Pittsburgh 2013 Energy Baseline

Consumption, Trends & Opportunities

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ACRONYMS AND ABBREVIATIONS

Btu	British thermal units
CDD	Cooling Degree Day
CH_4	Methane
CHP	Combined heat and power
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DC-AMPS	Direct Current Architecture of Modern Power Systems
DOE	Department of Energy
EIA	Energy Information Administration
ESPA	Energy Sector Planning and Analysis
GHG	Greenhouse gas
HDD	Heating Degree Day
HVAC	Heating, Ventilation and Air Conditioning
ISO	Independent system operator
kW	Kilowatt
kWh	Kilowatt hour
LCA	Life cycle analysis
LPG	Liquefied petroleum gas
Mcf	Thousand cubic feet
MESA	Mission Execution and Strategic Analysis
mi^2	Square mile
MMBtu	Million British thermal units
MOU	Memorandum of Understanding
MW	Megawatt
MWh	Mega-watt hour (electric)
NETL	National Energy Technology Laboratory
NOAA	National Oceanic and Atmospheric Administration
PA	Pennsylvania
PADD	Petroleum Administration for Defense Districts
PJM	PJM Interconnection
RFC	Reliability First Corporation
SEDS	State Energy Data System
U.S.	United States
VMT	Vehicle miles traveled
WtW	Well-to-Wheels/Well-to-Wake
yr	Year
ZIP	Zone Improvement Plan
°C	Degrees Celsius
°F	Degrees Fahrenheit

EXECUTIVE SUMMARY

The United States (U.S.) Department of Energy (DOE) and the National Energy Technology Laboratory (NETL) are working in conjunction with the City of Pittsburgh (City) to transform how energy is produced, transported, and consumed in the City. This transformation will rely on 21st Century Energy Infrastructure designs, which leverage advanced technology and design techniques to modernize energy infrastructure, create new business models and markets, and expand technology research and development opportunities.

Achieving this vision will require developing solutions that are unique to the City: its climate, topography, energy needs, resources, and existing infrastructure.[a] In this way, the City will demonstrate what the American "City of the Future" looks like, with all its attendant environmental, economic, and job-creation benefits. It will also serve as a template for other cities seeking to reinvent their energy systems.

The first step in the process of transforming the energy landscape of a metropolitan area is understanding current usage patterns, e.g., how much energy is used by what sector, seasonal variations in usage, and what types of fuel types are used. Analyzing these metrics serves three purposes:

1. Establishing a baseline for consumption – and by extension, emissions – for comparative purposes in future analyses;
2. Allowing identification of major opportunities for emissions reductions and improved efficiencies; and
3. Enabling policy makers and investors to prioritize how limited resources are initially deployed.

Following this approach will foster the development of systems that meet the unique needs of a metropolitan area at the lowest cost, and with the greatest impact. Furthermore, implementing these solutions can serve as a proof of concepts that results in additional deployments in nearby locations.[b]

Analyzing the electricity and natural gas consumption data[c] for the City and the surrounding region found the following:

- The City consumed 59.6 trillion British thermal units (Btu) of natural gas and electricity in 2013.[d]
- Natural gas consumption dominates non-transportation energy use, with consumption just over double that of electricity. Most usage occurs during the cold weather months when gas is used to heat buildings.

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[a] While the identified and implemented solutions may be tailored to the City, the process of identifying and implementing these solutions will serve as a template for other cities. The "Pittsburgh model" will also likely have direct applicability to similar cities and towns in the region.

[b] These concepts are in line with DOE Regional Clean Energy Innovation Partnerships (RCEIPs) initiative, which recognizes that rather than a "one size fits all" approach, energy solutions will be developed to meet regional needs and priorities.

[c] This analysis focuses on natural gas and electricity usage, due to lack of data availability of petroleum consumption for the region. A qualitative consumption estimate of petroleum usage is reported in this study, but more work will be required in the future to better quantify this data.

[d] 2013 is the most recent year that energy consumption data was available for at the time this study was undertaken.

- Residential and commercial sectors utilize nearly equivalent amounts of energy (47 and 45 percent of total, non-transportation energy use, respectively). Industrial customers constitute the remaining 8 percent.
- Residential and commercial sectors have different energy use characteristics, representing different opportunities for energy savings and emissions reductions. For example, natural gas usage represents 80% of the energy consumed in the residential sector, while the commercial sector has a more even split between electricity and natural gas.
- Electricity usage dominate the greenhouse gas (GHG) emissions associated with non-transportation energy use in the City. This is true despite direct use of natural gas (primarily for space heating) being double that of electricity and the relatively low GHG emissions profile of the region's electricity mix.[e]
- Seasonal variations in natural gas usage are substantial, with consumption in peak winter months exceeding summer consumption by 9 to 11 times. While peak loads in electricity are less pronounced (only exceeding shoulder month usage by 1.3 to 1.5 times), a strong correlation of electricity load to hot weather exists, which may represent an opportunity.

In addition to the above findings, several regions within the City were identified as high energy usage areas. In some cases, these areas are contiguous, and constitute a significant portion of total usage. Some examples include:

- The contiguous neighborhoods of Downtown, the Strip, Oakland, Uptown, Herron Hill, and Schenley Heights consume the most energy in the City.
- Taken together, these neighborhoods constitute 35% of the City's electricity consumption, and approaching 50% of all commercial sector electricity consumption in the City.
- Thirty-two percent of all residential natural gas consumption is centralized in five Zone Improvement Plan (ZIP) codes (representing over 13 neighborhoods): 15235, 15221, 15217, 15210, and 15212.

These geographic areas represent opportunities for energy usage reduction. In some cases, action is already being taken through the development or updating of energy districts in these areas or initiatives such as Pittsburgh 2030 District, although an increased focus may be warranted.

Energy Consumption Breakdown

Exhibit ES-1 provides the breakdown of electricity and natural gas use by sector. In 2013, the City consumed 19.3 trillion Btu of electricity and 40.3 trillion million Btu (MMBtu) of natural gas through residential, commercial, and industrial consumption.

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[e] In 2013, the GHG emissions profile of the region's electricity mix was 1,294 pounds of carbon dioxide equivalents per megawatt-hour of electricity (1,294 lb CO_2e/MW_e), compared to a national emissions profile of 1,351 lb CO_2e/MW_e.

Natural gas usage constitutes over 80 percent of the energy use in the residential sector. Commercial energy usage is more equally divided between natural gas and electricity, while Industrial energy usage relies heavily on natural gas, although monthly consumption data points to this being less driven by home heating, and more by direct usage of gas in industrial processes.

A qualitative estimate of transportation fuel usage was also performed to determine the order of magnitude as compared to electricity and natural gas usage. By evaluating state-level consumption data, transportation fuels were estimated to be less than the amount of natural gas usage within the City, but above the direct electricity consumption figures. When including this estimate in the total energy usage figures, natural gas consumption was found to be 44 percent of total energy usage, transportation fuels were 35 percent, and electricity was 21 percent. Total energy required for electricity, however, is slightly greater than described here due to inefficiencies in electricity generation, as is discussed in detail in the report.

Consumption was also evaluated on a monthly level to better understand seasonal usage patterns and the magnitude of peak usage compared to baseline usage. As shown in Exhibit ES-2, electricity consumption was found to peak twice a year: first in the summer months when power is used for cooling, then in the winter months, presumably due to increases in space heating usage, shorter daylight hours (and associated increases in electricity for lighting, etc.), etc. Peak consumption months have loads that are 1.3 above usage in the shoulder months in the spring and fall.

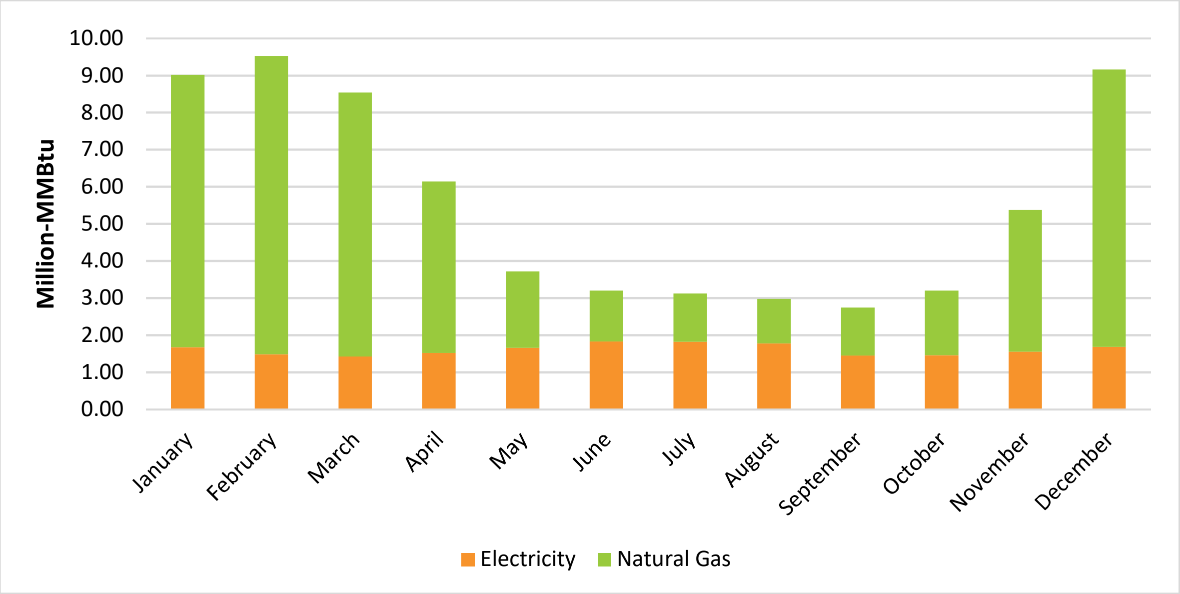
Natural gas consumption is greatest in the winter months when there is a large demand for space heating, and experiences much greater seasonal swings in consumption. These trends are described below.

The data was further demarcated to the ZIP-code level to highlight the regions of the city where electricity and natural gas consumption was highest, both on an annual level as well as during peak consumption months, for both residential and commercial consumption. Industrial consumption was both steady throughout the course of the year, and a minor

Exhibit ES-1 The City and surrounding ZIP codes 2013 energy consumption

Sector	Electricity (trillion Btu)	Natural Gas (trillion Btu)
Residential	5.1	22.9
Commercial	13.0	13.6
Industrial	1.1	3.7
Total	**19.3**	**40.3**
Total Energy Consumption	**59.6 trillion Btu**	
Total with Petroleum Estimate	*93.1 trillion Btu*	

Exhibit ES-2 the City's monthly combined consumption in 2013



contributor, relatively, to total consumption. Heat maps were developed to highlight the highest energy consumers for residential and commercial consumption of both electricity and natural gas for annual consumption, as well as for February and July, the peak natural gas and electricity utilization months, respectively.

Seasonal Natural Gas Usage

The City's relatively cool climate results in a seasonal energy consumption being related more to space heating than space cooling. Similarly, the relatively mild summer limits the amount of energy consumed for space cooling.[f] As a result, peak demand for electricity in the summer is not dramatically above that the base level of consumption in the shoulder months.

The seasonal demand for natural gas in the winter, however, is significant and is responsible for as much as 56 percent of annual natural gas demand, making space heating not only the largest end use for natural gas in the city, but the largest non-transportation use of energy in the city. This is particularly pronounced in the residential sector, where 68 percent of the sector's gas use is related to heating, and where peak gas usage can be 9 to almost 11 times higher in the coldest months of the year as compared to the summer base gas usage.

The commercial sector has less of seasonal dependency on gas, both in overall usage – 52 percent compared to 68 percent for the residential sector – and in terms of magnitude of peak usage. As to the latter, peak usage only increases by 5 to almost 7 times the summer base usage, compared to levels almost double that for the residential sector.

The increased peak usage for the residential over the commercial sector is explored further by examining monthly gas usage per heating degree day (HDD) in each sector. Residential gas

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[f] Space heating and space cooling reference the normal heating and cooling of buildings via Heating, Ventilation and Air Conditioning (HVAC) and other systems.

usage almost reaches 1,900 MMBtu per HDD in the coldest months, compared to 1,000 MMBtu/HDD for the commercial sector in the same month. Overall, residential consumers use substantially more natural gas – from 34 percent to almost 80 percent in cold months – for space heating than commercial customers.

Greenhouse Gas Emissions from Energy Consumption

Fossil energy sources such coal, natural gas, and transportation fuels produce GHG emissions when they are combusted.[g] GHG emissions also occur in the process of extracting, processing, or converting these fuels to electricity. Evaluating the entire life cycle of the energy source gives a more complete picture of the GHG emissions associated with the energy used, as well as insights into opportunities for emissions reductions.

Life cycle emissions from natural gas and electricity usage totaled 6.7 million tons of carbon dioxide equivalents (CO_2e) in 2013, with electricity usage being the largest source of emissions at 55 percent, particularly in the commercial sector (37 percent of total city GHG emissions). Natural gas usage in the residential sector was the second largest source of emissions, accounting for 26 percent of total emissions in the city. These emissions are primarily associated with space heating, which is likely to be associated with between 17 percent and 26 percent of total emissions when both the residential and commercial sectors are considered.

Transportation fuel emissions were estimated to be 3.4 million tons of CO_2e in 2013, midway between natural gas-related emissions (3.0 million tons CO_2e) and electricity-related emissions (3.7 million tons CO_2e). This number has a considerable amount of uncertainty, however, as a result of the uncertainty in the total consumption estimate. Therefore, while it can be concluded that qualitatively, emissions from transportation fuel consumption are of the same magnitude as either natural gas or electricity, the actual quantity of emissions should be considered an estimate. In the future, this uncertainty can be reduced by utilizing mileage reported to the Commonwealth of Pennsylvania as part of the annual vehicle registration process for the ZIP codes in question. That data was not available to the authors at the time this analysis was performed.[h]

Exhibit ES-3 GHG emissions by sector and fuel type

Fuel	Total	Residential	Commercial	Industrial	% of Emissions by Fuel
Gas	3.0	1.7	1.0	0.3	**45%**
Electric	3.7	1.0	2.5	0.2	**55%**
Total	**6.7**	**2.7**	**3.5**	**0.5**	
% of Total		**40%**	**52%**	**7%**	
Total Emissions Including Transportation Emissions				*10.2*	

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[g] As do non-fossil, carbonaceous fuels such as wood, ethanol, and other biomass types and biofuels.

[h] The Commonwealth of Pennsylvania requires vehicle owners to report the current odometer reading of their vehicle as part of the annual vehicle registration process. This data can be utilized to determine the total mileage traversed in a year, broken down by class and age of vehicle. By combining this data with average fuel efficiency data for different vehicle types, a more accurate estimate of transportation fuel consumption and GHG emissions can be calculated.

Exhibit ES-4 GHG emission fractions by sector, end use, and fuel type

Fuel	Residential	Commercial	Industrial
Gas %	26%	15%	4%
Electric %	15%	37%	3%
Heating Related	14% - 17%	3% - 8%	N\A
Total Heating Related	17% - 25%		

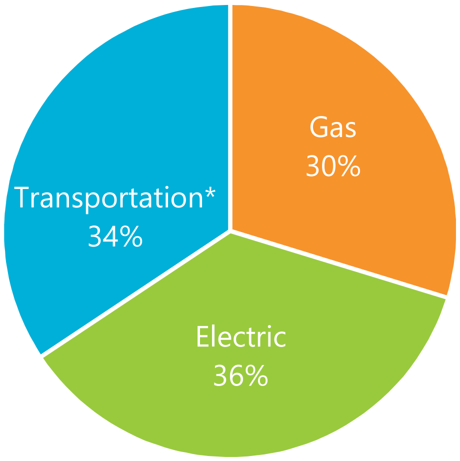
Opportunities for Energy Usage and Emissions Reductions

Three key opportunities for reduction in energy usage and/or GHG emissions can be discerned from the data presented above:

- Heating-related natural gas usage constitutes up to 56% of all natural gas usage in the City, 38% of all non-transportation energy usage, and up to 25% of the non-transportation-related GHG emissions in the City. The residential sector is of interest, as up to 68% of gas usage in that sector is heating-related, equating to an estimated 17% of total energy use for the City (not including transportation sector emissions).
- Commercial sector electricity usage constitutes 37% of total non-transportation energy usage in the City, and an estimated 25% of total overall energy usage.
- Transportation sector energy usage and GHG emissions have been estimated to be of a similar magnitude to electricity and natural gas-related energy usage and emissions. This estimate, however, has a considerable amount of uncertainty based on the lack of detailed data available for transportation fuel consumption.

The City has a robust energy innovation ecosystem, with numerous institutions focused on technology development, as well as a commercial sector that has shown a willingness to innovate and deploy new technologies. As such, action is already underway to address some of these opportunities, which are described in the body of the report.

Exhibit ES-5 GHG emissions breakdown by usage



* Transportation emissions are estimated should be considered only to be of this general order of magnitude.

The Role of Energy Districts

The City's focus on energy districts – or the "grid of microgrids" concept – is based on the increasing global recognition of the value that district scale energy systems can bring. Designing systems around the energy needs of a neighborhood or city allows developers to tailor make systems that take advantage of local resources, infrastructure, and other regional features. While these systems may require more up-front engineering, they can be made to be highly efficient and often more cost effective than traditional, off-the-shelf technologies.[i]

District-scale energy systems have several other notable benefits:

- Provide resiliency by ensuring localized energy generation.
- Higher utilization rates due to broader customer base: when one customer isn't using any energy, another customer may be.
- Single point of maintenance (compared to having to go into each commercial and residential building served by the system), streamlining maintenance, which requires only one system to be monitored for optimal operation.
- Increased upgrade and expansion options, as there is a reduced overhead of upgrading a single system, compared to many systems deployed in many buildings. An example would be Duquesne University, which has continued to upgrade its combined heat and power (CHP) system, integrating cooling systems, and thermal storage.
- Reduced costs due to economies of scale (compared to individual building-sized).
- Potentially broader range of systems available at larger scale.

It is the hope of the authors that this paper will inform potential developers as to the opportunities for future energy districts in the City by identifying hot-spots of energy usage and characterizing energy usage trends throughout the City. These districts will be heterogeneous, tailored to the energy footprint and needs of each district, yet many similarities are to be expected based on the dominance of seasonal impacts on energy usage.

The creation of multiple energy districts in the City seems likely to inspire cross-pollination of ideas and accelerate the technology evolution and maturation. In this way, the City can become a center for innovation not just in energy district and "eco-district" design, but also in the advanced energy technologies that will underpin those districts. Furthermore, the successful design and deployment of these districts will enable these designs to be replicated throughout the region.

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[i] District energy systems, particularly combined heat and power systems, offer efficiency and fuel savings benefits when compared to the alternative of implementing separate systems for a building's heating, onsite electricity generation, and in some cases, cooling. [1] [2] [3] [4] Furthermore, the implementation of a district-scale system can often balance perturbations in load or enable higher utilization rates. This enables more efficient operation, as transient and part-load operation causes less efficient operation in these types of energy systems (heating, cooling, electric generators). [5] [6] Cost savings compared to purchasing power from the electric grid and utilizing a building-scale heating and cooling unit, however, are dependent on local energy costs, as regions with extremely low electricity prices result in lower cost benefits associated with fuel savings, and therefore may not offset the cost of capital and operating expenditures compared to utilizing grid electricity.

1 INTRODUCTION

The United States (U.S.) Department of Energy (DOE) and the National Energy Technology Laboratory (NETL) are working in conjunction with the City of Pittsburgh (City) to transform how energy is produced, transported, and consumed in the City. This transformation will rely on 21st Century Energy Infrastructure designs, which leverage advanced technology and design techniques to modernize energy infrastructure, create new business models and markets, and expand technology research and development opportunities.

Achieving this vision will require developing solutions that are unique to the City: its climate, topography, energy needs, resources, and existing infrastructure.[j] In this way, the City will demonstrate what the American "City of the Future" looks like, with all its attendant environmental, economic, and job-creation benefits. It will also serve as a template for other cities seeking to reinvent their energy systems.

The first step in the process of transforming the energy landscape of a metropolitan area is understanding current usage patterns, e.g., how much energy is used by what sector, seasonal variations in usage, and what types of fuel types are used. Analyzing these metrics serves three purposes:

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Following this approach will foster the development of systems that meet the unique needs of a metropolitan area at the lowest cost, and with the greatest impact. Furthermore, implementing these solutions can serve as a proof of concepts that results in additional deployments in nearby locations.

These concepts are in line with an increasing global awareness—rather than a "one size fits all" approach, energy solutions will be developed to meet regional needs and priorities.

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[j] While the identified and implemented solutions may be tailored to the City, the process of identifying and implementing these solutions will serve as a template for other cities. In addition, the "Pittsburgh model" will likely have direct applicability to similar cities and towns in the region.

2 SCOPE AND METHODOLOGY

This study reports energy consumption within the City and adjacent boroughs on an annual and monthly basis. Consumption data was then evaluated to determine trends, identify opportunities for energy use reduction, and ascertain locations where local energy districts could provide heightened environmental performance and improved resiliency.[k] The life cycle greenhouse gas (GHG) emissions associated with City-wide energy use were then determined to assess the climate impacts of City-wide energy use.

2.1 SCOPE

The goal of this study was to evaluate energy usage and trends within the City. An area slightly greater than the geographical boundaries of the City was evaluated due to limitations in data granularity, resulting in several surrounding boroughs also being evaluated.[l] This had the side effect of a greater population being assessed: approximately 578,000 compared to the City population of just over 300,000.

Three types of energy consumption were evaluated based on data availability: natural gas, electricity, and petroleum. Other fuel types, such as wood, biomass, biogas, or distributed generation (e.g., rooftop solar or wind energy) were not captured, but are expected to be relatively small within the boundaries of the City.[m]

A "GRID OF MICRO-GRIDS"

Pittsburgh has several district energy systems in which a central facility generates steam, hot water, and/or chilled water that is then piped to residential or commercial consumers, just as a utility would provide water or natural gas. These "energy districts" are currently independent, run by different entities, and have different characteristics.

The City of Pittsburgh envisions the development of additional energy districts, in which neighborhood-sized systems provide energy services to local customers, but can also be connected to other districts. This "grid of micro-grids" will improve resiliency through the ability to island itself in times of need, but also reduce overall cost through shared services when connected to other districts.

Several such districts have already been proposed, and each is distinct in design. They range from a campus micro-grid powered by a micro-turbine and renewable generation to a solar array combined with a geothermal heating loop for a large mixed-use building.

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[k] An "energy district" is defined here as an area within a City – such as a neighborhood or city block – where energy services are shared. The "energy district" of the 21st Century can take many forms, from the traditional combined heat and power (CHP) system providing district heating, cooling, and electricity, to a micro-grid that has integrated renewable energy electricity generation and battery storage.

[l] This is due to ZIP code boundaries the data was provided in do not exactly match the city boundaries.

[m] Distributed generation sources are predominantly consumed directly at the point of generation, which effectively "hides" energy consumption at that location (i.e., actual consumption at the home is higher than what is reported by the utility meter). However, even mature distributed

2.2 DATA

Natural gas and electricity consumption data were gleaned from data provided by the gas and electric utility companies, while petroleum consumption was estimated utilizing state-level data reported by the U.S. DOE's Energy Information Administration (EIA).

Data provided by the utilities was collated by location to the ZIP code level, which was then summed to provide a City-wide assessment. Monthly data was available for electricity usage and a portion of the City's gas usage, whereas two gas utilities only provided gas usage on an annual level. All data was delineated by sector: residential, commercial, and industrial.

2.2.1 Natural Gas

Data for natural gas consumption was provided by the local utility companies – Peoples Gas, Equitable Gas (now Peoples Gas), and Columbia Gas – for 2013, at ZIP code level.[n] Because several of the ZIP codes do not align directly with the boundaries of the City, several surrounding boroughs were included in the dataset, resulting in an area slightly larger than the city limits being evaluated.

Two of the natural gas utilities – Peoples Gas and Columbia Gas – provided consumption data on an annual level, while Equitable Gas (Equitable) provided a monthly consumption breakdown.

The desire to analyze monthly consumption trends, coupled with the absence of a full dataset for monthly consumption made it necessary to scale up the monthly data from Equitable Gas to achieve a usable estimate of City-wide natural gas consumption. This was achieved by examining the sector-level monthly natural gas consumption, provided by Equitable, and dividing it by the fraction that the Equitable data constituted of the total, City-wide gas consumption for that sector. For example, if Equitable gas sales constituted 70 percent of total gas sales in the industrial sector, the monthly industrial sector data would be divided by 0.7 to determine estimated City-wide gas consumption for the industrial sector in that month. The sector-wide consumption breakdowns are shown in Exhibit 2-1.

This methodology is an approximation for monthly gas utilization, as Equitable Gas sales constituted 55 percent of total gas consumption in the City: 49 percent of residential, 61 percent of commercial, and 70 percent of industrial. However, City-wide consumption data is an obvious next step for improving this study, particularly as less than half of the residential consumption (the sector that consumes the most gas in the City) is associated with Equitable sales.

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generation sources compose a small – albeit growing – fraction of total generation. For example, on a national level, distributed solar energy composed less than 0.2 percent of the electricity produced in 2014 (the first year the metric was reported), and 0.09 percent of Pennsylvania's energy generation. Wind composed a greater portion of Pennsylvania's electricity generation, but is predominantly generated at utility-scale generators. While it is possible that wood or other waste fuels could be used in measurable amounts within the City (presumably for home heating), these are still expected to constitute a tiny fraction of total consumption.**Invalid source specified.**

[n] Not all information was available for each ZIP code. This is due in part due to certain ZIP codes being associated with post office boxes or specific institutions (e.g., the University of Pittsburgh is ZIP codes 15261 and 15260, the latter of which it shares with Carnegie Mellon University).

A final note on the natural gas consumption data is that one data point in the Equitable dataset appeared to be an anomaly, and was consequently normalized prior to the analysis.[o]

Detailed natural gas consumption data can be found in Appendix A, broken down by ZIP code and sector.

Exhibit 2-1 Equitable Gas sales as a fraction of total sales in 2013

Sector	Equitable Gas (MMBtu)	Total Gas Sales (MMBtu)	% of Total Sales
Residential	11,164,541	22,920,822	49%
Commercial	8,339,220	13,623,366	61%
Industrial	2,600,469	3,732,323	70%
Total	**22,104,231**	**40,276,512**	**55%**

2.2.2 Electricity

Monthly data for electricity consumption was provided by the local electric utility, Duquesne Light Company, for 2013, at ZIP code level.[p] Because several ZIP codes do not align directly with the boundaries of the City, several surrounding boroughs were included in the dataset, resulting in an area slightly larger than the city limits being evaluated. Detailed electricity consumption data can be found in Appendix A, broken down by ZIP code and sector.

2.2.3 Petroleum Estimate

Petroleum consumption data for smaller geographical regions are difficult accurately estimate due to lack of data granularity (gas stations have many users, compared to utility meters for each customer) and the mobility of users.[q]

No petroleum consumption data was available for the City at either the City-wide or ZIP code level. State-level data is available from the EIA, however, and the expected magnitude of petroleum consumption was significant enough to warrant an assessment. Therefore, petroleum consumption was estimated from state-level EIA consumption data using a methodology similar to that used in the Power of 32 energy baseline report and described below in the Section 2.3.1.

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[o] Specifically, the January commercial gas consumption in Homestead (15120) was reported to be 7,153,800 MMBtu. Comparing this to figures in Exhibit 2-1, it is apparent that this consumption level is almost twice the annual industrial consumption for the entire City, and half of the annual commercial sector consumption for the City. For an additional point of comparison, the commercial sector gas consumption for the adjacent months of December and February was approximately 33,000 MMBtu, or 0.4 percent of the reported January commercial sector consumption. These adjacent months had a similar number of heating degree days (HDDs): 953 for December and 1016 for February compared to 1036 for January.

The data point was normalized to a value of 33,950 MMBtu (a reduction of over 7 million MMBtu) by taking the average gas consumption per HDD per customer for the adjacent months of December and February, then multiplying it by the number of HDD and customers in January. The inclusion of the number of customers in the metric was dictated by the fact that the number of customers for a ZIP code can vary from month to month, as it did in this ZIP code.

[p] Not all information was available for each ZIP code. This is due in part due to certain ZIP codes being associated with post office boxes or specific institutions (e.g., the University of Pittsburgh is ZIP codes 15261 and 15260, the latter of which it shares with Carnegie Mellon University).

[q] For an example of the latter, an individual may commute each day to the City, often filling up within the City. This could skew consumption data, perhaps by a statistically significant amount.

