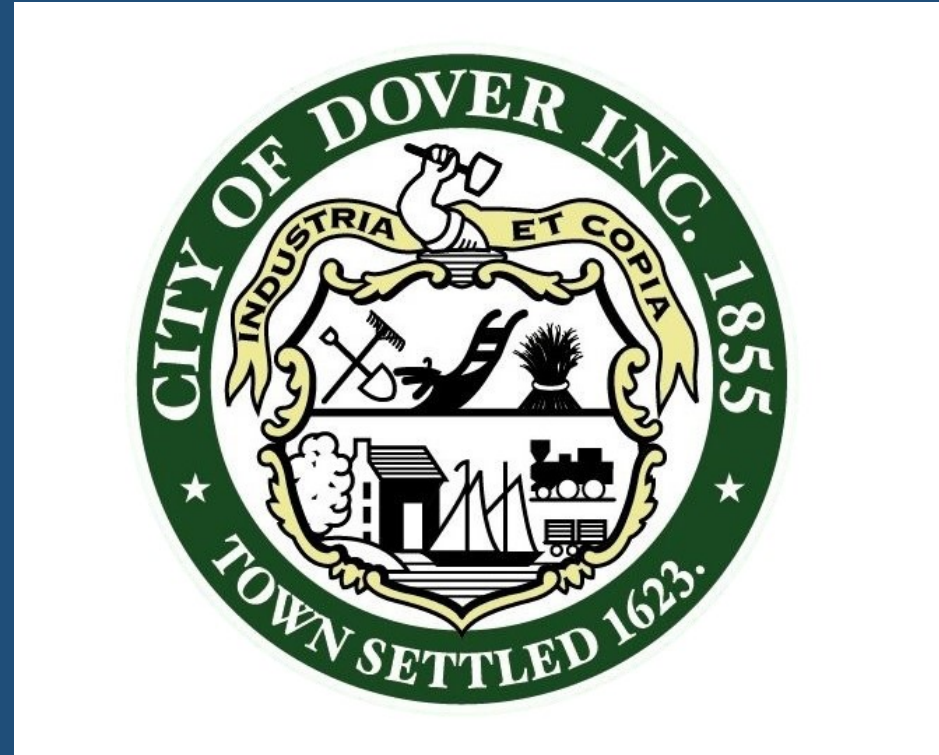


# Measuring Municipal Carbon and Nitrogen Footprints



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# Introduction

As a result of this project, Dover will become the first city to establish a combined GHG and nitrogen inventory for its local government operations (LGO)

- **Carbon Footprint:** Total amount of greenhouse gases (GHGs) produced to directly and indirectly support human activities.<sup>1</sup>
- **Nitrogen Footprint:** The amount of reactive nitrogen released to the environment as a result of an organization's resource consumption.<sup>2</sup>
- **Footprint Baseline:** A selected time period to which future footprints are compared.<sup>3</sup>



# The Nitrogen Dilemma

## Benefit

- Use of synthetic fertilizer is necessary to sustain the Earth's growing human population



## Drawbacks

- The release of excess reactive nitrogen negatively impacts environmental and human health

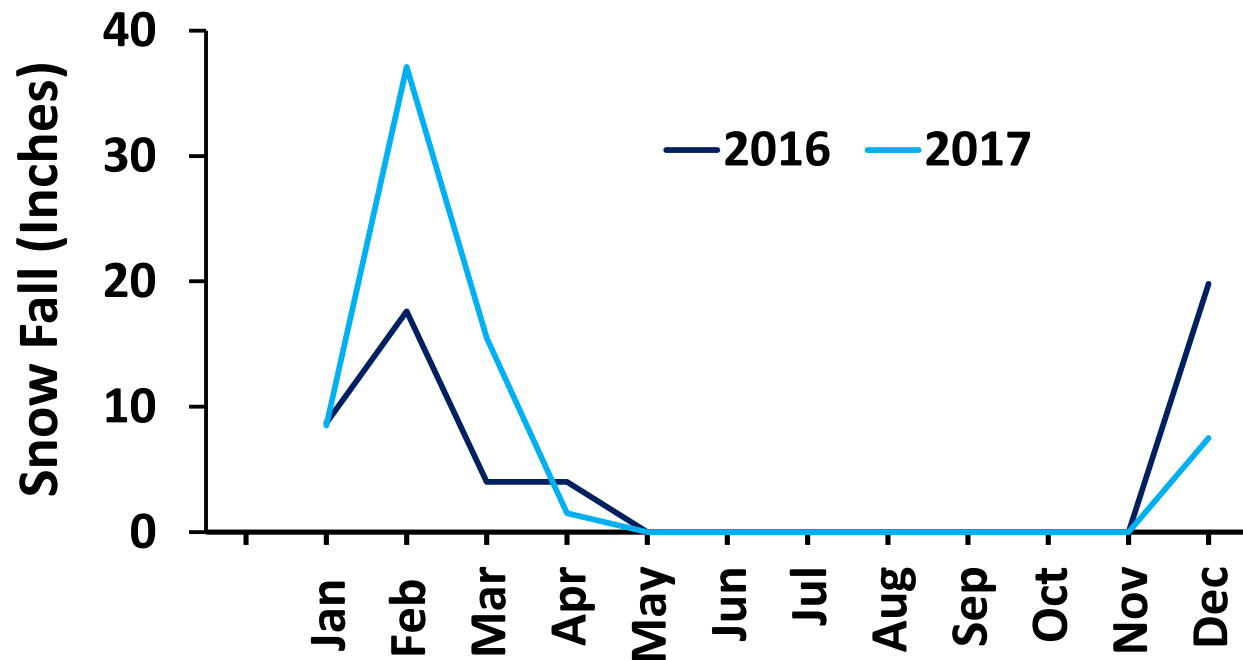


# Emissions Sectors

| Sectors                            | Scope 1<br>Direct<br>Emission | Scope 2<br>Indirect<br>Emission | Scope 3<br>Indirect<br>Emission |
|------------------------------------|-------------------------------|---------------------------------|---------------------------------|
| Stationary Fuels                   | X                             |                                 |                                 |
| Municipal Fleet                    | X                             |                                 |                                 |
| Fertilizer and Animals             | X                             |                                 |                                 |
| Purchased Electricity              |                               | X                               |                                 |
| Transmission & Distribution Losses |                               |                                 | X                               |
| Employee Commuting                 |                               |                                 | X                               |
| Employee Travel                    |                               |                                 | X                               |
| Solid Waste                        |                               |                                 | X                               |
| School Food                        |                               |                                 | X                               |
| Paper                              |                               |                                 | X                               |
| Wastewater                         |                               |                                 | X                               |

