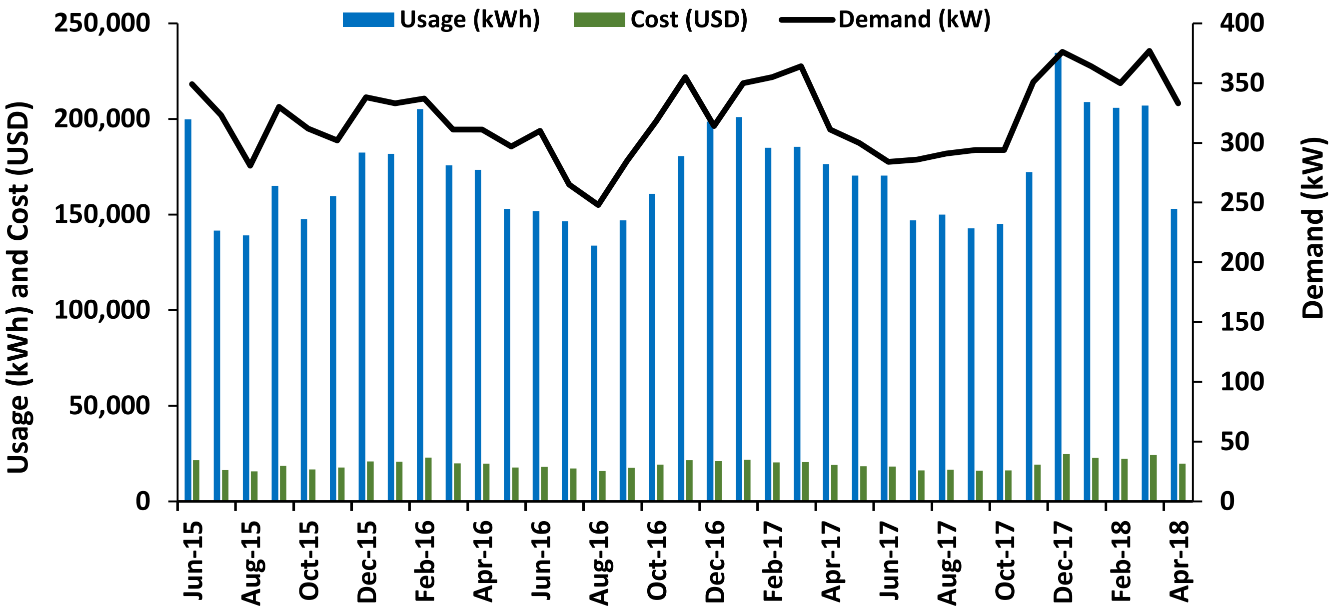

Figure 31. Historical electrical usage, cost and demand for the Wastewater Treatment Plant.

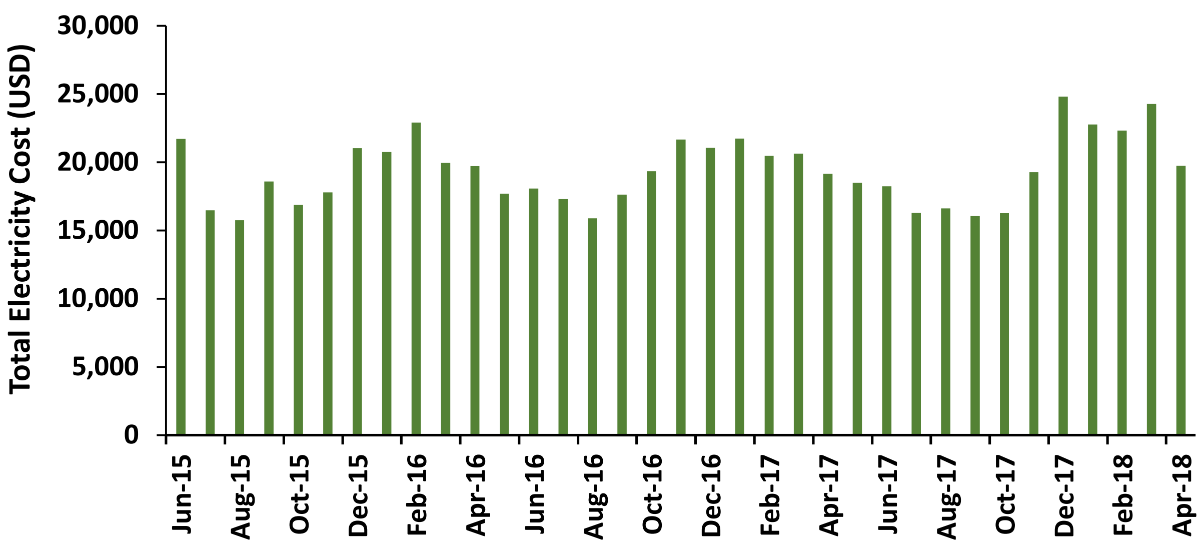

Figure 32. Historical costing data for the Wastewater Treatment Plant separated out so the trends are more apparent than what is visible in Figure 31.