2.3 METHODOLOGY

This section describes the methodology utilized to estimate petroleum consumption at a City-wide level, calculate metrics for specific energy consumption (e.g., natural gas usage per heating degree day), and assess the life cycle GHG emissions associated with energy use and production in the City.

2.3.1 Petroleum Consumption Estimate

Petroleum consumption for the City and surrounding boroughs was estimated using vehicle miles traveled (VMT) and transportation energy consumption data from the EIA's State Energy Data System (SEDS). [7] This data was scaled based on the City's population (as compared to Pennsylvania's) and a DOE heuristic for calculating urban versus rural VMT for a given state. [8] [9] This methodology is similar to that used to estimate energy consumption in a recent Power of 32 report, except for the VMT calculation.[r] [10]

Future analyses are likely to utilize odometer readings reported to the Commonwealth of Pennsylvania as part of the annual vehicle registration process. By combining the annual miles traveled by class and age of vehicle with average fuel efficiency data for different vehicle types, a more accurate estimate of transportation fuel consumption and associated GHG emissions can be determined. Detailed mileage data from the Commonwealth, however, was not available to the authors at the time this analysis was performed.

Petroleum consumption metrics and a more detailed discussion of the estimation calculations can be found in Section 3.5 of this report.

2.3.2 Neighborhood Specific Metrics

ZIP code metrics such as population, ZIP code land area, ZIP code water area, and neighborhood names were compiled from several sources to identify areas of high energy usage that might be candidates for early energy district deployments. This was done by calculating usage metrics such as "energy usage per capita" and "energy usage per square mile," which were then evaluated further to identify potential hot spots and to create an energy baseline from which future energy consumption data may be compared.

ZIP code-related metrics are reported in Appendix A, and the resulting energy consumption metrics are reported in Section 5 of the report.

2.3.3 Weather Related Energy Usage

Statistically significant amounts of residential and commercial energy usage are related to heating and cooling buildings (space heating and space cooling). This can result in seasonal energy usage trends, and these trends, in turn, are important to understand when developing energy systems whose performance is optimized for that regional climate.

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[r] The VMT calculation is appropriate in this analysis given that City is the definition of an urban area, whereas it may not be appropriate for the Power of 32, in which it may be more difficult to determine the portion of urban versus rural population.

Monthly natural gas and electricity usage data for the City was first evaluated qualitatively to identify easily apparent usage trends, such as high natural gas usage in winter months (space heating needs) or increased electricity usage in either the summer (space cooling) or winter (space heating or other increased usage drivers). Metrics such as increased usage multiplier over base/shoulder month usage, usage per customer per heating degree day (HDD) or cooling degree day (CDD), and amount of total energy utilized for heating or cooling were then quantified to identify opportunities for energy use and emissions reduction opportunities.

Weather-related energy usage results are reported both in Section 3 and Section 4 of this report. The historic HDD and CDD data used in these calculations can be found in Appendix B, which contains the last 15 years of data for the City. This data was compiled from National Oceanic and Atmospheric Administration (NOAA) data logged at the Pittsburgh International Airport. [11]

2.3.4 Greenhouse Gas Emission Life Cycle Analysis

A life cycle analysis (LCA) was performed as part of this study to better understand the relative climate impacts associated with energy use in the City. This type of analysis examines emissions and impacts throughout the whole life cycle of energy use, starting with the extraction of the resource through its conversion to electricity or combustion. In this way, important issues such as methane leakage during natural gas or oil production, energy used to transport coal, and energy losses during transmission are accounted for.

2.3.4.1 *Electricity*

GHG emissions associated with electricity usage were determined using NETL's Grid Mix Explorer tool in conjunction with the regional electricity generation mix for the City. [12] As the system boundary selected in defining the generation mix used can have a

ELECTRICITY GENERATION MIX

The way electricity is generated in the United States varies greatly by region: from the massive wind farms in Texas, to the hydro-electric power in the Pacific Northwest, and the coal plants in the Ohio River Valley Basin.

Consequently, the electricity consumers receive at home varies widely by the region of the country.

The electricity generation mix or "grid mix" describes how electricity comes from each type of generator in a region.

SPACE HEATING

The terms "space heating" and "space cooling" (used throughout this document) refer to the energy associated with heating or cooling a building. This includes everything from traditional heating, ventilation, and cooling (HVAC) systems, such as central heating and air-conditioning systems, to the electric space heater used in a residential home.

significant impact on the results, it is recommended that a range of emissions factors be reported. [13] Based on recommendations in the literature and from other noted experts, both sub-regional and regional electricity mixes were utilized for this assessment. [14] The western portion of the Reliability First Corporation (RFC), known as RFC-W, was chosen as a representative sub-regional mix. For a regional mix, the PJM Interconnection (PJM) – the Independent System Operator (ISO) territory which the City falls within – was selected as representative. United States national average values were also evaluated to provide a third data point.

A 2013 base year – consistent with the consumption data reporting year – was utilized, although a sensitivity analysis was performed using the grid mix of PJM in 2015, in recognition that changes in the mix have occurred over that time.

2.3.4.2 Natural Gas

The GHG emissions associated with natural gas consumption were calculated from the emissions during the production and delivery of gas to the customer (upstream emissions), combined with the emissions associated with the combustion of natural gas (end use emissions).[s]

Upstream emissions were based on data published by NETL for gas produced in Appalachia. [9] Sensitivity analyses were performed using the national average for upstream emissions in the United States, as well as the emissions level for gas produced at new wells in Appalachia, which comply with recently enacted regulations.

2.3.4.3 Transportation

Transportation sector fuel usage is the most complex to assess and has the most uncertainty (as it is estimated from state-level data (as described above in Section 2.3.1)). The complexity is based on the wide-range of fuels consumed within the Commonwealth, nine in total, and uncertainty associated with the emissions profiles of some of the fuels.

GHG emission profiles were available for the fuels that were estimated to constitute 98 percent of total consumption: gasoline, diesel fuel, and jet fuel. The Well-to-Wheels (WtW) GHG profiles for gasoline, diesel fuel and jet fuel[t] were provided by NETL's Systems Engineering and Analysis organization. [9] Emissions for two fuels – natural gas and electricity – were omitted from the transportation sector emissions calculations, as they were assumed to have been captured in the calculations for those fuels in the relevant sector-level calculations (i.e., natural gas or electricity).

Unfortunately, an emissions profile was not available in the case of the remaining fuel types of transportation sector fuel use. These situations warranted the use of a proxy value from a similar fuel type, to provide a placeholder value until a more detailed assessment can be

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[s] The primary use of natural gas is for combustion, either for heat or other useful energy. Alternative outcomes for the gas, i.e., leakage or conversion into other products within industrial or other processes, are thought to be small in comparison.

[t] It is anticipated that no jet fuel was consumed in the City, given that the Pittsburgh International Airport does not lie within the study area. Nonetheless, this value was kept for consistency with data sources cited.

performed. Proxy values for aviation gasoline and residual fuel oil were based on motor gasoline and diesel fuel, as those fuels have very similar properties.

In the case of liquefied petroleum gas (LPG) and lubricants, estimates for combustion emissions were available, but upstream emissions were not. The methodology used in these cases was that upstream emissions were estimated based on the refined fuel – gasoline, diesel, or jet – whose path through the refinery was thought to be most like that fuel, and these were added to the combustion emissions value. These fuels and how their proxy values were calculated are listed in Exhibit 2-2.

These fuels constituted 1.6 percent of the energy consumption in the sector and the use of proxy values is not expected to impact the findings of the report, particularly given the level of certainty associated with the petroleum consumption estimate (as described above in Section 2.3.1).

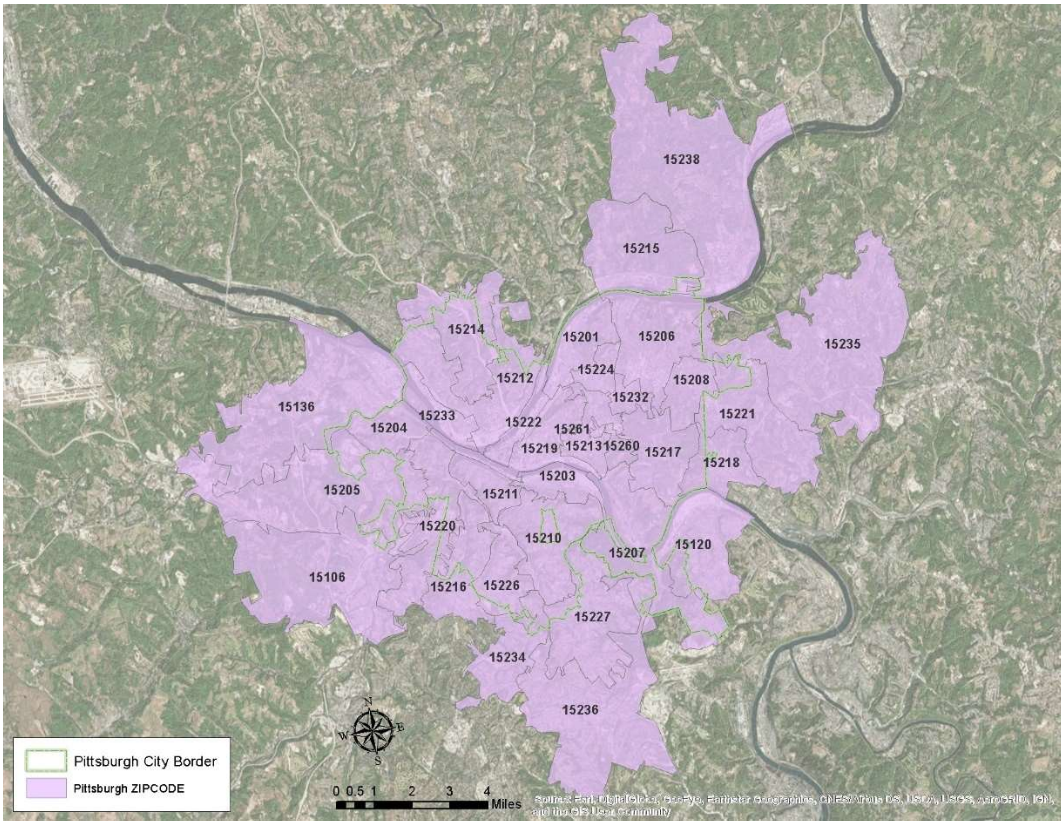
Exhibit 2-2 Secondary transportation fuels as a fraction of total sales in 2013

Fuel	% of Total Transportation Energy	Description
Aviation Gasoline	0.06%	Assumed to be identical to motor gasoline.
LPG	0.17%	Assumed to have gone through similar refinery units as gasoline, but has its own combustion profile.
Lubricants	0.66%	Assumed to have gone through similar refinery units as diesel, and used a light oil combustion profile.
Residual Fuel Oil	0.69%	Assumed to be similar to diesel, but heavier and less refined. Value equivalent to 10% above diesel.
Total	**1.58%**	

3 PITTSBURGH ENERGY CONSUMPTION PROFILE

This study evaluated the energy usage in the City, home to roughly 300,000 residents, and several surrounding boroughs. The study area, shown in Exhibit 3-1, encompasses approximately 165 square miles and a population of 578,000 people. [15] Of that area, approximately 96 percent is land (161 mi^2). The city has its electricity provided by Duquesne Light and natural gas utilities provided by Equitable Gas, Peoples Gas, and Columbia Natural Gas, as well as a few other minor providers. In Exhibit 3-1, the City is defined within the green border, while the ZIP codes included in the analysis are shown in purple.

Exhibit 3-1 The City and surrounding ZIP codes



The City's energy consumption in 2013 is described in Exhibit 3-2. As shown, the City and the surrounding region consumed over 19 million-million British Thermal Units (million-MMBtu) of electricity; and just over 2 times that amount (over 40 million-MMBtu) of natural gas (Exhibit 3-2).[u] The dominance of natural gas usage is the result of substantial seasonal consumption of gas for home heating purposes.

The residential and commercial sectors were the responsible for almost 92 percent of total consumption in the City, or 54.8 million-MMBtu, and the energy consumption by those two sectors was nearly equivalent (28 million-MMBtu and almost 27 million-MMBtu, respectively), with consumption in the industrial sector constituting the balance. The type of energy

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[u] 19 million-MMBtu of electricity consumption is equivalent to 5.65 billion kilowatt-hours.

Exhibit 3-2 The City and surrounding ZIP codes 2013 energy consumption

Sector	Electricity (Million-MMBtu)	Natural Gas (Million-MMBtu)
Residential	5.1	22.9
Commercial	13.0	13.6
Industrial	1.1	3.7
Total	**19.3**	**40.3**

consumed, however, varied distinctly by sector: the commercial sector was responsible for the majority of electricity consumption, accounting for nearly 68 percent of total electricity use, and the residential sector dominated gas consumption, accounting for 57 percent of gas usage. The industrial sector used over 3.5 times more gas than electricity, but only constituted a small percentage of the total consumption of those fuels, 9 percent and 6 percent respectively.

For comparative purposes, petroleum consumption in the City was estimated to be 34 million-MMBtu, falling between electricity and natural gas usage.   This order of magnitude estimate should be used with caution, as it is scaled from state-level data as opposed to actual meter readings. Petroleum consumption is described in Section 4.

This section provides an examination of 2013 energy use by type and sector in the City and the surrounding region. A detailed assessment of seasonal variations in energy use is also provided.

3.1 ELECTRICITY

Electricity usage can be evaluated both in terms of total consumption (reported in kWh) and instantaneous load on the system. Both characteristics are important as one describes the total amount of energy being used – helpful for monitoring progress on energy use reduction – and the other describes how much electric generating capacity must be available at any given juncture. Load data can also provide insights on usage patterns and potential for energy efficiency programs, which can reduce emissions and costs through peak shaving or demand response.

Both consumption and load are evaluated in this section: consumption data is specific to the study area, while load data is based on data for a wider area – the entire Duquesne Light service territory – and will therefore be used in a more qualitative fashion.

While this section does cover monthly consumption data, a more detailed analysis of seasonal trends in electricity usage is provided below in Section 3.4.

Electricity consumption in the City varies seasonally, with consumption peaking in the summer and winter. This is illustrated in Exhibit 3-3, which shows peak usage in the summer months of June, July, and August, with a secondary peak in the winter months of December and January. Peak consumption during these periods is primarily due to space cooling (i.e., air conditioning) in the summer and space heating in the winter.[v]

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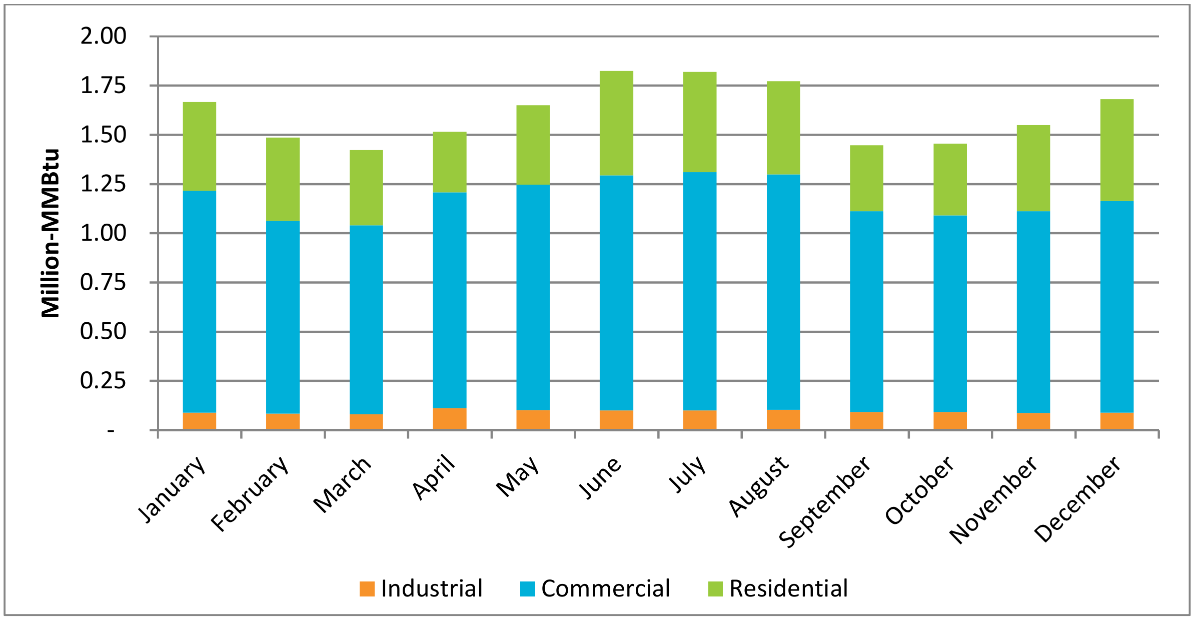
[v] Increased electricity loads in the summer are primarily due to space cooling, and the predominant type of space cooling device is air-conditioners powered by electricity. In contrast, space heating during winter months is achieved through a variety of fuels, including oil, natural

Exhibit 3-3 The City's monthly electricity consumption in 2013



Electricity usage is normally at its combined minimum during spring months and fall months, and these months are consequently referred to as the "shoulder months." The months of March, April, September, and October generally fall into the shoulder category, although seasonal variations from year to year result in minor shifts in load patterns. For example, while February is not always considered a shoulder month, demand in that month for 2013 was less than that of March. Furthermore, shoulder month consumption may vary by sector due to different characteristics of each sector. This will be described in more detail below in the seasonal analysis.

Seasonal variations in electricity use in the City are the result of variations in the residential and commercial sectors. As shown in Exhibit 3-3, industrial electricity use remained nearly constant throughout the year. This does not seem unusual, as electricity in this sector is likely to be dominated by use for industrial equipment (as opposed to space heating or cooling) and therefore would remain constant based on the constant operation of industrial or manufacturing processes throughout the year.

Exhibit 3-4 summarizes the minimum and maximum monthly electricity use for the City and each sector, as well as the month in which the minimum or maximum occurs. A detailed analysis of seasonal trends in electricity usage is provided below in Section 3.4.

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gas, and electricity (via heat pumps or resistance heating in electric heaters). In the cases when electricity is not the primary energy source for heating, auxiliary equipment required for heating system operation, e.g., fans and blowers for forced-air heating systems and pumps for hydronic systems, require electricity and contribute to winter consumption peaks.**Invalid source specified.**

Exhibit 3-4 Minimum and maximum monthly electricity consumption rates

Sector	Minimum Consumption		Maximum Consumption	
	Month	*million kWh*	*Month*	*million kWh*
Residential	April	90.1	June	155
Commercial	March	281	July	355
Industrial	March	23.4	April	32.6
All Sectors	**March**	**417**	**June**	**534**

3.1.1 Regional Load Profile

While the sections above describe electricity consumption, it is also valuable to examine real-time demand for electricity, and how it varies hourly, daily, monthly, and quarterly. Better understanding the instantaneous load on the electric grid can provide insights on usage patterns. This has the benefit of allowing for the better quantification of real-time emissions, but perhaps more importantly it can help quantify the potential benefits of different policy options, as many emissions reduction programs work by reducing peak energy demand. Programs such as demand response (i.e., peak demand reduction incentives), energy efficiency, and load shifting (i.e., real-time pricing of electricity) all have the potential to reduce emissions, energy consumption, and costs to the consumer by preventing inefficient and costly "peakers" from having to generate electricity.[w] Consequently, understanding usage patterns and the behavior or factors that drive those patterns can help inform policy makers and regulators as to what programs might have the most potential for their region.

Using electrical grid load information reported for Duquesne Light's service territory, of which the study region is a subset, real-time demand for electricity from 2005 to 2015 was analyzed to determine seasonal and weather-related trends in peak demand.

Exhibit 3-5 shows how hourly load profiles in 2013 vary by day of the week, averaged over the course of the year. As shown, demand for electricity is the highest during the week – particularly Monday through Thursday – and is at its highest between 10:30 am and 8 pm, on average surpassing 1,900 MW of load during those hours and peaking at 5 pm. At 8 pm, load starts dropping off as people start going to bed.

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[w] Electric generating stations in the United States, which are inefficient and/or costly to operate remain in service to provide electricity during times of peak electricity demand. These "peakers" only dispatch in the electricity market when demand – and therefore prices – is high. If these units can be prevented from having to dispatch (by reducing peak loads), it brings down electricity costs to the consumer and reduces emissions. Natural gas combustion turbines make up a large portion of the nation's peakers, as do old oil-fired steam generators, and certain older coal plants.

Exhibit 3-5 Hourly electric load in Duquesne Light territory by day of the week

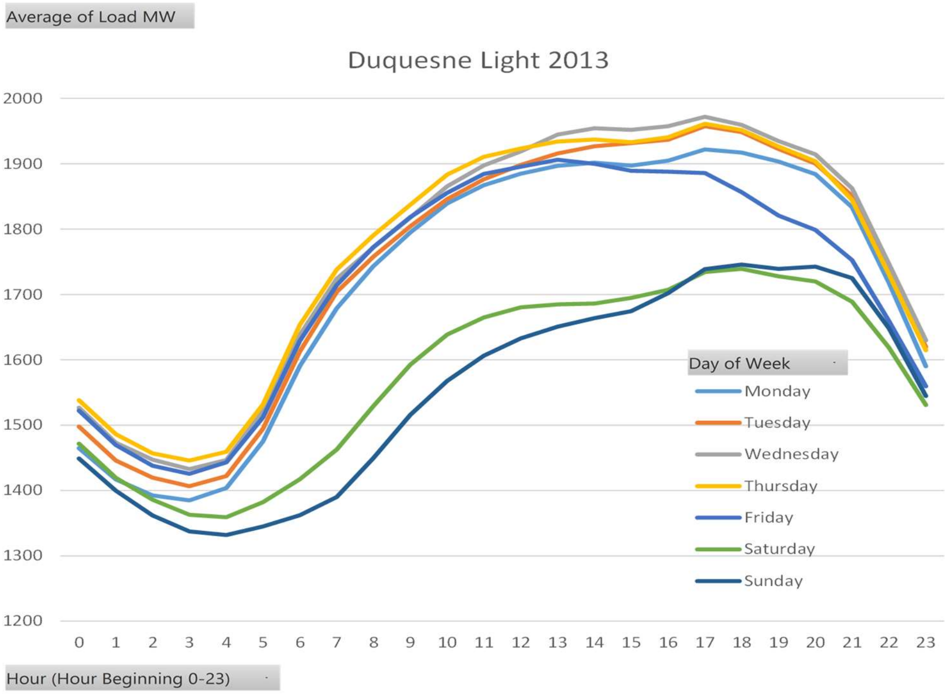
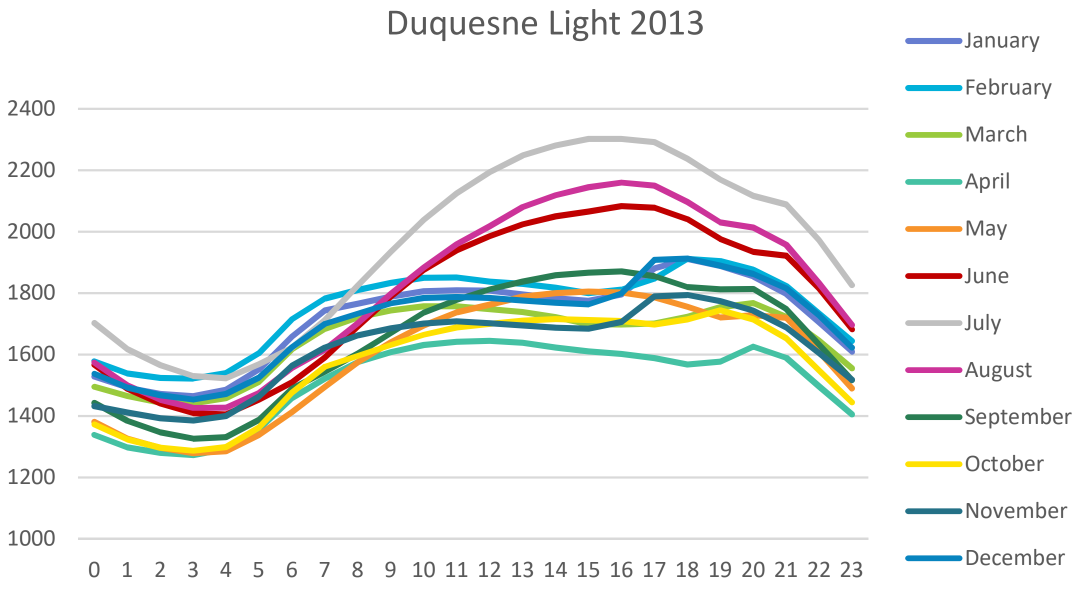


Exhibit 3-6 describes how hourly load profiles change throughout the year, with the profile for each month of 2013 provided. As could be expected, the warm summer months of June, July, and August experience the highest demand for electricity, and the demand comes in the middle of the day when temperatures are highest. Even within these months, the demand varies significantly, with July having a 7 percent higher load than August and a 10 percent higher load than June.

Exhibit 3-6 Hourly electric load in Duquesne Light territory by month



Also, worth noting is that the shape of the load profile varies from month to month as the type of consumer demand varies. Winter months, for example, have two peaks – one in the morning, one in the evening – while summer months only peak once. This could have implications when deploying technologies such as solar panels, which would have a beneficial effect of reducing peak loads in the summer, but may require power plants to ramp up and down more in other months if energy storage of some nature is not implemented to buffer loads.

The relationship between ambient temperatures – and therefore seasons – and demand for electricity are explored in more detail below.

Finally, Exhibit 3-7 examines historic hourly load profiles from 2005 to 2015, examined on a quarterly basis. This provides a clearer look at how system load profiles vary seasonally, both in characteristics and magnitude.

3.2 NATURAL GAS CONSUMPTION

Monthly natural gas consumption for the City ranged from 1.0 to 6.8 million-MMBtu (0.98 to 6.6 million thousand cubic feet (Mcf)) with the lowest demand occurring in August and the highest demand occurring in February. This is based on data extrapolated from the monthly data provided by one of the three natural gas utilities, as described above in Section 2.2.1. These results, shown in Exhibit 3-8, indicate the seasonality of gas consumption, as dominated by demand from the residential sector, and to a lesser extent the commercial sector, in the winter months. This demand is linked directly to space heating.