# Weather

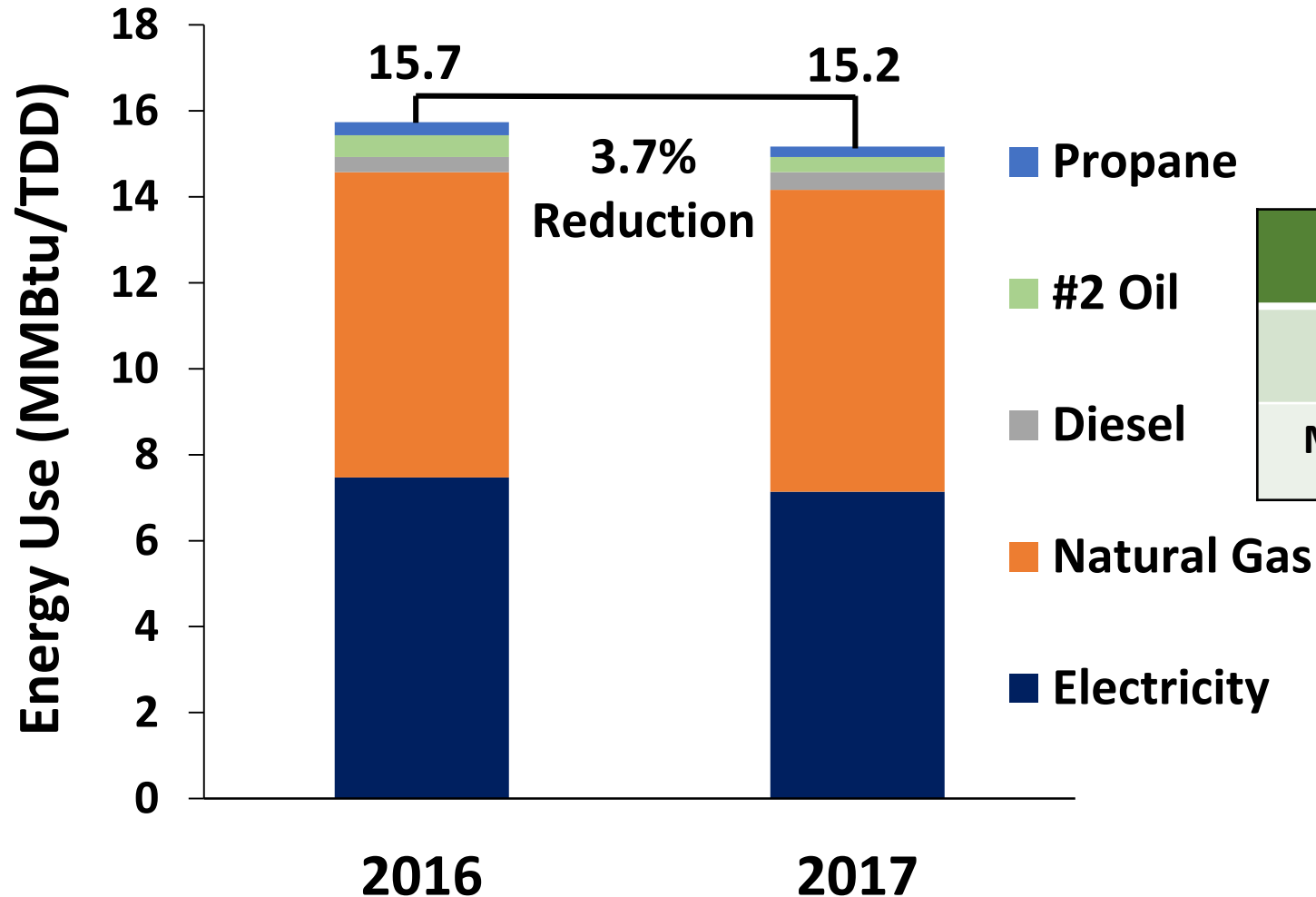
|                  | 2016 | 2017 | % Change |
|------------------|------|------|----------|
| HDD <sup>4</sup> | 5976 | 6147 | 3        |
| CDD <sup>4</sup> | 685  | 623  | -9       |
| TDD              | 6661 | 6770 | 2        |



| Cumulative Snow Fall (in) <sup>5</sup> |      |
|----------------------------------------|------|
| 2016                                   | 2017 |
| 54.1                                   | 70.1 |

