Final Report:

Building Energy Use Intensity Targets

ECOTOPE

Consulting
Research
Design

City of Seattle, Office of Sustainability and Environment

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Glossary of Terms & Acronyms

ACS	American Community Survey from the U.S. Census Bureau
BAU	Business as usual
CAP	City of Seattle Climate Action Plan
CBSA	Commercial Building Stock Assessment
CPA	Conservation Potential Assessment
DPD	Seattle Department of Planning & Development (currently the Seattle Department of Construction & Inspection and the Office of Planning & Development)
EUI	Energy use intensity (kBtu/sq.ft./year)
GHG	Greenhouse gas
NEEA	Northwest Energy Efficiency Alliance
NPCC	Northwest Power and Conservation Council
OSE	Seattle Office of Sustainability & Environment
PSE	Puget Sound Energy
RBSA	Residential Building Stock Assessment
RTF	Regional Technical Forum
SCL	Seattle City Light

Executive Summary

The City of Seattle has the ambitious goal to be a carbon neutral city by 2050. Seattle's Climate Action Plan (CAP), adopted in 2013, identifies the projected emission reductions needed to get to carbon neutral (OSE 2013). With 33% of Seattle's core emissions from building energy, the carbon emissions from buildings will need to be reduced by 82% from a 2008 baseline. The goal is to achieve these reductions by both reducing building energy use—a 45% reduction in the commercial buildings and a 63% reduction in the residential buildings—and by reducing the greenhouse gas (GHG) intensity of the fuels supplying these buildings by 63%. Overall building energy use (i.e., the total energy consumed in any given year, inclusive of all buildings existing in that year) will need to drop from 48.8 trillion Btu in 2008 to 23.3 trillion Btu in 2050 and GHG Intensity from 28.7 to 10.6 tCO_2e/GJ.[1] All while Seattle continues to gain new people and new jobs; an additional 120,000 people and 115,000 jobs are projected by 2035 (DPD 2015).

The broad energy and GHG reduction targets mentioned above provide a critical starting point for assessing progress and identifying next steps, but they are less useful in understanding whether individual building performance aligns with citywide policy goals. Policymakers do not have a sufficient level of detail to focus priorities and building owners have no metric for how their buildings' performance relates to the overall goal. To address this gap, the City contracted Ecotope, Inc., to develop a baseline model and conduct analysis that establishes granular energy use intensity and greenhouse gas emissions targets for each building type (e.g., office, grocery, mid-rise multifamily), at 5–10 year intervals through 2050. Results of the analysis will be used to identify priority building types, to track progress, to communicate additional policy intervention needs, and as a planning tool to evaluate the impact of specific approaches.

Ecotope assembled data from local utility conservation potential assessments, building stock assessments, population and employment forecasts, and the City's climate goals to inform energy use intensity and GHG forecasts and targets by building type, building end use, and fuel type. This report documents the methodology for calculating EUI and GHG emissions for the base-year, forecasts, and targets by building type. The report also presents highlights of the results. More detailed summary tables are included in the Excel worksheets in the baseline model.

Ecotope assembled building stock characteristics, EUI, and GHG emissions data for the base year and the business-as-usual (BAU) forecasts from many data sources, including city, state, regional, and national data sets on population and energy consumption. These data sets provided the foundation for a generalized building end use (space conditioning, hot water, etc.) model by building type. Coupled with fuel use saturations, Ecotope constructed a BAU forecast of total energy consumption and GHG emissions. The forecast assumes buildings will achieve the goals of existing policies and utility energy efficiency incentives, such as appliance standards and recent code adoptions, but does not include future policy decisions. The energy and GHG reduction goals from the City's CAP were then overlaid to identify the gap between the BAU

[1] Targets and projections are based on a proof of concept analysis conducted for OSE by the Stockholm Environment Institute (OSE and SEI 2011) and on additional analysis by OSE during the development of the Climate Action Plan.

forecast and the CAP goals. The information on areas where the BAU indicates a shortfall highlights building types and sectors where policy intervention will be needed.

The results of the model show that the BAU forecast for energy use and GHG emissions for 2050 are significantly higher than the CAP goals. In these forecasts, the programs, codes, etc., that are driving the BAU energy use and emissions reductions help offset the impact of load growth, which keeps levels fairly close to the 2015 base year. However, the BAU forecast delivers only modest reductions below the CAP reference year (2008), with total building energy use decreasing 10% from 2008 to 2050 and building related GHG emissions decreasing by 12% (Table ES-1). Figure ES-1 and Figure ES-2 illustrate the magnitude of reductions below BAU that will be necessary to meet the CAP goals. The solid lines represent the BAU forecast energy use and emissions through 2050. The dotted lines represent the CAP goals.

Table ES-1. BAU Forecast Energy and GHG Changes by Sector (2008 to 2050)

	Energy	GHG
Residential	-27%	-28%
Commercial	6%	7%
Total	-10%	-12%

Figure ES-1. Commercial and Residential Sector BAU Energy Use Forecast vs. CAP Energy Reduction Goals (kBtu)

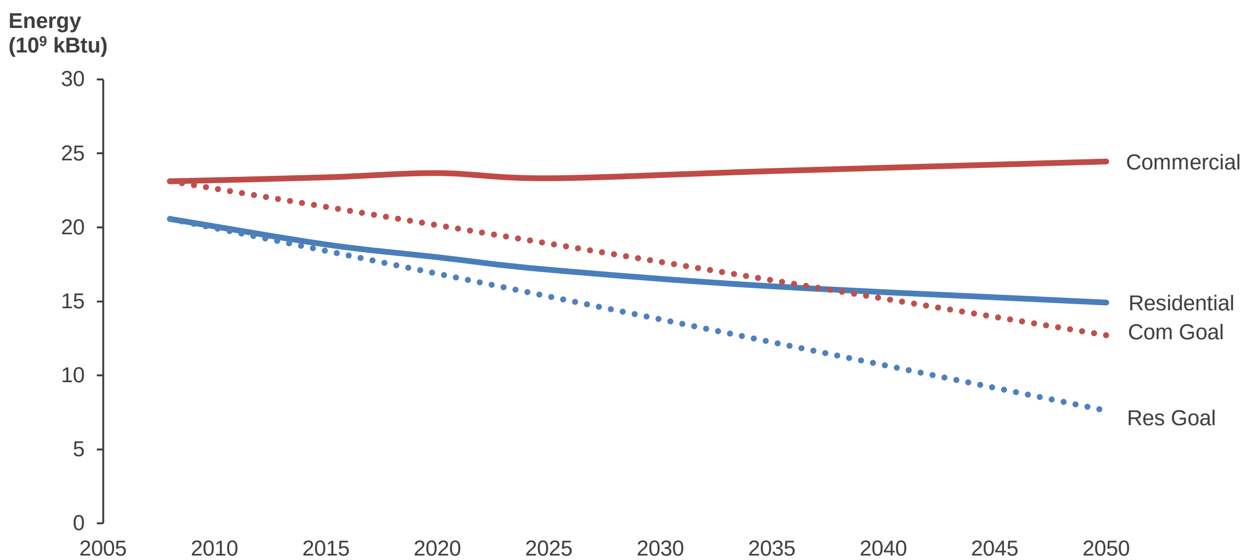
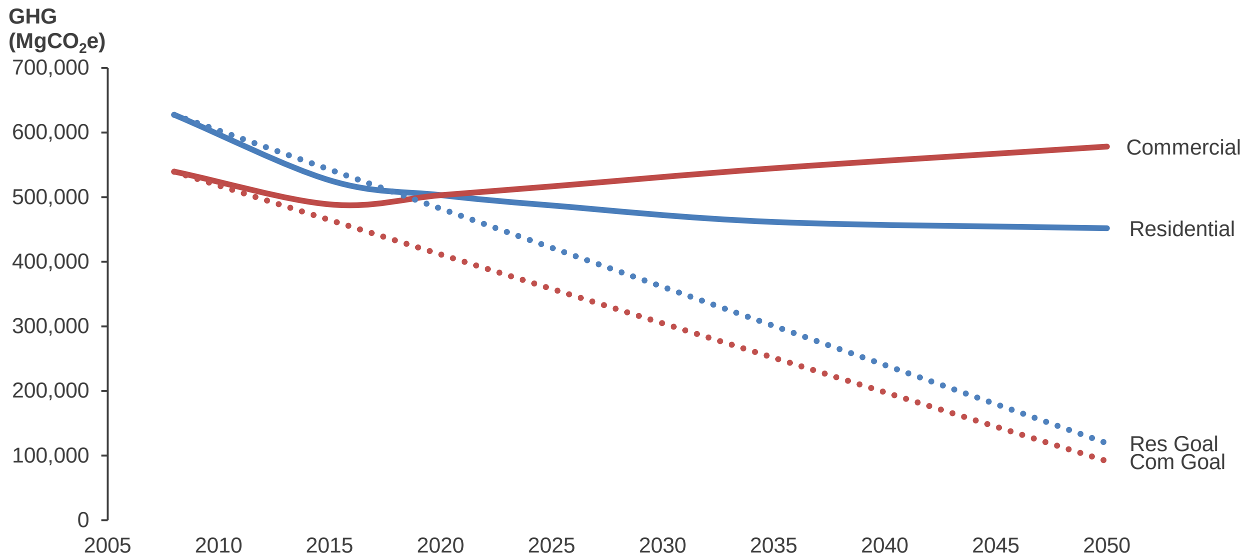


Figure ES-2. Commercial and Residential Sector BAU GHG Emissions Forecast Compared to CAP Emission Reduction Goals ($MgCO_2e$)



To explore the impacts of energy efficiency vs. fuel switching approaches to reaching an 82% reduction in building related emission, Ecotope developed the following three scenarios for meeting the CAP GHG emission targets:

- **Scenario 1: Gas & Electric Energy Use Reductions and Fuel-Switching.** This scenario is structured to achieve both the energy reduction goals (45% commercial, 63% residential) and the overall GHG reduction goal (82%) outlined in the Climate Action Plan (CAP).The GHG reduction goal is achieved in this scenario by first applying gas efficiency measures and then by fuel switching to carbon-neutral electricity. Finally, additional efficiency reductions are applied to electric usage to reach the 45% and commercial and 63% residential energy reduction goals.

- **Scenario 2: Fuel-Switching Only.** This scenario achieves the 82% GHG reduction goal through fuel-switching alone, with energy efficiency reductions achieved only as a by-product of this approach. GHG emitting fuels are replaced with carbon-neutral electricity to achieve the 82% emissions reduction. Energy use efficiency is inherent to the conversion to heat pump technologies required under this scenario, but no additional energy efficiency reductions are made to either gas or electric usage.

- **Scenario 3: Fuel-Switching plus Electric Use Reductions**. This scenario is the same as Scenario 2, but also applies additional efficiency reductions to the electricity usage to offset the increased electricity required for the fuel switching and to keep total electric consumption stable at 2008 levels.

This report presents energy use, GHG emissions, EUI, and GHG intensity targets by building type for each of these three scenarios. This analysis can be used by the City as a foundation for analyzing the impact of potential policies and for making decisions regarding the role of electrification and efficiency targets in achieving the CAP goals. The tables below present the 2050 target forecast energy use and GHG emission reductions over the 2008 baseline. All three scenarios deliver 82% GHG reductions, but the total energy reduction in kBtus vary in each scenario due to additional electric energy reductions in Scenario 1 and 3.