Exhibit 3-7 Hourly electric load in Duquesne Light territory by quarter

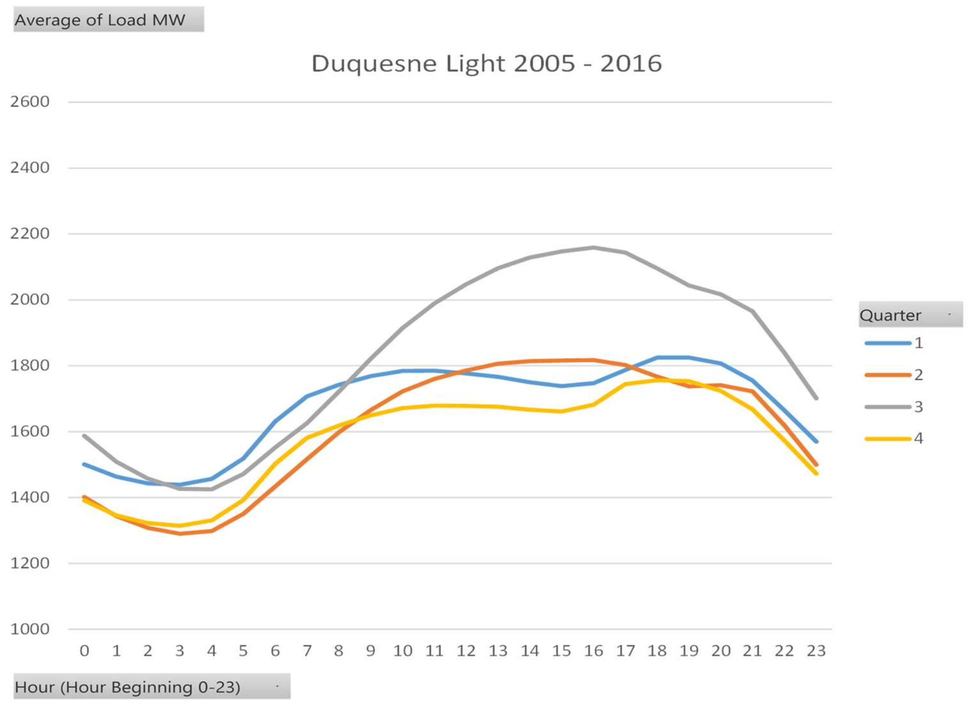
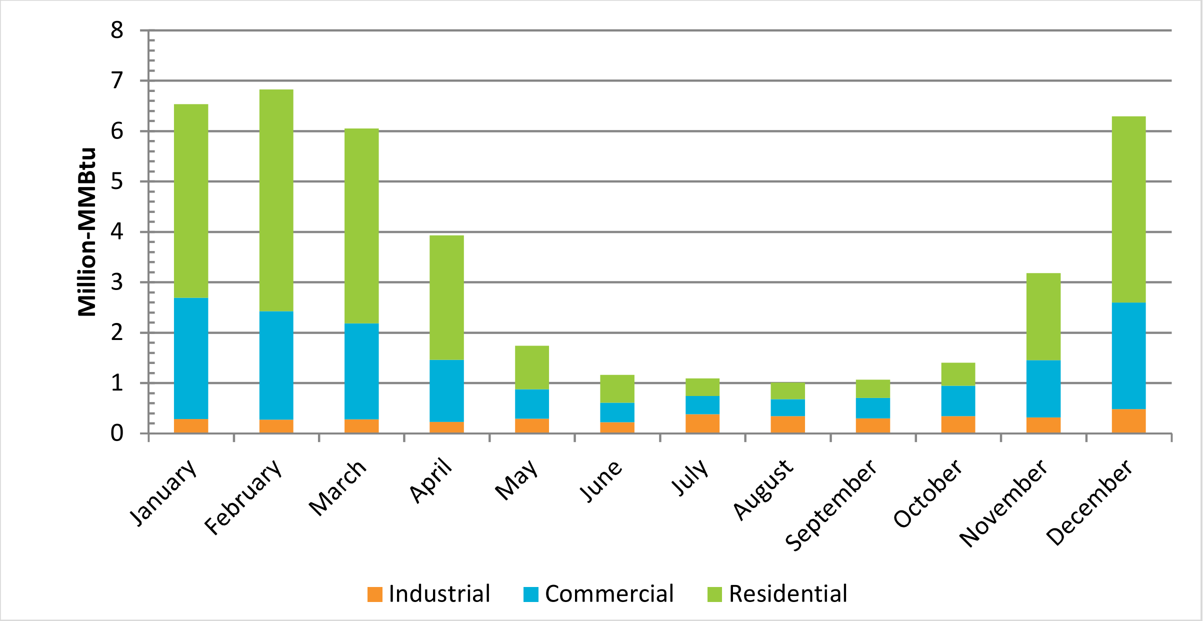


Exhibit 3-8 The City's monthly natural gas consumption in 2013[x]



Like electricity demand, industrial natural gas consumption is essentially constant throughout the year with respect to total natural gas consumption.

Exhibit 3-9 summarizes the minimum and maximum monthly natural gas use for the City and each sector, as well as in the month that that minimum or maximum occurs. A detailed analysis of seasonal trends in natural gas usage is provided below in Section 3.4.1.

3.3 COMBINED ELECTRICITY AND NATURAL GAS CONSUMPTION

Examining the combined electricity and natural gas consumption for the City, demand for energy ranges from 2.5 to 8.3 million-MMBtu per month, with the highest periods of demand occurring in the winter.[y] This is shown in Exhibit 3-10, which also illustrates 1) how natural gas dominates the energy consumed in the City (not considering petroleum), and 2) the magnitude of seasonal variation in natural gas usage.

Exhibit 3-9 Minimum and maximum monthly natural gas consumption rates

Sector	Minimum Consumption		Maximum Consumption	
	Month	*MMBtu*	*Month*	*MMBtu*
Residential	August	327,172	February	4,400,794
Commercial	August	342,225	January	2,404,898
Industrial	June	219,229	December	480,704
All Sectors	**August**	**1,007,975**	**February**	**6,825,393**

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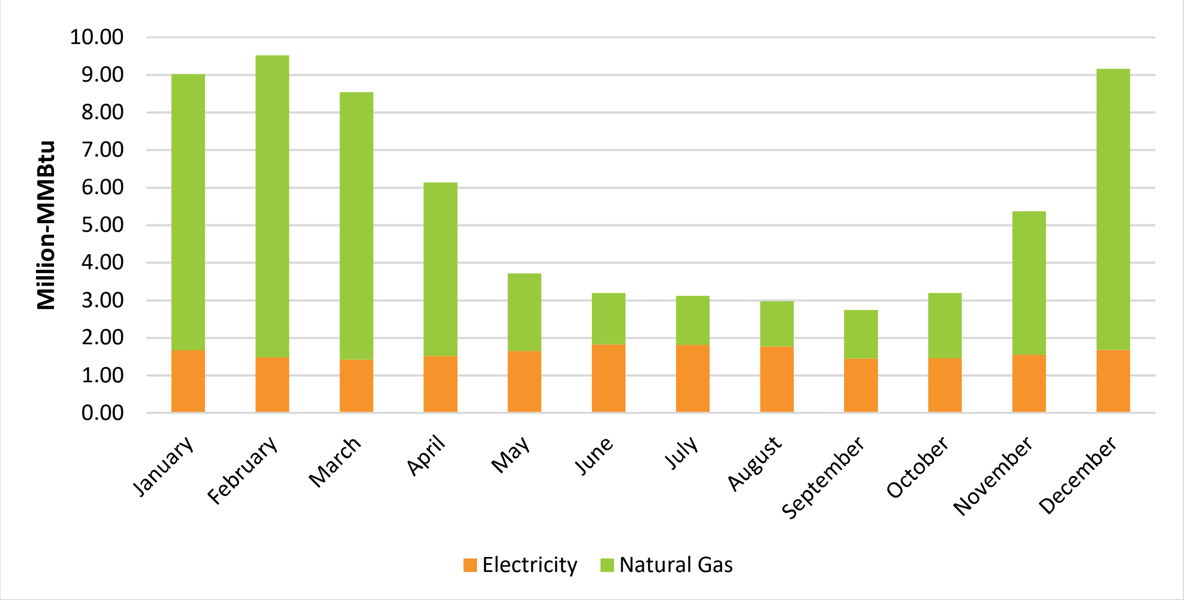
[x] January data for commercial end users in 15120 was 7,427,484 Mcf. This value was nearly an order of magnitude larger than any other ZIP code, as well as February consumption in 15120. This data point was suspect and was adjusted as described in detail in Section 2.2.1.

[y] As noted above, only electricity and natural gas consumption is considered in this section. Petroleum consumption is omitted due to the lack of specific consumption data.

Exhibit 3-10 The City's monthly combined consumption in 2013



When comparing natural gas and electricity consumption, natural gas dominates energy consumption in the City in all but the warmest months of the year, with consumption at levels 3.7 to 4.6 times that of electricity use in December through March. Gas consumption also dominates in the shoulder months of April and November, exceeding electricity by a factor of 2.1 to 2.6. Electricity usage exceeds natural gas in the summer months of June, July, and August, but never by more than a factor 1.5.[z]

Examining the large seasonal variations in energy use, in peak natural gas usage months, gas consumption is between 6 and 7 times greater than periods of low demand in the summer. Comparatively, electricity usage is somewhat constant, with monthly consumption during peak summer usage only exceeding shoulder month consumption by 1.3 times.

Exhibit 3-11 summarizes the range of combined monthly energy use for the City and each sector, as well as the month in which the minimum or maximum occurs. A detailed breakdown of monthly consumption data for each energy type is provided in Exhibit 3-12. A detailed breakdown of monthly consumption data by each sector is provided in Exhibit 3-13.

Exhibit 3-11 Minimum and maximum monthly combined consumption rates

Sector	Minimum Consumption		Maximum Consumption	
	Month	MMBtu	Month	MMBtu
Residential	September	699,679	February	4,823,629
Commercial	September	1,424,688	January	3,532,302
Industrial	June	319,244	December	569,310
Total	**September**	**2,513,969**	**February**	**8,310,498**

---

[z] Electricity and natural gas usage were nearly equivalent in the shoulder months of May and October, with gas consumption edging out electricity in the former.

Exhibit 3-12 Electricity and natural gas consumption in 2013

Month	Electricity		Natural Gas		Combined Electricity and Natural Gas Consumption
	Million kWh	Million-MMBtu	Million Mcf	Million-MMBtu	Million-MMBtu
January	488	1.67	6.35	6.54	8.20
February	435	1.49	6.63	6.83	8.31
March	417	1.42	5.87	6.05	7.47
April	444	1.52	3.81	3.93	5.44
May	483	1.65	1.69	1.74	3.39
June	534	1.82	1.12	1.16	2.98
July	533	1.82	1.06	1.09	2.91
August	519	1.77	0.98	1.01	2.78
September	424	1.45	1.04	1.07	2.51
October	426	1.45	1.36	1.40	2.86
November	454	1.55	3.09	3.18	4.73
December	493	1.68	6.11	6.29	7.97
Total	**5,651**	**19.3**	**39.1**	**40.3**	**4.96**
Average	*471*	*1.61*	*3.26*	*3.36*	*8.20*

Exhibit 3-13 Total electricity and natural gas consumption by sector

Month	Commercial (Million-MMBtu)	Industrial (Million-MMBtu)	Residential (Million-MMBtu)	Total (Million-MMBtu)
January	3.53	0.38	4.29	8.20
February	3.13	0.36	4.82	8.31
March	2.87	0.36	4.25	7.47
April	2.33	0.34	2.77	5.44
May	1.73	0.39	1.27	3.39
June	1.58	0.32	1.08	2.98
July	1.57	0.48	0.86	2.91
August	1.54	0.44	0.80	2.78
September	1.42	0.39	0.70	2.51
October	1.60	0.43	0.82	2.86
November	2.16	0.40	2.17	4.73
December	3.19	0.57	4.21	7.97
Total	**2.22**	**0.40**	**2.34**	**4.96**
Monthly Average	*3.53*	*0.38*	*4.29*	*8.20*

Taken in total, over the course of 2013, the City consumed 5,561 million kWh of electricity, nearly 2.5 percent of the electricity use in Pennsylvania (PA). Commercial electricity use made up 68 percent and residential was 27 percent, with the remaining 5 percent consumed through the industrial sector. Monthly electricity consumption averaged nearly 471 million kWh, with peak electricity consumption in the summer months about 35 percent above the yearly average.

Natural gas consumption was 46.1 million Mcf, or roughly 4 percent of all natural gas consumed in PA in 2013. Residential natural gas consumption made up 48 percent of all consumption, while commercial natural gas consumed 44 percent, with industrial consumption making up the remaining 8 percent. Natural gas was consumed on average 3.84 million Mcf per month, but the peak natural gas consumption month, February, more than doubled the average, and January and December nearly doubled average consumption as well.

Combined consumption, when put in the same units, was 80 million Mcf in 2013, with a monthly average of 6.67 million Mcf. The months of January, February, and December consumed over 50 percent more than the monthly average, dominated by natural gas demand. Overall, natural gas made up 57 percent of total energy consumption in 2013.

3.4 SEASONAL ENERGY DEMAND ANALYSIS

As discussed above, energy demand in the City varies seasonally, with total energy demand in the winter being more than triple that of demand in the shoulder months, and winter natural gas demands of almost 7 times that of demand in the summer. Seasonal trends such as these will be different for every geographic location in the country based on that locations' unique weather patterns, but it will also vary based on factors such as building codes, median age of housing stock, and historic energy prices.[aa]

This section examines monthly energy use as it compares to weather patterns for the City, looking for trends and opportunities for energy reductions. Differences in weather-related consumption between sectors was also evaluated.

The City's relatively cool climate results in a seasonal energy consumption being related more to space heating than space cooling. Similarly, the relatively mild summer limits the amount of energy consumed for space cooling. As a result, peak demand for electricity in the summer is not dramatically above that the base level of consumption in the shoulder months.

The seasonal demand for natural gas in the winter, however, is significant and is responsible for as much as 56 percent of annual natural gas demand, making space heating not only the largest end use for natural gas in the city, but the largest non-transportation use of energy in the city. This is particularly pronounced in the residential sector, where 68 percent of the sector's gas use is related to heating, and where peak gas usage can be 9 to almost 11 times higher in the coldest months of the year as compared to the summer base gas usage.

[aa] One would expect more stringent building codes and/or newer housing to be more energy efficient, while factors such as historically low energy prices might result in higher energy consumption per capita, as consumption has a lesser effect on consumer's bills, and therefore consumption habits.

The commercial sector has less of seasonal dependency on gas, both in overall usage – 52 percent compared to 68 percent for the residential sector – and in terms of magnitude of peak usage. As to the latter, peak usage only increases by 5 to almost 7 times the summer base usage, compared to levels almost double that for the residential sector.

The increased peak usage for the residential over the commercial sector is explored further by examining monthly gas usage per HDD in each sector. Residential gas usage almost reaches 1,900 MMBtu per HDD in the coldest months, compared to 1,000 MMBtu/HDD for the commercial sector in the same month. Overall, residential consumers use substantially more natural gas – from 34 percent to almost 80 percent in cold months – for space heating than commercial customers.[bb]

3.4.1 Cold and Hot Weather Metrics

A common metric used to track and compare weather across different time series is the "degree day." A degree day compares the outdoor temperature to a reference temperature of 65°F.[cc] The more extreme the temperature, the higher the number of degree days. A higher number of degree days will require more energy for space heating or cooling. [16]

Hot days are measured in cooling degree day (CDD). On a day with a mean temperature of 80°F, for example, 15 CDDs would be recorded. Cold days are measured in heating degree day (HDD). For a day with a mean temperature of 40°F, 25 HDDs would be recorded.

The degree day metric is very useful in tracking how energy consumption – and energy expenditures – increase based on weather, or in comparing the relative intensity of a month or season, as compared to other years. However, caution should be exercised when using the degree days metric as it has several shortcomings, ranging from a long reporting period (normal reporting is on a monthly or annual basis) to the metric not adequately capturing how energy usage will be higher during times of extreme temperature (i.e., days when the weather is farther away from the reference point).[dd] Therefore, this analysis should be considered a starting point in quantifying energy and emissions reductions opportunities via reducing seasonal energy use. Future analyses will leverage advanced sensors and controls as well as big data processing, which the City and Carnegie Mellon are already working to address in other efforts.

Historic HDD and CDD for the City are shown below, and detailed data is provided in Appendix B. [11]

[bb] "Cold months" here are defined as those months with more than 500 HDDs.

[cc] The reference temperature used in HDD and CDD calculations can vary by data source. This report uses a reference temperature of 65°F, as that is the convention used by NOAA data.

[dd] Space heating and cooling energy requirements are not linear based on a HDD/CDD basis (energy use per HDD/CDD). In periods of extreme temperature, the temperature differential between the space inside the building and ambient temperatures is larger, resulting in faster energy losses from the building. Consequently, this results in increased heating or cooling loads – to keep up with the faster losses –and therefore increased energy expenditures. For example, the degree day metric does not differentiate between 30 days at 60°F (30 x 5 = 150 HDD) and 5 days at 35°F (5x30 = 150 HDD), but the heating bill for the latter will be much higher than the former.

3.4.1.1 Heating Degree Days

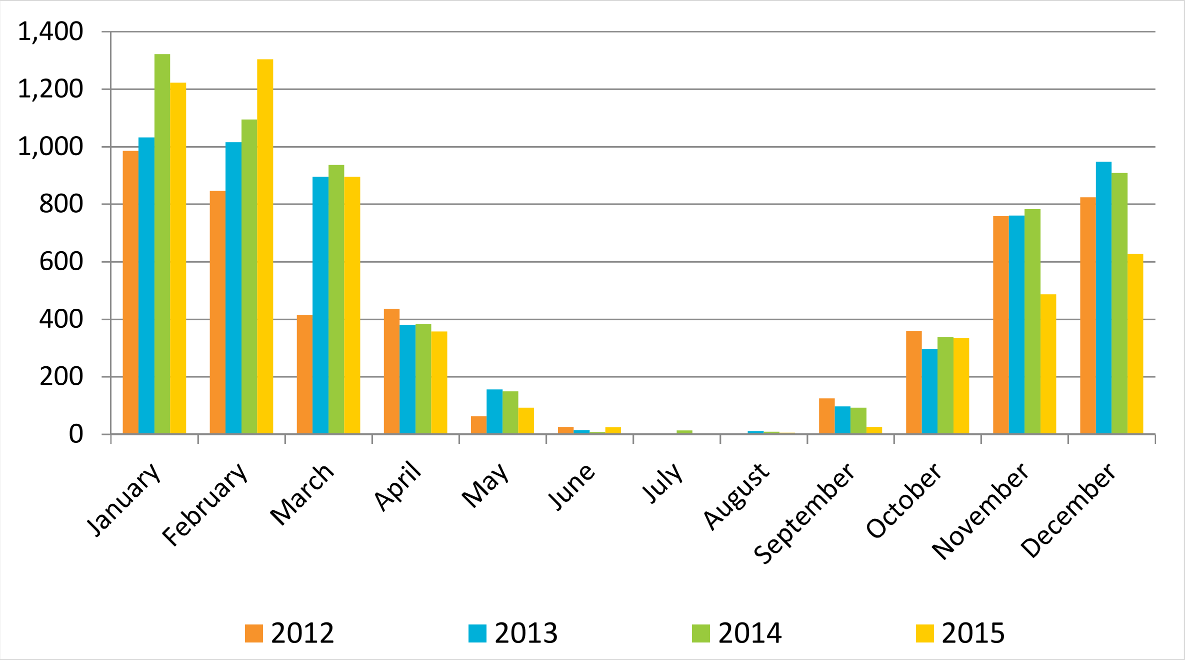
The City has had an average of 5,581 HDDs a year over the last 15 years. Over that period, 2012 was the warmest year – in terms of HDD – at roughly 4,900 HDD, while 2014 was the coldest with just under 6,100 HDD. The months of December through February are historically the coldest, averaging from 970 to 1,140 HDD per month in those months, while March and November average between 650 and 770 HDD per month. Exhibit 3-14 provides a summary of the City's HDD data ranging from 2000 to 2015, including minimum and maximum numbers of HDD for each month over that period and 15-year average values.

Exhibit 3-15 shows the trends in HDDs over the past four years (2012 to 2015), covering the coldest and warmest years in recent history (2014 and 2012, respectively), which bookend the year being evaluated (2013). 2013 was a slightly colder than average year in terms of total HDD, but two of the three historically coldest months (December and January) were warmer than normal. These were offset by a late winter (February and March) and late fall (November) months, which were colder than normal.

Exhibit 3-14 Historic cold weather trends, sorted by average HDDs

Month	Minimum HDDs	Maximum HDDs	15-year Average	Coldest Year (2000-2015)
January	831	1,349	1,140	2003
February	836	1,301	995	2015
December	631	1,219	971	2010
March	425	943	772	2014
November	494	783	648	2014
April	307	524	389	2007
October	228	461	372	2002
May	65	280	166	2002
September	27	133	82	2012
June	10	59	27	2003
August	0	25	6	2004
July	0	17	4	2001
Total	**4,905**	**6,082**	**5,572**	**2014**

Exhibit 3-15 Recent history of heating degree days for the City



3.4.1.2 Cooling Degree Days

The City has had an average of 790 CDDs a year over the last 15 years. Over that period, 2002 was the warmest year – in terms of CDD – at roughly 1,012 CDD, while 2003 was the coldest with just under 575 CDD. The months of July and August are historically the warmest, averaging from 221 to 247 CDD per month in those months, June averaging 157, and May and September averaging between 60 and 81 CDD per month. Exhibit 3-16 provides a summary of the City's CDD data ranging from 2000 to 2015, including minimum and maximum numbers of CDD for each month over that period and 15-year average values.

Exhibit 3-16 Historic warm weather trends, sorted by average CDDs

Month	Minimum CDDs	Maximum CDDs	15-year Average	Warmest Year[ee] (2000-2015)
July	142	371	247	2011
August	139	294	221	2010
June	84	218	157	2005
September	12	167	81	2015
May	7	129	60	2015
April	0	37	12	2002
October	0	54	11	2007
Total	**575**	**1,012**	**790**	**2012**

[ee] The year with the largest number of CDDs in that month from 2000 to 2015. During several the shoulder months, determining the warmest year by means of largest number of CDDs gave a different result than determining it from the year with the least amount of HDDs. As a result, the CDD metric was used for consistency.

Exhibit 3-17 shows the trends in HDDs over the past four years (2012 to 2015), which includes one of the warmest years in recent history (2012), and the year being evaluated (2013). 2013 was a slightly warmer than average year in terms of total CDD, with a warm May and July offsetting colder than normal June, August, and September.

3.4.2 Establishing Baseline (Non-Seasonal) Gas and Electricity Usage Levels

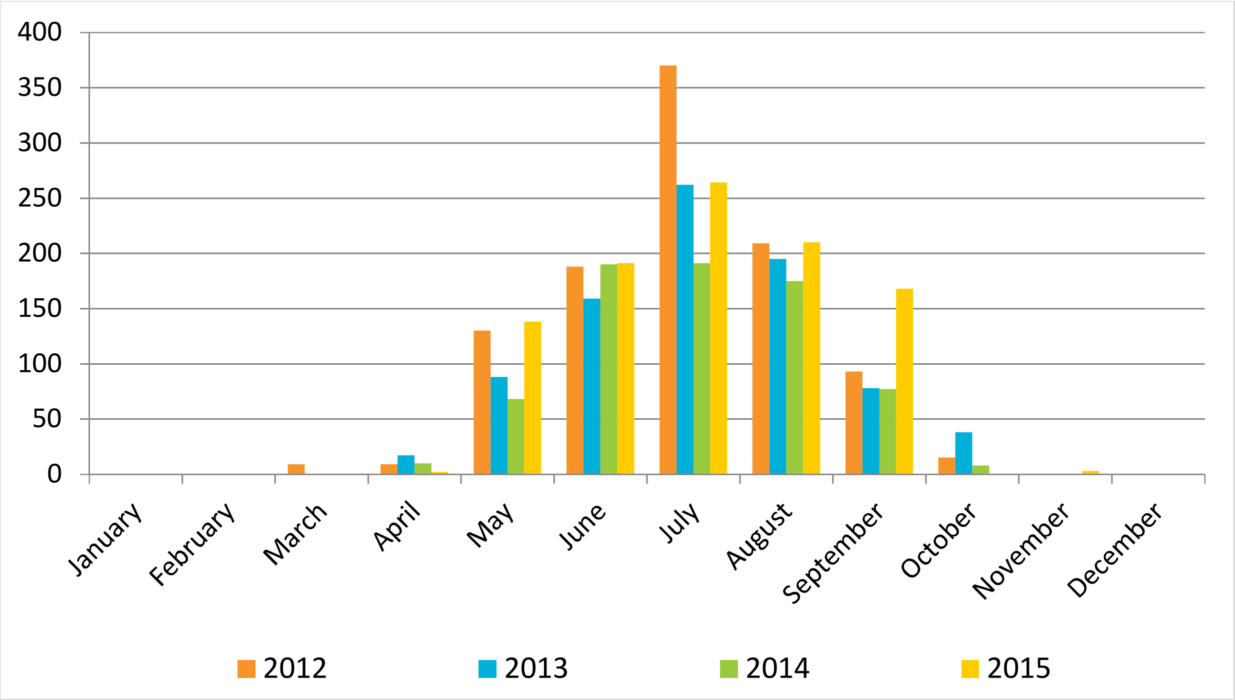
To evaluate the magnitude of seasonal-related energy usage, it is necessary to first determining the baseline energy usage throughout the year for each fuel type. This was achieved by examining average energy use during periods when weather-related energy usage is at a minimum: summer months for natural gas usage and spring and fall shoulders months for electricity usage.

Baseline energy consumption levels were not calculated for the industrial sector, as consumption patterns did not appear to follow any seasonal trends for that sector.

3.4.2.1 Natural Gas

Natural gas consumption during summer months when few to no HDDs occurred was used as an approximation for a baseline of non-weather-related natural gas usage. Initially, it was expected that the months of June, July, and August would be used as baseline months due to the lack of HDDs during these months. Examining the data, however, revealed a more complicated picture, as while these months do represent the lowest consumption months for the commercial sector, it was not the case for the residential sector.

Exhibit 3-17 Recent history of cooling degree days for the City

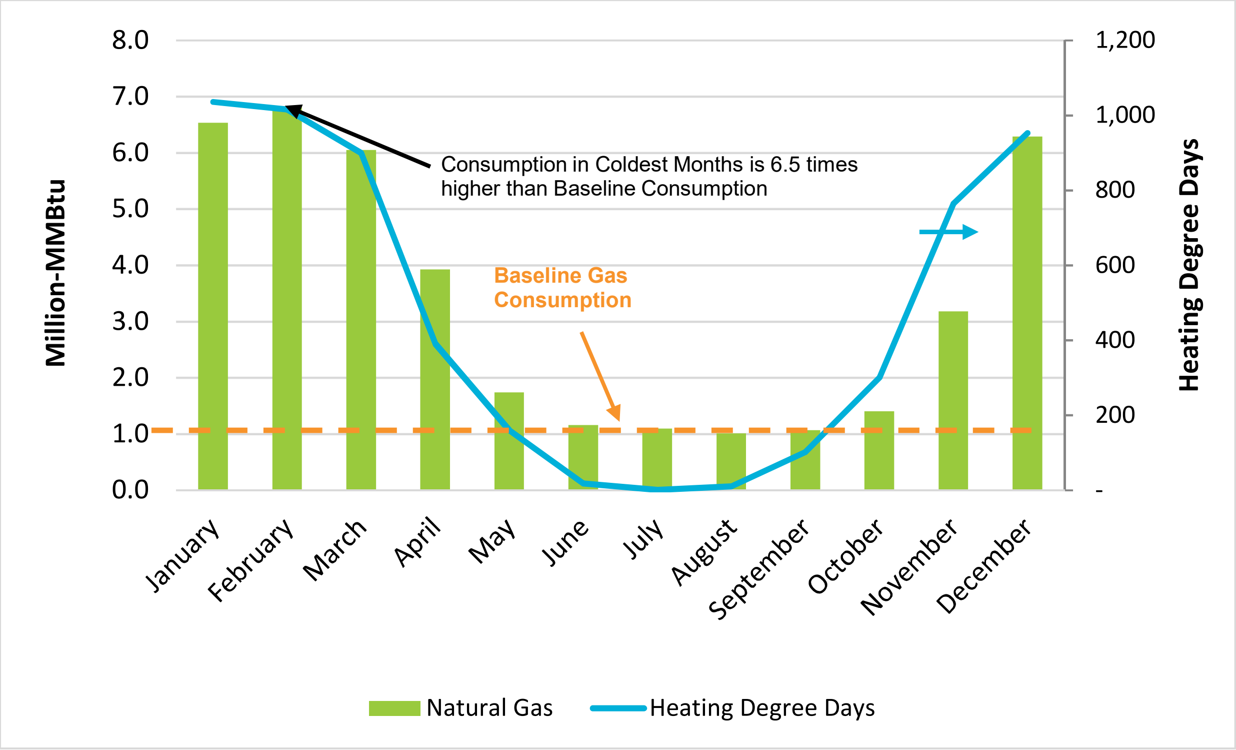


Consumption in the residential sector is lowest during July, August, and September, with each of these months having similar consumption levels. In contrast to the commercial sector, June consumption in the residential sector is significantly higher than consumption in September or even October, both of which have more HDDs – 100 and 300, respectively – compared to June's 18 HDD.

This data point is puzzling and may reflect the lack of granularity that the HDD metric provides, or simply a human behavior factor that is difficult to account for. For example, one possible scenario is that June in the City is a cool enough month – with cool evenings being common – that residential customers are still using their heat at night, and/or haven't switched their HVAC systems into "cooling only" mode.[ff] Another scenario is that a "one month only" load exists, which is not being accounted for, such as people using natural-gas fired heaters for their swimming pools. This is an area which should be examined in more detail in future work.

As alluded to above, the data also revealed that natural gas consumption in September for both sectors was closer to the magnitude as the summer months, despite a significant number for HDDs. This is shown in Exhibit 3-18, which illustrates how combined monthly natural gas consumption stays at summer levels, even though the number of HDDs starts to increase.

Exhibit 3-18 Natural gas consumption and heating degree days



[ff] A separate explanation for the difference in June natural gas usage trends between the commercial and residential sector may simply be that commercial buildings have different usage and physical characteristics that would reduce June gas usage. Lack of occupancy during evening hours when the weather is cool may result in less heat usage, or the higher number of occupants per square foot and/or the presence of equipment (from office equipment to other industrial equipment) may generate enough low-level heat in buildings that the need for additional heating is obviated. Alternatively, it may be as simple as better energy management practices in the commercial sector based on impacts to the bottom line. The authors hope that future collaborations with City entities such as the Green Building Alliance may provide clarity in this area.