**Figure 1.** Snowfall trends for Dover New Hampshire between 2016 and 2017.

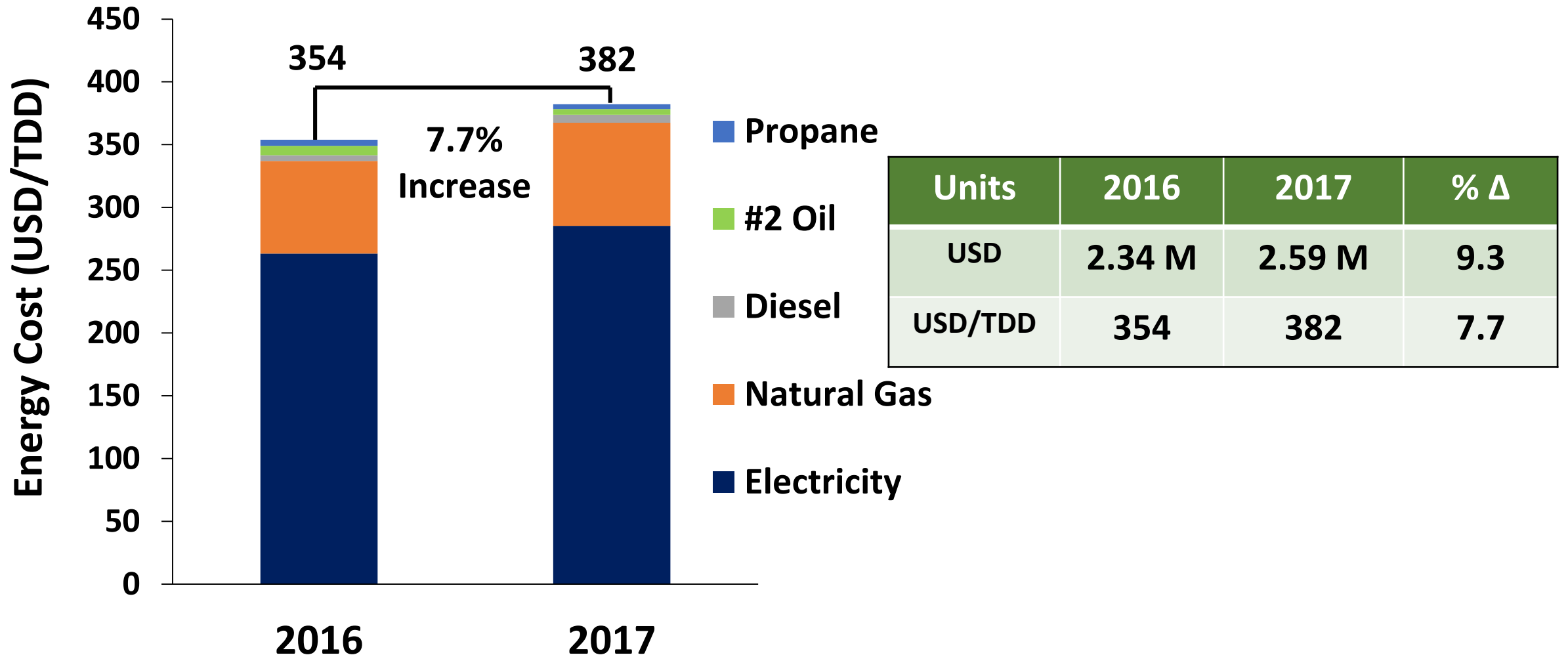
# Normalized Energy Usage



| Units     | 2016    | 2017    | % Δ  |
|-----------|---------|---------|------|
| MMBtu     | 104,800 | 102,670 | -2   |
| MMBtu/TDD | 15.7    | 15.2    | -3.7 |

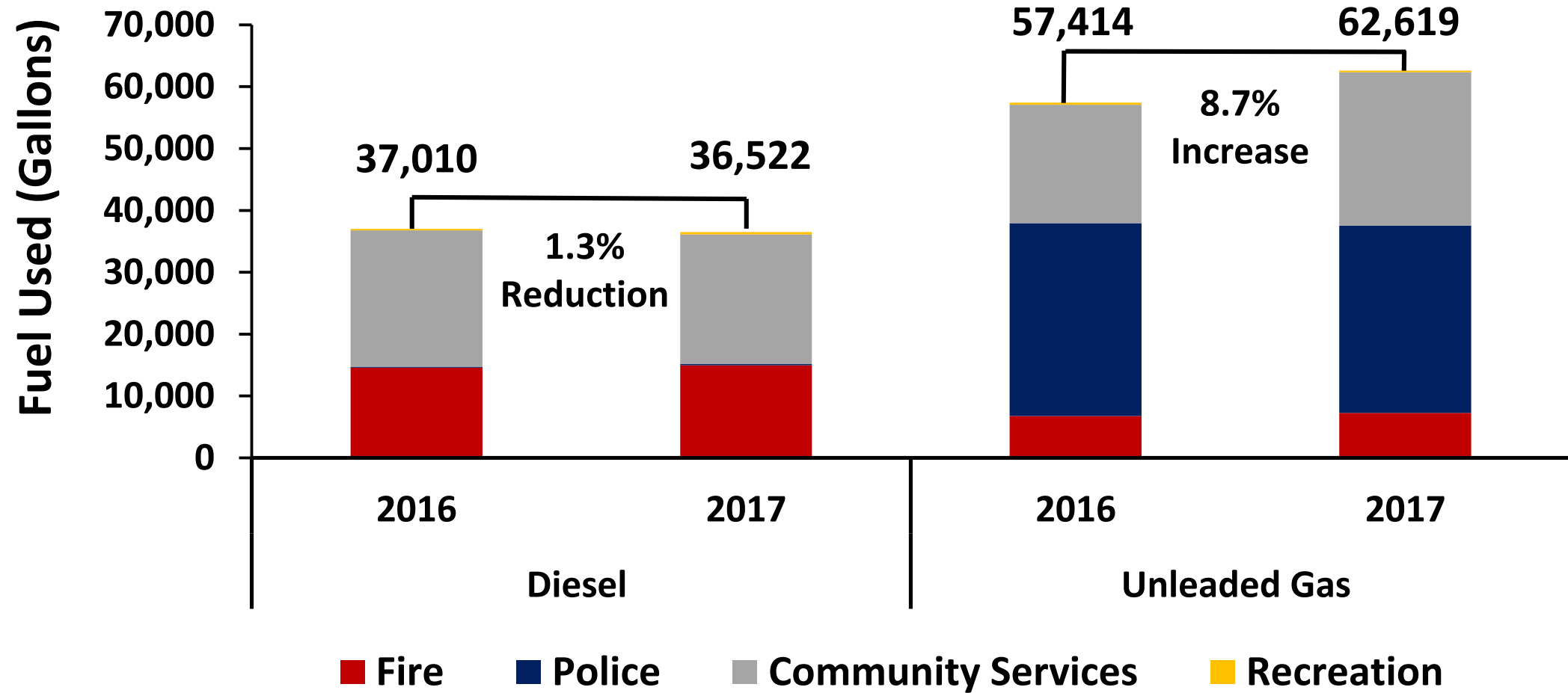
**Figure 2.** A comparison of Dover's normalized LGO energy use by source between 2016 and 2017.