Table ES-2. Scenario 1 2050 Target Forecast Energy and GHG Change Over 2008 Baseline

	kBtu Reduction	GHG Reduction
Multifamily (1-3)	-16%	26%
Multifamily (4-6)	41%	60%
Multifamily (7+)	54%	79%
Single Family	76%	84%
Dry Goods Retail	48%	93%
Grocery	57%	82%
Hospital	34%	95%
Hotel Motel	67%	80%
Office	37%	96%
Other Commercial	52%	89%
Restaurant	88%	31%
School	85%	90%
University	34%	95%
UW	-3%	100%
Warehouse	42%	94%
Residential	63%	81%
Commercial	45%	83%
Total	53%	82%

Table ES-3. Scenario 2 2050 Target Forecast Energy and GHG Change Over 2008 Baseline

	kBtu Reduction	GHG Reduction
Multifamily (1-3)	-58%	26%
Multifamily (4-6)	11%	60%
Multifamily (7+)	40%	79%
Single Family	59%	84%
Dry Goods Retail	21%	93%
Grocery	30%	82%
Hospital	-1%	95%
Hotel Motel	2%	80%
Office	23%	96%
Other Commercial	15%	89%
Restaurant	-16%	31%
School	35%	90%
University	5%	95%
UW	-6%	100%
Warehouse	13%	94%
Residential	44%	81%
Commercial	11%	83%
Total	26%	82%

Table ES-4. Scenario 3 2050 Target Forecast Energy and GHG Change Over 2008 Baseline

	kBtu Reduction	GHG Reduction
Multifamily (1-3)	-58%	26%
Multifamily (4-6)	11%	60%
Multifamily (7+)	40%	79%
Single Family	59%	84%
Dry Goods Retail	27%	93%
Grocery	36%	82%
Hospital	7%	95%
Hotel Motel	17%	80%
Office	26%	96%
Other Commercial	23%	89%
Restaurant	7%	31%
School	46%	90%
University	11%	95%
UW	-5%	100%
Warehouse	20%	94%
Residential	44%	81%
Commercial	18%	83%
Total	30%	82%

The forecasts and targets produced by the baseline model can be used to identify building types with the biggest opportunity for emission reductions, and where to focus policy development. For instance:

- Single-family buildings are often not considered a priority, as the return per building is small. However, the model has revealed that due to high saturations of gas space and water heating, and the overall size of the single-family market, single-family buildings are responsible for nearly half of Seattle's 2015 GHG emissions from residential and commercial buildings combined. According to the BAU forecast the ratio will drop to about 30% of total emissions by 2050, but this is still a large component of the total building emissions. Therefore, any policy strategy to achieve a carbon-neutral City will need to address these homes.
- SCL and PSE conservation potential assessments project that new construction for some building types will include increasing ratios of gas fueled end uses. For example, low-rise multifamily units, which have typically included high ratios of electric space heating and DHW, are forecast to increase by 84,000 units by 2050 with an associated increase of about 20,000 $MgCO_2e$. Since multifamily buildings are typically all-electric it is important to ensure specific building types like this do not start to trend toward gas-fueled end uses in new construction.
- Restaurants and hospitals have high EUIs, high energy use, and high emissions on average for each building and in aggregate. These building types have process loads that often preclude deep efficiencies. However, these building types and their process loads must be addressed seriously in order to meet the building level reductions required to meet the CAP emissions goals.

- The BAU forecasts depend on assumptions from the CPAs that a significant amount of conservation in both new and existing buildings will stabilize energy use and emissions at near 2015 levels through 2050. However, this conservation cannot be taken for granted. The support for and effectiveness of these BAU actions remains critical and must be considered part of overall efforts, along with programs focused on incremental reductions, to dramatically reduce emissions below the 2008 reference year.

To fully leverage the model for policy analysis, as a next step we recommend an in-depth analysis of the model results. Profiles of each building type that summarize and interpret the forecasts by end use, fuel types, and population changes can be used to brainstorm the direct technical mechanisms for reducing emissions and energy for specific end uses in specific building types. Then policy frameworks can be developed around these mechanisms. This approach will allow the model to be used as a bottom-up strategy for designing effective policies, where the structure of the policy is directly informed by the technical mechanisms required to reduce emissions. The model can then be used to analyze the impact of the policies based on clear performance metrics. We also recommend exploring opportunities for collaboration with other cities or organizations to support further model refinements, analysis, and maintenance.

1. Introduction

The City of Seattle has the ambitious goal to be a carbon neutral city by 2050. Seattle's Climate Action Plan (CAP), adopted in 2013, identifies the projected emission reductions needed to get to carbon neutral (OSE 2013). With 33% of Seattle's core emissions from building energy, the carbon emissions from buildings will need to be reduced by 82% from a 2008 baseline. The goal is to achieve these reductions by both reducing building energy use—a 45% reduction in the commercial buildings and a 63% reduction in the residential buildings—and by reducing the greenhouse gas (GHG) intensity of the fuels supplying these buildings by 63%.

Overall building energy use (i.e., the total energy consumed in any given year, inclusive of all buildings existing in that year) will need to drop from 48.8 trillion Btu in 2008 to 23.3 trillion Btu in 2050 and GHG Intensity from 28.7 to 10.6 tCO_2e/GJ.[2] All while Seattle continues to gain new people and new jobs; an additional 120,000 people and 115,000 jobs are projected by 2035 (DPD 2015). The City's CAP identifies projected energy and GHG reductions at two points in time, 2030[3] and 2050, with a greater proportion of the reductions projected in the 2030–2050 timeframe. However, for the purposes of tracking progress and developing policy, Seattle's Office of Sustainability & Environment (OSE) evaluates against simple average annual reductions for the full planning horizon 2008–2050 (i.e., 1.95% per year over 42 years to achieve a total 82% GHG emissions reduction).

These broad goals are a critical starting point, but less useful in understanding whether the sum of individual building performance aligns with the policy goal. Policymakers do not have a sufficient level of detail to focus priorities and building owners have no metric for how their buildings' performance relates to the overall goal. To address this gap, the City contracted Ecotope, Inc., to develop a baseline model and conduct analysis that establishes granular energy use intensity and greenhouse gas emissions targets for each building type (e.g., office, grocery, mid-rise multifamily), at 5–10 year intervals through 2050. Results will be used to communicate the need for policy interventions, to identify priority building types, and to track progress. Ecotope assembled data from local utility conservation potential assessments, building stock assessments, population and employment forecasts, and the City's climate goals to inform energy use intensity and GHG business-as-usual forecasts and targets by building type, building end use, and fuel type.

Seattle currently has two primary means of tracking reductions in GHG emissions and energy use: 1) annual Building Energy Benchmarking data and 2) Community Greenhouse Gas Emissions Inventories. Each is valuable for its own purpose, but both have limitations for a comprehensive understanding of building energy and GHG emissions.

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[2] Targets and projections are based on a proof of concept analysis conducted for OSE by the Stockholm Environment Institute (OSE and SEI 2011) and on additional analysis by OSE during the development of the Climate Action Plan.

[3] 2030 targets are tied to goals previously established by Seattle City Council in 2011: 10% commercial energy use reduction; 20% residential energy use reduction; and 25% GHG intensity reduction (City of Seattle 2011)

Benchmarking: Seattle has had mandatory Building Energy Benchmarking since 2010 for non-residential and multifamily buildings 20,000 square feet or larger. This program provides annual aggregate energy use for individual buildings, which the City uses to establish total energy use for these buildings and average energy use intensities (EUI) by building type (OSE and EMI Consulting 2015). While benchmarked buildings comprise over 70% of the non-residential and multifamily square footage,[4] buildings smaller than 20,000 square feet, including single-family homes, townhouses, and smaller multifamily buildings, leave over 60% of the total building square footage untracked.

Greenhouse Gas (GHG) Emissions Inventory: Seattle's Community GHG Emissions inventories are prepared every 2–3 years and utilize energy consumption data from Seattle City Light (electricity), Puget Sound Energy (natural gas), Enwave (steam), and the University of Washington (steam), as well as estimates for fuel oil. Consumption is based on customer accounts and is distinguished broadly as commercial or residential. Energy consumption in industrial buildings is accounted for separately as part of the industrial operations emissions.

Based on Seattle's most recent Community GHG Emission Inventory, from 2008–2012 total GHG emissions in the building sector have gone down 10%, or 2.5% per year (OSE and SEI 2014). This meets the goal of a 1.95% per year average GHG reduction. However, reductions in building energy use are not on track, which is a key component of Seattle's approach. In residential buildings, total energy use has declined 1.25% per year (vs. a goal of approximately 1.5% per year) and only 0.25% per year in commercial buildings (vs. an approximate 1.1% per year goal). More recent energy use data for buildings benchmarked in both 2012 and 2013 (those 20,000 square feet and larger) indicates a 0.6% reduction. This reduction was driven by a decrease in electric consumption of 1.7%, but balanced somewhat by an increase in natural gas consumption of 2.8% (OSE and EMI 2015).

Having both GHG emissions targets and energy reduction targets for the building sector allows a more tailored analysis within the city-wide goals of reducing GHG emissions in buildings, transportation, and industry. Switching to a less carbon-intense energy source reduces emissions in the building sector; using less energy overall provides an opportunity to use this low carbon energy in other sectors, such as transportation.

This report documents the methodology for calculating EUI and GHG emissions for the base-year, business-as-usual (BAU) forecasts, and targets by building type. The report also presents highlights of the results. More detailed summary tables are included in the Excel model worksheets. Results of the analysis will be used to track progress, to communicate additional policy intervention needs, and as a planning tool to evaluate the impact of specific approaches.

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[4] Calculation based on data from the benchmarking database and total floor area estimates from King County Assessor data, SCL customer database, decennial Census, the Washington State Office of Financial Management intercensal population estimates and Small Area Estimate Program, and the American Community Survey.

2. Methodology Overview

Ecotope assembled building stock characteristics, EUI, and GHG emissions data for the base year and the business-as-usual (BAU) forecasts from many data sources, including city, state, regional, and national data sets on population and energy consumption. These data sets provided the foundation for a generalized building end use (space conditioning, hot water, etc.) model by building type. Coupled with fuel use saturations, Ecotope constructed a BAU forecast of total energy consumption and GHG emissions. The forecast assumes buildings will achieve the goals of existing policies and utility energy efficiency incentives, such as appliance standards and recent code adoptions, but does not include future policy decisions. The energy and GHG reduction goals from the City's CAP were then overlaid to identify the gap between the BAU forecast and the CAP goals. The information on areas where the BAU indicates a shortfall highlights building types and sectors where policy intervention will be needed.

Data sources used to establish the BAU include:

- City of Seattle Department of Planning and Development (DPD) population, household count, and employment estimates;
- SCL floor space estimates from nonresidential customer database;
- U.S. Census Bureau decennial census and American Community Survey;
- U.S. Green Building Council (USGBC) estimates of floor space per employee;
- SCL 2016 Conservation Potential Assessment;
- Puget Sound Energy (PSE) 2016 Conservation Potential Assessment;
- City of Seattle 2014 building energy benchmarking database;
- Northwest Energy Efficiency Alliance (NEEA) Residential Building Stock Assessment (RBSA) and Commercial Building Stock Assessment (CBSA) (including SCL oversample for each of these assessments); and
- 2012 Seattle Community Greenhouse Gas Emissions Inventory.