Transportation Center

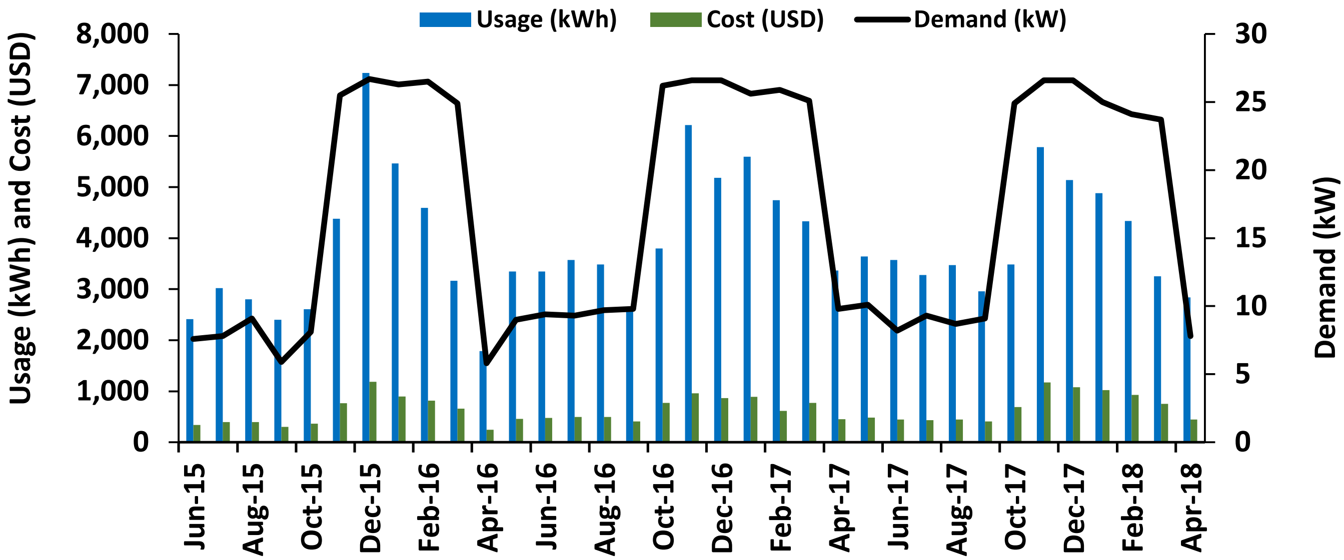

Figure 33. Historical electrical usage, cost and demand for the Transportation Center.

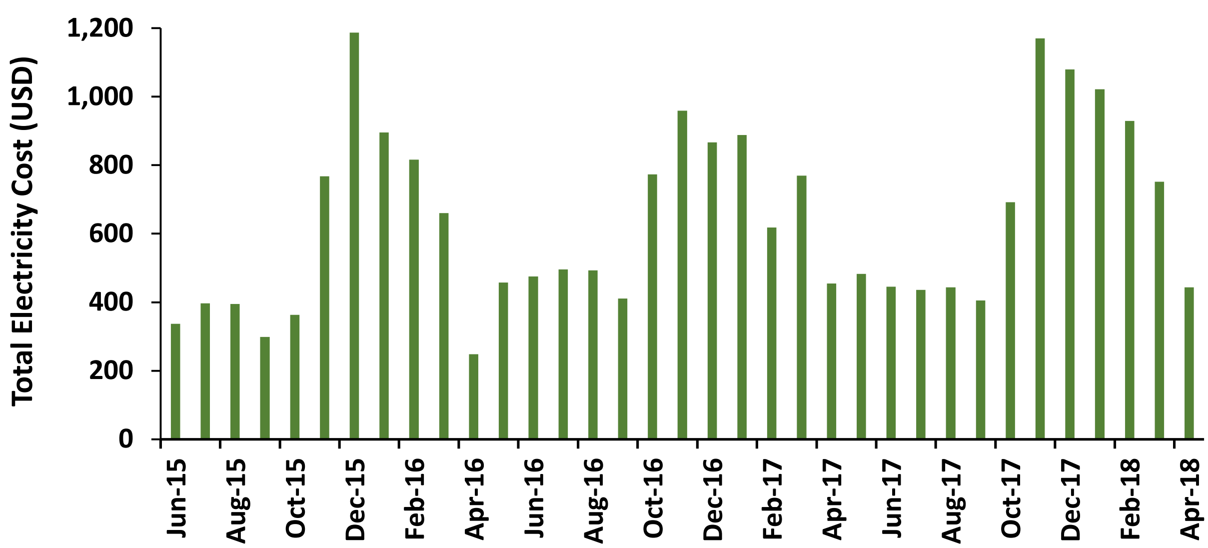

Figure 34. Historical costing data for the Transportation Center separated out so the trends are more apparent than what is visible in Figure 33.