# Normalized Energy Cost



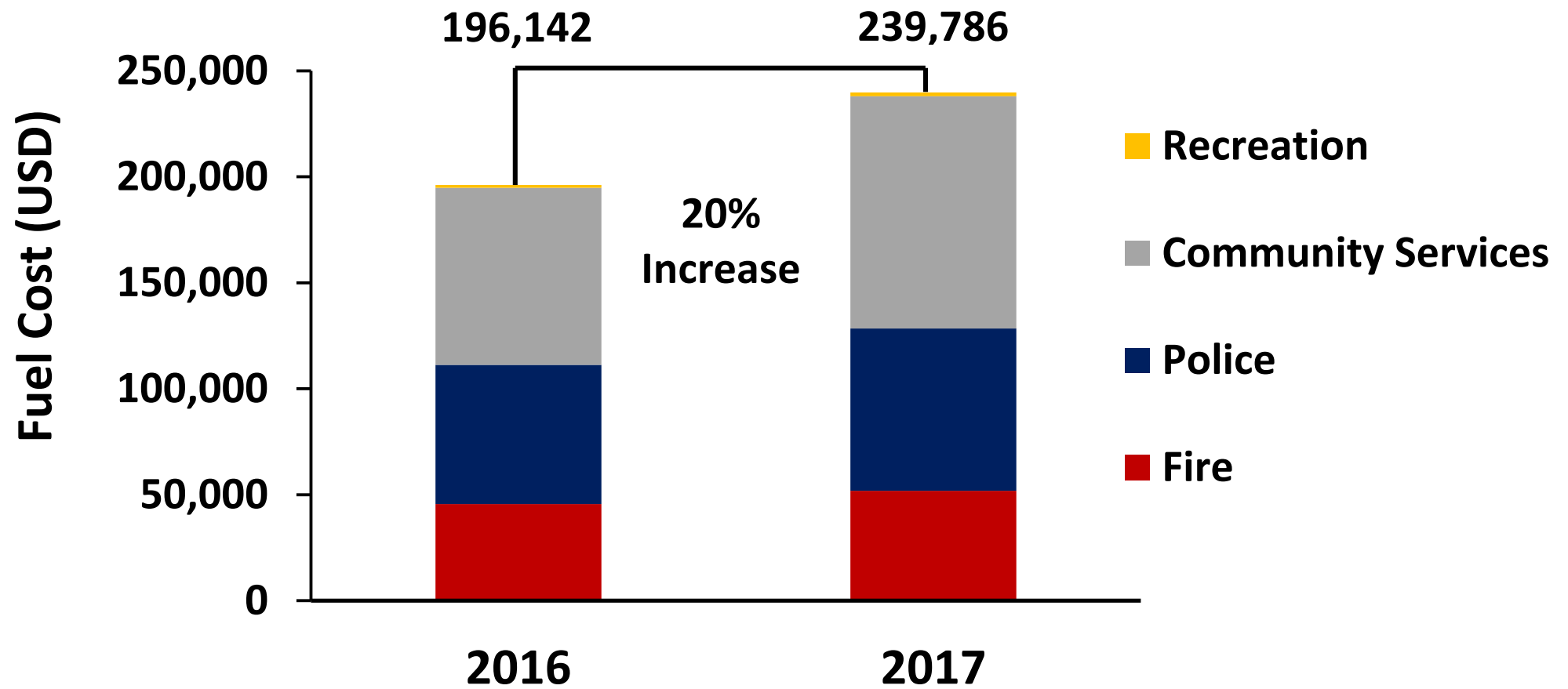
**Figure 3.** A comparison of Dover's normalized LGO energy cost by source between 2016 and 2017.