Three methodological options seemed to be appropriate in establishing the baseline for non-weather-related natural gas usage: 1) use consumption from the summer months with few HDDs (June, July, August), 2) expand that dataset to include September given the low consumption level during that month for the residential sector and relatively low level in the commercial sector (4.7 percent above the next highest month), or 3) use the three lowest months of consumption for each sector. The decision was made to use average consumption during the months of June through September as a baseline for energy consumption for each sector to use a consistent across both sectors and until the high June consumption levels for the residential sector are better understood.

Exhibit 3-19 details the non-weather-related natural gas consumption for the residential and commercial sectors, based on the average consumption in the months of June, July, August, and September. As shown, the baseline gas consumption for the city is approximately 775,000 MMBtu/month (750,000 Mcf/month), broken down to roughly 400,000 MMBtu/month for the residential sector and 375,000 MMBtu/month for the commercial sector. Industrial gas usage ranges between 219,000 MMBtu/month and 480,000 MMBtu/month throughout the year, and would add approximately 300,000 MMBtu/month to the baseline consumption levels.

The baseline consumption rates calculated by the two alternate methodologies are also reported, along with how much they vary from the June-September case. As shown, using the "three minimum month" method significantly reduces the residential baseline consumption estimate – by almost 13 percent - and reduces the City-wide baseline by 8 percent. Care should be taken when comparing these data points and methodologies, however, as the monthly data used here was extrapolated from data provided by one gas provider (see discussion in Section 2.2.1 above on natural gas data), which could introduce and amplify apparent trends that would not exist if a more complete dataset was available. Work is being done to collect a more complete dataset for future work.

Exhibit 3-19 Baseline natural gas usage

Sector	Average Consumption (MMBtu/month)	Months in Dataset	Change from Jun-Sep Dataset
Residential	399,094	Jun – Sep	N\A
Commercial	373,705		
Total w/o Industrial	**772,799**		
Alternate Perspective #1: Low HDD Months			
Residential	410,626	Jun – Aug	3%
Commercial	363,434		-3%
Total w/o Industrial	**774,060**		0.2%
Alternate Perspective #2: Minimum 3 Months of Consumption			
Residential	347,821	Jul – Sep	-13%
Commercial	363,434	Jun – Aug	-3%
Total w/o Industrial	**711,255**	N\A	-8%

3.4.2.2 Electricity

Shoulder month electricity usage is similar to natural gas usage in that the commercial and residential sectors experience different shoulder months. Additionally, the amplitudes of the peaks are different, with the residential sector experiencing greater variations in consumption during peak months – up to 53 percent more than in shoulder months – while the commercial sector experienced no more than a 21 percent increase.

Exhibit 3-20 lists the baseline electric energy usage for the shoulder months by sector, while Exhibit 3-21 shows how the consumption by sector changes throughout the year. As is clearly illustrated, the commercial sector shoulder months appear to be February, March, September, and October. The residential shoulder months appear to be shifted out one month in the spring, occurring in March and February, while the fall months are consistent with the commercial sector.

3.4.3 Overall Seasonal Energy Consumption

By examining natural gas – and to a lesser extent, electricity usage – and comparing it with historic weather data, it is possible to: 1) quantify how much energy is used for space heating or cooling, 2) investigate how weather-related consumption varies across sectors, and 3) identify opportunities for energy and emissions reductions.

Exhibit 3-20 Monthly electricity usage by sector

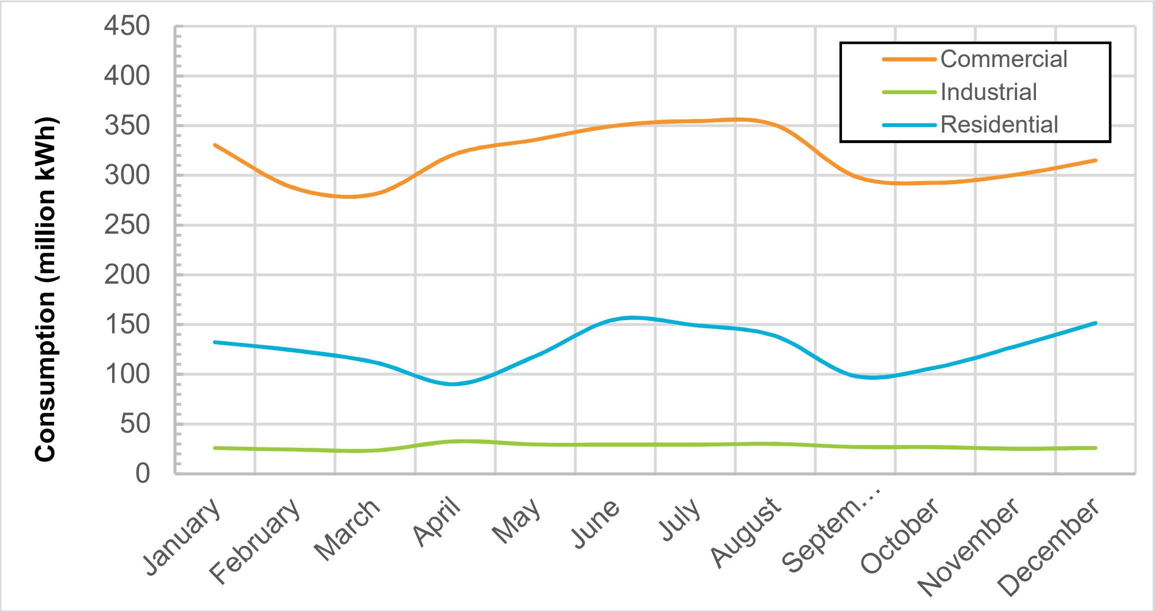


Exhibit 3-21 Baseline electricity usage

Sector	Average Consumption (kWh/month)	Months in Dataset
Residential	101,745,866	Mar, Apr, Sep, Oct
Commercial	289,991,062	Feb, Mar, Sep, Oct
Total w/o Industrial	**397,973,810**	**Feb, Mar, Apr, Sep, Oct**

The City's relatively cool climate results in a seasonal energy consumption being related more to space heating than space cooling. Similarly, the relatively mild summer limits the amount of energy consumed for space cooling. As a result, peak demand for electricity in the summer is not dramatically above that the base level of consumption in the shoulder months. Seasonal impacts on natural gas consumption, as well as electricity consumption and load, are described in the following sections.

3.4.3.1 *Winter*

The seasonal demand for natural gas in the winter is responsible for as much as 56 percent of annual natural gas demand, making space heating not only the largest end use for natural gas in the city, but the largest non-transportation use of energy in the city. This is particularly pronounced in the residential sector, where 68 percent of the sector's gas use is related to heating, and where peak gas usage can be 9 to almost 11 times higher in the coldest months of the year as compared to the summer base gas usage. These results are summarized in Exhibit 3-22 and Exhibit 3-23, which show gas consumption for heating and the comparative magnitude of gas use to summer usage, and are based on comparisons to the summer base usage on a per sector basis, as reported above in Exhibit 3-19.

These results are further broken down by the relative amount of heating needed in each month (as described by number of HDDs) to better understand how gas usage varies with cold weather. Three categories are utilized: months in which heating may be required (>200 HDD), cold months (>500 HDD), and coldest months of the year (>900 HDD).

The commercial sector has less of dependency on gas, both in overall usage (as reported above), for winter usage as a percentage of total sector use – 52 percent compared to 68 percent for the residential sector – and in terms of magnitude of peak usage. As to the latter, peak usage only increases by 5 to almost 7 times the summer base usage, compared to levels almost double that for the residential sector.

Exhibit 3-22 Gas usage for heating by sector

Sector	Heating Months (>200 HDD)		Cold Months (>500 HDD)	
	MMBtu	% of Sector	MMBtu	% of Sector
Residential	15,670,450	68%	12,745,990	56%
Commercial	7,061,896	52%	5,222,763	38%
Total[99]	**22,732,346**	**56%**	**17,968,753**	**45%**

Exhibit 3-23 Peak monthly gas usage multiplier for heating by sector

Sector	Coldest Months (>900 HDD)		Cold Months (>500 HDD)
	Minimum Multiplier	Maximum Multiplier	Minimum Multiplier
Residential	9.0	10.7	4.2
Commercial	5.2	6.6	3.1

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[99] "Percentage of Sector" for the Total line represents the percentage of total gas usage in the entire City.

The increased peak usage for the residential over the commercial sector is further explored in Exhibit 3-24, which describes the monthly gas usage per HDD in each sector. As shown, residential gas usage almost reaches 1,900 MMBtu per HDD in the coldest months, compared to 1,000 MMBtu/HDD for the commercial sector in the same month. Overall, residential consumers use substantially more natural gas – from 34 percent to almost 80 percent in cold months – for space heating than commercial customers.[hh] While this metric is certainly very qualitative, it represents a first step in illustrating how the commercial sector is more efficient than the residential sector in using natural gas for space heating. This result was somewhat expected, as the commercial sector has several potential advantages related to heating cost awareness and ability to heating-related energy usage, not the least being access to capital for improvements (insulation, more efficient HVAC systems, etc.) and reduced energy losses due to building types.

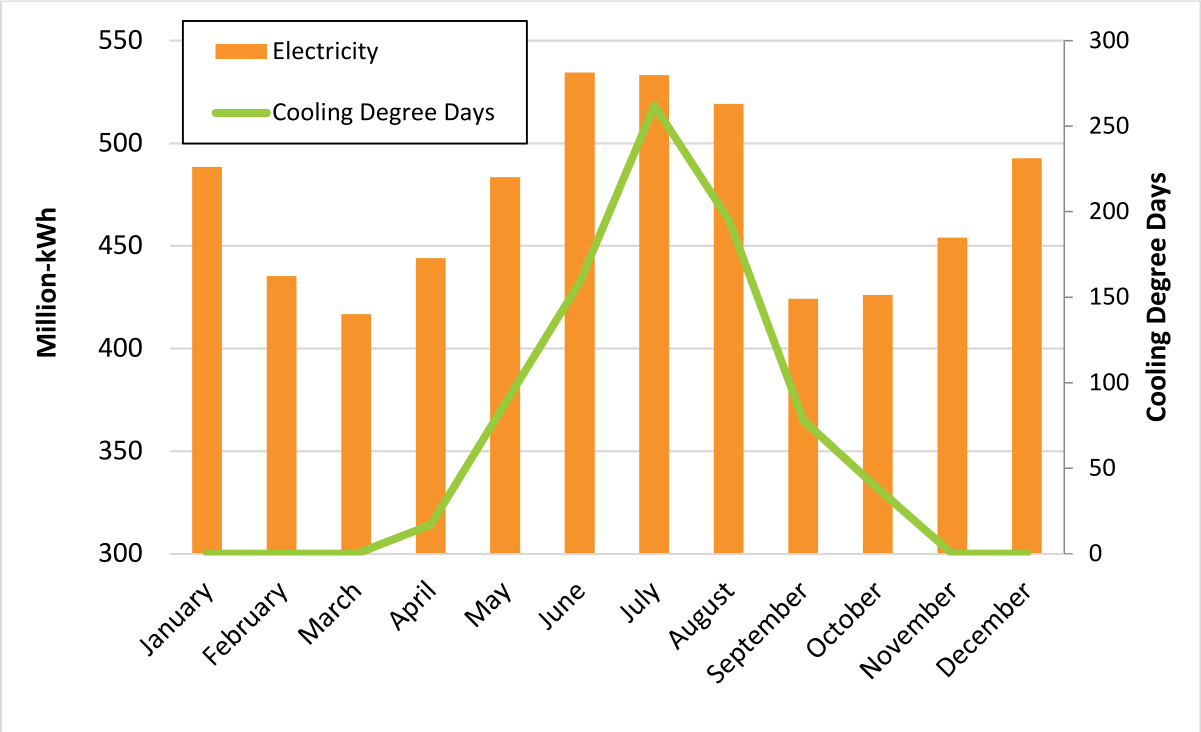
When examining how winter electricity usage varied from the shoulder month usage, the results were far less clear. While a slight increase in total usage did occur, as evidenced by the winter month peaks shown in Exhibit 3-25, there was no clear correlation to total usage with how cold the month was (number of HDDs). When examining electricity demand on the system; however, a correlation was found, as is described in Section 3.4.4 below.

Exhibit 3-24 Sector natural gas usage by HDD

Heating Months (>200 HDD)	**HDDs**	**Sector Gas Usage (MMBtu/HDD)**		
		Residential	***Commercial***	**% Increase for Residential**
January	1,036	1,567	1,174	34%
February	1,016	1,857	1,045	78%
March	900	1,815	1,018	78%
April	391	2,485	1,326	87%
October	301	77	474	-84%
November	765	815	599	36%
December	953	1,630	1,091	49%

[hh] "Cold months" here are defined as those months with more than 500 HDDs.

Exhibit 3-25 Electricity consumption and cooling degree days



3.4.3.2 Summer

Seasonal energy consumption in the summer is primarily associated with electricity usage for space cooling (i.e., air conditioning). The relatively mild summers in the City result in a measurable increase in electricity usage, with overall electricity consumption levels at 1.3 times that of the shoulder month consumption, and somewhat higher levels of peak consumption in the residential sector (1.53 in June). These increases, detailed in Exhibit 3-26, are more pronounced in the residential sector than the commercial sector, which remains much more constant throughout the season. Electricity consumption per CDD, on the other hand, is higher in the commercial sector for all the months where space cooling is likely to be needed, but this is the result more of that sector's larger dependency on electricity as an energy source, as evidenced by the smaller amplitude of electricity use in the summer. These results are summarized in The fact that summer-related seasonal energy usage is less pronounced compared to that experienced in the winter – with peak consumption levels up to 10.7 times that of summer month consumption – is to be expected given the reduced number of CDDs – on average, there are 790 CDDs per year – as compared to the almost 5,600 HDDs.

While no strong correlation was found when examining electricity consumption to CDDs, a much more pronounced effect was noted in electricity demand on the system in relationship to hot weather. This relationship is described in Section 3.4.4 below.

Exhibit 3-27.

Exhibit 3-26 Peak summer electricity usage multiplier by sector

Sector	June	July	August	Warm Months (>150 CDD)	
				Minimum Multiplier	Maximum Multiplier
Residential	1.53	1.47	1.36	1.36	1.53
Commercial	1.20	1.21	1.20	1.20	1.21
Total	**1.25**	**1.24**	**1.21**	**1.21**	**1.25**

The fact that summer-related seasonal energy usage is less pronounced compared to that experienced in the winter – with peak consumption levels up to 10.7 times that of summer month consumption – is to be expected given the reduced number of CDDs – on average, there are 790 CDDs per year – as compared to the almost 5,600 HDDs.

While no strong correlation was found when examining electricity consumption to CDDs, a much more pronounced effect was noted in electricity demand on the system in relationship to hot weather. This relationship is described in Section 3.4.4 below.

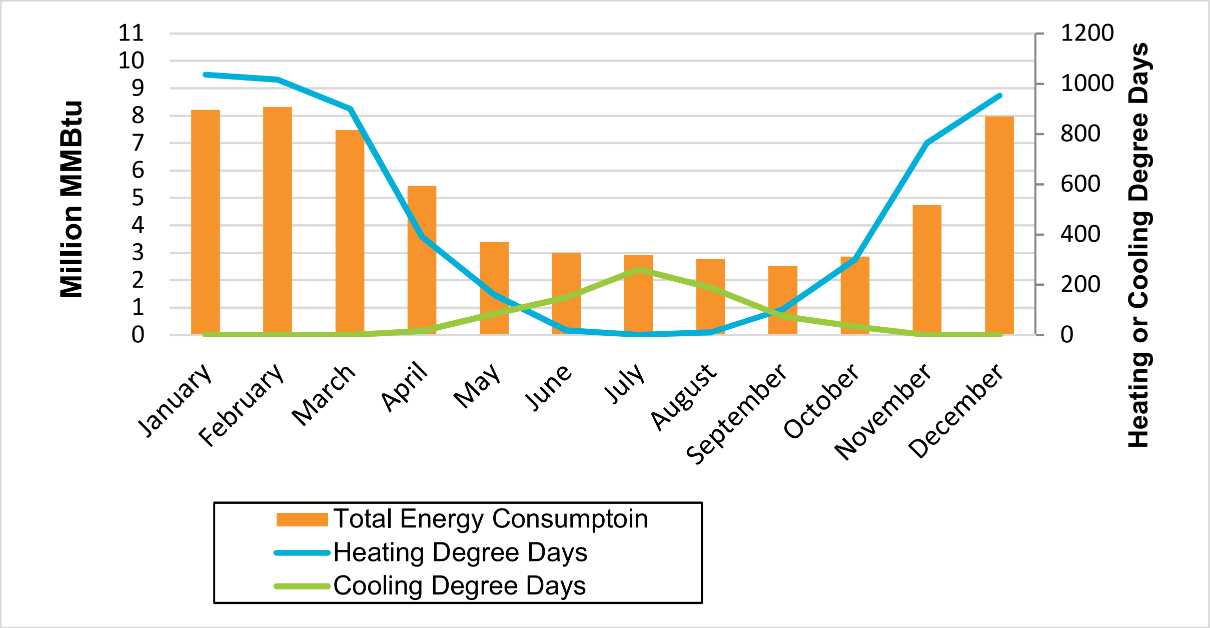
Exhibit 3-27 Sector electricity usage by CDD

Cooling Months (>50 CDD)	CDDs	Sector Electricity Usage (kWh/CDD)	
		Residential	*Commercial*
May	85	192,698	539,418
June	150	356,198	399,956
July	261	182,285	247,448
August	188	195,463	322,809
September	74	N\A	121,682

3.4.3.3 Combined Seasonal Effects

When combining the energy consumption and overlaying both heating and cooling degree day lines (Exhibit 3-28), the heating and cooling degree day lines cross in May and September. These months are usually months with relatively low energy consumption because ambient air temperatures are in the range of where minimal space heating and/or space cooling are required. Exhibit 3-28 also shows that technologies that can provide space heating during winter months may be preferred technologies with respect to reducing energy demand.

Exhibit 3-28 Combined consumption and cooling and heating degree days



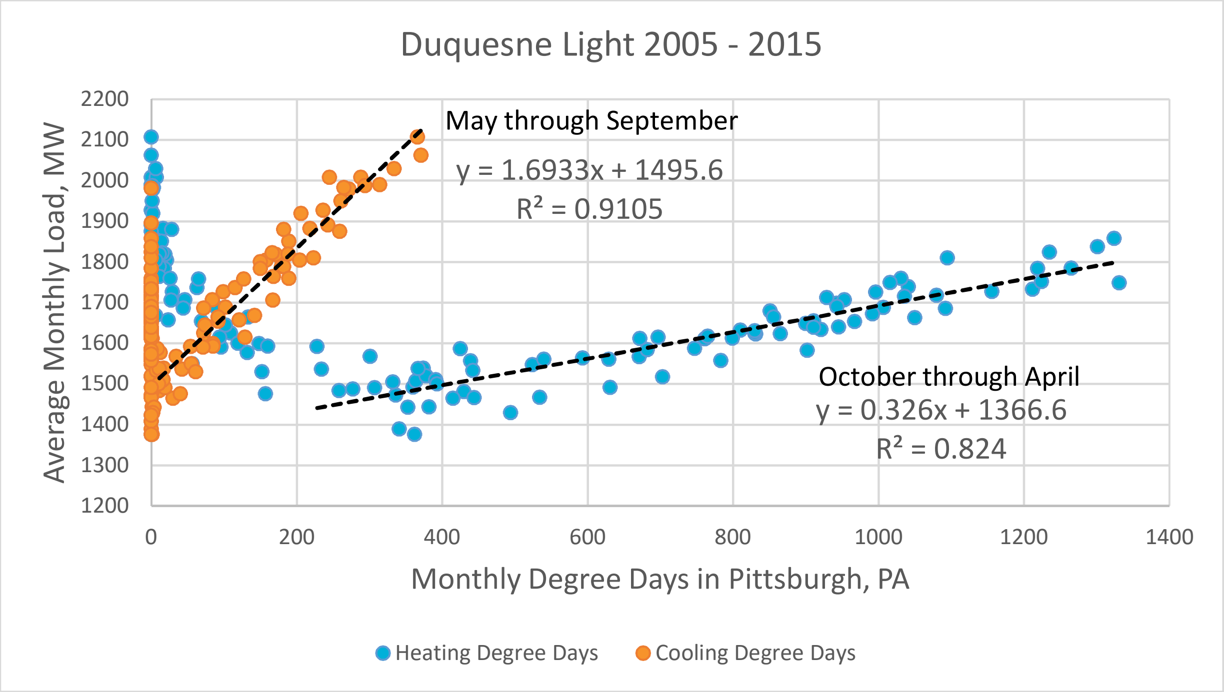
3.4.4 Seasonal Electricity Load

While the sections above describe seasonal electricity consumption, it is also valuable to examine real-time demand for electricity, and how it varies seasonally. Better understanding the instantaneous load on the electric grid can provide insights on usage patterns. This has the benefit of allowing for the better quantification of real-time emissions, but perhaps more importantly it can help quantify the potential benefits of different policy options, as many emissions reduction programs work by reducing peak energy demand. Programs such as demand response (i.e., peak demand reduction incentives), energy efficiency, and load shifting (i.e., real-time pricing of electricity) all have the potential to reduce emissions, energy consumption, and costs to the consumer by preventing inefficient and costly "peakers" from having to generate electricity.[ii] Consequently, understanding usage patterns and the behavior or factors that drive those patterns can help inform policy makers and regulators as to what programs might have the most potential for their region.

Using electrical grid load information reported for Duquesne Light's service territory, of which the study region is a subset, real-time demand for electricity from 2005 to 2015 was analyzed to determine seasonal and weather-related trends in peak demand. The results presented in Exhibit 3-29 show how demand for electricity increases sharply during summer months in response to CDDs, whereas the same effect – albeit to a lesser degree – can be observed during the winter in response to HDDs.

[ii] Electric generating stations in the United States, which are inefficient and/or costly to operate remain in service to provide electricity during times of peak electricity demand. These "peakers" only dispatch in the electricity market when demand – and therefore prices – is high. If these units can be prevented from having to dispatch (by reducing peak loads), it brings down electricity costs to the consumer and reduces emissions. Natural gas combustion turbines make up a large portion of the nation's peakers, as do old oil-fired steam generators, and certain older coal plants.

Exhibit 3-29 Monthly electricity load in Duquesne Light territory compared to HDD/CDD



3.5 PITTSBURGH PETROLEUM CONSUMPTION ESTIMATE

The transportation sector – and therefore petroleum usage – is known to be a substantial contributor to the City and region's energy consumption profile and GHG emissions. [17] Yet as noted above in Section 2.2.3, petroleum consumption data for smaller geographical regions are difficult accurately estimate due to lack of data granularity (gas stations have many users, compared to utility meters for each customer), the mobility of users, and other factors. Hence, it is important to have at least a qualitative estimate for consumption in this sector to put it in context of the City's energy footprint.

Petroleum consumption was estimated using state-level data available from EIA's SEDS as consumption data was not available at either the City-wide or ZIP code level. [7] This data as then scaled down the City level by using VMT as an approximation for relative consumption levels. VMT for the City were estimated through a mix of U.S. Census Bureau and DOE reported information on urban versus rural populations and VMT, respectively. [15] [8] This method is a coarse approximation and should be considered very qualitative.[jj]

The U.S. Census Bureau reported the population of PA to be 12.7 million and 12.8 million in 2010 and 2015, respectively. [15] By interpolation, the population of PA in 2013 was 12.77 million, and most of this population was in urban areas – an estimated 10.04 million people.

The DOE reports that in 2013, PA residents drove 98.6 billion VMT, and that 64.2 percent of these VMT were urban (rather than rural). [8] If urban VMT were predominantly driven by

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[jj] Obtaining VMT data at the ZIP-code level, for example, could certainly improve the quality of the estimate, but that data was not available at the time this report was written.

urban residents[kk] – a very coarse assumption – and that energy consumption directly corresponds with VMT in a region, urban drivers were then responsible for 64.2 percent of the energy used in the transportation sector.

Taking this analysis a step further, it was assumed that 578,000 residents in the study region (5.8 percent of PA's population) are classified as urban residents, and therefore fall within the 10.04 urban residents consuming 62.4 percent of the transportation energy. As a result, the Pittsburgh region is assumed to have consumed 3.7 percent of the total transportation energy in PA (62.4 percent multiplied by 5.8 percent).

PA transportation sector energy usage, as reported by the EIA, and the estimated City energy usage are reported in Exhibit 3-30. [7] The City's energy consumption was estimated to be 33.54 trillion Btu, most of which – 89 percent - was gasoline (22 trillion Btu) and diesel fuel (8 trillion Btu). When compared to the electricity and natural gas consumption levels above, transportation consumption constitutes 37 percent of the City's energy demand, while electricity is 21 percent and natural gas is 42 percent. In these calculations, the natural gas and electricity consumed within the transportation sector have been subtracted from the respective energy source calculation. These results are summarized in Exhibit 3-31.

Exhibit 3-30 2013 PA transportation sector energy consumption, by fuel

Fuel Type	Energy Usage by Fuel Type Trillion Btu	
	PA	Pittsburgh Region Estimate
Natural Gas	40.1	1.48
Retail Electricity Sales	2.8	0.1
Petroleum-derived Fuels		
Aviation Gasoline	0.5	0.02
Distillate Fuel Oil (includes Diesel)	215.9	7.98
Jet Fuel	41.5	1.53
LPG	1.5	0.06
Lubricants	6	0.22
Motor Gasoline	593.2	21.92
Residual Fuel Oil	6.3	0.23
Total End-Use Energy	**907.8**	**33.54**

Exhibit 3-31 City of Pittsburgh estimated 2013 energy consumption

	Electricity	Natural Gas	Transportation
Total (million MMBtu)	19.2	38.8	33.5
% of Total	21%	42%	37%

[kk] This works out to 10.04 million urban residents driving 63.3 trillion VMT, or each urban resident driving just over 6,300 VMT.

4 LIFE CYCLE GREENHOUSE GAS EMISSIONS FROM ENERGY USAGE

Energy sources such coal, natural gas, transportation fuels – both petroleum- and biomass-derived – produce GHG emissions when they are combusted. GHG emissions also occur in the process of extracting, processing, or converting these fuels to electricity. Evaluating the GHG emissions over the entire life cycle of the energy source gives a more complete picture of the relative climate impact of the energy used, as well as insights into opportunities for emissions reductions.

Life cycle emissions from natural gas and electricity usage totaled 6.7 million tons of carbon dioxide (CO_2) equivalents (CO_2e) in 2013, with electricity usage being the largest source of emissions at 55 percent, particularly in the commercial sector (37 percent of total city GHG emissions). Natural gas usage in the residential sector was the second largest source of emissions, accounting for 26 percent of total emissions in the city. These emissions are primarily associated with space heating, which is likely to be associated with between 17 percent and 26 percent of total emissions when both the residential and commercial sectors are considered.

Transportation fuel emissions were estimated to be 3.4 million tons of CO_2e in 2013, midway between natural gas-related emissions (3.0 million tons CO_2e) and electricity-related emissions (3.7 million tons CO_2e). This number has a considerable amount of uncertainty, however, as a result of the uncertainty in the total consumption estimate. Therefore, while it can be concluded that qualitatively, emissions from transportation fuel consumption are of the same magnitude as either natural gas or electricity, the actual quantity of emissions should be considered an estimate.

4.1 ELECTRICITY EMISSIONS

GHG emissions from electricity usage were evaluated by taking the electric generation mix ("grid mix") for the region – the PJM Interconnection – in 2013, and utilizing NETL's Grid Mix Explorer to determine the life cycle GHG emissions associated with that grid mix. A sensitivity analysis was also performed to assess how the annual emissions level would change for other grid mixes, notably the sub-regional mix or the national grid mix. Given recent changes in the national and regional electric grid, a fourth case was also evaluated in which the 2015 regional grid mix was utilized.

Exhibit 4-1 and Exhibit 4-2 describe the grid mixes evaluated for this study and the resultant emissions levels for the City and surrounding region. These grid mixes, and the choice for their selection is described in more detail in Section 2.3.4 above.

Exhibit 4-3 and Exhibit 4-4 illustrate the data presented in the tables, and clearly illustrate differences in magnitude between the GHG emissions profiles of the different grid mixes, as well as how the annual emissions vary based on different grid mix assumptions. These figures also show how CO_2 emissions dominate the total emissions – constituting about 95 percent of the impact – with methane (CH_4) emissions, though they are more potent, only constitute roughly 3 to 4 percent of the impact.