After developing the EUI estimates for each building type (e.g., office, grocery, single family) and sector (i.e., residential or commercial) in the base-year, results were compared against local, regional, and national datasets as a reasonableness check. These include:

- Seattle Energy Benchmarking
- Residential and Commercial Building Stock Assessments for SCL (RBSA/CBSA)
- Residential Energy Consumption Survey (RECS)
- Commercial Building Energy Consumption Survey (CBECS)
- California Energy Use Survey (CEUS)

Ecotope started with initial baseline data developed as part of a larger Conservation Potential Assessment (CPA) conducted for Seattle City Light (SCL) (SCL 2015). A similar CPA was developed for PSE gas energy. These CPA datasets include base-year energy use and GHG emissions data for 2015, as well as the BAU forecast for 2015–2035 for gas and electricity.

Steam and oil data from the City's GHG inventory data and Enwave's operating agreement with the City were also developed into a forecast model, albeit a more simplistic model in comparison to the gas and electricity models. Performance goals identify the energy and GHG intensities by building type that would be needed for Seattle to achieve its climate goals.

The following definitions are used in this report and in the end-use model:

- The **reference year** is 2008, which is the starting year for referencing the CAP GHG emission reduction goal.
- The **base year** is 2015, which is the latest year for data availability.
- The **forecast years** are 2020, 2025, 2035, and 2050.
- The "**business-as-usual**" (BAU) forecast is the scenario where the conservation and fuel reduction potential in Conservation Potential Assessments (CPAs) are taken as the baseline conditions independent of any carbon reduction strategy; the BAU forecast includes utility programs, already-legislated codes and standards, and naturally occurring conservation (market transformation).
- The **targets** are a linear application of the CAP reduction targets (e.g., 82% for GHG emissions in 2050) back to the reference year (0% in 2008) by sector and building type. EUI and GHG intensity are also included in the summaries.

2.1. Reconciling Datasets

The goal of the baseline forecast is to generate anticipated building energy use characteristics over time given the current trajectory of efficiency, codes, and standards. The forecast is disaggregated by building type, end use, and fuel type to allow for detailed analysis of energy conservation policy scenarios. The purpose of this section is to provide an overview of the data inputs and decisions made in the analysis. The discussion below shows the development of the workbooks from the initial data sets, to connecting the data sets together, to making input decisions where data may be lacking or inconsistent between data sets. Throughout this section there are notes about data issues, data decisions, and where to tweak the models when new information is available.

The main two data sets to start the analysis were provided by Cadmus:

- Seattle Energy Intensities 18AUG15.xlsx – Provides the base year (2015) energy use intensities by building type and by fuel type. The workbook has detailed background information about data sources and decisions, including the Seattle benchmarking data and decisions for when to use the benchmarking data and when to use alternative datasets. Cadmus also included population forecasts provided by the City of Seattle and PSE natural gas end use forecasting through 2035 from the 2016 PSE Conservation Potential Assessment (CPA).
- SCL CPA Baseline Forecasts.xlsx – This is an augmentation to the previous data set. It includes electricity forecasting by building type and end use through 2035 from the 2016 Seattle City Light (SCL) CPA.

Additional data sets were also used to provide energy use breakdowns, forecast rates, or simply for data validation purposes. Most of these datasets are from well-known regional and national sources and have been analyzed to provide the most relevant information about trends in Seattle.

- Census: American Community Survey (ACS) – Detailed housing and occupant data since 2005. This was formerly the long form of the decennial census, but was pulled out and is now collected annually. The ACS is used in this project to look at short term housing trends and to parse single family from multifamily units.
- Census: American Housing Survey (AHS) – Seattle metropolitan data used to analyze building populations by building size. The AHS contains number of floors in the building, while the ACS does not. The Seattle survey has been collected 10 times over the past 40 years.
- Commercial Buildings Energy Consumption Survey (CBECS) – National sample survey of energy-related building characteristics for commercial buildings. The main use of CBECS for this project is for comparisons for reasonableness.
- Commercial Building Stock Assessment (CBSA) – Regional study of the commercial building stock in the Northwest (Washington, Oregon, Idaho, and Montana). Within the regional study, SCL funded an oversample of buildings in their service territory. This SCL dataset was used as a reference when evaluating summaries from other datasets.
- Residential Building Stock Assessment (RBSA) – Regional study of the residential building stock in the Northwest. Within the regional study, SCL funded an oversample of buildings in their service territory. Various summaries were generated for both the single family and multifamily sectors using the SCL data files.
- King County Assessor Data – Public record of parcels in King County. The apartment, condo, and parcel datasets were filtered and summarized for Seattle multifamily housing units.
- LUV_Controls_030915_SEATTLE - with actuals_2014-04-27_updated.xlsx – Population estimates provided by the City of Seattle Department of Planning & Development
- Seattle Community GHG Inventory – Results from the 2012 GHG inventory and preliminary data from the 2014 GHG inventory were used to calibrate the model.
- Seventh Northwest Power Plan (2016) – The Power Plan is a twenty year planning document for electric utilities in the Northwest. The plan forecasts electric demand and plans for meeting the demand by allocating resources, including both power-generation and energy efficiency.
- Seattle OSE Benchmarking (2015) – Energy consumption and building characteristics dataset maintained by the City. All non-residential and multifamily buildings (20,000 Sq.Ft. or larger) must submit annual data to the City.

2.1.1. Residential Populations

The residential and commercial population forecasts use two different analysis paths, so they will be discussed separately in this section.

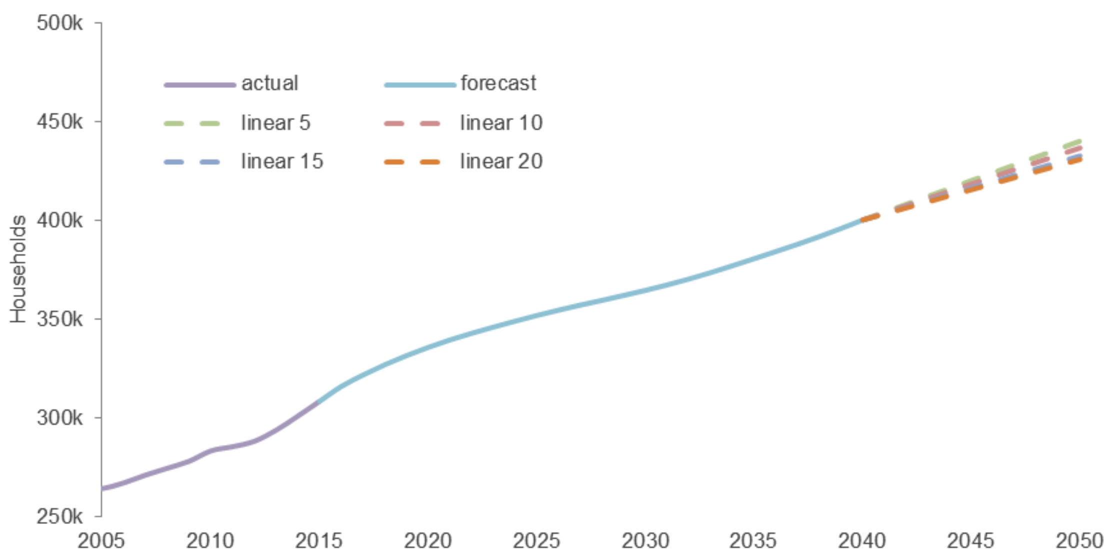
The residential forecast is built from data provided by the City in the LUV_Controls workbook. This workbook provides the historical number of households from 2000 to 2014 and forecasted number of households from 2016 to 2040. This is the same data source provided within the Energy Intensities workbook from Cadmus. Households are total number of single family and multifamily units. Single family includes manufactured homes and townhouses for the purpose of these workbooks.

In the Cadmus Energy Intensities workbook, the total households were broken into housing types in two steps: first, split apart single family and multifamily, then split multifamily into the three size designations. To split the single family and multifamily apart, Cadmus used the ACS to find the ratio of single family to multifamily and then applied this to the Seattle data. However, multifamily was defined as more than one unit in their analysis. For our workbooks we want to be consistent with the regional definition of five or more units to define multifamily. This means duplexes, triplexes, and fourplexes are included in the single family category in our model, along with manufactured homes and townhouses. We reanalyzed the ACS data using this new definition and following the same data flow Cadmus originally used.

For the multifamily size split, RBSA provided the ratios of low-rise (1–3 stories), mid-rise (4–6 stories), and high-rise (7+ stories) units for the current mix of units. Data summarized from the AHS and King County Assessor data allowed for a reasonableness check on these ratios.

The Seattle population forecast ends at 2040, so data through 2050 used a simple linear extrapolation. A review of linear extrapolation from the preceding 5, 10, 15, and 20 years show slight deviations from each other, as seen in Figure 1 below. Based on the general shape of the forecast, the extrapolation for the analysis uses the 5-year trend.

Figure 1. Extrapolating Seattle Population through 2050

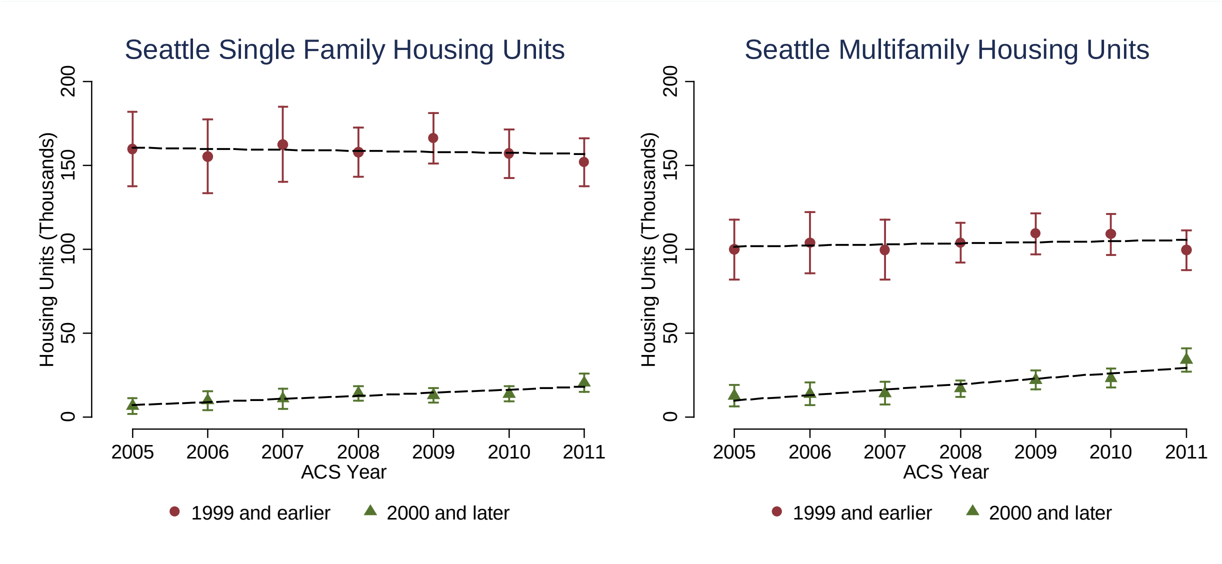


The ratio of single family, low-rise multifamily, mid-rise multifamily, and high-rise multifamily can then be applied to each year in this 2050 forecast to find the number of households by building type. But there is one more necessary disaggregation to divide the forecasted population into "existing" and "new" categories for each building type. Existing refers to existing as of the base year, 2015. Any buildings built after 2015 are in the new category. There are no new households added to the existing category after 2015 and the existing population will decline because of demolitions. The new category will rise based on construction rates. Also, the ratios between the building types may change over time. The following bullets describe the methods to generate these building type ratios:

- For 2015, the ratio of SF to MF units is set by using the ACS analysis summary and King County Assessor data. Then the ratio of low-rise, mid-rise, and high-rise units within the multifamily category are the ratios found in RBSA.
- For the four residential building types in 2050, we built an optimization calculation. The idea for the optimization is we know the starting and ending population, and we assume that Seattle is not going to expand geographically to accommodate this increase in units, so the density of the residential geography must increase. Seattle has 83.78 square miles of land area, of which 49% is currently zoned single family and 8% multifamily, so in the tool we increase the density in this fixed area. The calculation starts with the results of the unit breakdown for 2015, described in the previous bullet. From RBSA, we know the number of units per building type, so we can convert number of units to number of buildings. Then we summarize the Seattle ZIP codes from the King County multifamily assessor data to find the average lot size by building type, which turns out to be fairly consistent at 0.75 acres for all three multifamily building types (slightly larger for mid-rise, but we are going to assume equal sizes for our calculations). The 8% of multifamily area in the city is then divided up by the number of buildings in each building type. We then calculate a metric of number of units per lot Sq.Ft. by building type, and assume this is a fixed value for all forecast years (this is our residential density by building type). We use this metric and the total population for 2050 to tune our new ratios. In practice, this involves using judgement to set the expected land area ratio of mid-rise and high-rise buildings, and then running Goal Seek in Excel to calculate the low-rise ratio, which will then also set the single-family ratio.
- The next step is to break out the existing and new buildings for each of the building type populations just calculated. Since the city will be moving toward higher density buildings, we assume those higher density buildings to be demolished at their natural rates (we assume -0.23% from the Seventh Plan), but we assume a much faster demolition rate for single family as that land is converted to multifamily buildings for single family homes built in multifamily zones. The calculations are set up so that only the demolition rate is needed for each building type, and the new construction population is just the difference between the existing and the total, though a construction rate is still calculated for reference.

As mentioned above, the selected demolition rate for multifamily is from the Seventh Plan. An alternative method of determining the demolition rate from the ACS can be seen in Figure 2 below. These graphs are just for reference, but do seem to indicate the growth of single family housing is already stagnating and existing single family housing have started to decline at a faster rate. On the multifamily side, there has been only minimal decline in the existing population, and large growth in the new population, even through the recession.

Figure 2. Analyzing ACS Data for Construction and Demolition Rates



Using all of the bulleted assumptions above generates the unit forecasts for the four building types with two building vintages (existing and new) across the reference year (2008), base year (2015), and four forecast years (2020, 2025, 2035, and 2050).

One additional extension of this analysis is to convert the unit populations into total Sq.Ft. This is just for reference and allows a comparison of residential floor areas to commercial floor areas. A summary of floor area per unit by building size from a number of data sets is included in the workbook, including results from the SCL RBSA, PSE RBSA, AHS, and from Cadmus. The chosen average floor areas by unit type is the Seattle RBSA. The data for floor area is in the 'Sq.Ft.' sheet.

2.1.2. Commercial Populations

The commercial population analysis begins with the base year total floor area provided in the Cadmus Energy Intensities workbook, which references the City as the source. Note that in the mapping, Assembly and Residential Care are combined with the Other Commercial category. This means the energy breakdowns in the next section for these two building types will not be available by themselves, so they will use the Other Commercial values.

As with the residential sector, the commercial sector forecast uses construction and demolition rates to generate population estimates. However, the commercial sector does not have a total population forecast specifically for the City of Seattle like the residential sector, so adjustments to the provided datasets are necessary before segmenting the population into existing and new buildings. The SCL CPA has total population forecasts through 2035 by building type, so that trend can be used to forecast the total for Seattle. The SCL territory is slightly larger than Seattle, so a ratio of 2015 building area between the two territories provides a translation of SCL forecasted area to Seattle forecasted area. The PSE CPA only has consumption forecasts and not population forecasts, and spans a much larger geographic area, so that data is of limited use for the time being (see below for gas breakdown, which is the main use for the PSE data set).

The total population using the trend from the SCL CPA only goes through 2035, so linear extrapolation extends the values through 2050. To separate new from existing buildings, demolition rates from the Seventh Plan estimate the decline in population and the difference between this existing population and total is the new population.

2.1.3. Gas and Electricity End Use Ratios

The two data summaries necessary in the end use breakdown workbook are:

- Fuel saturation disaggregation by fuel, end use, and forecast year
- Total EUI per building type by forecast year

Multiplying the saturations by the EUI will provide any desired end use EUI for any fuel. To get the disaggregations there are two distinct data flows. For gas and electricity, the PSE and SCL CPA data already provide the necessary information; the data just need to be categorized, summarized, and extrapolated to 2050. The other fuel types require more customized solutions, including engineering judgment.

The PSE and SCL CPA data include forecasts through 2035 by building type, end use, and other detailed subcategories. Summarizing the data includes setting up lookup tables to recategorize into four main end uses: HVAC, DHW, Process, and Other. The initial end use lookup simply assigns the main category to the detailed end use, but a second lookup table then provides access to detailed overrides of end use type by building type as well. For instance, cooking may be assigned to the Other category for multifamily buildings, but be assigned as a Process load for Restaurants. Per ASHRAE 90.1, process loads are, “Energy consumed in support of a manufacturing, industrial, or commercial process other than conditioning spaces and maintaining comfort and amenities for the occupants of a building.”

After creating the category lookup tables, the CPA data are summarized by the four main end use types and by building type to generate a total consumption for each category. For each building type, the end use consumption is divided by the total consumption to get an end use consumption ratio. Data are only available for 2015, 2020, 2025, and 2035 in the CPAs, so a linear model of the ratios generates data for 2008 and 2050. The results of the linear extrapolation models are reviewed and adjusted if necessary, followed by a normalization to make sure the ratios still add to 100% for each building type. This is a mostly automated process, so any adjustments to the model will flow through naturally.

2.1.4. Oil, Steam, and Biomass End Use Ratios

The three remaining fuel types represent a smaller proportion of the overall energy use and have a simpler mix of end uses compared to electricity and natural gas. Detailed data to build up the current end use ratios and forecast ratios, such as the level of detail provided in the CPAs, are not available for these other fuel types. The RBSA summarizes self-reported alternative fuel use (oil, wood, pellets, propane), which gives some indication of fuel use. RBSA also includes end use fuel types, which show, for instance, oil heating in Seattle single family homes almost always uses a forced air furnace (~95%) over a boiler system. Also, there were no homes in the Seattle RBSA with oil-fired water heaters – they were all natural gas or electric. For the workbook, oil is simply set with HVAC as the only end use for all years.

Steam and biomass are mostly intertwined. Except in the case of single family units, biomass refers to the steam generation from biomass, and the steam produced by natural gas is accounted for in the steam fuel type. End use breakdowns for steam and biomass are therefore assumed to be the same, and the ratio between these two fuels are accounted for in the cross-fuel ratios (see below). Steam end uses by building type are assumed to be constant across the forecast period for the baseline, and only the HVAC and DHW end uses are assumed non-zero. The big assumption for steam is the ratio of these two end uses per building type. In the current version of the workbook these have been set equal to the natural gas HVAC and DHW end use, with normalization. The thought being the gas ratios are roughly the consumption ratio we would expect with the district steam for HVAC and DHW by building type.

The exception for the steam/biomass relationship is single family homes. None of these homes have district heat, but some do have wood heat as secondary heating systems. The ratio for single family biomass is set to account for this heating end use if this use is high enough to account for in the cross-fuel ratios.

2.1.5. Cross-Fuel Ratios

The previous two sections described the development of end use ratios within each of the fuel types. These fuels are then tied together on the fuels tab of the end use workbook. On this tab, the Btu consumption ratio across the fuel types is defined for each forecast year. Natural gas and electricity will be a much higher percent than all other fuels on this sheet, except for a few exceptions, like district heat for hospitals.

Fuel use breakdowns for 2015 are supplied by the Cadmus workbook. For the baseline effort, these ratios are mostly set constant across the forecast period. The exception to this is steam vs biomass. In 2008, all of the steam production is assumed to be natural gas with no biomass. By 2015, the fuel mix is approximately 75% natural gas and 25% biomass for Enwave. In the agreement between the city and Enwave, new customers must be met with a 50/50 ratio of natural gas and carbon neutral fuel (biomass, in this tool), so the ratio of biomass will increase a bit over time. For now the tool assumes 30% by 2025, 35% by 2035, and 45% by 2050.

2.2. Establishing the Base Year

The base-year data provides the 2015 estimate of EUI, GHG intensity, and population by building type and fuel type. To facilitate the forecast, the base-year EUIs were disaggregated by end use and reported as fuel consumption per square feet and per housing unit. GHG emissions are calculated from this fuel disaggregation based on the mix of fuel use derived from the base-year data. Each building type is split into existing (2015 and earlier) and new (post-2015), which helps in accounting for code implementations and retrofits. Fuel types are Electricity, Natural Gas, Oil, and two district Steam types (natural gas fired steam and biomass generation).[5] District steam is separated from the general natural gas accounting because of the potential to convert to

[5] Electricity is provided by the municipal utility, Seattle City Light, gas by an investor owned utility, Puget Sound Energy, and steam by either Enwave (an investor owned steam utility in central Seattle) or by large campus systems.

biomass, or other carbon-neutral fuel source, on a large scale.[6] Building end uses are split into four major categories: HVAC (heating, ventilation, and air conditioning), DHW (domestic hot water), Process Loads (commercial cooking, laboratory equipment loads, refrigeration, etc.), and Other (lights, plug loads, etc.).[7] The intersection of building end uses and fuel uses can be seen in Table 1. There are fifteen building types in the model, which are shown in Table 2.