# Fleet Fuel Consumption



**Figure 4.** A comparison of Dover's LGO fleet fuel consumption between 2016 and 2017.

# Fleet Fuel Cost

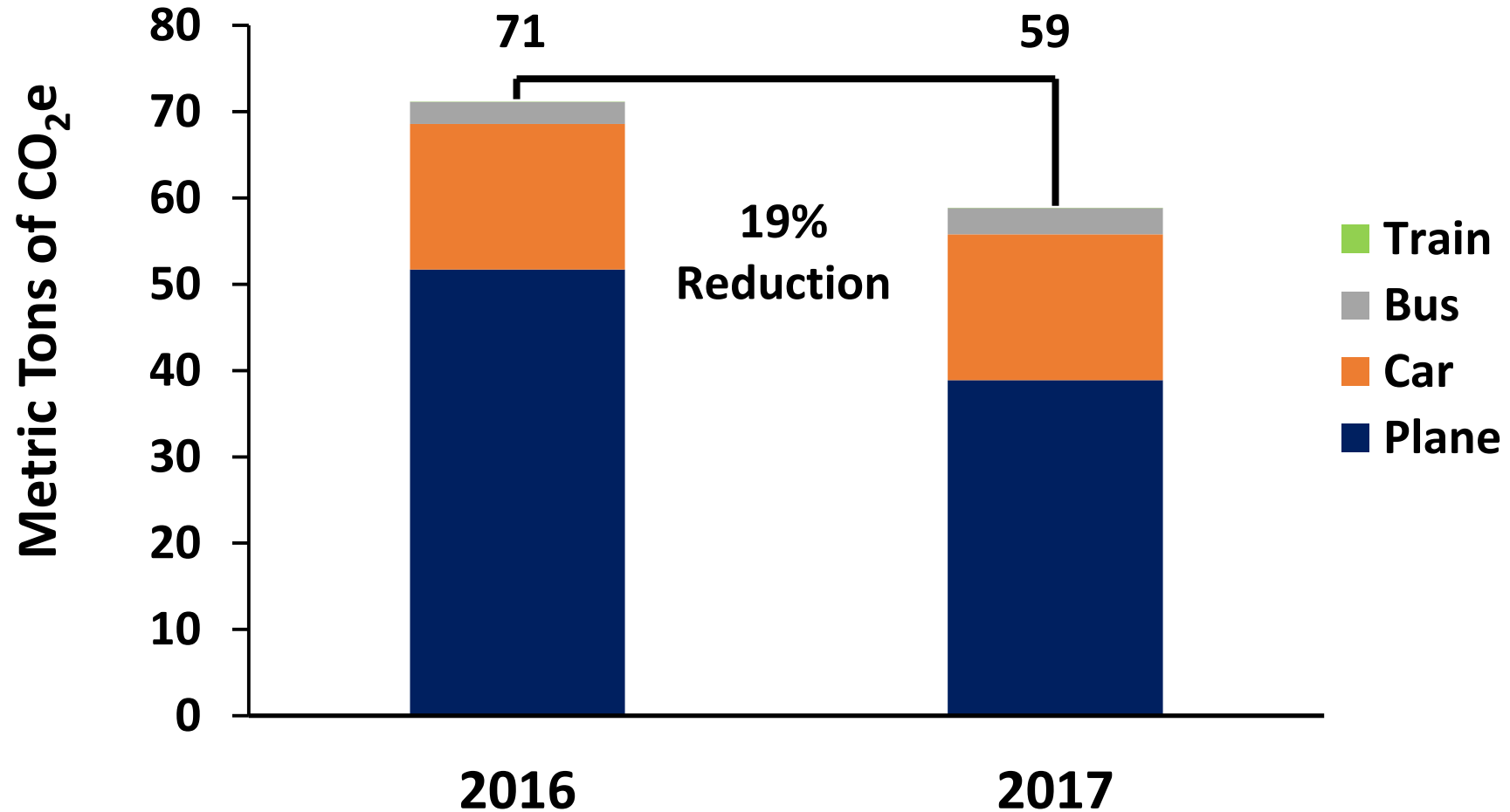


**Figure 5.** A comparison of Dover's LGO fleet fuel cost between 2016 and 2017.

# Employee Commuting

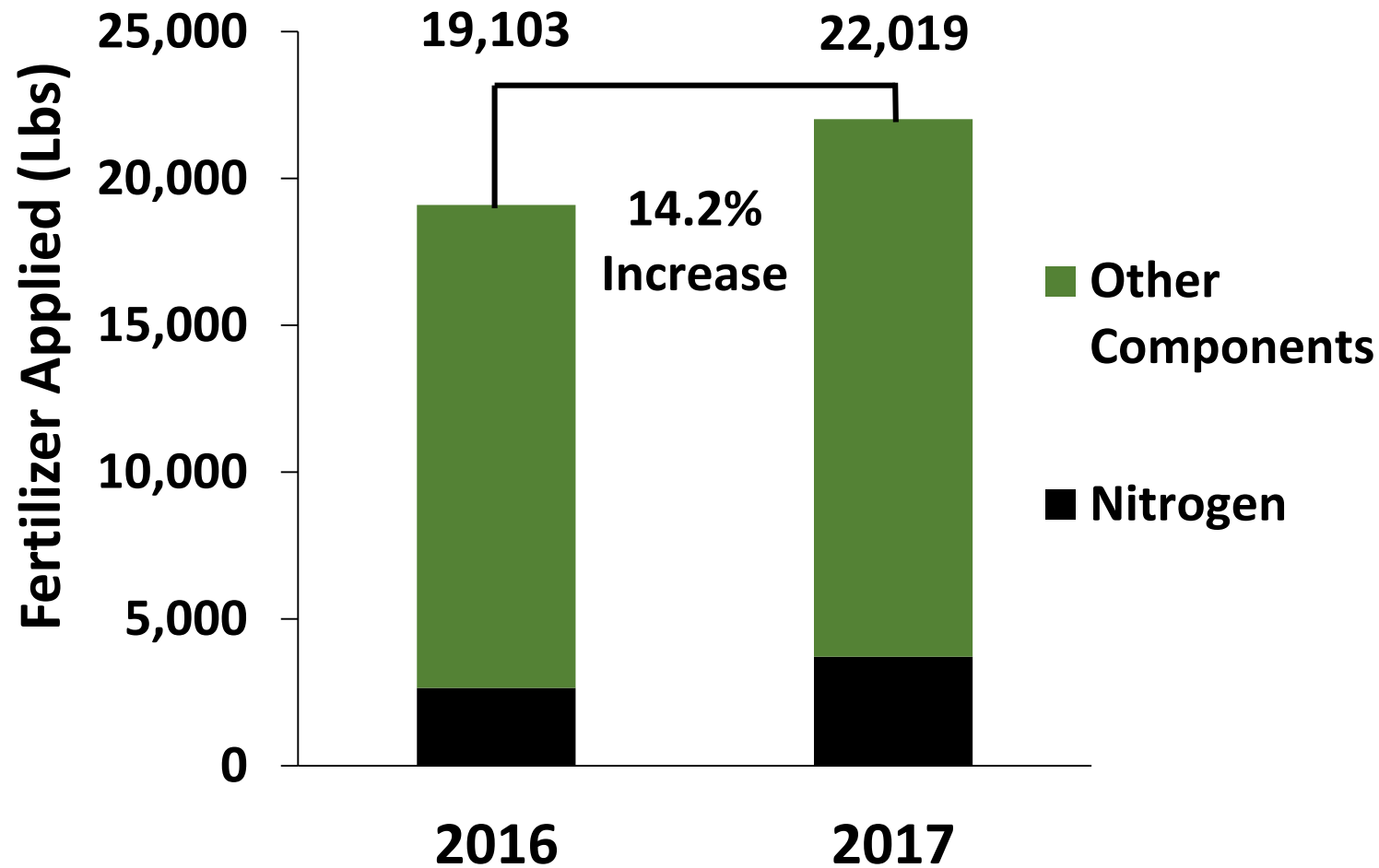
| Metric                              | Municipal Employees | School Employees | Percent Difference |
|-------------------------------------|---------------------|------------------|--------------------|
| Total One Way Miles                 | 2,229               | 5,640            | 8                  |
| No. of Car Commuters                | 230                 | 537              |                    |
| Avg. Miles / Trip                   | 9.7                 | 10.5             |                    |
| Total MTs of CO <sub>2</sub> e      | 407.2               | 1,028            | 8                  |
| MTs of CO <sub>2</sub> e / Commuter | 1.77                | 1.91             |                    |

# Employee Travel



**Figure 6.** A comparison of the GHG emissions emitted from municipal and school employee travel broken down by the mode of transportation.