Exhibit 4-1 Electric generation grid mixes for Pittsburgh region

Grid Mix Name	2013			2015
	PJM	RFC-W	U.S. National Average	PJM
Scope	Regional	Sub-Regional	National	Regional
Percentage of Total Annual MWh by Fuel Type				
Coal	44.4%	63.8%	39.0%	36.6%
Natural Gas	16.4%	10.3%	27.8%	23.0%
Nuclear	35.1%	22.3%	19.4%	35.8%
Hydropower	1.0%	0.8%	6.6%	1.0%
Petroleum	0.1%	0.1%	0.3%	0.1%
Petroleum Coke	0.1%	0.2%	0.3%	0.1%
Solar	0.0%	0.1%	0.2%	0.1%
Wind	1.9%	1.8%	4.1%	2.1%
Wood	0.2%	0.1%	1.0%	0.2%
Municipal Solid Waste	0.5%	0.1%	0.5%	0.5%
Geothermal	0%	0%	0.4%	0%
Other Gas	0.3%	0.3%	0.3%	0.3%
Other	0%	0.2%	0.3%	0%
Emissions Profile (lb CO_2e/MWh, 100-yr)	**1,294**	**1,700**	**1,351**	**1,188**

Exhibit 4-2 Total electricity GHG emissions by grid mix for Pittsburgh region

Grid Mix Name	2013			2015
	PJM	RFC-W	U.S. National Average	PJM
2013 Emissions (millions of tons CO_2e)	**3.66**	**4.80**	**3.82**	**3.36**
Emissions Contribution by GHG (millions of tons of CO_2e)				
CO_2	3.51	4.66	3.63	3.2
N_2O	0.0197	0.0281	0.0181	0.0164
CH_4	0.103	0.0979	0.146	0.120
SF_6	0.0208	0.0210	0.0209	0.0207

Exhibit 4-3 Sensitivity of electricity GHG emissions profile to grid mix for Pittsburgh region

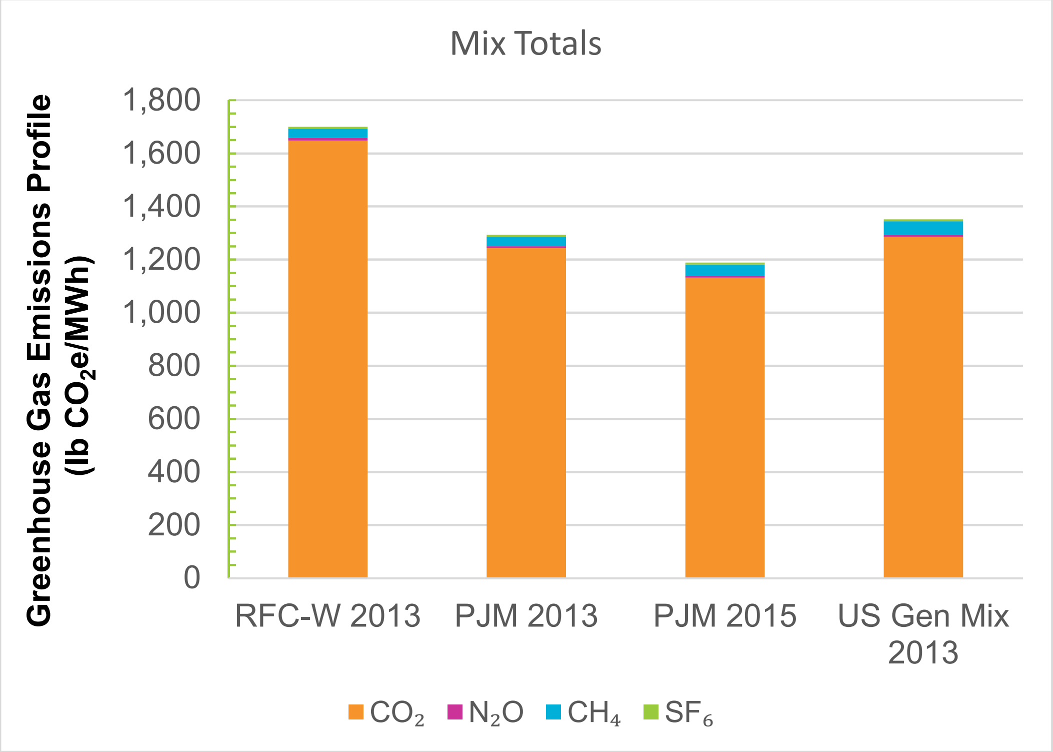
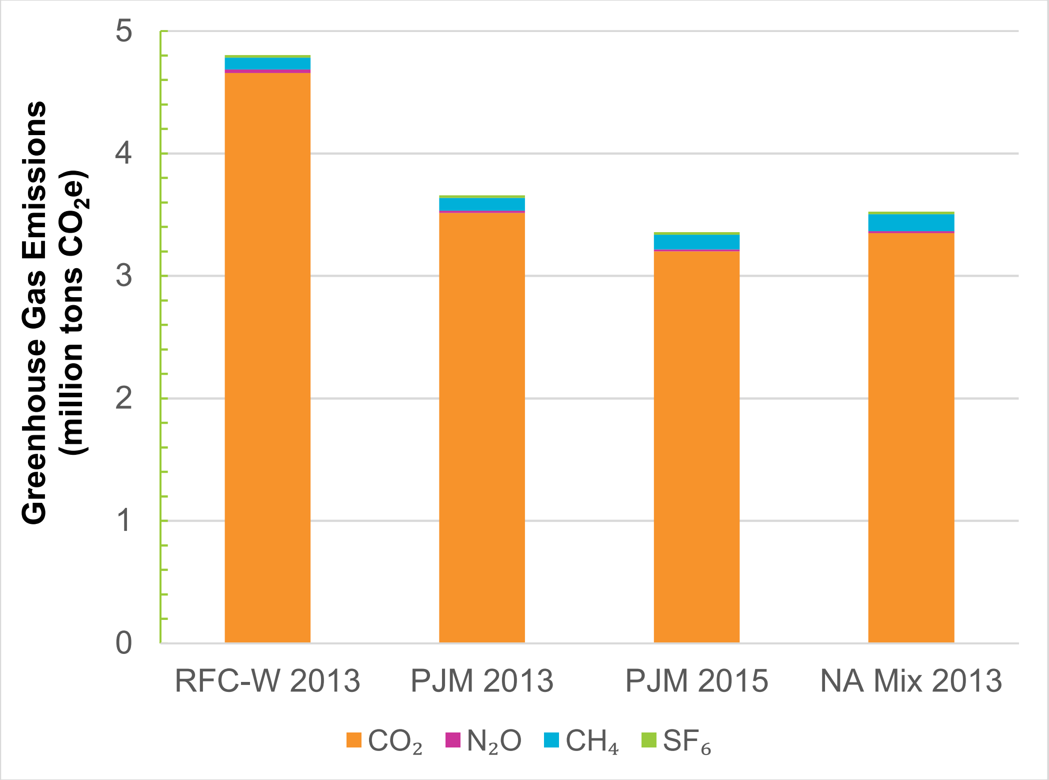


Exhibit 4-4 Sensitivity of total electricity GHG emissions to grid mix for Pittsburgh region



4.2 NATURAL GAS EMISSIONS

GHG emissions from natural gas usage was evaluated by taking upstream natural gas emissions profile for the extraction, processing, transportation, and distribution of natural gas, and assuming that natural gas is fully combusted. Natural gas is assumed to be produced from existing wells in Appalachia based on the proximity of the City to those wells. A sensitivity analysis was performed to assess how the annual emissions level would change for other natural gas upstream emissions profiles, notably the average profile for natural gas in the United States ("national average") and for new wells in Appalachia ("Appalachia - next well"). The national average emissions profile is higher than the Appalachia profile, while gas produced from new wells in Appalachia have less upstream emissions due to increased oversight, more stringent regulations, and better best practices. These emissions profiles are detailed in the recent NETL report entitled "Life Cycle Analysis of Natural Gas Extraction and Power Generation." [18]

Exhibit 4-5 and Exhibit 4-6 describe the natural gas sources evaluated for this study and the resultant emissions levels for the City and surrounding region. As shown, emissions from the combustion of natural gas constitute between 77 and 81 percent of the total emissions associated with natural gas usage. Consequently, differences in the upstream profiles of gas production has a muted effect on the total emissions profiles of gas from different locations. The tables also show that gas currently produced in Appalachia has a similar profile to the national average (resulting in just 0.8 percent less emissions for the Appalachia gas), but gas produced from future wells will have a more measurably reduced impact – 3.6 percent less emissions per million Btu – due to changes in regulation and industrial practices.

Exhibit 4-5 GHG emissions profiles for natural gas in Pittsburgh region

Life Cycle Stage	Emissions Profile (lb CO_2e/MMBtu)		
	Appalachia		U.S. National Average
	Current	Next Well	
Upstream (LC Stages 1-4)	33.3	27.9	34.4
Combustion [19]	117	117	117
Total	**150.3**	**144.9**	**151.4**
% Associated with Combustion	*78%*	*81%*	*77%*
% Change from Appalachia	*N\A*	*-3.6%*	*0.8%*

Exhibit 4-6 Sensitivity of natural gas-related GHG emissions to gas source for Pittsburgh region

	2013 Emissions, by Profile		
	Appalachia		U.S. National Average
	Current	Next Well	
Total Annual Emissions (millions of tons CO_2e)	3.03	2.92	3.05

4.3 TRANSPORTATION FUEL EMISSIONS

Transportation sector GHG emissions were estimated by first estimating transportation sector energy consumption, then using the appropriate GHG emissions profile for each fuel type to determine the emissions associated with utilizing that fuel. Emissions associated with natural gas or electricity used in the transportation sector were omitted from these calculations as they are accounted for under their relevant fuel types. As mentioned above, emissions estimates reported in this section should be considered a qualitative assessment based on the uncertainty associated with the consumption estimates.

4.3.1 Specific Emissions per Fuel Type

Life cycle GHG emissions vary substantially between different types of transportation fuels, due to differences in refining requirements, energy content, and carbon content of the fuel. Furthermore, the emissions profile of a given fuel will vary based on the crude oil it is derived from, as different crude oils require different levels of processing, and the environmental impact of crude oil production varies regionally due to differences in (or lack of) environmental regulations, production modes (primary, secondary, tertiary), industrial practices, and other factors.

Exhibit 4-7 below lists the Well-to-Wheels (WTW) or Well-to-Wake (WTW) (in the case of aviation fuels) life cycle GHG emissions profile for different transportation fuels in the United States. [20] The values presented are average U.S. values for the year 2014, as opposed to being based on a particularly Petroleum Administration for Defense Districts (PADD), as was advised by experts within NETL's life cycle analysis team. The team also advised the use of 2014 year values (instead of the 2013 study) based on the availability of citable data. The GHG profiles for motor gasoline, diesel fuel, and jet fuel are well documented and these fuels – along with natural gas and electricity – were estimated to constitute over 98 percent of all transportation fuel consumption. [7] The profiles for residual fuel oil, aviation gasoline, lubricants, and LPG, however, are not published in the literature or otherwise available. The small magnitude of consumption for these remaining fuels, combined with the lack of emissions profiles, led the authors to omit emissions from these fuels, as it would add significant uncertainty but not substantially effect the magnitude of the emissions.

Two transportation fuels, natural gas and electricity, are omitted from Exhibit 4-7 as the emissions for these fuels are dealt with in Section 4.1 and Section 4.2 above. Both fuels represent an opportunity for a reduced dependency on fossil fuel imports (in the scenario where petroleum-derived fuels are supplanted by domestic natural gas or electricity). These

Exhibit 4-7 WTW GHG emissions profiles for transportation fuels

Fuel	WTW Emissions (lb CO_2e/MMBtu)	% of Total Consumption	Notes/Assumptions
Motor Gasoline	223.8	65.3%	N\A
Diesel Fuel	214.0	23.8%	N\A
Jet Fuel	204.7	4.6%	N\A
Aviation Gas	223.8	0.1%	Assumed to be identical to motor gasoline

fuels also represent a potential avenue for GHG emissions reductions from the transportation sector in select situations.

For GHG emissions benefits to be realized, the following key variables must be evaluated:

- Life cycle GHG emissions associated with fuel usage (emissions per unit of energy produced/combusted)
- Efficiency of the drivetrain (units of energy – either as fuel or electricity – required to move the vehicle one mile)
- Temporal or other variable effects that might impact the GHG profile of the fuel (e.g., charging an electric car at peak times will adversely affect life cycle emissions)
- Operating parameters of the vehicle (e.g., whether a hybrid electric vehicle is operating off the battery or the combustion engine)
- Timeframe to be evaluated, as different vehicle types have different maintenance requirements over their lifetime (e.g., battery replacement in electric vehicles)

Providing an assessment of the benefits of different transportation fuels, which considers the above variables is beyond the scope of this report. However, a qualitative observation can be made that supplanting petroleum with electricity for transportation energy has a substantial potential to reduce GHG emissions in that sector. For this to be successful, the electricity must be provided from low carbon sources of electricity. This could be from incremental renewable energy, nuclear energy, or low-carbon fossil energy, the latter coming either via high efficiency generators (e.g., fuel cells) or power plants equipped with carbon capture and storage.

4.3.2 Estimated Transportation Sector Emissions

GHG emissions from the transportation sector were estimated at 3.4 million tons of CO_2e in 2013, based on transportation fuel consumption estimates derived from state-level data. These emissions, summarized in Exhibit 4-8, omit emissions from natural gas and electricity used for transportation. Inclusion of those emissions would bring total transportation sector emissions to 3.6 million tons of CO_2e, predominantly due to natural gas usage for transportation, which constituted an estimated 4.4 percent of total transportation energy consumption (1.5 million MMBtu) compared to 0.3 percent provided by electricity (0.1 million MMBtu, or 30,300 MWh).

Exhibit 4-8 Estimated transportation sector GHG emissions for Pittsburgh region

Fuel	GHG Emissions (million tons CO_2e)	% of Total Emissions
Motor Gasoline	2.45	71%
Diesel Fuel	0.85	25%
Jet Fuel	0.16	4.5%
Aviation Gas	0.002	0.1%
Total	**3.46**	
Electricity	0.02	
Natural Gas	0.11	
Total w/ Electricity & Natural Gas	*3.60*	

4.4 TOTAL LIFE CYCLE EMISSIONS FOR THE REGION

Total life cycle emissions for the region from natural gas and electricity usage was 6.7 million tons of CO_2e in 2013 (shown in Exhibit 4-9), with electricity usage being the largest source of emissions at 55 percent, particularly in the commercial sector (37 percent of total city GHG emissions). Natural gas usage in the residential sector was the second largest source of emissions, accounting for 26 percent of total emissions in the city (shown in Exhibit 4-10). These emissions are primarily associated with space heating, which is likely to be associated with between 17 percent and 26 percent of total emissions when both the residential and commercial sectors are considered.

Transportation fuel emissions were estimated to be 3.4 million tons of CO_2e in 2013, midway between natural gas-related emissions (3.0 million tons CO_2e) and electricity-related emissions (3.7 million tons CO_2e). This number has a considerable amount of uncertainty, however, because of the uncertainty in the total consumption estimate. Therefore, while it can be concluded that qualitatively, emissions from transportation fuel consumption are of the same magnitude as either natural gas or electricity (shown in Exhibit 4-11), the actual quantity of emissions should be considered an order of magnitude estimate.

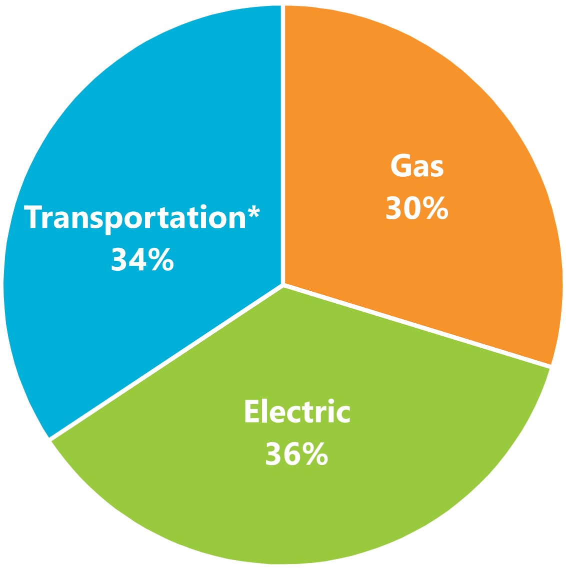
Exhibit 4-9 GHG emissions by sector and fuel type

Fuel	Total	Residential	Commercial	Industrial	% of Emissions by Fuel
Gas	3.0	1.7	1.0	**0.3**	**45%**
Electric	3.7	1.0	2.5	0.2	**55%**
Total	**6.7**	**2.7**	**3.5**	**0.5**	
% of Total		40%	52%	7%	
Total Emissions Including Transportation Emissions				*10.2*	

Exhibit 4-10 GHG emission fractions by sector, end use, and fuel type

Fuel	Residential	Commercial	Industrial
Gas %	26%	15%	4%
Electric %	15%	37%	3%
Heating Related	14 - 17%	3 - 8%	N\A
Total Heating Related	17 - 25%		

Exhibit 4-11 GHG emission fractions by fuel type



** Transportation emissions are estimated should be considered only to be of this general order of magnitude.*

5 ZIP CODE LEVEL ENERGY CONSUMPTION

This section provides electricity and natural gas consumption statistics broken down by ZIP code, on both an annual and monthly basis, as well as the peak consumption months of February (peak natural gas usage) and July (peak electricity consumption). Energy consumption is represented geographically in maps identifying areas of high and low consumption, and consumption metrics such as energy use per square mile and per meter are also reported. This data may be used to identify corridors suitable for early deployments of energy districts or other projects which and result in reduced energy use or reduced emissions.

5.1 TOTAL ENERGY CONSUMPTION

As previously described, electricity and natural gas consumption data was provided by the City, broken down by customer type – residential, commercial, and industrial – and ZIP code. Monthly data was available for all electricity consumption and available monthly natural gas was extrapolated to provide City-level consumption assessment.[ll]

This section reports energy consumption at the ZIP code level, with a focus on total energy consumption and the breakdown of total consumption in the residential and commercial sectors.

5.2 ENERGY CONSUMPTION – ALL SECTORS

Overall energy consumption in the City is concentrated in a small number of ZIP codes. Exhibit 5-1 shows that over 30 percent of all consumption is in top five consuming ZIP codes, and over 53 percent is in the top ten. The ZIP codes of 15219, 15222, 15213, and 15212 are areas of high energy consumption, particularly in the categories of total consumption, energy consumption density, and per capita consumption.

ZIP code 15213 is the highest in total energy consumption, third in in energy consumption per mi^2 and sixth in per capital consumption. ZIP codes 15219 and 15222 are in the top five for all three categories, and 15212 has the second highest total consumption, but it is a physically large ZIP code, resulting in a ranking of 11th in terms of energy per square mile.

Exhibit 5-1 Total energy consumption by ZIP code, 2013

Total Consumption			Per Square Mile		Per Capita 2010	
ZIP Code	MMBtu	Percentage of Total Consumption	ZIP Code	MMBtu/mi²	ZIP Code	MMBtu
15213	4,615,921	7.8%	15260	13,003,128	15222	880
15212	4,396,447	7.4%	15222	3,568,307	15233	288
15219	3,576,810	6.0%	15213	2,166,082	15219	214
15235	3,167,982	5.3%	15232	2,063,455	15212	158
15222	2,897,465	4.9%	15219	1,559,202	15201	151

[ll] One of the three natural gas utilities provided monthly consumption data. This data constituted 76 percent of the City's natural gas consumption, and was extrapolated to provide an estimate of monthly gas consumption data.

5.2.1 Electricity Consumption – All Sectors

The three ZIP codes (15213, 15219, and 15222) located in the center of the City, consume 35 percent of the total electricity demand (shown in Exhibit 5-2) for the region as well as per square mile. ZIP code 15213 has the highest volume of electricity consumption and per capita. These areas have large commercial sectors, which increase their consumption per capita. ZIP code 15290 has only six commercial meters making its consumption per meter very high.

Exhibit 5-2 Total electricity consumption, 2013

Total Consumption			Per Square Mile		Per Meter		Per Capita 2010	
ZIP Code	Million kWh	Percentage of Total Consumption	ZIP Code	Million kWh/mi²	ZIP Code	kWh/Meter	ZIP Code	Thousand kWh
15213	831	14.7%	15222	688	15290	2,044,467	15222	169.6
15219	594	10.5%	15213	390	15222	107,955	15233	45.7
15222	559	9.9%	15290	307	15219	85,218	15219	35.6
15205	366	6.5%	15219	259	15233	83,687	15213	26.9
15212	362	6.4%	15232	195	15213	70,445	15203	17.3

In February, the highest energy consumption month in 2013, the same three ZIP codes (15213, 15219, and 15222) located in the center of the City had the highest electricity consumption, shown in Exhibit 5-3. ZIP code 15213 had the largest consumption of electricity, using 57.1 million kWh, which made up 12 percent of all the electricity consumption in the mapped area. ZIP code 15213, 15219, and 15222 constitute 35.1 percent of the total electricity consumption in the City during February. This may be due to the prevalence of large commercial properties in the area.

Electricity consumption in July (Exhibit 5-4) mirrored that of February, where the largest areas of demand in the City were the ZIP codes with significant commercial activity (15219 and 15222) and high population density (15213).

Exhibit 5-3 Electricity consumption per ZIP code – February 2013

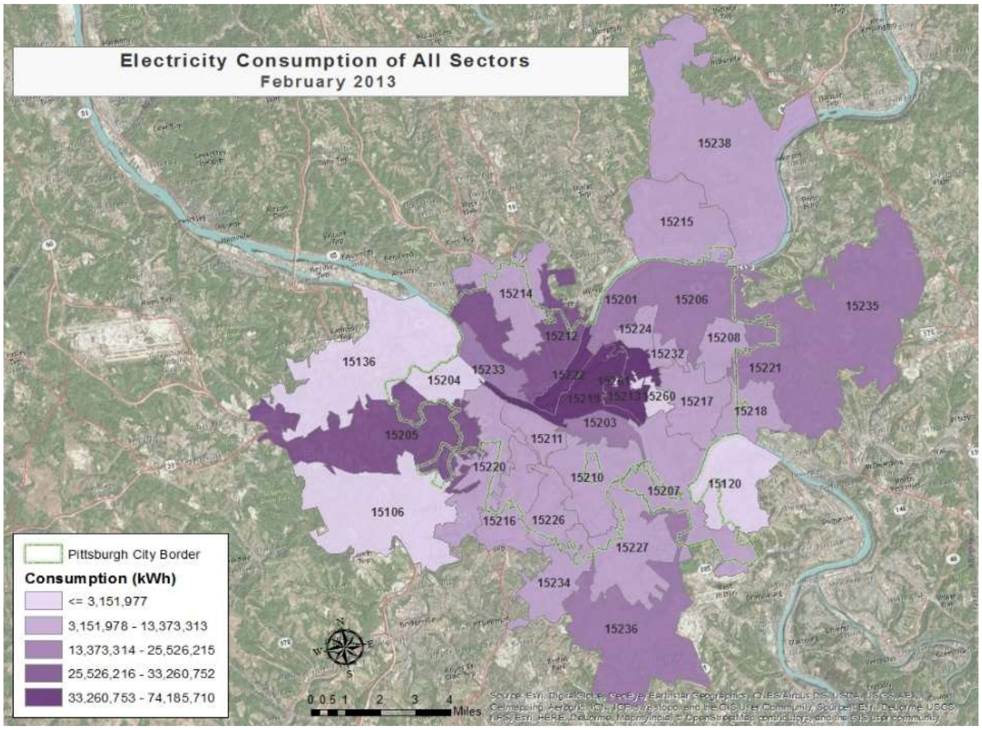
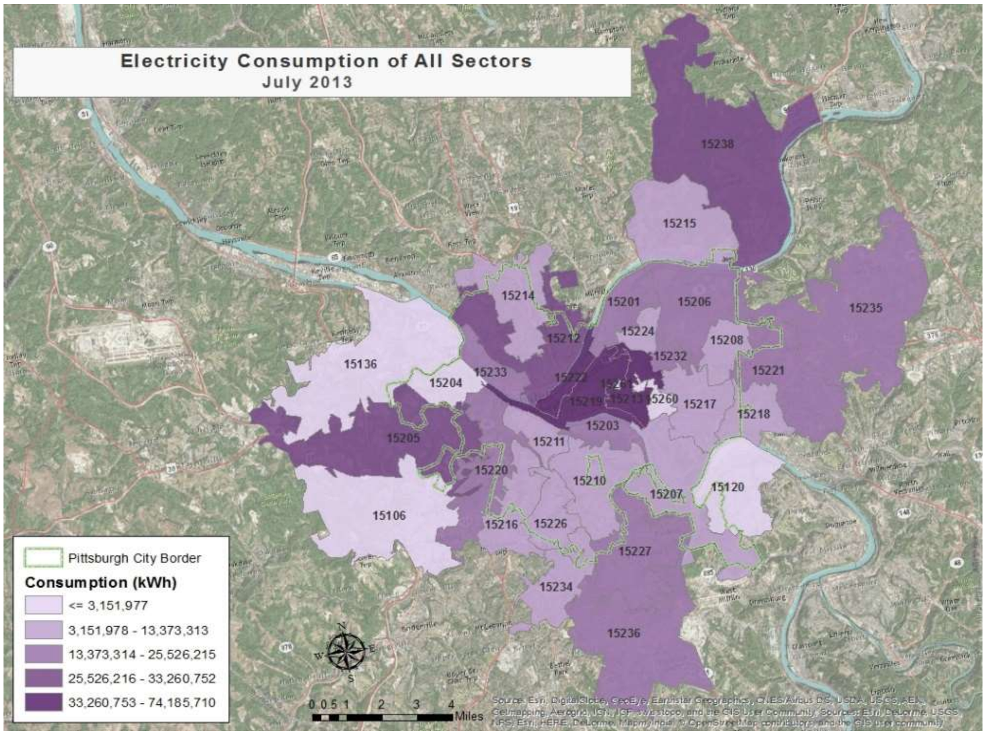


Exhibit 5-4 Electricity consumption per ZIP code – July 2013



5.2.2 Electricity Consumption – Residential

Residential electricity consumption, shown in Exhibit 5-5, shows that electricity consumption is higher in the suburbs directly adjacent to the large commercial sector of the City. Exhibit 5-6 shows the suburban areas with the highest electricity demand.