Table 1. Building End Uses and Fuel Types

Fuel Types	Building End Uses				Fuel Supplier
	HVAC	DHW	Process	Other	
Natural Gas	•	•	•	•	Puget Sound Energy (PSE)
Electricity	•	•	•	•	Seattle City Light (SCL)
Fuel Oil	•				(Various)
Steam	•	•			Enwave, Univ. of Wash., Seattle Center

Table 2. Model Building Types

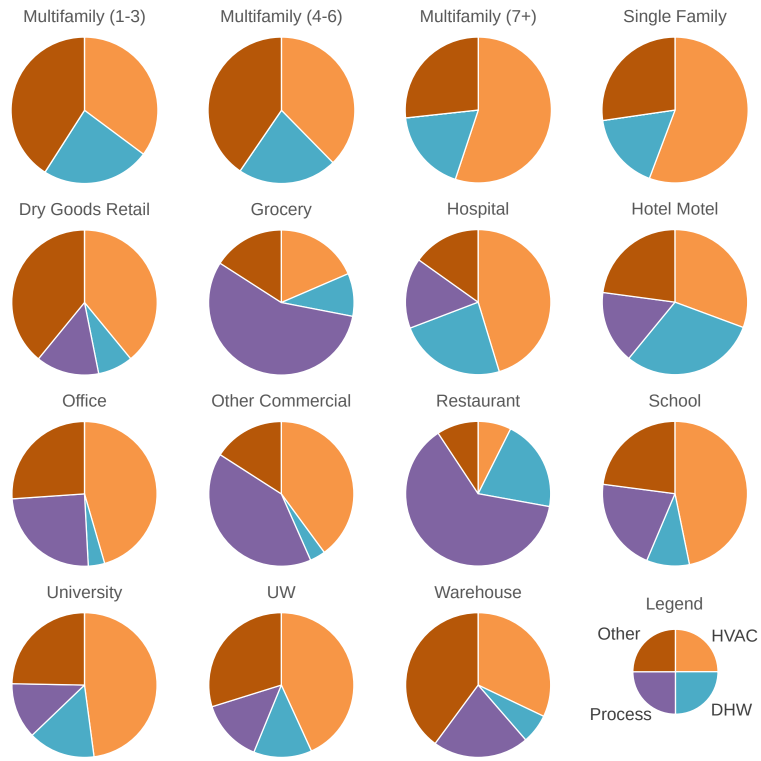
Commercial			Residential
Dry Goods Retail	Office	University	Single Family
Grocery	Other Commercial	UW	Multifamily (1–3)
Hospital	Restaurant	Warehouse	Multifamily (4–6)
Hotel Motel	School		Multifamily (7+)

The four main building end uses (HVAC, DHW, Process, and Other) were obtained for each building type by developing consumption ratios by fuel saturations by building type from the Seattle City Light (SCL) CPA and Puget Sound Energy (PSE) CPA. Once these estimates were totaled they were calibrated in the context of total consumption reported by these utilities for each building type. The PSE CPA covers a much larger area than just the City of Seattle, so the ratios are not always consistent with the building stock of the City. Adjustments for this inconsistency were developed using SCL data from the RBSA and CBSA (Ecotope 2014 and Navigant 2015). Figure 3 shows the end use disaggregation for 2015.

[6] The term “fuels” in this report is being used loosely since steam is not a fuel, but rather gets generated from natural gas and/or biomass. Natural gas steam and biomass steam are simply referred to as the steam fuel type and the model has an accounting for splitting natural gas steam and biomass steam.

[7] On-site renewables (e.g., solar PV) are treated as a change in the energy efficiency of the building and not as a separate “fuel” source.

Figure 3. Building End Use Disaggregation by Building Type (Base Year 2015)



Building end uses were obtained from the adjusted CPA models by fuel type, and then aggregated across fuels. Figure 3 shows the fraction of energy consumption in each building type for the four major end use categories. End uses for steam and oil are assigned directly from CBSA data, RBSA data, and the Seattle GHG inventory data. When combined with the building type populations, the BAU demand for GHG emitting fuels in each building type can be derived.

2.3. Developing the BAU Forecast

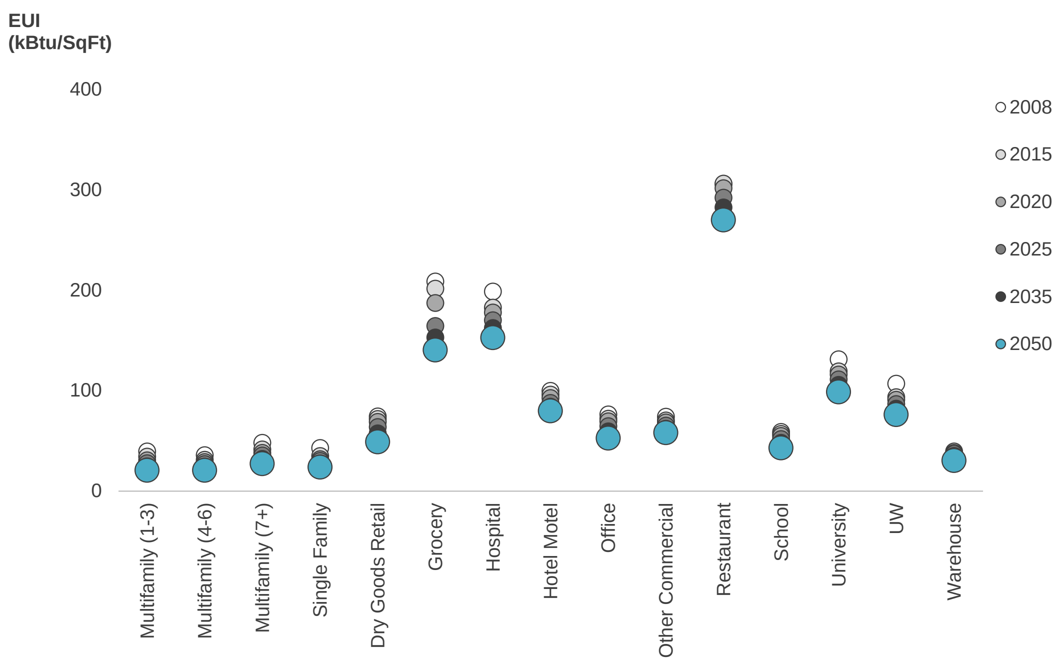
The energy use intensity (EUI) of buildings will change over time, through both intentional and unintentional conservation efforts, as well as through new building stock being added to the total building stock or replacing old building stock. New buildings, particularly in the State of Washington and City of Seattle, are subject to a more stringent energy code compared to the existing building stock in Seattle. The model splits out the existing population (2015 and earlier) from the new population (post-2015) to allow for different policy treatment of the two groups. This section describes the approach to forecasting EUIs and GHG emissions by building type and extending them across future building stock populations through 2050.

The BAU EUI forecast begins with the SCL and PSE CPA forecasts. Ecotope adjusted the CPA models to account for Seattle-specific building stock characteristics, but the overall time trends reflecting existing conservation efforts built into the CPA were retained. The Seattle-adjusted CPA models provide the building end use EUI forecasts for gas and electricity.

Steam and oil are much smaller components of the model when compared with gas and electricity, but do provide opportunity for GHG intensity reductions. Data for these fuels are more limited, but the models also are not as complex since these fuels are mostly used for heating with some domestic hot water use as well. In general, these fuels are held constant over the time horizon, except where data were available from the steam providers. The ratio of natural gas steam to biomass steam, however, does change over time based on the forecasts from Enwave and their agreement with the City to increase biomass generation.

Figure 4 shows the BAU forecasted Seattle EUI trends through 2050, by building type, using the Seattle-adjusted CPA values and steam and oil data. The total EUI is the sum of all the fuel EUIs.

Figure 4. Total BAU EUI Change over Time by Building Type



To get the aggregate energy use and GHG emissions across the planning horizon, Ecotope forecast the Seattle building stock population and applied the forecast EUIs and GHG emissions to the forecast building stock. The methodology for generating forecast building square feet and unit forecasts varies by building type. Section 2.1.1 discusses the residential population model and section 2.1.2 discusses the commercial population model.

2.4. Estimating EUI & GHG Targets

The EUI and GHG targets were generated for a few intermediate points (2020, 2025, 2035) using a linear interpolation from 2008 to 2050. These intermediate points give the City a checkpoint for assessing progress towards the GHG reduction goal. They also inform future program and regulatory actions to achieve the 2050 target. Reduction targets were generated by building type, so building owners can also assess their progress in relation to the city-wide goals.

The EUI and GHG targets use a top-down approach for each building type. This was done by reconciling the CAP targets with the EUI and GHG intensity reductions necessary to meet the CAP targets. The target setting included the following steps:

- **Establish 2050 Building Type Targets**. Use the original Seattle CAP 2050 targets and apply to building types developed for this plan. Each building type is given its own target based on the fuel type and end use saturations of each building type.
- **Establish 2020, 2025, 2035, 2050 Building Level EUI and Emission Targets**. Set the EUI and emission levels of fossil-fuel energy use across the building types included in the detailed BAU forecasts. These levels imply that non-carbon emitting substitutes such as efficient electric systems and biomass or waste-heat based district heating sources will be ramped up in each forecast period. The rate of this ramp is, in effect, set by the carbon reduction goal and by the total energy use and fuel use derived from the forecast population by 2050 in each building type.
- **Establish 2020, 2025, 2035, 2050 Electric Building Level EUI Targets**. Assuming continued carbon neutrality of SCL electricity through 2050, the main driver for setting electric EUI targets is to account for the increase in electricity required to offset the reduction in fossil-fuel energy use to meet the emissions targets. The current model does not include a calculation for offsets to electrify large parts of the transportation sector; however, the methodology would be similar.

3. Base Year & BAU Forecast Estimates

The BAU forecasts show changes in energy use and GHG emissions from the 2008 base year through 2050. These energy and GHG changes are driven by a combination of utility programs, codes and standards, and changes in total units and square feet across all residential and commercial building types. Overall energy use for the residential and commercial sectors combined decreases by 10%, whereas the GHG emissions decrease by 12% (Table 3). The residential energy use decreases by 27% which delivers a 28% reduction in GHG emissions. However, these reductions are offset by a 6% increase in commercial energy use and an associated 7% increase in commercial GHG emissions. Even with this offset, the total energy use and GHG emissions are forecast to remain relatively stable. This forecast shows that for both sectors combined, projected utility conservation program accomplishments, codes, and other market forces mitigate more than all growth in energy use and GHG emissions beyond 2008 levels. However, these actions do not bend the curve toward the CAP goals, which will require mitigation of all GHG emissions growth, plus an 82% reduction below 2008 levels.

Table 3. BAU Forecast Energy and GHG Changes by Building Type (2008 to 2050)

		Energy	GHG
Res	Multifamily (1-3)	71%	153%
	Multifamily (4-6)	-8%	31%
	Multifamily (7+)	-29%	-15%
	Single Family	-40%	-39%
Commercial	Dry Goods Retail	0%	32%
	Grocery	-15%	17%
	Hospital	25%	0%
	Hotel Motel	28%	30%
	Office	-13%	-8%
	Other Commercial	5%	2%
	Restaurant	34%	54%
	School	-4%	12%
	University	13%	-14%
	UW	7%	-35%
	Warehouse	8%	21%
Residential		-27%	-28%
Commercial		6%	7%
Total		-10%	-12%

The forecasts in Table 3 show that the residential and commercial sector energy use and GHG emissions vary greatly by building type. For example, low-rise multifamily GHG emissions are forecast to increase by 153% but single-family emissions are forecast to decrease by 39%. The single-family decrease dominates the low-rise increase, though, since the underlying GHG emissions from low-rise multifamily are only about 5% of the base emissions from the single-family sector. Offices and universities are the only commercial buildings forecast to decrease emissions between 2008 and 2050. The majority of commercial building types are forecast to increase emissions by between 12% and 54%. The sections below provide more details on the population and energy use changes driving these variations.

The connection (or seeming lack thereof) between energy and GHG emissions in these forecasts relates to the breakdown of end uses and fuel types included in the total energy use estimates. Due to the carbon-neutral status of Seattle's electricity, increases or decreases in electric energy use will affect the total energy use but will have no impact on GHG emissions. For example, large reductions in electric energy use combined with small increases in gas energy use for a particular building type would deliver overall energy reductions while increasing GHG emissions. Alternately, large energy increases for gas end uses, without similarly increases in electric energy use, would lead to a larger increase in emissions than energy use.