# Fertilizer and Animals

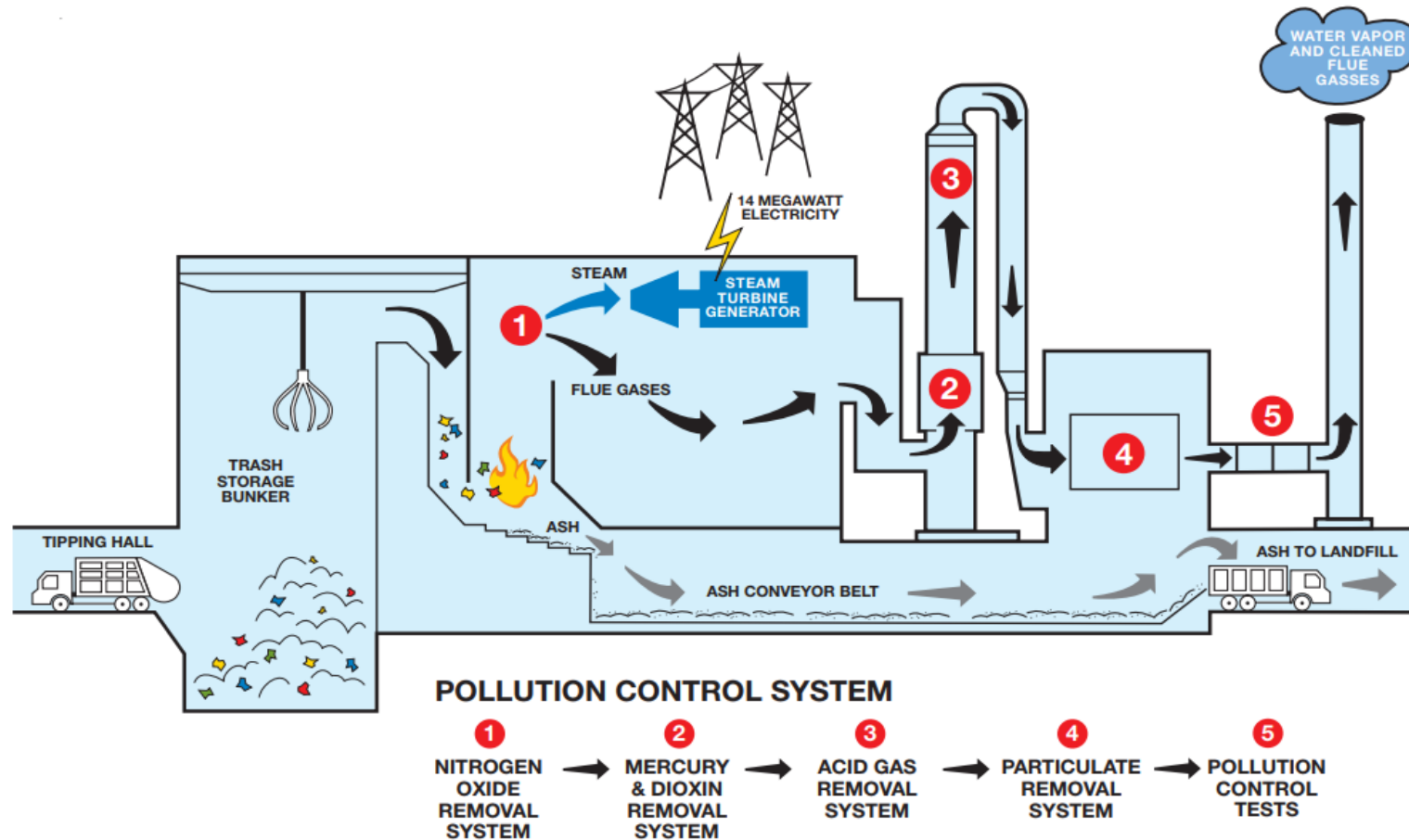


**Figure 6.** A comparison of the total quantity of nitrogen released via fertilizer applications between 2016 and 2017.

# Solid Waste

| Fill Scenario                      | Low       | Med       | High      | CO <sub>2</sub> e Reduction (MTs) |
|------------------------------------|-----------|-----------|-----------|-----------------------------------|
| Volume Filled (yrds <sup>3</sup> ) | 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 |                                   |

# Waste → Energy



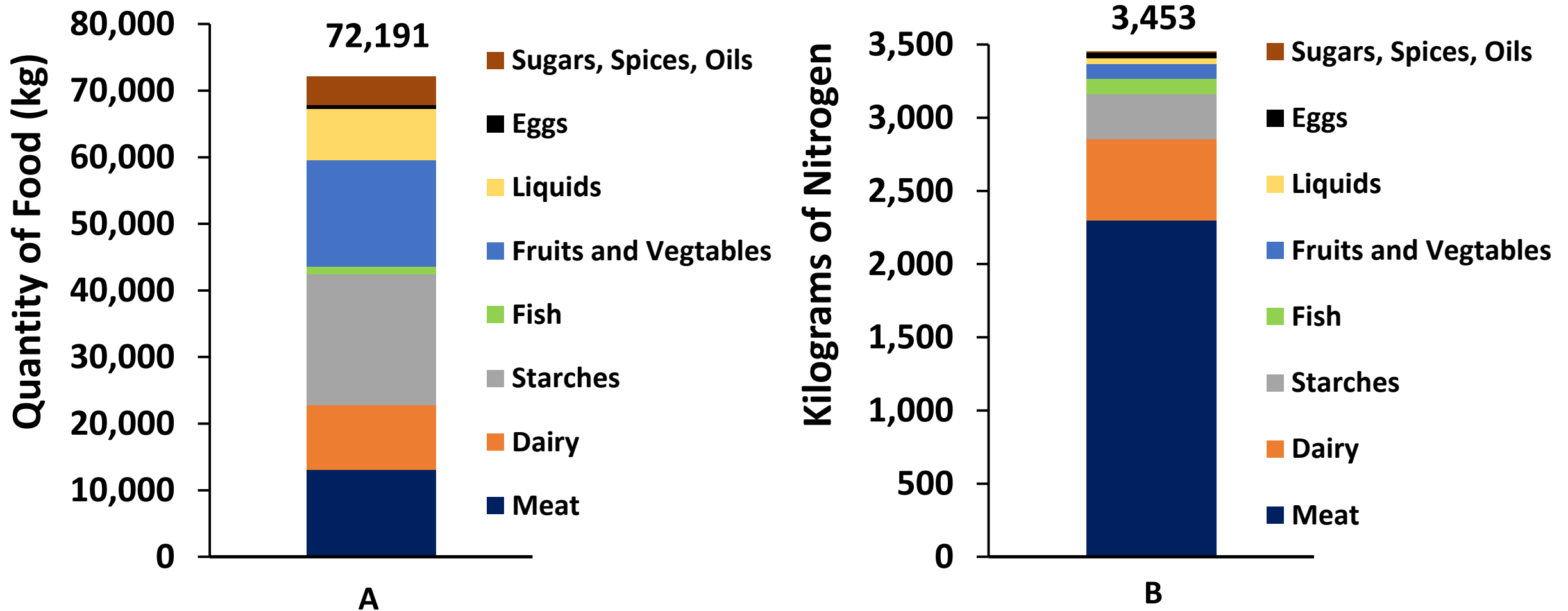
## Waste-to-Energy

- 90% reduction of trash volume
- Power generation
- Pollution control

# Paper

| Fill Scenario           | Low    | Med    | High   | GHG Emissions<br>(MTs CO <sub>2</sub> e) |
|-------------------------|--------|--------|--------|------------------------------------------|
| Volume Filled (gal)     | 480    | 720    | 960    | 97.6                                     |
| Weight Per Pickup (Lbs) | 907    | 1,361  | 1,814  |                                          |
| Annual Weight (Lbs)     | 47,174 | 70,762 | 94,349 |                                          |