Exhibit 5-5 Residential electricity consumption per ZIP code – February 2013

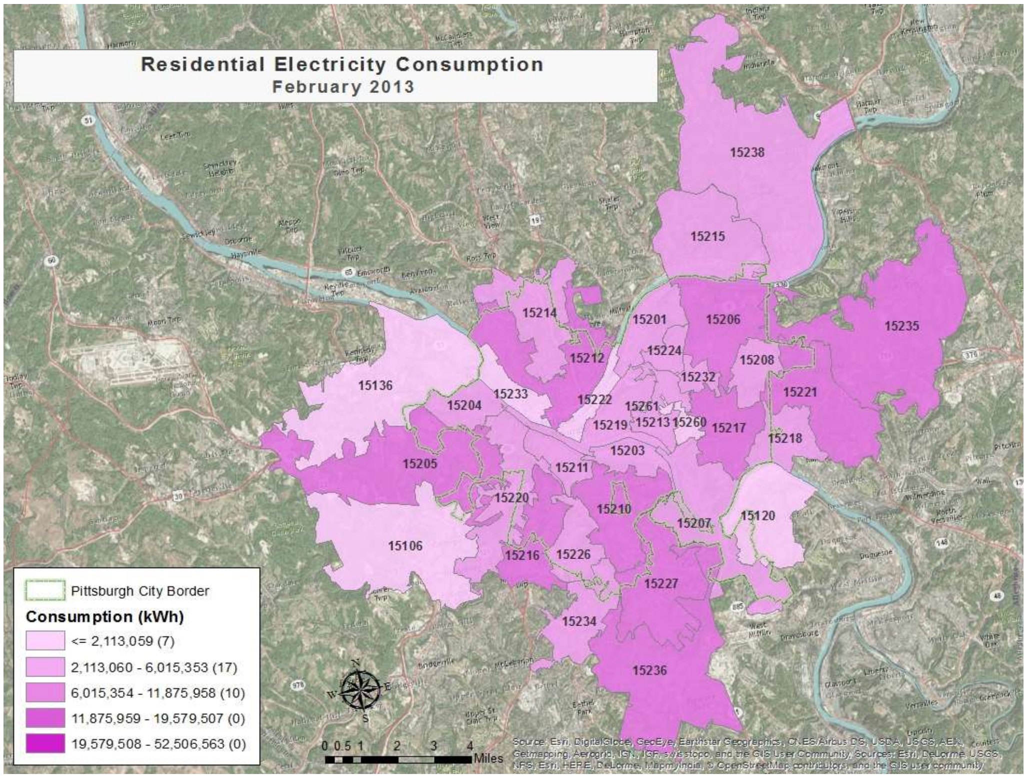


Exhibit 5-6 Residential electricity consumption, 2013

Total Consumption			Per Square Mile		Per Meter		Per Capita 2010	
ZIP Code	Total Consumption (Million-kWh)	Percentage of Total Consumption	ZIP Code	Million kWh/mi²	ZIP Code	kWh/ Meter	ZIP Code	Thousand kWh
15235	131.9	8.8%	15232	47.2	15215	8,403.9	15222	4.6
15221	104.4	6.9%	15224	32.6	15235	7,876.4	15203	3.9
15227	92.0	6.1%	15211	26.5	15204	7,269.8	15215	3.9
15206	88.2	5.9%	15203	26.2	15217	7,219.4	15235	3.8
15212	87.7	5.8%	15213	23.5	15214	7,172.8	15211	3.7

5.2.3 Electricity Consumption – Commercial

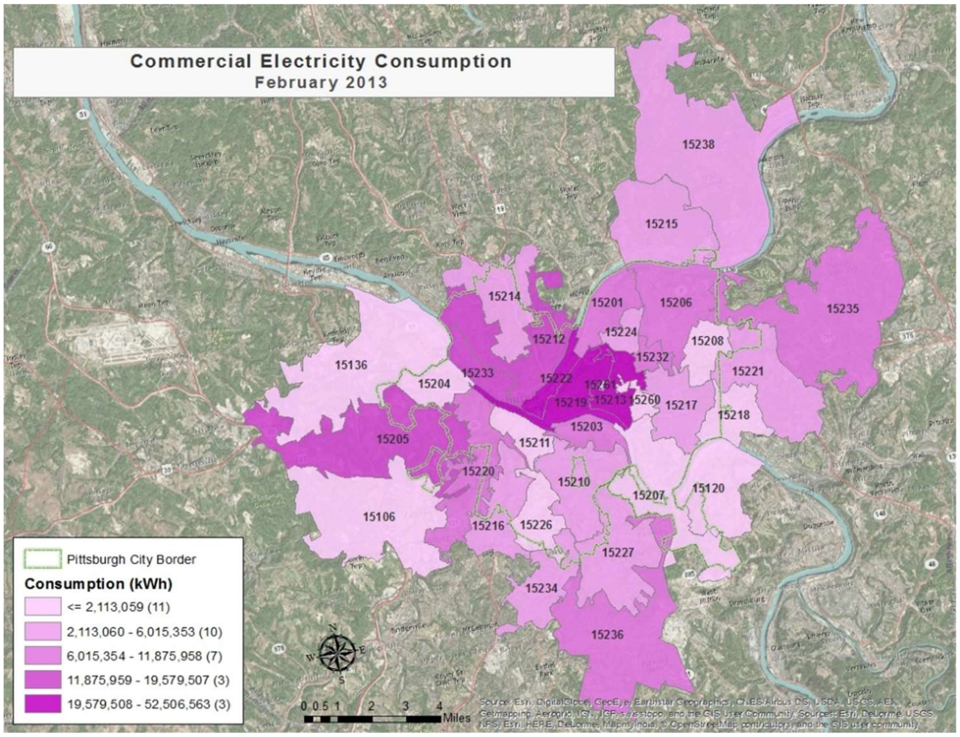
Unlike the residential sector, consumption of electricity for commercial businesses is more concentrated in the center of the City. Exhibit 5-7 shows that the 15213 ZIP Code (Oakland/Shadyside) has the highest commercial demand, the center of the City is next in demand, followed by an adjacent Zip code in the center of the City, along the Allegheny River. Between these three commercial districts, they make up nearly 48 of total commercial electricity demand.   The top five ZIP codes make up over 60 percent of all commercial electricity demand.

Commercial electricity consumption in February 2013, shown in Exhibit 5-78, matches the annual consumption trend, with the highest demand for electricity during that month occurring in the same ZIP codes as occurs during the remainder of the year.

Exhibit 5-7 Commercial electricity consumption, 2013

Total Consumption			Per Square Mile		Per Meter		Per Capita 2010	
ZIP Code	Total Consumption (Million-kWh)	Percentage of Total Consumption	ZIP Code	Million kWh/mi²	ZIP Code	kWh /Meter	ZIP Code	Thousand kWh
15213	779	20.5%	15222	635.5	15290	2,044	15222	156.7
15219	544	14.3%	15213	365.6	15213	270	15233	39.9
15222	516	13.6%	15219	237.3	15219	253	15219	32.6
15205	253	6.7%	15232	148.0	15233	195	15213	25.3
15212	242	6.3%	15233	142.8	15222	185	15203	12.2

Exhibit 5-8 Commercial electricity consumption per ZIP code – February 2013



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Sources: Esri, DeLorme, USGS, NPS, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

5.2.4 Natural Gas Consumption – All Sectors

Natural gas consumption is more evenly distributed across ZIP codes in the Pittsburgh region than electricity consumption. The top five natural gas consumers make up around 28.5 percent of all gas consumption, as shown in Exhibit 5-9, where the top five electricity consumers pulled around 48 percent. The North Side (15212) was the largest overall consumer of natural gas. This ZIP code has a balance of both residential and commercial consumers.

Natural gas data was collected and analyzed on the ZIP code level for both commercial and residential consumption for the month of February. As previously stated, February is the highest natural gas consumption month and industrial natural gas consumption is relatively constant throughout the year. Therefore, commercial and residential natural gas consumption are the most sensitive to heating demand in the cold months.

Exhibit 5-9 Total natural gas consumption, 2013

Total Consumption			Per Square Mile		Per Meter		Per Capita 2010	
ZIP Code	Total Consumption (MMBtu)	Percentage of Total Consumption	ZIP Code	MMBtu /mi^2	ZIP Code	MMBtu /Meter	ZIP Code	MMBtu
15212	3,161,947	7.9%	15260	13,003,128	15260	42,130	15222	301
15235	2,271,933	5.7%	15232	1,397,402	15290	14,942	15233	132
15221	2,077,224	5.2%	15222	1,220,781	15261	1,039	15212	113
15206	2,007,955	5.0%	15213	835,364	15222	792	15238	105
15217	1,865190	4.7%	15219	675,930	15233	393	15232	98

5.2.5 Natural Gas Consumption – Residential

Overall residential natural gas for the year 2013 (Exhibit 5-10) shows Penn Hills (15235) with the highest consumption, followed by Wilkinsburg (15221), Squirrel Hill (15217), Mount Oliver/Carrick (15210), then the Northshore (15212) rounding out the top five. The top 5 areas annually consume about 32 percent of all natural gas in the region.

Exhibit 5-10 Total residential natural gas consumption, 2013

Total Consumption			Per Square Mile		Per Meter		Per Capita 2010	
ZIP Code	Total Consumption (MMBtu)	Percentage of Total Consumption	ZIP Code	MMBtu/ mi^2	ZIP Code	MMBtu/ Meter	ZIP Code	MMBtu
15235	1,837,581	8.0%	15232	438,907	15210	121	15208	57
15221	1,627,658	7.1%	15224	434,747	15214	111	15218	57
15217	1,436,225	6.3%	15217	377,358	15204	107	15235	53
15210	1,265,559	5.5%	15208	370,874	15216	105	15217	53
15212	1,192,074	5.2%	15211	339,924	15215	103	15221	52

During the highest gas consumption month (February), ZIP code 15235 had the highest residential natural gas consumption, which is 8 percent of the total consumption in the study area. Exhibit 5-11 shows the residential natural gas consumption. This ZIP code encompasses the East Pittsburgh region, consisting of the Monroeville/Penn Hills area, and has the second highest population per mi^2 in the region and the largest number of households per mi^2. Other ZIP codes with high residential natural gas consumption are Wilkinsburg/Edgewood/Swissvale (15221), the North Side (15212), Mount Washington (15210), and Squirrel Hill (15217). All areas have population per mi^2 in the top 40 percent of the areas studied, except for 15217.

5.2.6 Natural Gas Consumption – Commercial

Annual commercial natural gas consumption is consistent with annual commercial electricity consumption, as ZIP codes 15213, 15222, 15219, and 15205 are in the top five consumers for both electricity and natural gas. Exhibit 5-12 shows that the top five consumers took up nearly 38 percent of commercial natural gas demand.

Exhibit 5-11 Residential natural gas consumption per ZIP code – February 2013

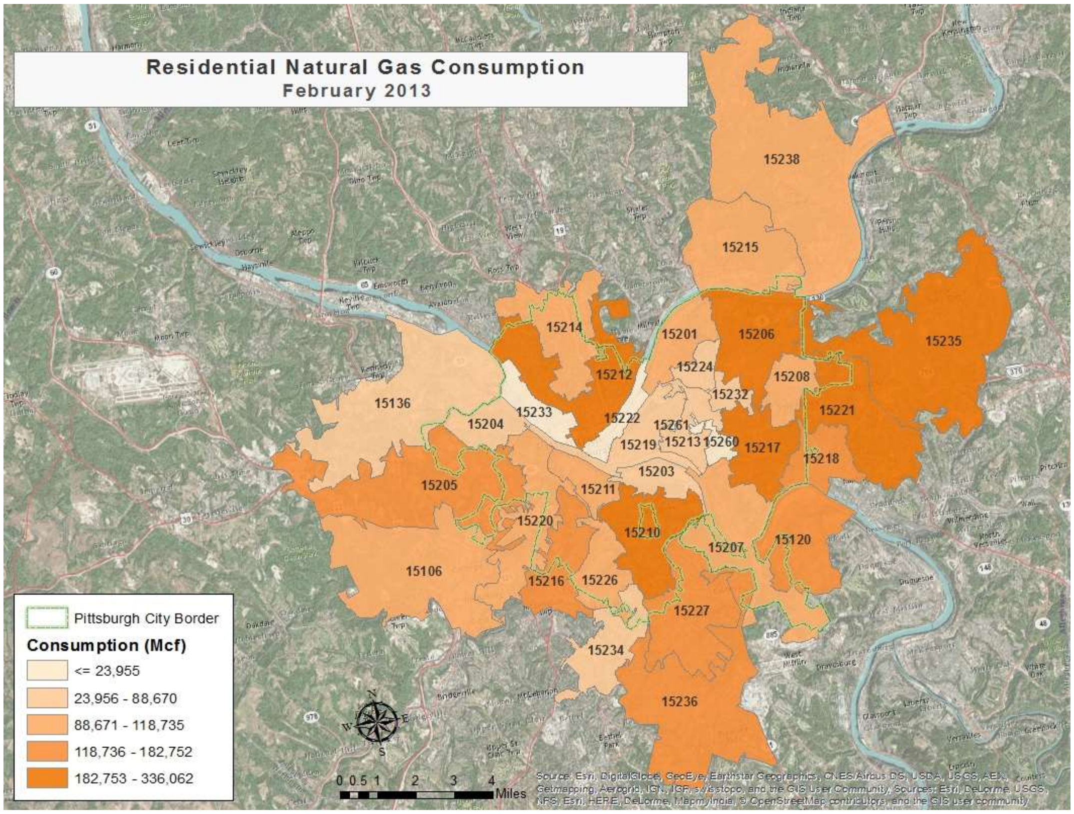
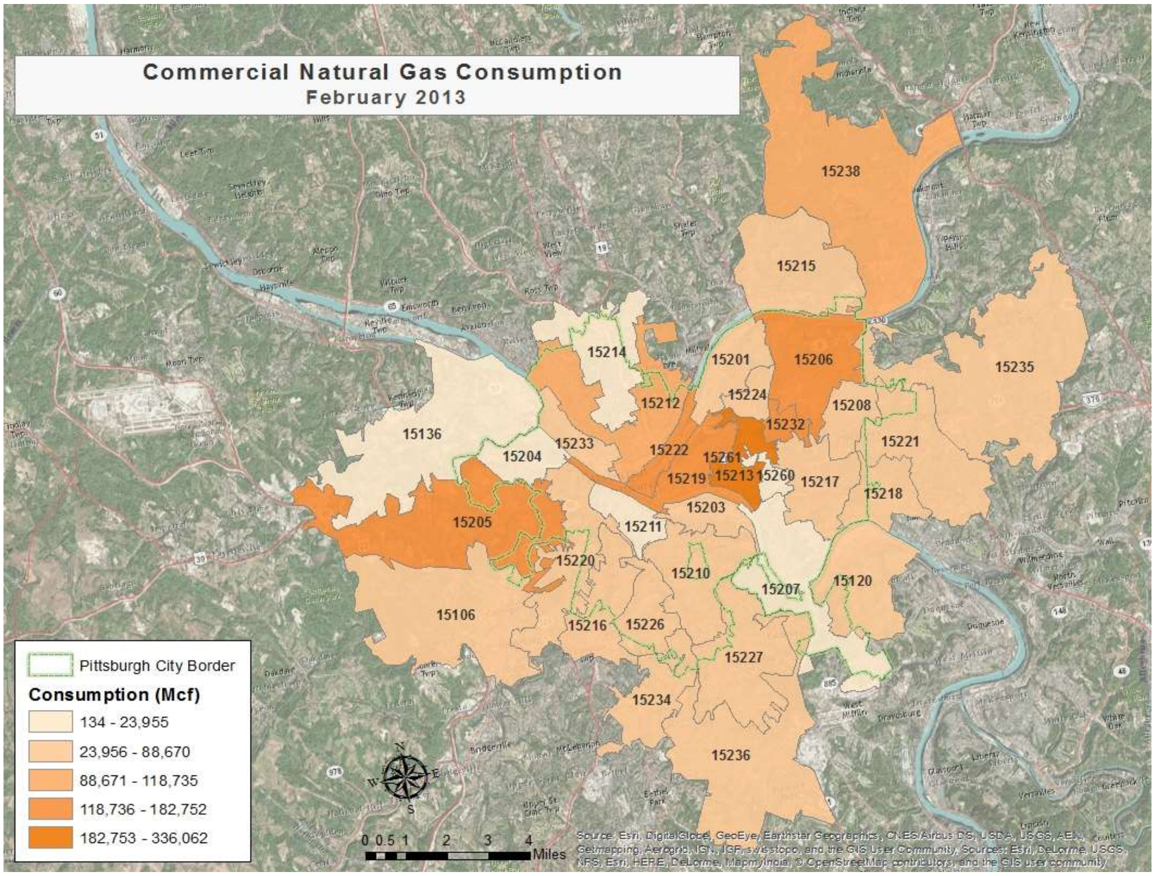


Exhibit 5-12 Total commercial natural gas consumption, 2013

Total Consumption			Per Square Mile		Per Meter		Per Capita 2010	
ZIP Code	Total Consumption (MMBtu)	Percentage of Total Consumption	ZIP Code	MMBtu/mi²	ZIP Code	MMBtu /Meter	ZIP Code	MMBtu
15213	1,292,532	9.5%	15222	1,166.836	15290	14,942	15222	288
15222	947,471	7.0%	15232	958,495	15233	1,996	15233	96
15219	925,799	6.8%	15213	606,538	15261	1,039	15232	67
15206	821,985	6.0%	15219	403,574	15120	1,015	15219	55
15205	785,139	5.8%	15290	373,542	15222	952	15201	48

In February, ZIP code 15213 had the highest commercial natural gas consumption (203,155 MMBtu), which is 9 percent of the overall consumption in the area analyzed. 15213 is the area where the University of Pittsburgh, Carnegie Mellon University, many hospitals, and small and large businesses reside, and has a diverse population consisting of single family homes and apartments. It is in the bottom third of land area (around 2.13 mi²), number of households per mi² (1,315), and population per mi² (3,581) in the study area, but has a large commercial demand. Exhibit 5-13 shows the commercial consumption for natural gas.

Exhibit 5-13 Commercial natural gas consumption per ZIP code – February 2013



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community, Sources: Esri, DeLorme, USGS, NPS, Esri, HERE, DeLorme, MapmyIndia, © OpenStreetMap contributors, and the GIS user community

6 OPPORTUNITIES FOR ENERGY USAGE AND EMISSIONS REDUCTIONS

Three key opportunities for reduction in energy usage and/or greenhouse gas emissions can be discerned from the data presented above:

- Heating-related natural gas usage constitutes up to 56% of all natural gas usage in the City, 38% of all non-transportation energy usage, and up to 25% of the non-transportation-related GHG emissions in the City. The residential sector is of interest, as up to 68% of gas usage in that sector is heating-related, equating to an estimated 17% of total energy use for the City (not including transportation sector emissions).
- Commercial sector electricity usage constitutes 37% of total non-transportation energy usage in the City, and an estimated 25% of total overall energy usage.
- Transportation sector energy usage and GHG emissions have been estimated to be of a similar magnitude to electricity and natural gas-related energy usage and emissions.

The City has a robust energy innovation ecosystem, with numerous institutions focused on technology development, as well as a commercial sector that has shown a willingness to innovate and deploy new technologies. As such, action is already underway to address some of these opportunities, as are described below.

To help inform the stakeholders in the City's energy innovation ecosystem, future work under this MOU will examine additional technology pathways which can be applied at a building, sector, or energy district (geographic) scale to reduce energy use and emissions in a sustainable and cost effective way.

6.1 COMMERCIAL SECTOR

One initiative, which is already having an impact on energy (and water) usage in the commercial sector, is the Pittsburgh 2030 District. The City is one of fifteen 2030 Districts in North America taking part in this initiative, in which the public and private sector work together to achieve a 50 percent reduction in energy and water usage, as well as a 50 percent reduction in transportation emissions. The Pittsburgh 2030 District has enrolled approximately 70 percent of the real estate square footage in Downtown, Oakland, and the Northside, densely populated and energy intensive sections of the City. The commercial entities in this area consume 48 percent and 24 percent of all commercial sector electricity and natural gas (respectively) in the City.[mm] This equates to 76 million square feet, more square footage committed than any other 2030 District. [21] Therefore, not only will the program directly impact both electricity usage and heating-related natural gas usage in the commercial sector, it will do so in one of the most energy intensive areas of the City.

This program is one of many that are poised to make a large impact, as well as ensuring the City continues to be recognized as an innovator in the field of energy use. Other initiatives,

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[mm] As noted above in Section 5.2.3 and Section 5.2.6.

such as Carnegie Mellon University's Smarter Buildings Initiative – a partnership with IBM focused on cloud-based analytics for building operation – and the University of Pittsburgh's Direct Current Architecture of Modern Power Systems (DC-AMPS) program are examples of the technology-based initiatives occurring within the City that support and underpin the progress in programs like the Pittsburgh 2030 District. [22] [23]

6.2 TRANSPORTATION SECTOR

The City is aggressively pursuing transportation emissions reductions through pathways ranging from the establishment of bicycle infrastructure to support for vehicle electrification and the integration of renewable energy with vehicle charging infrastructure. [24] [25] [26] [27] These initiatives aim to reduce transportation energy usage and emissions through pathways such as improved vehicle efficiency and a reduced private automobile VMT, either through increased ridership in in public transportation or a shift to other transportation modes such as bicycles or walking. The City looks to improve vehicle efficiency through the electrification of light-duty municipal vehicles and city buses, as well as by offering electric charging stations throughout the city.

6.3 FINANCIAL INCENTIVES FOR ENERGY REDUCTION IN BUILDINGS

The City's embrace of innovative and non-traditional approaches to energy and water use reduction is powered in part by a diverse number of energy incentives and financing opportunities. The Green Building Alliance and Duquesne University have compiled a list of regional and national programs that incentivize these projects. [28]

7 THE ROLE OF THE ENERGY DISTRICT

The purpose of this report is threefold:

1. To better quantify energy usage and trends in the City;
2. To identify opportunities for energy usage and GHG emissions reduction; and
3. To identify and characterize locations for early mover energy districts, by locating geographic areas of high consumption and quantifying usage trends in each City area for potential energy district developers.

The City's focus on energy districts – or the "grid of microgrids" concept – is based on the increasing global recognition of the value that district-scale energy systems can bring. Designing systems around the energy needs of a neighborhood or city allows developers to tailor make systems that take advantage of local resources, infrastructure, and other regional features. While these systems may require more up-front engineering, they can be made to be highly efficient and often more cost effective than traditional, off-the-shelf technologies. .[nn]

District-scale energy systems have several other notable benefits:

- Provide resiliency by ensuring localized energy generation.
- Higher utilization rates due to broader customer base: when one customer isn't using any energy, other customers may be. For example, a single building which installs a solar power array may only utilize a portion of the electricity generated at any given time of the day. One option to take advantage of this excess generating capacity would be to purchase batteries to store the electricity (incurring additional cost). A second option is to sell it back into the electric grid, but the ability-to and value-of doing this depends on state and local regulations, many of which are currently in a state of flux.[oo] If the building is connected to a microgrid, however, other local users can use the electricity directly. This has a range of benefits, from resiliency to opportunities to start new markets for energy internal to the microgrid or energy district.
- Single point of maintenance (compared to having to go into each commercial and residential building served by the system), streamlining maintenance, requiring only one system to be monitored for optimal operation.
- Increased upgrade and expansion options, as there is a reduced overhead of upgrading a single system, compared to many systems deployed in many buildings. An example is

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[nn] District energy systems, particularly combined heat and power systems, offer efficiency and fuel savings benefits when compared to the alternative of implementing separate systems for a building's heating, onsite electricity generation, and in some cases, cooling. [1] [2] [3] [4] Furthermore, the implementation of a district-scale system can often balance perturbations in load or enable higher utilization rates. This enables more efficient operation, as transient and part-load operation causes less efficient operation in these types of energy systems (heating, cooling, electric generators). [5] [6] Cost savings compared to purchasing power from the electric grid and utilizing a building-scale heating and cooling unit, however, are dependent on local energy costs, as regions with extremely low electricity prices result in lower cost benefits associated with fuel savings, and therefore may not offset the cost of capital and operating expenditures compared to utilizing grid electricity.

[oo] Net metering regulations exist in many states, allowing homes which generate more electricity they need to receive some value for it, either in the form of a monetary value or as a direct exchange for electricity consumed at another time. The value which these generators should receive is currently being debated or legally challenged in some states, in part due to an increased market penetration of onsite renewable energy.

Duquesne University, which has continued to upgrade its CHP system, integrating cooling systems and thermal storage. [4]

- Reduced costs due to economies of scale (compared to individual building-sized).
- Potentially broader range of systems available at larger scale.

It is the hope of the authors that this paper will inform potential developers as to the opportunities for future energy districts in the City by identifying hot-spots of energy usage and characterizing energy usage trends throughout the City. These districts will be heterogeneous, tailored to the energy footprint and needs of the district, yet many similarities are to be expected based on the dominance of seasonal impacts on energy usage.

The creation of multiple energy districts in the City seems likely to inspire cross-pollination of ideas and accelerate the technology evolution and maturation. In this way, the City can become a center for innovation not just in energy district and "eco-district" design, but also in the advanced energy technologies that will underpin those districts. Furthermore, the successful design and deployment of these districts will enable these designs to be replicated throughout the region.

8 REFERENCES

[1] A. Shipley, A. Hampson, B. Hedman, P. Garland and P. Bautista, "Combined Heat and Power: Effective Energy Solutions for a Sustainable Future," Oak Ridge National Laboratory, Oak Ridge, TN, 2008.

[2] International Energy Agency, "Linking Heat and Electricity Systems: Co-generation and District Heating and Cooling Solutions for a Clean Energy Future," International Energy Agency, Paris, France, 2014.

[3] U.S. Environmental Protection Agency Combined Heat and Power Partnership, "Catalog of CHP Technologies," U.S. Environmental Protection Agency, Washington, DC, 2017.

[4] D. Conti, "Cogeneration lets Duquesne University meet its heating, cooling goals," 14 June 2015. [Online]. Available: http://triblive.com/business/headlines/8449209-74/cogeneration-duquesne-university. [Accessed 2 11 2017].

[5] R. Hart, "Introduction to Commercial Building HVAC Systems and Energy Code Requirements," U.S. Department of Energy Building Energy Codes Program, Richland, WA, 2016.

[6] Office of Building Technology, State, and Community Programs, "Technology Fact Sheet: Right-Size Heating and Cooling Equpment," U.S. Department of Energy, Washington, DC, 2002.

[7] U.S. Energy Information Administration (EIA), "Pennsylvania State Profile and Energy Estimates," EIA, [Online]. Available: http://www.eia.gov/state/seds/?sid=PA. [Accessed 1 September 2016].

[8] U.S. Department of Energy (DOE), "Rural Versus Urban Vehicle Miles Traveled, by State," DOE, [Online]. Available: http://energy.gov/eere/vehicles/fact-902-december-7-2015-rural-versus-urban-vehicle-miles-travel-state. [Accessed 1 September 2016].

[9] U.S. Census Bureau, "Quick Facts: Pennsylvania," U.S. Census Bureau, [Online]. Available: http://www.census.gov/quickfacts/table/PST045215/42. [Accessed 1 September 2016].

[10] Energy for the Power of 32, "Energy for the Power of 32," Energy for the Power of 32, 11 Dec 2014. [Online]. Available: http://www.energy4p32.org/. [Accessed 24 May 2016].

[11] National Oceanic and Atmospheric Administration, "Weather Station Data," NOAA, [Online]. Available: http://www.ncdc.noaa.gov/cdo-web/datasets/GHCNDMS/stations/GHCND:USW00094823/detail. [Accessed 10 September 2016].

[12] National Energy Technology Laboratory (NETL), "Grid Mix Explorer (Model)," NETL, 28 January 2015. [Online]. Available: https://www.netl.doe.gov/research/energy-analysis/search-publications/vuedetails?id=757.

[13] J. Marriott, H. S. Matthews and C. T. Hendrickson, "Impact of Power Generation Mix on Life Cycle Assessment and Carbon Footprint Greenhouse Gas Results," *Journal of Industrial Ecology*, vol. 14, no. 6, 2010.

[14] J. Marriott, Interviewee, *Verbal communication with Joe Marriott.* [Interview]. 2016.

[15] United States Census Bureau, "Quick Facts: City of Pittsburgh, Pennsylvania," 2015. [Online]. Available: http://www.census.gov/quickfacts/table/PST045215/4261000. [Accessed 24 May 2016].

[16] U.S. Energy Information Administration (EIA), "Energy Units and Calculators Explained: Degree-Days," 15 Dec 2015. [Online]. Available: http://www.eia.gov/energyexplained/index.cfm?page=about_degree_days. [Accessed 24 May 2016].

[17] Sustainable Pittsburgh, "Energy Baseline for the Power of 32 Region," Dec 2014. [Online]. Available: http://www.energy4p32.org/RegionalEnergyBaselineforP32v.2.pdf . [Accessed 24 May 2016].

[18] National Energy Technology Laboratory (NETL), "Life Cycle Analysis of Natural Gas Extraction and Power Generation," NETL, Pittsburgh, PA, 2016.

[19] U.S. Energy Information Administration (EIA), "Frequently Asked Questions: How much carbon dioxide is produced when different fuels are burned?," EIA, 14 June 2016. [Online]. Available: https://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11. [Accessed 10 September 2016].

[20] G. Cooney, M. Jamieson, J. Marriott, J. Bergerson, A. Brandt and T. J. Skone, "Updating the U.S. Life Cycle GHG Petroleum Baseline to 2014 with Projections to 2040 Using Open-Source Engineering-Based Models," *Environmental Science & Technology*, vol. 51, no. 2, pp. 977-987, 2017.

[21] 2030 Districts, "Pittsburgh 2030 District," 2030 Districts, [Online]. Available: http://www.2030districts.org/pittsburgh. [Accessed 30 November 2016].

[22] A. Simmons and H. Haswell, "Carnegie Mellon and IBM Launch First Cloud-Based Analytics Partnership for Smarter Buildings," Carnegie Mellon University, 5 March 2015. [Online]. Available: https://www.cmu.edu/news/stories/archives/2015/march/partnership-for-smarter-buildings.html. [Accessed 30 November 2016].