The following is a demonstration from Table 3 of the complicated nature of the energy-GHG relationship. The low-rise multifamily energy use is projected to increase by 71% between 2008 and 2050, but over the same period the GHG emissions is expected to increase by 153%. In 2008, 76% of energy use in low-rise multifamily buildings are electric, so if we start with 100 Btu of total energy, then 24 Btu is gas. If we end at 171 Btu (71% increase in the total energy), and if the gas-electric ratio stayed the same, then gas should be at 41 Btu (24% of 171 Btu), and it would follow that GHG increase would be the same as the energy increase (about 71%). However, the CPA data assumes much more efficiency gains with electricity compared to gas, so instead of the 2050 electricity ratio being 76%, the ratio is only 65% electricity, so the final gas value is 60 Btu instead of 41 Btu. With 60 Btu, the change in gas use from 24 Btu is 150% (153% without rounding errors). Figure 8 later in the report shows the general EUI trends over time, indicating continued gains on the electricity loads, but almost no improvement in the natural gas end uses.

3.1. Population Forecast

The total square footage of residential and commercial sectors is forecast to continue increasing through 2050 (Figure 5). Residential square footage is estimated to increase by 33% and commercial by 38% from 2008 to 2050. With the exception of low-rise multifamily and single-family, most building types across both sectors are forecast to grow by about 25–60% by 2050 from 2008 levels (Figure 6). After a slight rise between 2008 and 2015, the number of single-family units are forecast to decrease and level out to about 2008 levels by 2050. Low-rise multifamily are forecast to more than double from 2008 to 2050 as population growth and geographic limitations force the city to develop more multifamily units.

Figure 5. Forecast Population by Sector (in Sq.Ft.)

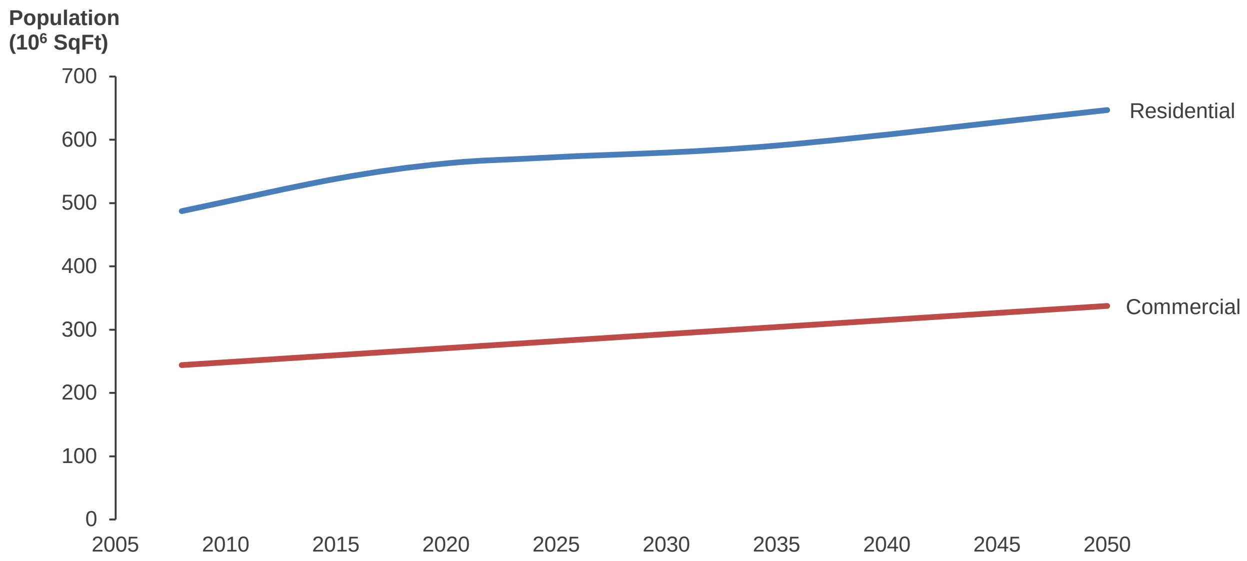
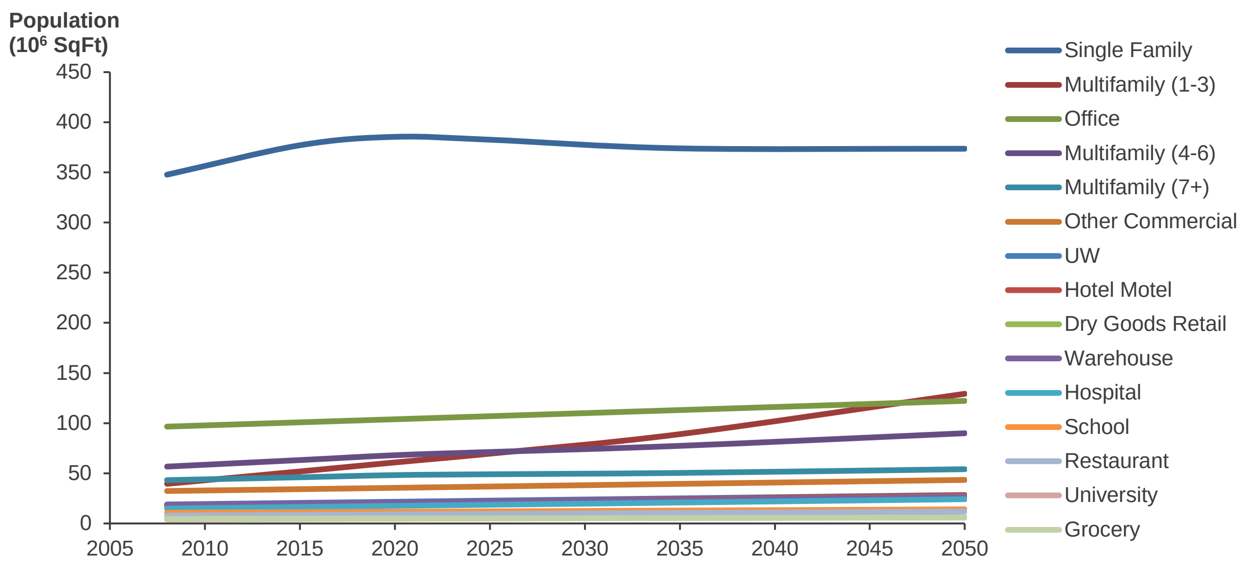


Figure 6. Forecast Population by Building Type (in Sq.Ft.)



3.2. Energy Use BAU Forecasts

As shown in Table 3 above, the total energy for both sectors combined declines by 10% between 2008 and 2050. Table 4 shows the projected changes in energy use for individual building types. Low-rise multifamily energy use is forecast to increase by 71% from 2008 to 2050, but single-family, mid-rise multifamily, and high-rise multifamily are forecast to decrease by 40%, 8%, and 29%, respectively. This is due to the emphasis on increasing the low-rise multifamily building stock in the population forecast model, which overwhelms any efficiency gains in the low-rise multifamily buildings causing an increase in energy consumption. Due to the overall size of the single-family market, a 40% reduction in energy use has a large impact on overall residential energy use contributing to the residential energy use decrease of 27%. On the commercial side, energy use is forecast to decrease for retail, grocery, offices, and schools, while increasing for hospitals, hotel/motel, restaurants, universities (including the University of Washington), and warehouses. The SCL CPA predicts much more efficiency gains on the electric side compared to the PSE CPA for gas (Figure 8), so building types with more electric end uses (particularly electric space heat, electric water heating, and refrigeration) generally show a decrease in energy consumption over the forecast period.

Residential buildings combined are forecast to grow by 33% in floor area, but the energy consumption is forecast to decline by 27% because of the efficiency improvements assumed in the CPAs for existing construction and new population being added mostly to low-rise multifamily, and much less consumption per capita compared to single-family. The commercial sector is forecast to grow by 38% in total square footage with only a 6% increase in total energy use. In the case of this sector, a 24% decrease in average EUI is not enough to outweigh the 38% increase in floor area for commercial buildings.

Figure 7. Base Year and BAU Forecast Energy Use by Building Type (kBtu)

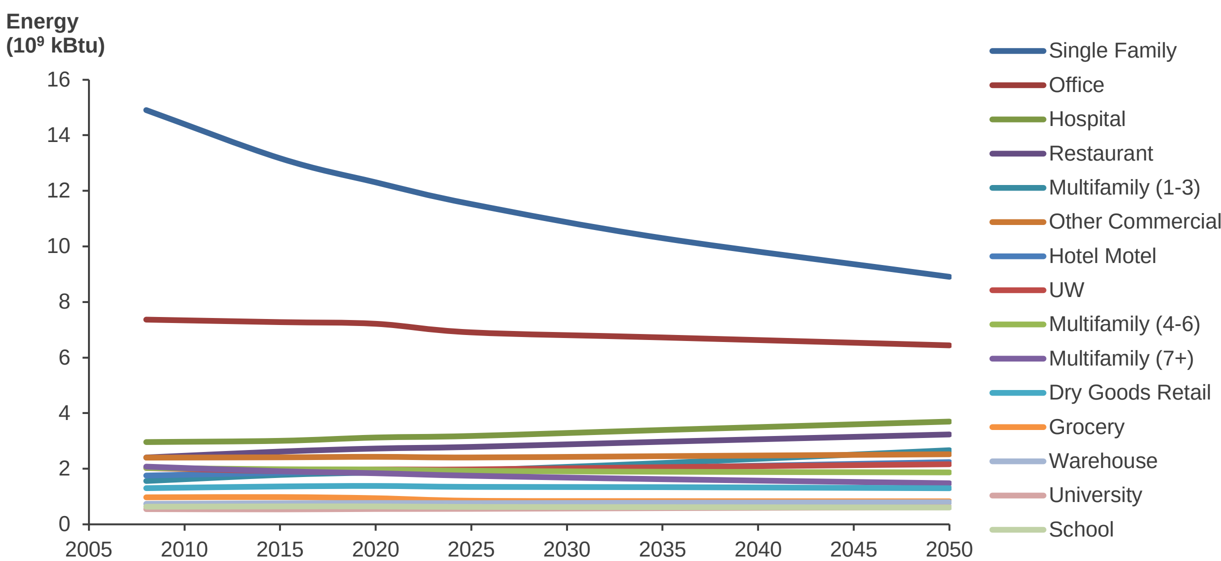


Table 4. Base Year and BAU Forecast Energy Use by Building Type (million kBtu)

		2008	2015	2020	2025	2035	2050
Res	Multifamily (1-3)	1,561	1,779	1,869	1,942	2,206	2,668
	Multifamily (4-6)	2,029	1,984	1,972	1,927	1,893	1,869
	Multifamily (7+)	2,077	1,912	1,840	1,749	1,625	1,479
	Single Family	14,905	13,171	12,306	11,523	10,298	8,907
Commercial	Dry Goods Retail	1,303	1,364	1,382	1,349	1,339	1,300
	Grocery	973	982	941	850	836	830
	Hospital	2,961	3,006	3,125	3,180	3,396	3,698
	Hotel Motel	1,757	1,856	1,907	1,914	2,045	2,240
	Office	7,366	7,276	7,217	6,908	6,725	6,440
	Other Commercial	2,402	2,413	2,431	2,407	2,454	2,523
	Restaurant	2,406	2,619	2,728	2,786	2,972	3,235
	School	636	646	646	628	620	607
	University	548	539	554	558	583	618
	UW	2,027	1,920	1,972	1,977	2,058	2,164
	Warehouse	738	761	770	764	778	796
Residential		20,572	18,846	17,987	17,141	16,023	14,923
Commercial		23,117	23,383	23,670	23,321	23,808	24,452
Total		43,689	42,229	41,657	40,463	39,831	39,376

Table 5 shows the total consumption found at the bottom of Table 4 for residential, commercial, and total and breaks the energy out by fuel type. Natural gas and electricity are clearly the dominant fuels.