# School Food

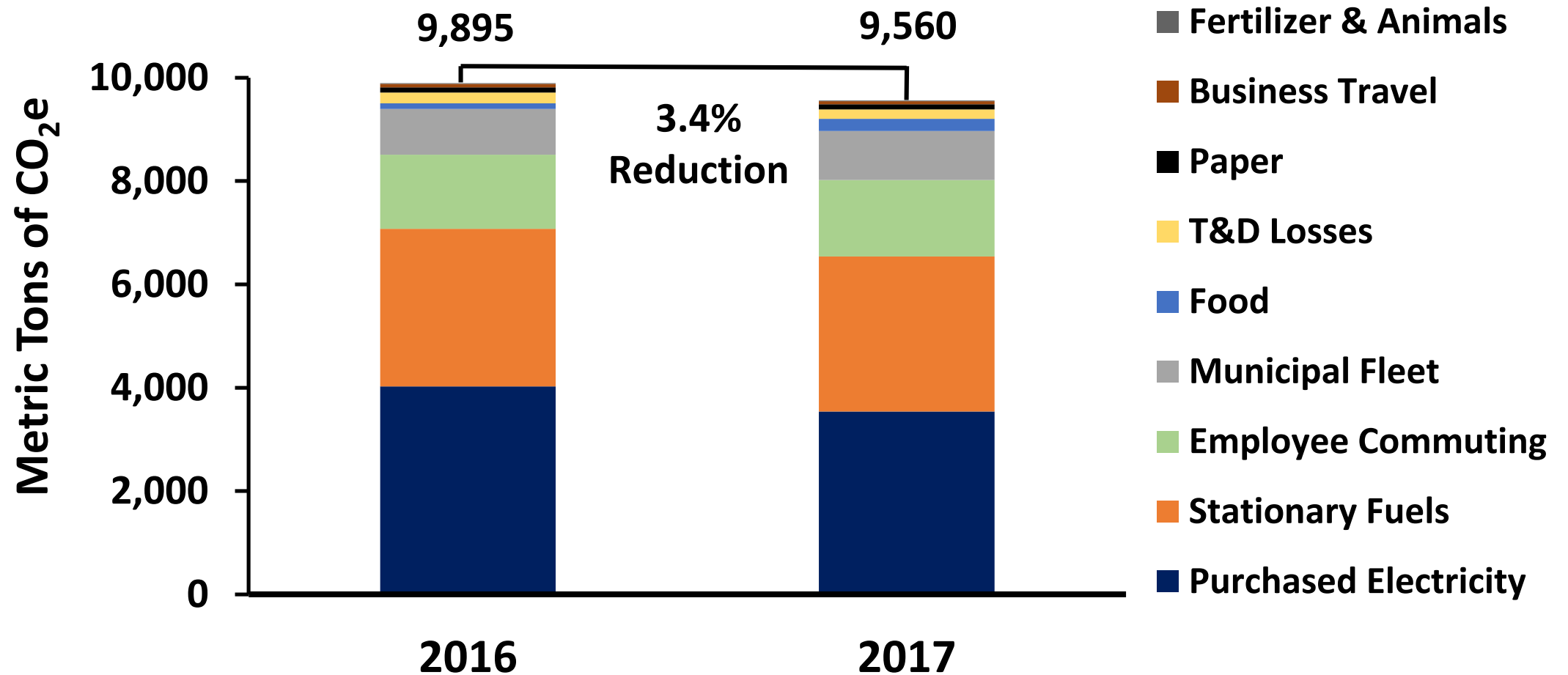


**Figure 7.** The quantity of food broken, broken up by category, delivered to the Dover schools in 2017 (A) and the nitrogen impact associated with those categories (B).

# Wastewater

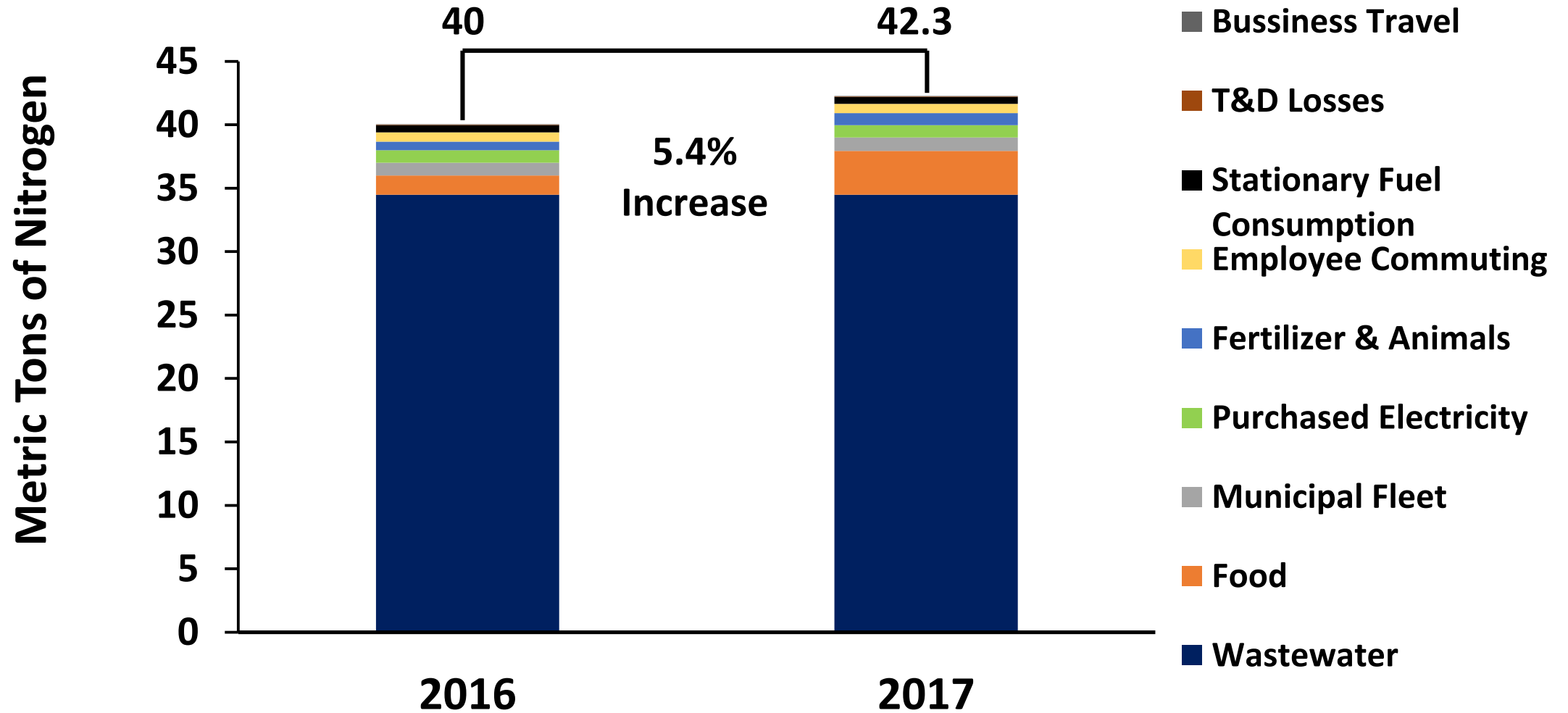
| Stream   | Nitrogen Content (mg/L) | Dover's Removal Efficiency | US National Average Removal Efficiency | Annual Nitrogen Released to the Environment (MTs) |
|----------|-------------------------|----------------------------|----------------------------------------|---------------------------------------------------|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