[23] J. Miksch, "Pitt Project Aims to Turn World On to DC Power," University of Pittsburgh, 17 November 2015. [Online]. Available: http://www.engineering.pitt.edu/News/2015/Hillman-Foundation-DC-AMPS-Grant/. [Accessed 30 November 2016].

[24] City of Pittsburgh, "Bicycling Information," Pittsburgh Department of City Planning, [Online]. Available: http://pittsburghpa.gov/dcp/bicycling. [Accessed 30 November 2016].

[25] Pittsburgh Bike Share, "PGH Bike Share," Pittsburgh Bike Share, [Online]. Available: http://pghbikeshare.org/. [Accessed 30 November 2016].

[26] R. Deto, "City reveals preliminary plans for new bike infrastructure Downtown," Pittsburgh City Paper, 15 December 2015. [Online]. Available: http://www.pghcitypaper.com/Blogh/archives/2015/12/16/city-reveals-preliminary-plans-for-new-bike-infrastructure-downtown. [Accessed 30 November 2016].

[27] Local Car Charging Stations, "Electric Vehicle (EV) Charging Stations in Pittsburgh, Pennsylvania," Local Car Charging Stations, 4 December 2016. [Online]. Available: http://www.localcarchargingstations.com/electric-charging-stations/Pennsylvania-PA/Pittsburgh. [Accessed 4 December 2016].

[28] Green Building Alliance, "Green Building Incentives Guide," Green Building Alliance, July 2013. [Online]. Available: https://www.go-gba.org/resources/green-building/green-building-incentives-guide/. [Accessed 30 November 2016].

[29] A. Lattanzi et al., *ZIP Code Information Search by City of Pittsburgh Employees,* City of Pittsburgh, 2015.

[30] City of Pittsburgh, "2014 PITTSBURGH POST OFFICE ZIP CODES - 15201 to 15243," City of Pittsburgh Finance Department, 2014. [Online]. Available: http://apps.pittsburghpa.gov/finance/2014-zip-codes.pdf. [Accessed 15 August 2016].

APPENDIX A: ZIP CODE-LEVEL DATA

A.1 PITTSBURGH ZIP CODES

Exhibit A-1 City of Pittsburgh ZIP code data and general locations [29] [30]

ZIP Code	Type	Population	Land Area mi^2	Water Area mi^2	Locale
15106	Standard	18,536	11.17	0.00	Carnegie
15120	Standard	18,931	4.67	0.28	Homestead
15136	Standard	21,849	11.13	0.38	McKees Rocks
15201	Standard	12,713	2.48	0.26	Lawrenceville/Stanton Heights
15203	Standard	9,949	1.48	0.22	Southside/Carson St.
15204	Standard	8,329	1.87	0.09	Sheraden, Elliott, Esplen & Broadhead
15205	Standard	21,865	10.30	0.00	Crafton Heights
15206	Standard	28,615	4.78	0.32	East Liberty, Morningside & East End
15207	Standard	11,268	4.80	0.34	Hazelwood, Greenfield, Glenwood, Glen Hazel, Hays & Lincoln Pl.
15208	Standard	10,406	1.61	0.00	Homewood, Brushton, East End & Point Breeze
15210	Standard	25,954	4.64	0.15	Knoxville, Beltzhoover, Carrick & Arlington
15211	Standard	11,081	1.56	0.00	Mt. Washington & Duquesne Heights
15212	Standard	27,895	6.22	0.36	Northside
15213	Standard	30,844	2.13	0.00	Oakland & Bellefield
15214	Standard	14,352	4.70	0.00	Northside & Observatory Hill
15215	Standard	12,615	6.15	0.30	Sharpsburg, Aspinwall & Fox Chapel
15216	Standard	23,350	3.42	0.00	Beechview
15217	Standard	27,220	3.81	0.04	Squirrel Hill, Greenfield & Browns Hill
15218	Standard	13,851	2.37	0.10	Regent Square & Swissvale
15219	Standard	16,696	2.29	0.38	Uptown, Herron Hill & Schenley Heights
15220	Standard	17,718	4.94	0.06	West End, Wabash, Westwood & Banksville
15221	Standard	31,060	6.15	0.01	Brushton, Homewood & East Hills
15222	Standard	3,294	0.81	0.26	Downtown & Strip
15224	Standard	10,141	1.01	0.00	Bloomfield & Garfield
15226	Standard	13,974	2.54	0.00	Brookline & Overbrook
15227	Standard	28,156	6.18	0.00	Carrick & Overbrook
15232	Standard	11,374	0.80	0.00	Shadyside & East End
15233	Standard	4,451	1.24	0.45	Manchester, Northside, Kilbuck & Brunot Island
15234	Standard	14,056	3.17	0.00	Overbrook
15235	Standard	34,580	14.66	0.00	Penn Hills
15236	Standard	29,724	11.10	0.00	Baldwin
15238	Standard	13,162	16.38	0.80	Blawnox/Fox Chapel

ZIP Code	Type	Population	Land Area mi^2	Water Area mi^2	Locale
15260	Standard	0	0.08	0.00	Carnegie Mellon University/University of Pittsburgh
15261	Unique	0	0.00	0.00	University of Pittsburgh
15290	Standard	0	0.04	0.00	P.O. Box – U.S. Court House, 7th & Grant
TOTAL		578,009	160.68	4.8	

A.2 TOTAL ENERGY CONSUMPTION

Exhibit A-2 Total energy consumption

ZIP Code	Total Consumption (MMBtu)	% of Total Consumption
15106	954,255	1.60%
15120	1,393,654	2.34%
15136	537,238	0.90%
15201	1,919,123	3.22%
15203	1,401,579	2.35%
15204	529,108	0.89%
15205	2,870,500	4.82%
15206	2,861,972	4.81%
15207	1,246,934	2.09%
15208	1,052,736	1.77%
15210	1,890,664	3.17%
15211	848,757	1.43%
15212	4,396,447	7.38%
15213	4,615,921	7.75%
15214	982,972	1.65%
15215	1,137,171	1.91%
15216	1,656,714	2.78%
15217	2,392,847	4.02%
15218	1,299,274	2.18%
15219	3,576,810	6.01%
15220	1,577,441	2.65%
15221	2,703,264	4.54%
15222	2,897,465	4.86%
15224	948,974	1.59%
15226	1,001,673	1.68%
15227	1,846,416	3.10%
15232	1,640,447	2.75%
15233	1,282,442	2.15%
15234	969,910	1.63%
15235	3,167,982	5.32%
15236	1,468,670	2.47%
15238	1,379,031	2.32%
15260	1,053,253	1.77%
15261	1,039	0.00%
15290	56,798	0.10%

Exhibit A-3 Total consumption per square mile

ZIP Code	Total Consumption (MMBtu)	Land Area (mi^2)	Total Consumption (MMBtu/mi^2)
15260	1,053,253	0.081	13,003,128
15222	2,897,465	0.812	3,568,307
15213	4,615,921	2.131	2,166,082
15232	1,640,447	0.795	2,063,455
15219	3,576,810	2.294	1,559,202
15290	56,798	0.04	1,419,943
15233	1,282,442	1.243	1,031,731
15203	1,401,579	1.476	949,579
15224	948,974	1.007	942,377
15201	1,919,123	2.48	773,840
15212	4,396,447	6.223	706,484
15208	1,052,736	1.609	654,280
15217	2,392,847	3.806	628,704
15206	2,861,972	4.776	599,240
15218	1,299,274	2.371	547,986
15211	848,757	1.564	542,683
15216	1,656,714	3.423	483,995
15221	2,703,264	6.147	439,770
15210	1,890,664	4.64	407,471
15226	1,001,673	2.536	394,981
15220	1,577,441	4.937	319,514
15234	969,910	3.166	306,352
15227	1,846,416	6.18	298,773
15120	1,393,654	4.673	298,235
15204	529,108	1.865	283,704
15205	2,870,500	10.302	278,635
15207	1,246,934	4.795	260,049
15235	3,167,982	14.663	216,053
15214	982,972	4.696	209,321
15215	1,137,171	6.152	184,846
15236	1,468,670	11.099	132,324
15106	954,255	11.171	85,423
15238	1,379,031	16.381	84,185
15136	537,238	11.133	48,256
15261	1,039	0	N/A

Exhibit A-4 Total consumption per capita

ZIP Code	Total Consumption (MMBtu)	Current Population	Total Consumption (MMBtu Per Capita)
15222	2,897,465	3294	879.62
15233	1,282,442	4451	288.12
15219	3,576,810	16696	214.23
15212	4,396,447	27895	157.61
15201	1,919,123	12713	150.96
15213	4,615,921	30844	149.65
15232	1,640,447	11374	144.23
15203	1,401,579	9949	140.88
15205	2,870,500	21865	131.28
15207	1,246,934	11268	110.66
15238	1,379,031	13162	104.77
15208	1,052,736	10406	101.17
15206	2,861,972	28615	100.02
15218	1,299,274	13851	93.80
15224	948,974	10141	93.58
15235	3,167,982	34580	91.61
15215	1,137,171	12615	90.14
15220	1,577,441	17718	89.03
15217	2,392,847	27220	87.91
15221	2,703,264	31060	87.03
15211	848,757	11081	76.60
15120	1,393,654	18931	73.62
15210	1,890,664	25954	72.85
15226	1,001,673	13974	71.68
15216	1,656,714	23350	70.95
15234	969,910	14056	69.00
15214	982,972	14352	68.49
15227	1,846,416	28156	65.58
15204	529,108	8329	63.53
15106	954,255	18536	51.48
15236	1,468,670	29724	49.41
15136	537,238	21849	24.59
15260	1,053,253	0	N/A
15261	1,039	0	N/A
15290	56,798	0	N/A

A.3 TOTAL ELECTRICITY CONSUMPTION, 2013

Exhibit A-5 Total electricity use and percentage of total consumption

ZIP Code	Total Consumption (Million kWh)	% of Total Consumption
15213	831.1	14.71%
15219	593.8	10.51%
15222	558.6	9.89%
15205	365.9	6.47%
15212	361.8	6.40%
15235	262.6	4.65%
15206	250.3	4.43%
15201	215.5	3.81%
15233	203.4	3.60%
15221	183.5	3.25%
15203	172.5	3.05%
15227	172.1	3.05%
15220	170.6	3.02%
15232	155.2	2.75%
15217	154.6	2.74%
15216	119.4	2.11%
15210	114.8	2.03%
15215	105.6	1.87%
15224	99.1	1.75%
15234	86.0	1.52%
15226	79.1	1.40%
15214	74.4	1.32%
15218	74.1	1.31%
15208	69.5	1.23%
15207	67.3	1.19%
15211	62.7	1.11%
15204	35.3	0.62%
15290	12.3	0.22%
15106	0.0	0.00%
15120	0.0	0.00%
15136	0.0	0.00%
15236	0.0	0.00%
15238	0.0	0.00%
15260	0.0	0.00%
15261	0.0	0.00%

Exhibit A-6 Total electricity consumption per square mile

ZIP Code	Total Consumption (Million kWh)	Land Area (mi^2)	Total Consumption (Million kWh/mi^2)
15222	558.6	0.81	688.0
15213	831.1	2.13	390.0
15290	12.3	0.04	306.7
15219	593.8	2.29	258.9
15232	155.2	0.80	195.2
15233	203.4	1.24	163.6
15203	172.5	1.48	116.9
15224	99.1	1.01	98.4
15201	215.5	2.48	86.9
15212	361.8	6.22	58.1
15206	250.3	4.78	52.4
15208	69.5	1.61	43.2
15217	154.6	3.81	40.6
15211	62.7	1.56	40.1
15205	365.9	10.30	35.5
15216	119.4	3.42	34.9
15220	170.6	4.94	34.6
15218	74.1	2.37	31.2
15226	79.1	2.54	31.2
15221	183.5	6.15	29.8
15227	172.1	6.18	27.9
15234	86.0	3.17	27.2
15210	114.8	4.64	24.8
15204	35.3	1.87	18.9
15235	262.6	14.66	17.9
15215	105.6	6.15	17.2
15214	74.4	4.70	15.9
15207	67.3	4.80	14.0
15261	0.0	0.00	N/A
15106	0.0	11.17	0.0
15120	0.0	4.67	0.0
15136	0.0	11.13	0.0
15236	0.0	11.10	0.0
15238	0.0	16.38	0.0
15260	0.0	0.08	0.0

Exhibit A-7 Total energy consumption per customer meter

ZIP Code	Total Consumption (kWh)	Residential Meters	Commercial Meters	Industrial Meters	Total Consumption (kWh/Meter)
15290	12,266,800		6		2,044,467
15222	558,649,632	2,320	2,786	69	107,955
15219	593,828,968	4,771	2,152	45	85,218
15233	203,415,267	1,447	910	74	83,687
15213	831,079,363	8,890	2,890	17	70,445
15205	365,860,675	10,927	3,531	66	25,192
15201	215,528,582	6,921	1,995	131	23,824
15212	361,796,323	14,166	2,813	39	21,259
15203	172,536,353	6,443	2,324	45	19,579
15232	155,184,760	6,407	2,001	0	18,457
15220	170,616,581	8,745	1,732	28	16,243
15215	105,607,348	5,773	1,331	39	14,785
15206	250,287,797	14,363	3,606	60	13,883
15224	99,134,759	5,623	1,550	6	13,809
15235	262,606,338	16,742	2,450	39	13,656
15208	69,460,097	4,641	794	46	12,673
15227	172,117,678	13,032	1,388	12	11,926
15214	74,441,078	6,036	501	2	11,384
15207	67,321,794	5,297	723	24	11,140
15217	154,641,210	12,134	1,987	5	10,947
15234	86,018,221	6,661	1,404	12	10,650
15226	79,090,399	6,602	1,031	11	10,348
15221	183,474,257	16,040	2,756	35	9,743
15216	119,432,025	11,448	1,864	2	8,971
15211	62,669,294	6,438	726	0	8,747
15218	74,071,162	7,261	1,276	18	8,658
15204	35,298,377	3,712	422	22	8,493
15210	114,847,909	11,963	1,891	11	8,283
15106	0				N/A
15120	0				N/A
15136	0				N/A
15236	0				N/A
15238	0				N/A
15260	0				N/A
15261	0				N/A

Exhibit A-8 Total consumption per capita

ZIP Code	Thousand kWh	Population	Thousand kWh Per Capita
15222	558,650	3294	169.6
15233	203,415	4451	45.7
15219	593,829	16696	35.6
15213	831,079	30844	26.9
15203	172,536	9949	17.3
15201	215,529	12713	17.0
15205	365,861	21865	16.7
15232	155,185	11374	13.6
15212	361,796	27895	13.0
15224	99,135	10141	9.8
15220	170,617	17718	9.6
15206	250,288	28615	8.7
15215	105,607	12615	8.4
15235	262,606	34580	7.6
15208	69,460	10406	6.7
15234	86,018	14056	6.1
15227	172,118	28156	6.1
15207	67,322	11268	6.0
15221	183,474	31060	5.9
15217	154,641	27220	5.7
15226	79,090	13974	5.7
15211	62,669	11081	5.7
15218	74,071	13851	5.3
15214	74,441	14352	5.2
15216	119,432	23350	5.1
15210	114,848	25954	4.4
15204	35,298	8329	4.2
15106	0	18536	N/A
15120	0	18931	N/A
15136	0	21849	N/A
15236	0	29724	N/A
15238	0	13162	N/A
15260	0	0	N/A
15261	0	0	N/A
15290	12,267	0	N/A

A.3 TOTAL RESIDENTIAL ELECTRICITY CONSUMPTION, 2013

Exhibit A-9 Total residential consumption

ZIP Code	Total Residential Consumption (Million kWh)	Percentage of Total Residential Consumption
15235	131.9	8.77%
15221	104.4	6.94%
15227	92.0	6.11%
15206	88.2	5.86%
15212	87.7	5.83%
15217	87.6	5.82%
15210	79.0	5.25%
15205	78.1	5.19%
15216	77.2	5.13%
15220	59.7	3.97%
15213	50.0	3.33%
15215	48.5	3.23%
15234	46.6	3.10%
15218	46.5	3.09%
15226	45.5	3.03%
15214	43.3	2.88%
15211	41.5	2.76%
15201	40.9	2.72%
15203	38.7	2.57%
15232	37.5	2.49%
15207	34.3	2.28%
15224	32.8	2.18%
15208	32.5	2.16%
15219	28.1	1.87%
15204	27.0	1.79%
15222	15.1	1.00%
15233	9.7	0.65%
15106	N/A	N/A
15120	N/A	N/A
15136	N/A	N/A
15236	N/A	N/A
15238	N/A	N/A
15260	N/A	N/A
15261	N/A	N/A
15290	N/A	N/A

Exhibit A-10 Total residential consumption per square mile

ZIP Code	Total Residential Consumption (Million kWh)	Land Area (mi^2)	Total Residential Consumption (Million kWh/mi^2)
15232	37.5	0.8	47.2
15224	32.8	1.0	32.6
15211	41.5	1.6	26.5
15203	38.7	1.5	26.2
15213	50.0	2.1	23.5
15217	87.6	3.8	23.0
15216	77.2	3.4	22.6
15208	32.5	1.6	20.2
15218	46.5	2.4	19.6
15222	15.1	0.8	18.5
15206	88.2	4.8	18.5
15226	45.5	2.5	17.9
15210	79.0	4.6	17.0
15221	104.4	6.1	17.0
15201	40.9	2.5	16.5
15227	92.0	6.2	14.9
15234	46.6	3.2	14.7
15204	27.0	1.9	14.5
15212	87.7	6.2	14.1
15219	28.1	2.3	12.2
15220	59.7	4.9	12.1
15214	43.3	4.7	9.2
15235	131.9	14.7	9.0
15215	48.5	6.2	7.9
15233	9.7	1.2	7.8
15205	78.1	10.3	7.6
15207	34.3	4.8	7.1
15106	N/A	11.2	N/A
15120	N/A	4.7	N/A
15136	N/A	11.1	N/A
15236	N/A	11.1	N/A
15238	N/A	16.4	N/A
15260	N/A	0.1	N/A
15261	N/A	0.0	N/A
15290	N/A	0.0	N/A

Exhibit A-11 Total residential consumption per customer meter

ZIP Code	Total Residential Consumption (Million kWh)	Meters	Total Residential Consumption (kWh/meter)
15215	48.52	5,773	8,404
15235	131.87	16,742	7,876
15204	26.99	3,712	7,270
15217	87.60	12,134	7,219
15214	43.30	6,036	7,173
15205	78.11	10,927	7,149
15227	91.95	13,032	7,056
15208	32.48	4,641	6,999
15234	46.61	6,661	6,998
15226	45.51	6,602	6,893
15220	59.68	8,745	6,825
15216	77.20	11,448	6,743
15233	9.73	1,447	6,724
15210	78.97	11,963	6,601
15221	104.39	16,040	6,508
15222	15.06	2,320	6,491
15207	34.27	5,297	6,470
15211	41.49	6,438	6,444
15218	46.46	7,261	6,399
15212	87.66	14,166	6,188
15206	88.17	14,363	6,138
15203	38.69	6,443	6,005
15201	40.88	6,921	5,907
15219	28.06	4,771	5,881
15232	37.50	6,407	5,853
15224	32.78	5,623	5,830
15213	50.02	8,890	5,627
15106	N/A	N/A	N/A
15120	N/A	N/A	N/A
15136	N/A	N/A	N/A
15236	N/A	N/A	N/A
15238	N/A	N/A	N/A
15260	N/A	N/A	N/A
15261	N/A	N/A	N/A
15290	N/A	N/A	N/A

Exhibit A-12 Total residential consumption per capita

Zip Code	Total Residential Consumption (Million kWh)	Population	Total Residential Consumption (Thousand kWh Per Capita)
15222	15.06	3,294	4.57
15203	38.69	9,949	3.89
15215	48.52	12,615	3.85
15235	131.87	34,580	3.81
15211	41.49	11,081	3.74
15205	78.11	21,865	3.57
15220	59.68	17,718	3.37
15221	104.39	31,060	3.36
15218	46.46	13,851	3.35
15234	46.61	14,056	3.32
15216	77.20	23,350	3.31
15232	37.50	11,374	3.30
15227	91.95	28,156	3.27
15226	45.51	13,974	3.26
15204	26.99	8,329	3.24
15224	32.78	10,141	3.23
15217	87.60	27,220	3.22
15201	40.88	12,713	3.22
15212	87.66	27,895	3.14
15208	32.48	10,406	3.12
15206	88.17	28,615	3.08
15210	78.97	25,954	3.04
15207	34.27	11,268	3.04
15214	43.30	14,352	3.02
15233	9.73	4,451	2.19
15219	28.06	16,696	1.68
15213	50.02	30,844	1.62
15106	N/A	18536	N/A
15120	N/A	18931	N/A
15136	N/A	21849	N/A
15236	N/A	29,724	N/A
15238	N/A	13,162	N/A
15260	N/A	0	N/A
15261	N/A	0	N/A
15290	N/A	0	N/A

A.4 TOTAL COMMERCIAL ELECTRICITY CONSUMPTION, 2013

Exhibit A-13 Total commercial consumption

ZIP Code	Total Commercial Consumption (Million kWh)	Percentage of Total Commercial Consumption
15213	779.0	20.40%
15219	544.5	14.26%
15222	516.0	13.51%
15205	253.2	6.63%
15212	241.5	6.32%
15233	177.6	4.65%
15206	151.5	3.97%
15235	124.1	3.25%
15203	121.6	3.18%
15232	117.7	3.08%
15201	116.2	3.04%
15220	109.3	2.86%
15221	72.1	1.89%
15217	67.0	1.75%
15224	66.3	1.74%
15215	53.5	1.40%
15216	42.2	1.10%
15234	38.7	1.01%
15210	34.6	0.91%
15227	32.9	0.86%
15214	31.0	0.81%
15226	27.0	0.71%
15218	25.1	0.66%
15211	21.2	0.55%
15208	20.2	0.53%
15207	14.7	0.38%
15290	12.3	0.32%
15204	7.7	0.20%
15106	N/A	N/A
15120	N/A	N/A
15136	N/A	N/A
15236	N/A	N/A
15238	N/A	N/A
15260	N/A	N/A
15261	N/A	N/A

Exhibit A-14 Total commercial consumption per square mile

ZIP Code	Total Commercial Consumption (Million kWh)	Land Area (mi^2)	Total Commercial Consumption (Million kWh/mi^2)
15222	516.0	0.8	635.5
15213	779.0	2.1	365.6
15219	544.5	2.3	237.3
15232	117.7	0.8	148.0
15233	177.6	1.2	142.8
15203	121.6	1.5	82.4
15224	66.3	1.0	65.8
15201	116.2	2.5	46.8
15212	241.5	6.2	38.8
15206	151.5	4.8	31.7
15205	253.2	10.3	24.6
15220	109.3	4.9	22.1
15217	67.0	3.8	17.6
15211	21.2	1.6	13.5
15208	20.2	1.6	12.5
15216	42.2	3.4	12.3
15234	38.7	3.2	12.2
15221	72.1	6.1	11.7
15226	27.0	2.5	10.7
15218	25.1	2.4	10.6
15215	53.5	6.2	8.7
15235	124.1	14.7	8.5
15210	34.6	4.6	7.5
15214	31.0	4.7	6.6
15227	32.9	6.2	5.3
15204	7.7	1.9	4.1
15207	14.7	4.8	3.1
15106	N/A	11.2	N/A
15120	N/A	4.7	N/A
15136	N/A	11.1	N/A
15236	N/A	11.1	N/A
15238	N/A	16.4	N/A
15260	N/A	0.1	N/A
15261	N/A	0.0	N/A
15290	12.3	0.0	N/A

Exhibit A-15 Total commercial consumption per customer meter

ZIP Code	Total Commercial Consumption (Million kWh)	Meters	Total Commercial Consumption (kWh/meter)
15290	12	6	2,044,467
15213	779.0	2,890	269,526
15219	544.5	2,152	253,008
15233	177.6	910	195,186
15222	516.0	2,786	185,218
15212	241.5	2,813	85,843
15205	253.2	3,531	71,721
15220	109.3	1,732	63,115
15214	31.0	501	62,004
15232	117.7	2,001	58,814
15201	116.2	1,995	58,231
15203	121.6	2,324	52,325
15235	124.1	2,450	50,668
15224	66.3	1,550	42,772
15206	151.5	3,606	42,007
15215	53.5	1,331	40,226
15217	67.0	1,987	33,705
15211	21.2	726	29,169
15234	38.7	1,404	27,535
15226	27.0	1,031	26,227
15221	72.1	2,756	26,160
15208	20.2	794	25,402
15227	32.9	1,388	23,718
15216	42.2	1,864	22,637
15207	14.7	723	20,288
15218	25.1	1,276	19,671
15210	34.6	1,891	18,296
15204	7.7	422	18,261
15106	N/A	N/A	N/A
15120	N/A	N/A	N/A
15136	N/A	N/A	N/A
15236	N/A	N/A	N/A
15238	N/A	N/A	N/A
15260	N/A	N/A	N/A
15261	N/A	N/A	N/A

Exhibit A-16 Total commercial electricity consumption per capita

Zip Code	Total Commercial Consumption (Million kWh)	Population	Total Commercial Consumption (Thousand kWh Per Capita)
15222	516.02	3,294	156.65
15233	177.55	4,451	39.89
15219	544.45	16,696	32.61
15213	779.02	30,844	25.26
15203	121.62	9,949	12.22
15205	253.25	21,865	11.58
15232	117.68	11,374	10.35
15201	116.16	12,713	9.14
15212	241.51	27,895	8.66
15224	66.30	10,141	6.54
15220	109.29	17,718	6.17
15206	151.47	28,615	5.29
15215	53.54	12,615	4.24
15235	124.14	34,580	3.59
15234	38.66	14,056	2.75
15217	66.98	27,220	2.46
15221	72.09	31,060	2.32
15214	31.04	14,352	2.16
15208	20.17	10,406	1.94
15226	27.03	13,974	1.93
15211	21.18	11,081	1.91
15218	25.10	13,851	1.81
15216	42.19	23,350	1.81
15210	34.60	25,954	1.33
15207	14.66	11,268	1.30
15227	32.93	28,156	1.17
15204	7.70	8,329	0.92
15106	N/A	18536	N/A
15120	N/A	18931	N/A
15136	N/A	21849	N/A
15236	N/A	29,724	N/A
15238	N/A	13,162	N/A
15260	N/A	0	N/A
15261	N/A	0	N/A
15290	12.27	0	N/A

A.4 TOTAL INDUSTRIAL ELECTRICITY CONSUMPTION, 2013

Exhibit A-17 Total Industrial Electricity Consumption

ZIP Code	Total Industrial Consumption (Million kWh)	Percentage of Total Industrial Consumption
15201	58.5	17.79%
15227	47.2	14.37%
15205	34.5	10.49%
15212	32.6	9.92%
15222	27.6	8.39%
15219	21.3	6.48%
15207	18.4	5.60%
15208	16.8	5.11%
15233	16.1	4.91%
15203	12.2	3.72%
15206	10.7	3.24%
15221	7.0	2.13%
15235	6.6	2.01%
15226	6.6	1.99%
15215	3.6	1.08%
15218	2.5	0.76%
15213	2.0	0.62%
15220	1.6	0.50%
15210	1.3	0.39%
15234	0.7	0.23%
15204	0.6	0.18%
15214	0.1	0.03%
15217	0.1	0.02%
15224	0.1	0.02%
15216	0.0	0.01%
15232	0.0	0.00%
15211	0.0	0.00%
15290	0.0	0.00%
15106	NA	NA
15120	NA	NA
15136	NA	NA
15236	NA	NA
15238	NA	NA
15260	NA	NA
15261	NA	NA

Exhibit A-18 Total Industrial Electricity Consumption per Square Mile

ZIP Code	Total Industrial Consumption (Million kWh)	Land Area (mi^2)	Total Industrial Consumption (Million kWh / mi2)
15222	27.6	0.8	34.0
15201	58.5	2.5	23.6
15233	16.1	1.2	13.0
15208	16.8	1.6	10.4
15219	21.3	2.3	9.3
15203	12.2	1.5	8.3
15227	47.2	6.2	7.6
15212	32.6	6.2	5.2
15207	18.4	4.8	3.8
15205	34.5	10.3	3.3
15226	6.6	2.5	2.6
15206	10.7	4.8	2.2
15221	7.0	6.1	1.1
15218	2.5	2.4	1.1
15213	2.0	2.1	1.0
15215	3.6	6.2	0.6
15235	6.6	14.7	0.5
15220	1.6	4.9	0.3
15204	0.6	1.9	0.3
15210	1.3	4.6	0.3
15234	0.7	3.2	0.2
15224	0.1	1.0	0.1
15214	0.1	4.7	0.0
15217	0.1	3.8	0.0
15216	0.0	3.4	0.0
15232	0.0	0.8	0.0
15211	0.0	1.6	0.0
15106	NA	11.2	NA
15120	NA	4.7	NA
15136	NA	11.1	NA
15236	NA	11.1	NA
15238	NA	16.4	NA
15260	NA	0.1	NA
15261	NA	0.0	NA
15290	0.0	0.0	NA