Table 5. Base Year and BAU Forecast Energy Use by Fuel Type (million kBtu)

		2008	2015	2020	2025	2035	2050
Res	Natural Gas	9,686	8,750	8,599	8,509	8,300	8,318
	Electricity	9,361	9,255	8,747	8,141	7,422	6,440
	Oil	1,473	786	583	433	239	99
	Steam	52	41	42	42	40	37
	Biomass	0	14	16	18	21	30
Com	Natural Gas	6,279	6,841	7,042	7,274	7,744	8,463
	Electricity	14,487	14,648	14,628	13,942	13,746	13,352
	Oil	108	28	29	30	32	35
	Steam	2,242	1,399	1,439	1,453	1,486	1,431
	Biomass	0	466	532	623	800	1,171
Total	Natural Gas	15,965	15,591	15,641	15,783	16,043	16,781
	Electricity	23,848	23,903	23,375	22,082	21,168	19,792
	Oil	1,581	814	612	463	271	134
	Steam	2,294	1,441	1,481	1,495	1,526	1,468
	Biomass	0	480	548	641	822	1,201

The energy tables and figures above show the data as total consumption, which is the product of energy intensity and population. The energy intensity itself can be seen below. Figure 8 shows the energy use intensity forecast by fuel type and Figure 9 shows the total EUI forecast by building type. Table 6 shows the EUIs from Figure 9 in tabular form.

Figure 8. Fuel EUI Forecast across All Building Types for BAU Scenario

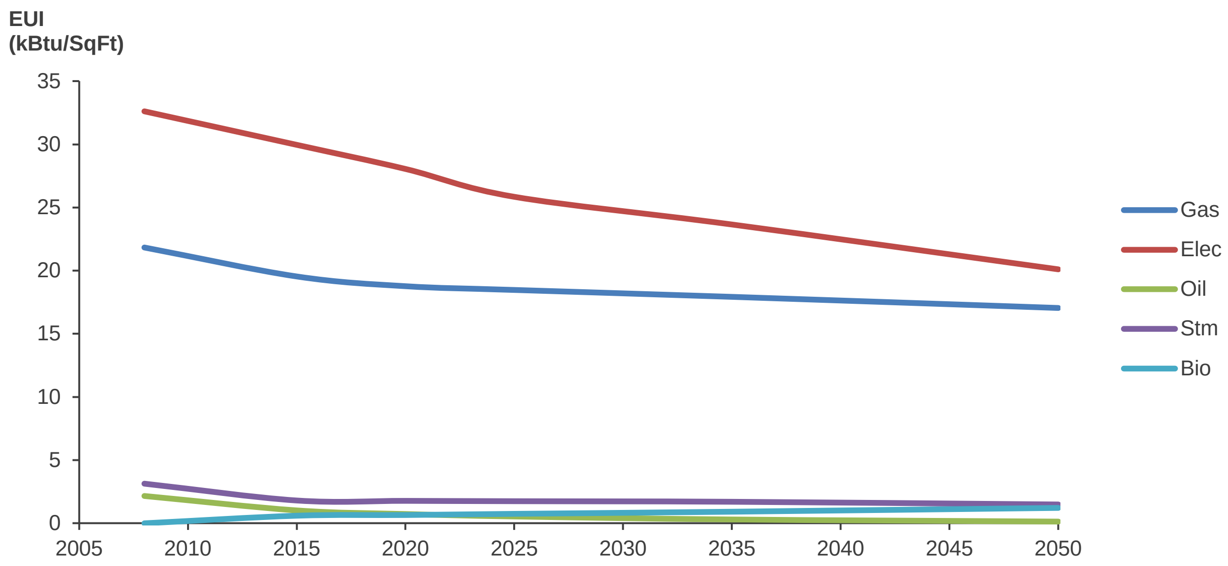


Figure 9. Energy Use Intensity Forecast by Building Type for BAU Scenario

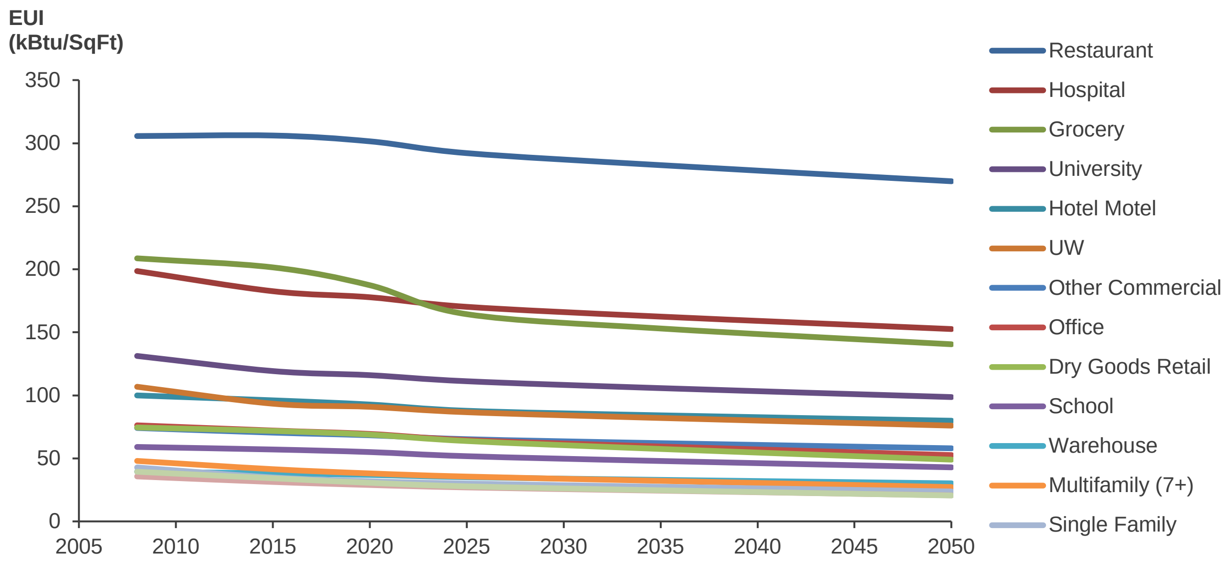


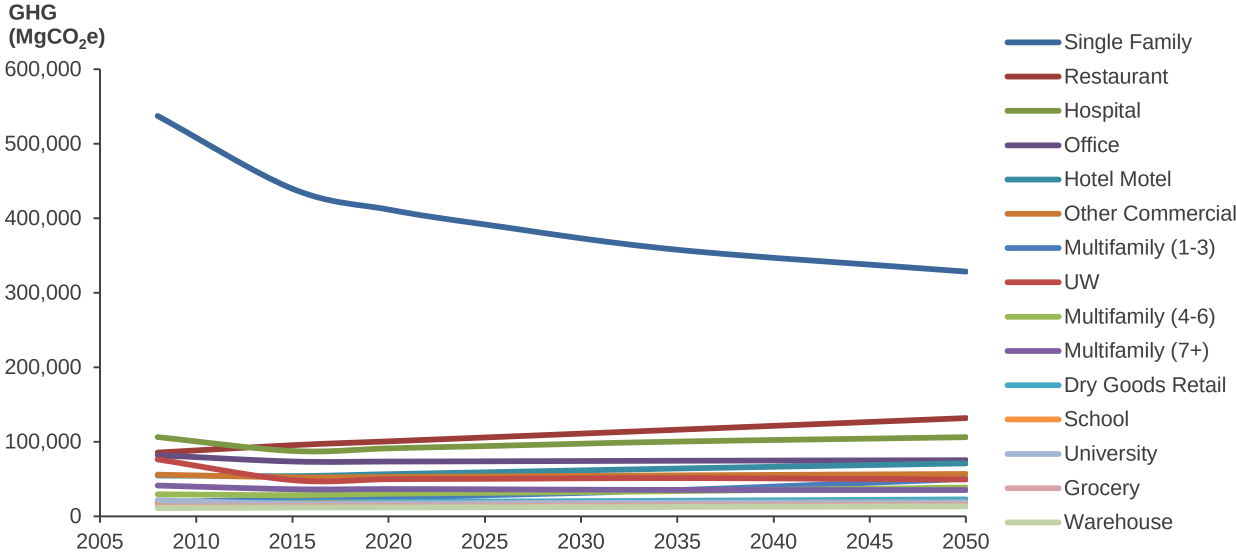
Table 6. Energy Use Intensity Forecast by Building Type for BAU (kBtu/unit or kBtu/Sq.Ft.)

		2008	2015	2020	2025	2035	2050
Res (Unit)	Multifamily (1-3)	37,448	32,534	29,126	26,468	23,507	19,579
	Multifamily (4-6)	40,520	35,549	32,826	30,632	27,711	23,545
	Multifamily (7+)	63,237	54,628	50,213	46,918	42,431	35,964
	Single Family	88,849	72,402	66,180	62,433	57,082	49,422
Res (Sq.Ft.)	Multifamily (1-3)	39.5	34.3	30.7	27.9	24.8	20.6
	Multifamily (4-6)	35.8	31.4	29.0	27.0	24.5	20.8
	Multifamily (7+)	48.0	41.5	38.1	35.6	32.2	27.3
	Single Family	42.9	34.9	31.9	30.1	27.5	23.8
Commercial (Sq.Ft.)	Dry Goods Retail	74.6	71.8	68.9	63.8	57.5	49.1
	Grocery	208.7	201.5	187.4	164.4	153.1	140.6
	Hospital	198.6	182.6	177.8	170.2	162.5	152.6
	Hotel Motel	100.0	96.1	92.8	87.8	84.2	79.9
	Office	76.3	72.2	69.5	64.6	59.5	52.7
	Other Commercial	74.2	70.5	68.4	65.3	62.1	58.1
	Restaurant	305.7	306.1	301.5	292.1	282.6	269.8
	School	59.1	57.1	55.1	51.8	48.0	43.0
	University	131.3	119.3	116.1	111.2	105.8	98.7
	UW	106.9	93.4	91.0	86.7	82.1	76.0
	Warehouse	39.6	38.2	36.9	35.1	33.0	30.3
Residential (kBtu/Unit)		70,366	57,561	51,860	47,864	42,067	34,149
Residential (kBtu/SqFt)		42.2	35.0	32.0	29.9	27.1	23.1
Commercial (kBtuSqFt)		94.7	90.1	87.4	82.7	78.3	72.5
Total (kBtu/SqFt)		59.7	52.9	50.0	47.4	44.5	40.0

3.3. GHG BAU Emission Forecasts

Due to the carbon neutral status of Seattle's electricity and the end-uses fuel splits in new construction for various building types, forecast changes in GHG emissions do not always align directly with changes in energy use. In addition, due to variations in population size, large percentage increases in emissions for various building types do not always indicate a big impact on the overall emissions across a sector. There is a 12% overall decrease in emissions across all building types from 2008 to 2050 in spite of emissions increases for most building types (Table 3). Single-family, high-rise multifamily, offices, and universities are the building types where emissions are forecast to decrease from 2008 to 2050 (Figure 10 and Table 7), and these building types have enough floor area to drive the overall emissions down over the forecast period.