# Total Carbon Footprints



**Figure 8.** A comparison of the total carbon footprints for 2016 and 2017 as a result of Dover's LGO.

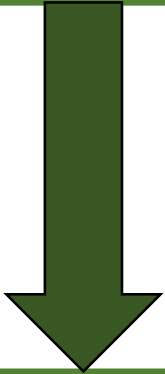
# Total Nitrogen Footprints



**Figure 9.** A comparison of the total nitrogen footprints for 2016 and 2017 as a result of Dover's LGO.

# Equivalencies

**11,260 acres of fully developed forest were required to sequester Dover's 2017 LGO GHG emissions <sup>6</sup>**



**11,260 acres of forest is equivalent to ~66% of Dover's total land area <sup>7</sup>**



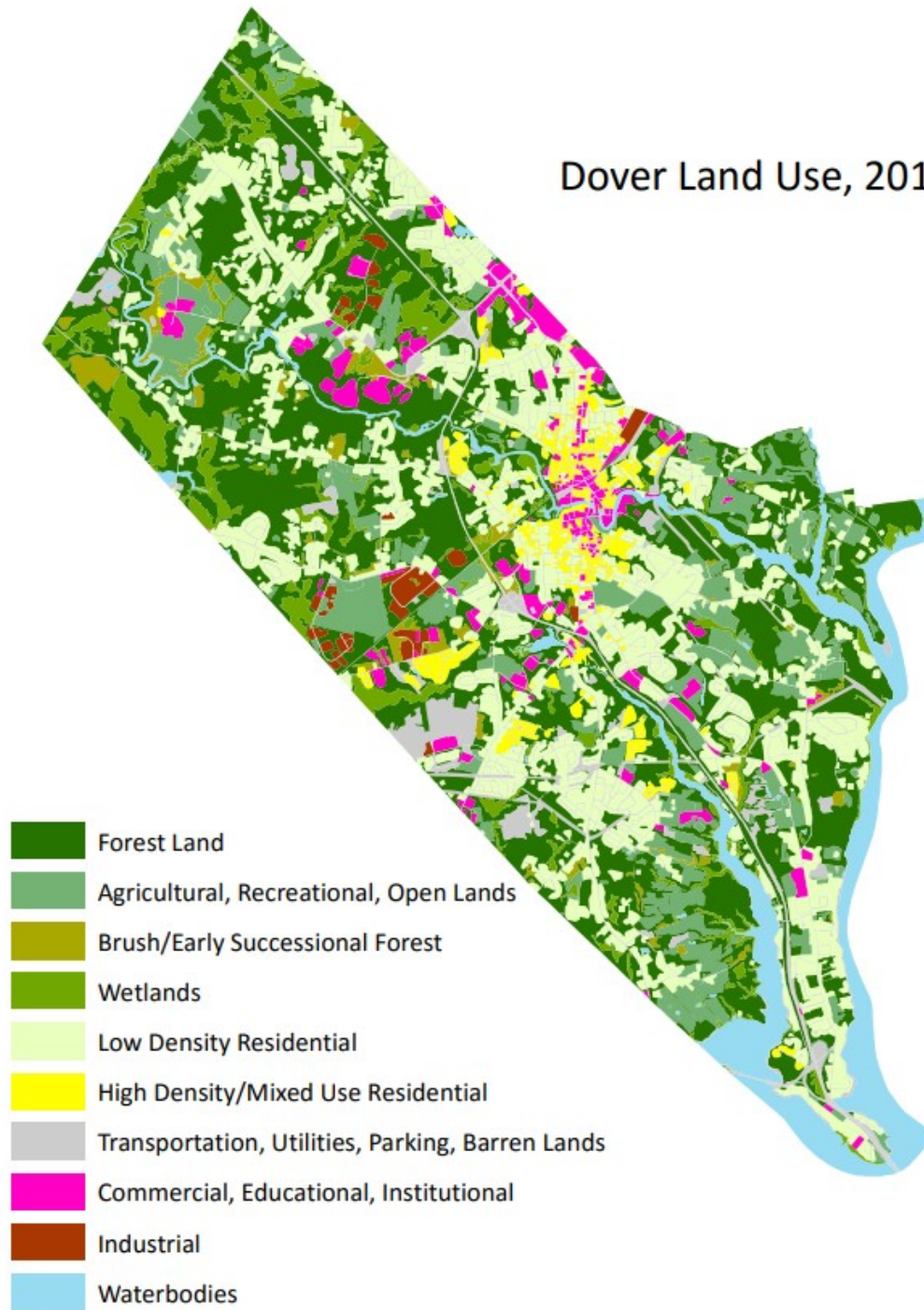
**The amount of nitrogen emitted by Dover's 2017 LGO equated to enough food to feed ~8,600 people for one year <sup>9</sup>**



**8,600 people = ~28% of Dover's population <sup>7</sup>**



## Dover Land Use, 2015



# Sites with Solar Potential

| Potential Site        | 2017 Usage (kWh) | Estimated Roof Mounted Production (kWh) | Estimated Ground Mounted Production (kWh) | % Usage Covered |
|-----------------------|------------------|-----------------------------------------|-------------------------------------------|-----------------|
| Ice Arena             | 1,438,000        | 268,667                                 | 1,912,644                                 | 150             |
| WWTP                  | 2,080,291        | 131,646                                 | 2,080,000                                 | 106             |
| Transportation Center | 49,360           | 1,091,200                               |                                           | 2,211           |
| Varney Brook          | 163,500          |                                         | 48,563                                    | 30              |

## Notes:

- Roof area estimates include areas for walkways
- Parking coverage includes output reduction associated with sloped carport panels
- Ground mounts assume 5 acres per MW of production
- Arrays may exceed the 1 MW cap if there are addition meters located on site or if an output inverter is utilized

# References

1. Time for Change. What is a carbon footprint – definition. <https://timeforchange.org/what-is-a-carbon-footprint-definition> (accessed June 15, 2018)
2. Galloway, J. N.; Winiwarter, W.; Leip, A.; Leach, A. M.; Bleeker, A.; Erismann, J. W.; Nitrogen footprints: past, present and future. *Environ. Res. Lett.* **2014**, 9.
3. Fong, W. K.; Sotos, M.; Doust, M.; Schultz, S.; Marques, A.; Deng-Beck, C.; *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*.
4. Weatherdatadepot. <https://www.weatherdatadepot.com/> (accessed August 1, 2018)
5. National Centers for Environmental Information. <https://www.ncdc.noaa.gov/cdo-web/datasets/GHCND/stations/GHCND:US1NHST0019/detail> (accessed July 23, 2018)
6. Greenhouse Gas Equivalencies Calculator. <https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator>. (accessed July 6, 2018)
7. Economic + Labor Market Information Bureau. <https://www.nhes.nh.gov/elmi/products/cp/profiles-htm/dover.htm> (accessed July 31, 2018)
8. Galloway, J. N. Department of Environmental Sciences, University of Virginia, Charlottesville, VA. Personal communication, August 2018.