Exhibit A-19 Total Industrial Electricity Consumption per Customer Meter

ZIP Code	Total Industrial Consumption (Million kWh)	Meters	Total Industrial Consumption (kWh / meter)
15227	47.2	1,388	34,027
15201	58.5	1,995	29,323
15207	18.4	723	25,461
15208	16.8	794	21,171
15233	16.1	910	17,732
15212	32.6	2,813	11,595
15219	21.3	2,152	9,906
15222	27.6	2,786	9,897
15205	34.5	3,531	9,772
15226	6.6	1,031	6,359
15203	12.2	2,324	5,261
15206	10.7	3,606	2,954
15235	6.6	2,450	2,696
15215	3.6	1,331	2,670
15221	7.0	2,756	2,537
15218	2.5	1,276	1,964
15204	0.6	422	1,441
15220	1.6	1,732	952
15213	2.0	2,890	705
15210	1.3	1,891	677
15234	0.7	1,404	531
15214	0.1	501	209
15224	0.1	1,550	36
15217	0.1	1,987	33
15216	0.0	1,864	25
15290	0	6	0
15232	0.0	2,001	0
15211	0.0	726	0
15106	NA	NA	NA
15120	NA	NA	NA
15136	NA	NA	NA
15236	NA	NA	NA
15238	NA	NA	NA
15260	NA	NA	NA
15261	NA	NA	NA

Exhibit A-20 Total Industrial Electricity Consumption per Capita

Zip Code	Total Industrial Consumption (Million-kWh)	Population	Total Industrial Consumption (Thousand kWh Per Capita)
15222	27.57	3,294	8.37
15201	58.49	12,713	4.60
15233	16.13	4,451	3.62
15227	47.24	28,156	1.68
15207	18.40	11,268	1.63
15208	16.81	10,406	1.62
15205	34.50	21,865	1.58
15219	21.32	16,696	1.28
15203	12.23	9,949	1.23
15212	32.62	27,895	1.17
15226	6.55	13,974	0.47
15206	10.65	28,615	0.37
15215	3.55	12,615	0.28
15221	6.99	31,060	0.23
15235	6.60	34,580	0.19
15218	2.51	13,851	0.18
15220	1.65	17,718	0.09
15204	0.61	8,329	0.07
15213	2.04	30,844	0.07
15234	0.75	14,056	0.05
15210	1.28	25,954	0.05
15214	0.10	14,352	0.01
15224	0.06	10,141	0.01
15217	0.07	27,220	0.00
15216	0.05	23,350	0.00
15232	0.00	11,374	0.00
15211	0.00	11,081	0.00
15106	NA	18536	NA
15120	NA	18931	NA
15136	NA	21849	NA
15236	NA	29,724	NA
15238	NA	13,162	NA
15260	NA	0	NA
15261	NA	0	NA
15290	0.00	0	NA

A.5 TOTAL NATURAL GAS CONSUMPTION, 2013

Exhibit A-220 Total NG consumption and percentage of total consumption

ZIP Code	Total Consumption (MMBtu)	Percentage of Total Consumption
15212	3,161,947	7.85%
15235	2,271,933	5.64%
15221	2,077,224	5.16%
15206	2,007,955	4.99%
15217	1,865,190	4.63%
15213	1,780,161	4.42%
15205	1,622,132	4.03%
15219	1,550,582	3.85%
15210	1,498,787	3.72%
15236	1,468,670	3.65%
15120	1,393,654	3.46%
15238	1,379,031	3.42%
15227	1,259,126	3.13%
15216	1,249,195	3.10%
15201	1,183,709	2.94%
15232	1,110,935	2.76%
15260	1,053,253	2.62%
15218	1,046,533	2.60%
15207	1,017,223	2.53%
15220	995,274	2.47%
15222	991,275	2.46%
15106	954,255	2.37%
15208	815,729	2.03%
15203	812,861	2.02%
15215	776,824	1.93%
15226	731,805	1.82%
15214	728,969	1.81%
15234	676,404	1.68%
15211	634,920	1.58%
15224	610,712	1.52%
15233	588,360	1.46%
15136	537,238	1.33%
15204	408,665	1.01%
15290	14,942	0.04%
15261	1,039	0.00%

Exhibit A-21 Total NG consumption per square mile

ZIP Code	Total Consumption (MMBtu)	Land Area (mi^2)	Total Consumption (MMBtu / mi^2)
15260	1,053,253	0.081	13,003,128
15232	1,110,935	0.795	1,397,402
15222	991,275	0.812	1,220,781
15213	1,780,161	2.131	835,364
15219	1,550,582	2.294	675,930
15224	610,712	1.007	606,467
15203	812,861	1.476	550,719
15212	3,161,947	6.223	508,107
15208	815,729	1.609	506,979
15217	1,865,190	3.806	490,066
15201	1,183,709	2.48	477,302
15233	588,360	1.243	473,339
15218	1,046,533	2.371	441,389
15206	2,007,955	4.776	420,426
15211	634,920	1.564	405,959
15290	14,942	0.04	373,542
15216	1,249,195	3.423	364,942
15221	2,077,224	6.147	337,925
15210	1,498,787	4.64	323,014
15120	1,393,654	4.673	298,235
15226	731,805	2.536	288,567
15204	408,665	1.865	219,123
15234	676,404	3.166	213,646
15207	1,017,223	4.795	212,142
15227	1,259,126	6.18	203,742
15220	995,274	4.937	201,595
15205	1,622,132	10.302	157,458
15214	728,969	4.696	155,232
15235	2,271,933	14.663	154,943
15236	1,468,670	11.099	132,324
15215	776,824	6.152	126,272
15106	954,255	11.171	85,423
15238	1,379,031	16.381	84,185
15136	537,238	11.133	48,256
15261	1,039	0	NA

Exhibit A-22 Total NG consumption per customer meter

ZIP Code	Total Consumption (MMBtu)	Meters	Total Consumption (MMBtu / meter)
15260	1,053,253	25	42,130
15290	14,942	1	14,942
15261	1,039	1	1,039
15222	991,275	1,252	792
15233	588,360	1,496	393
15212	3,161,947	12,345	256
15205	1,622,132	9,743	166
15120	1,393,654	8,536	163
15232	1,110,935	6,886	161
15215	776,824	5,605	139
15210	1,498,787	11,086	135
15203	812,861	6,150	132
15214	728,969	5,558	131
15106	954,255	7,329	130
15201	1,183,709	9,352	127
15216	1,249,195	9,886	126
15204	408,665	3,338	122
15226	731,805	6,222	118
15211	634,920	5,564	114
15136	537,238	4,726	114
15236	1,468,670	13,016	113
15234	676,404	6,020	112
15206	2,007,955	17,988	112
15227	1,259,126	11,838	106
15220	995,274	9,428	106
15219	1,550,582	16,033	97
15224	610,712	7,070	86
15238	1,379,031	17,120	81
15213	1,780,161	44,884	40
15208	815,729	28,558	29
15207	1,017,223	40,261	25
15217	1,865,190	96,798	19
15221	2,077,224	140,302	15
15218	1,046,533	72,327	14
15235	2,271,933	164,594	14

Exhibit A-23 Total NG consumption per capita 2010

ZIP Code	Total Consumption (MMBtu)	Population	Total Consumption (MMBtu per Capita)
15222	991,275	3,294	301
15233	588,360	4,451	132
15212	3,161,947	27,895	113
15238	1,379,031	13,162	105
15232	1,110,935	11,374	98
15201	1,183,709	12,713	93
15219	1,550,582	16,696	93
15207	1,017,223	11,268	90
15203	812,861	9,949	82
15208	815,729	10,406	78
15218	1,046,533	13,851	76
15205	1,622,132	21,865	74
15120	1,393,654	18,931	74
15206	2,007,955	28,615	70
15217	1,865,190	27,220	69
15221	2,077,224	31,060	67
15235	2,271,933	34,580	66
15215	776,824	12,615	62
15224	610,712	10,141	60
15210	1,498,787	25,954	58
15213	1,780,161	30,844	58
15211	634,920	11,081	57
15220	995,274	17,718	56
15216	1,249,195	23,350	53
15226	731,805	13,974	52
15106	954,255	18,536	51
15214	728,969	14,352	51
15236	1,468,670	29,724	49
15204	408,665	8,329	49
15234	676,404	14,056	48
15227	1,259,126	28,156	45
15136	537,238	21,849	25
15260	1,053,253	0	NA
15261	1,039	0	NA
15290	14,942	0	NA

A.6 TOTAL RESIDENTIAL NATURAL GAS CONSUMPTION, 2013

Exhibit A-24 Total residential NG use and percentage of total consumption

ZIP Code	Total Residential Consumption (MMBtu)	Percentage of Total Residential Consumption
15235	1,837,581	8.02%
15221	1,627,658	7.10%
15217	1,436,225	6.27%
15210	1,265,559	5.52%
15212	1,192,074	5.20%
15206	1,182,327	5.16%
15227	1,005,050	4.38%
15216	974,761	4.25%
15236	940,263	4.10%
15218	792,757	3.46%
15205	765,743	3.34%
15120	750,070	3.27%
15238	671,467	2.93%
15214	599,659	2.62%
15208	596,736	2.60%
15106	576,240	2.51%
15201	572,657	2.50%
15226	565,865	2.47%
15207	562,464	2.45%
15220	539,787	2.36%
15215	533,490	2.33%
15211	530,656	2.32%
15213	487,262	2.13%
15234	476,299	2.08%
15224	437,790	1.91%
15203	436,441	1.90%
15136	371,113	1.62%
15219	354,782	1.55%
15232	348,931	1.52%
15204	347,413	1.52%
15233	126,574	0.55%
15222	15,064	0.07%
15260	63	0.00%
15261	0	0.00%
15290	0	0.00%

Exhibit A-25 Total residential NG consumption per square mile

ZIP Code	Total Residential Consumption (MMBtu)	Land Area (mi^2)	Total Residential Consumption (MMBtu / mi^2)
15232	348,931	0.795	438,907
15224	437,790	1.007	434,747
15217	1,436,225	3.806	377,358
15208	596,736	1.609	370,874
15211	530,656	1.564	339,294
15218	792,757	2.371	334,356
15203	436,441	1.476	295,692
15216	974,761	3.423	284,768
15210	1,265,559	4.64	272,750
15221	1,627,658	6.147	264,789
15206	1,182,327	4.776	247,556
15201	572,657	2.48	230,910
15213	487,262	2.131	228,654
15226	565,865	2.536	223,133
15212	1,192,074	6.223	191,559
15204	347,413	1.865	186,281
15227	1,005,050	6.18	162,630
15120	750,070	4.673	160,511
15219	354,782	2.294	154,656
15234	476,299	3.166	150,442
15214	599,659	4.696	127,696
15235	1,837,581	14.663	125,321
15207	562,464	4.795	117,302
15220	539,787	4.937	109,335
15233	126,574	1.243	101,829
15215	533,490	6.152	86,718
15236	940,263	11.099	84,716
15205	765,743	10.302	74,330
15106	576,240	11.171	51,584
15238	671,467	16.381	40,991
15136	371,113	11.133	33,335
15222	15,064	0.812	18,551
15260	63	0.081	782
15290	0	0.04	0
15261	0	0	NA

Exhibit A-26 Total residential NG consumption per customer

ZIP Code	Total Residential Consumption (MMBtu)	Meters	Total Residential Consumption (MMBtu / meter)
15210	1,265,559	10,434	121
15214	599,659	5,425	111
15204	347,413	3,235	107
15216	974,761	9,315	105
15215	533,490	5,201	103
15212	1,192,074	11,673	102
15233	126,574	1,277	99
15211	530,656	5,412	98
15226	565,865	5,895	96
15120	750,070	8,026	93
15205	765,743	8,624	89
15227	1,005,050	11,385	88
15106	576,240	6,754	85
15234	476,299	5,606	85
15136	371,113	4,441	84
15236	940,263	11,786	80
15203	436,441	5,501	79
15206	1,182,327	15,469	76
15224	437,790	5,759	76
15201	572,657	7,780	74
15232	348,931	5,504	63
15260	63	1	63
15220	539,787	8,788	61
15222	15,064	254	59
15238	671,467	16,265	41
15219	354,782	13,371	27
15208	596,736	26,646	22
15217	1,436,225	90,325	16
15207	562,464	38,463	15
15213	487,262	36,990	13
15221	1,627,658	131,355	12
15218	792,757	67,822	12
15235	1,837,581	157,648	12
15261	0	0	NA
15290	0	0	NA

Exhibit A-27 Total Residential NG consumption per capita 2010

ZIP Code	Total Residential Consumption (MMBtu)	Population	Total Residential Consumption (MMBtu per Capita)
15208	596,736	10,406	57
15218	792,757	13,851	57
15235	1,837,581	34,580	53
15217	1,436,225	27,220	53
15221	1,627,658	31,060	52
15238	671,467	13,162	51
15207	562,464	11,268	50
15210	1,265,559	25,954	49
15211	530,656	11,081	48
15201	572,657	12,713	45
15203	436,441	9,949	44
15224	437,790	10,141	43
15212	1,192,074	27,895	43
15215	533,490	12,615	42
15214	599,659	14,352	42
15216	974,761	23,350	42
15204	347,413	8,329	42
15206	1,182,327	28,615	41
15226	565,865	13,974	40
15120	750,070	18,931	40
15227	1,005,050	28,156	36
15205	765,743	21,865	35
15234	476,299	14,056	34
15236	940,263	29,724	32
15106	576,240	18,536	31
15232	348,931	11,374	31
15220	539,787	17,718	30
15233	126,574	4,451	28
15219	354,782	16,696	21
15136	371,113	21,849	17
15213	487,262	30,844	16
15222	15,064	3,294	5
15260	63	0	NA
15261	0	0	NA
15290	0	0	NA

A.7 TOTAL COMMERCIAL NATURAL GAS CONSUMPTION, 2013

Exhibit A-28 Total commercial NG consumption and percentage of total consumption

ZIP Code	Total Commercial Consumption (MMBtu)	Percentage of Total Commercial Consumption
15213	1,292,532	9.49%
15222	947,471	6.95%
15219	925,799	6.80%
15206	821,985	6.03%
15205	785,139	5.76%
15232	762,004	5.59%
15238	624,267	4.58%
15201	604,899	4.44%
15212	570,105	4.18%
15120	515,601	3.78%
15236	513,796	3.77%
15220	455,487	3.34%
15221	449,566	3.30%
15217	428,964	3.15%
15233	425,123	3.12%
15235	420,422	3.09%
15203	356,642	2.62%
15216	272,882	2.00%
15227	254,076	1.86%
15106	244,030	1.79%
15215	241,191	1.77%
15210	233,228	1.71%
15208	218,993	1.61%
15234	200,105	1.47%
15218	177,789	1.31%
15224	171,486	1.26%
15136	155,513	1.14%
15226	147,451	1.08%
15214	120,375	0.88%
15211	104,264	0.77%
15207	101,961	0.75%
15204	61,252	0.45%
15290	14,942	0.11%
15260	2,989	0.02%
15261	1,039	0.01%

Exhibit A-29 Total commercial NG consumption per square mile

ZIP Code	Total Commercial Consumption (MMBtu)	Land Area (mi^2)	Total Commercial Consumption (MMBtu / mi^2)
15222	947,471	0.812	1,166,836
15232	762,004	0.795	958,495
15213	1,292,532	2.131	606,538
15219	925,799	2.294	403,574
15290	14,942	0.04	373,542
15233	425,123	1.243	342,014
15201	604,899	2.48	243,911
15203	356,642	1.476	241,628
15206	821,985	4.776	172,107
15224	171,486	1.007	170,294
15208	218,993	1.609	136,105
15217	428,964	3.806	112,707
15120	515,601	4.673	110,336
15220	455,487	4.937	92,260
15212	570,105	6.223	91,613
15216	272,882	3.423	79,720
15205	785,139	10.302	76,212
15218	177,789	2.371	74,985
15221	449,566	6.147	73,136
15211	104,264	1.564	66,665
15234	200,105	3.166	63,204
15226	147,451	2.536	58,143
15210	233,228	4.64	50,265
15236	513,796	11.099	46,292
15227	254,076	6.18	41,113
15215	241,191	6.152	39,205
15238	624,267	16.381	38,109
15260	2,989	0.081	36,897
15204	61,252	1.865	32,843
15235	420,422	14.663	28,672
15214	120,375	4.696	25,634
15106	244,030	11.171	21,845
15207	101,961	4.795	21,264
15136	155,513	11.133	13,969
15261	1,039	0	NA

Exhibit A-30 Total commercial NG consumption per meter

ZIP Code	Total Commercial Consumption (MMBtu)	Meters	Total Commercial Consumption (MMBtu / meter)
15290	14,942	1	14,942
15233	425,123	213	1,996
15261	1,039	1	1,039
15120	515,601	508	1,015
15222	947,471	995	952
15214	120,375	131	919
15212	570,105	667	855
15238	624,267	837	746
15220	455,487	640	712
15205	785,139	1,112	706
15211	104,264	152	686
15215	241,191	403	598
15204	61,252	103	595
15227	254,076	453	561
15203	356,642	644	554
15232	762,004	1,382	551
15136	155,513	283	550
15234	200,105	414	483
15216	272,882	570	479
15226	147,451	325	454
15106	244,030	568	430
15236	513,796	1,229	418
15201	604,899	1,570	385
15210	233,228	652	358
15219	925,799	2,658	348
15206	821,985	2,517	327
15260	2,989	15	199
15213	1,292,532	7,884	164
15224	171,486	1,310	131
15208	218,993	1,912	115
15217	428,964	6,473	66
15235	420,422	6,937	61
15207	101,961	1,796	57
15221	449,566	8,947	50
15218	177,789	4,495	40

Exhibit A-32 Total commercial NG consumption per capita 2010

ZIP Code	Total Commercial Consumption (MMBtu)	Population	Total Commercial Consumption (MMBtu per Capita)
15222	947,471	3,294	288
15233	425,123	4,451	96
15232	762,004	11,374	67
15219	925,799	16,696	55
15201	604,899	12,713	48
15238	624,267	13,162	47
15213	1,292,532	30,844	42
15205	785,139	21,865	36
15203	356,642	9,949	36
15206	821,985	28,615	29
15120	515,601	18,931	27
15220	455,487	17,718	26
15208	218,993	10,406	21
15212	570,105	27,895	20
15215	241,191	12,615	19
15236	513,796	29,724	17
15224	171,486	10,141	17
15217	428,964	27,220	16
15221	449,566	31,060	14
15234	200,105	14,056	14
15106	244,030	18,536	13
15218	177,789	13,851	13
15235	420,422	34,580	12
15216	272,882	23,350	12
15226	147,451	13,974	11
15211	104,264	11,081	9
15207	101,961	11,268	9
15227	254,076	28,156	9
15210	233,228	25,954	9
15214	120,375	14,352	8
15204	61,252	8,329	7
15136	155,513	21,849	7
15260	2,989	0	NA
15261	1,039	0	NA
15290	14,942	0	NA

A.8 TOTAL COMMERCIAL NATURAL GAS CONSUMPTION, 2013

Exhibit A-33 Total commercial NG consumption and percentage of total consumption

ZIP Code	Total Industrial Consumption (MMBtu)	Percentage of Total Industrial Consumption
15212	1,399,768	37.50%
15260	1,050,201	28.14%
15207	352,797	9.45%
15219	270,002	7.23%
15106	133,985	3.59%
15120	127,984	3.43%
15238	83,297	2.23%
15218	75,986	2.04%
15205	71,250	1.91%
15233	36,663	0.98%
15222	28,740	0.77%
15203	19,778	0.53%
15226	18,489	0.50%
15236	14,611	0.39%
15235	13,930	0.37%
15136	10,612	0.28%
15214	8,935	0.24%
15201	6,153	0.16%
15206	3,644	0.10%
15215	2,143	0.06%
15216	1,552	0.04%
15224	1,436	0.04%
15213	367	0.01%
15204	0	0.00%
15208	0	0.00%
15210	0	0.00%
15211	0	0.00%
15217	0	0.00%
15220	0	0.00%
15221	0	0.00%
15227	0	0.00%
15232	0	0.00%
15234	0	0.00%
15261	0	0.00%
15290	0	0.00%

Exhibit A-31 Total commercial NG consumption per square mile

ZIP Code	Total Industrial Consumption (MMBtu)	Land Area (mi^2)	Total Industrial Consumption (MMBtu / mi2)
15260	1,050,201	0.081	12,965,449
15212	1,399,768	6.223	224,935
15219	270,002	2.294	117,699
15207	352,797	4.795	73,576
15222	28,740	0.812	35,394
15218	75,986	2.371	32,048
15233	36,663	1.243	29,496
15120	127,984	4.673	27,388
15203	19,778	1.476	13,399
15106	133,985	11.171	11,994
15226	18,489	2.536	7,291
15205	71,250	10.302	6,916
15238	83,297	16.381	5,085
15201	6,153	2.48	2,481
15214	8,935	4.696	1,903
15224	1,436	1.007	1,426
15236	14,611	11.099	1,316
15136	10,612	11.133	953
15235	13,930	14.663	950
15206	3,644	4.776	763
15216	1,552	3.423	454
15215	2,143	6.152	348
15213	367	2.131	172
15204	0	1.865	0
15208	0	1.609	0
15210	0	4.64	0
15211	0	1.564	0
15217	0	3.806	0
15220	0	4.937	0
15221	0	6.147	0
15227	0	6.18	0
15232	0	0.795	0
15234	0	3.166	0
15290	0	0.04	0
15261	0	0	NA

Exhibit A-32 Total commercial NG consumption per meter

ZIP Code	Total Industrial Consumption (MMBtu)	Meters	Total Industrial Consumption (MMBtu / meter)
15212	1,399,768	5	279,954
15207	352,797	2	176,399
15260	1,050,201	9	116,689
15219	270,002	4	67,501
15120	127,984	2	63,992
15106	133,985	7	19,141
15236	14,611	1	14,611
15205	71,250	7	10,179
15222	28,740	3	9,580
15226	18,489	2	9,244
15218	75,986	10	7,599
15233	36,663	6	6,111
15136	10,612	2	5,306
15238	83,297	18	4,628
15214	8,935	2	4,467
15203	19,778	5	3,956
15201	6,153	2	3,077
15215	2,143	1	2,143
15206	3,644	2	1,822
15216	1,552	1	1,552
15235	13,930	9	1,548
15224	1,436	1	1,436
15213	367	10	37
15204	0	0	NA
15208	0	0	NA
15210	0	0	NA
15211	0	0	NA
15217	0	0	NA
15220	0	0	NA
15221	0	0	NA
15227	0	0	NA
15232	0	0	NA
15234	0	0	NA
15261	0	0	NA
15290	0	0	NA

Exhibit A-36 Total commercial NG consumption per capita 2010

ZIP Code	Total Industrial Consumption (MMBtu)	Population	Total Industrial Consumption (MMBtu per Capita)
15212	1,399,768	27,895	50.18
15207	352,797	11,268	31.31
15219	270,002	16,696	16.17
15222	28,740	3,294	8.72
15233	36,663	4,451	8.24
15106	133,985	18,536	7.23
15120	127,984	18,931	6.76
15238	83,297	13,162	6.33
15218	75,986	13,851	5.49
15205	71,250	21,865	3.26
15203	19,778	9,949	1.99
15226	18,489	13,974	1.32
15214	8,935	14,352	0.62
15236	14,611	29,724	0.49
15136	10,612	21,849	0.49
15201	6,153	12,713	0.48
15235	13,930	34,580	0.40
15215	2,143	12,615	0.17
15224	1,436	10,141	0.14
15206	3,644	28,615	0.13
15216	1,552	23,350	0.07
15213	367	30,844	0.01
15204	0	8,329	0
15208	0	10,406	0
15210	0	25,954	0
15211	0	11,081	0
15217	0	27,220	0
15220	0	17,718	0
15221	0	31,060	0
15227	0	28,156	0
15232	0	11,374	0
15234	0	14,056	0
15260	1,050,201	0	NA
15261	0	0	NA
15290	0	0	NA

APPENDIX B: HISTORICAL HEATING AND COOLING DEGREE DATA

Exhibit B-1 Historic heating degree days (HDDs) summary for Pittsburgh, 2000-2015

Month	15-year HDD Trends				Number of HDDs in 2013 vs. Average Year
	Average HDDs	Maximum HDDs	Minimum HDDs	Least HDD Year	
January	1,140	1,349	831	2006	-9%
February	995	1,301	836	2001	2%
March	772	943	425	2012	17%
April	389	524	307	2010	1%
May	166	280	65	2012	-3%
June	27	59	10	2014	-32%
July	4	17	-	2001	-74%
August	6	25	-	N\A	89%
September	82	133	27	2015	24%
October	372	461	228	2007	-19%
November	648	783	494	2015	18%
December	971	1,219	631	2015	-2%
Annual Average	**5,572**				

Exhibit B-2 Historic cooling degree days (CDDs) summary for Pittsburgh, 2000-2015

Month	15-year CDD Trends				Number of CDDs in 2013 vs. Average Year
	Average CDDs	Maximum CDDs	Minimum CDDs	Most CDD Year	
January	N\A	N\A	N\A	N\A	N\A
February	N\A	N\A	N\A	N\A	N\A
March	1	8	0	N\A	-100%
April	12	37	0	2002	38%
May	60	129	7	2015	42%
June	157	218	84	2005	-4%
July	247	371	142	2011	6%
August	221	294	139	2010	-15%
September	81	167	12	2015	-9%
October	11	54	0	2007	220%
November	0	2	0	2015	-100%
December	N\A	N\A	N\A	N\A	N\A
Annual Average	**790**				

Exhibit B-3 Historic heating degree days (HDDs) for Pittsburgh, 2000-2015

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
January	1,155	1,132	915	1,349	1,325	1,092	831	1,007	1,041	1,331	1,212	1,265	996	1,036	1,324	1,224
February	839	836	840	1,078	966	911	967	1,235	1,031	945	1,080	929	856	1,016	1,095	1,301
March	625	920	746	744	690	921	830	672	865	703	671	799	425	900	943	902
April	446	353	403	352	422	382	336	524	332	415	307	364	442	391	393	362
May	138	173	280	191	95	277	234	109	258	157	119	148	65	160	152	94
June	36	45	16	59	32	16	46	21	19	23	14	15	28	18	10	26
July	9	17	-	-	4	-	3	4	-	6	6	-	-	1	11	-
August	15	2	-	-	25	2	-	7	2	9	1	-	2	11	11	6
September	161	128	40	101	47	29	132	63	44	56	69	89	133	102	96	27
October	324	346	461	448	364	374	439	228	430	444	360	378	367	301	353	341
November	765	503	740	565	570	629	593	697	747	534	682	540	761	765	783	494
December	1,297	852	1,063	1,002	981	1,156	810	942	992	1,050	1,219	851	830	953	911	631
Annual Total	**5,810**	**5,307**	**5,504**	**5,889**	**5,521**	**5,789**	**5,221**	**5,509**	**5,761**	**5,673**	**5,740**	**5,378**	**4,905**	**5,654**	**6,082**	**5,408**

Exhibit B-4 Historic cooling degree days (CDDs) for Pittsburgh, 2000-2015

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015
January	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
March	5	0	0	0	0	0	0	1	0	0	0	0	8	0	0	0
April	2	33	37	5	9	1	0	0	2	30	19	14	7	16	10	1
May	63	20	24	8	111	7	42	72	11	40	76	85	127	85	61	129
June	176	148	185	84	110	218	84	158	171	121	189	166	182	150	179	189
July	127	179	343	196	200	314	265	177	236	142	334	371	366	261	182	259
August	142	254	281	237	139	272	245	288	150	223	294	243	206	188	168	204
September	80	42	113	45	72	99	12	115	72	55	92	102	92	74	71	167
October	6	12	29	0	0	17	0	54	1	0	2	0	11	34	4	0
November	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
December	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Annual Total	**601**	**688**	**1012**	**575**	**641**	**928**	**648**	**865**	**643**	**611**	**1006**	**981**	**999**	**808**	**675**	**951**

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