Figure 10. Base Year and BAU Forecast GHG Emissions by Building Type (in $MgCO_2e$)



Low-rise multifamily (1-3 stories) emissions are forecast to increase by 153% over 2008 levels. However, the low-rise multifamily buildings only contribute 3% of the residential emissions in 2008 and only 11% in 2050. On the other hand, the 39% emissions reduction in the much larger single-family market causes an absolute emissions reduction of about 209,000 $MgCO_2e$ and accounts for almost all of the GHG reduction in the residential sector from 2008 to 2050. In spite of these substantial reductions, the single-family, hospital, and restaurant markets are forecast to be the highest emitters with absolute combined emissions of 566,120 $MgCO_2e$ by 2050. These three building types contribute more emissions than all remaining building types combined (464,148 $MgCO_2e$) (Table 7).

Table 7. Base Year and BAU Forecast GHG Emissions by Building Type (in $MgCO_2e$)

			2008	2015	2020	2025	2035	2050
Res	Total	Multifamily (1-3)	19,718	21,988	24,942	28,065	35,092	49,970
		Multifamily (4-6)	29,384	28,332	30,194	31,386	33,672	38,553
		Multifamily (7+)	41,165	36,253	36,477	36,134	35,266	35,115
		Single Family	537,203	439,521	411,563	391,610	357,632	328,334
Commercial	Total	Dry Goods Retail	17,090	18,667	19,101	19,662	20,810	22,592
		Grocery	13,218	13,973	14,122	14,334	14,774	15,468
		Hospital	106,194	87,599	91,116	94,112	100,174	106,073
		Hotel Motel	54,645	53,844	56,443	58,956	64,019	70,915
		Office	81,870	73,462	73,409	73,697	74,447	75,169
		Other Commercial	55,836	52,214	52,699	53,379	54,841	56,691
		Restaurant	85,408	95,356	100,508	105,688	116,073	131,713
		School	16,696	17,014	17,147	17,390	17,896	18,683
		University	21,483	16,642	17,082	17,407	18,094	18,477
		UW	76,238	48,426	49,675	50,118	51,154	49,333
		Warehouse	10,875	11,661	11,787	12,005	12,459	13,183
Residential			627,470	526,093	503,175	487,196	461,662	451,972
Commercial			539,552	488,858	503,087	516,749	544,741	578,296
Total			1,167,022	1,014,952	1,006,262	1,003,945	1,006,403	1,030,268

The overall BAU scenario developed here depends on the utility forecasts and the utility program projections as developed for the CPA analysis in both utilities. Both the Seattle City Light electricity reductions and the PSE gas conservation initiatives are reflected in these numbers. The model combines these projections into a single model, with conservation impacts from both fuels. The impact on GHG emissions is largely driven by the improved efficiency in natural gas in the existing uses. The model does, however, see reduction in GHG emissions as a result of more electrified HVAC loads in new construction compared to existing construction for some building types.

In spite of these trends from the utility programs and load forecasts, the overall impact of GHG emissions only drops by 12% between 2008 and 2050. To achieve the goal of 82% GHG reduction from 2008 to 2050, substantial reductions beyond this BAU forecast will be necessary. These changes must include substantial fuel switching, especially in the HVAC and domestic hot water loads across the entire population of buildings in the City of Seattle.

4. Targets

The BAU forecast for energy use and GHG emissions for 2050 are significantly higher than the CAP goals. In these forecasts, the programs, codes, etc., that are driving the BAU energy use and emissions reductions help offset the impact of load growth, which keeps levels fairly close to the 2015 base year. However, the BAU forecast delivers only modest reductions below the CAP reference year (2008), with total building energy use decreasing 10% from 2008 to 2050 and building related GHG emissions decreasing by 12% (Table 8). Figure 11 and Figure 12 illustrate the magnitude of reductions beyond BAU that will be necessary to meet the CAP goals. For comparison with the CAP goals, all figures and tables in this section refer to the CAP reference year of 2008.

Table 8. BAU Forecast Energy and GHG Changes by Sector (2008 Reference Year and 2050)

	Energy	GHG
Residential	-27%	-28%
Commercial	6%	7%
Total	-10%	-12%

Figure 11. Commercial and Residential Sector BAU Energy Use Forecast vs. CAP Energy Reduction Goals (kBtu)

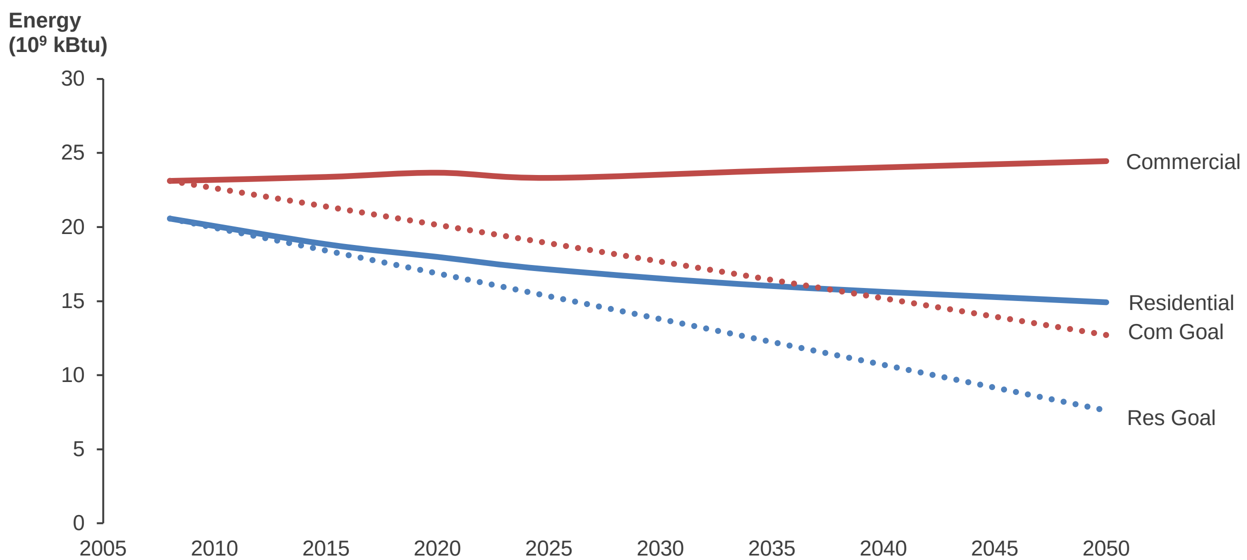
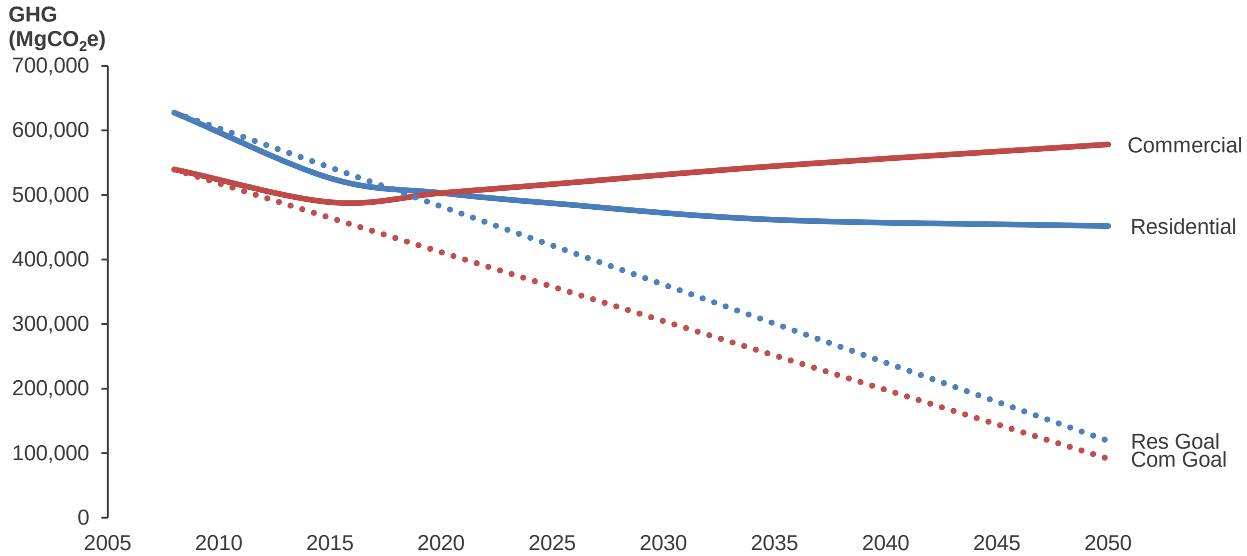


Figure 12. Commercial and Residential Sector BAU GHG Emissions Forecast Compared to CAP Emission Reduction Goals ($MgCO_2e$)



To explore the impacts of energy efficiency vs. fuel switching approaches to reaching an 82% reduction in building related emission, Ecotope developed the following three scenarios for meeting the CAP GHG emission targets:

- **Scenario 1: Gas & Electric Energy Use Reductions and Fuel-Switching.** This scenario is structured to achieve both the energy reduction goals (45% commercial / 63% residential) and the overall GHG reduction goal (82%) outlined in the Climate Action Plan (CAP).The GHG reduction goal is achieved in this scenario by first applying gas efficiency measures and then by fuel switching to carbon-neutral electricity. Finally, additional efficiency reductions are applied to electric usage to reach the 45% and commercial and 63% residential energy reduction goals.
- **Scenario 2: Fuel-Switching Only.** This scenario achieves the 82% GHG reduction goal through fuel-switching alone, with energy efficiency reductions achieved only as a by-product of this approach. GHG emitting fuels are replaced with carbon-neutral electricity to achieve the 82% emissions reduction. Energy use efficiency is inherent to the conversion to heat pump technologies required under this scenario, but no additional energy efficiency reductions are made to either gas or electric usage.
- **Scenario 3: Fuel-Switching plus Electric Use Reductions**. This scenario is the same as Scenario 2, but also applies additional efficiency reductions to the electricity usage to offset the increased electricity required for the fuel switching and to keep total electric consumption stable at 2008 levels.

This section includes energy use, GHG emissions, EUI, and GHG intensity targets by building type for each scenario. This analysis can be used by the City as a foundation for analyzing the impact of targeted policies and for making decisions regarding the role of electrification and efficiency targets in achieving the CAP goals.

To achieve the deep reductions implied by the CAP, the following fossil fuel reduction strategies were required for all three scenarios. These strategies were based on an assessment of the main sources of emissions by building type and an exploration of various combinations of adjustments that could deliver the desired reductions.

- Assume 100% of the district steam systems still using fossil fuels are converted to carbon-neutral fuel (e.g. biomass or waste heat).
- Assume electricity is also carbon-neutral.
- Convert 75% of residential gas and oil used for HVAC and DHW to electricity, assuming the electric HVAC and DHW systems have three times the site efficiency as the gas/oil system.
- Convert 68% of residential Other gas to electricity, assuming the electric system has the same site consumption as the gas system.
- Assume only 40% commercial gas Process load is converted to electricity, and the conversion is done with the same site energy use for both fuels.
- Assume 68% commercial Other is converted from gas to electricity
- Assume 95% of the commercial gas and oil for HVAC and DHW are converted to electricity using an electric system with twice the site efficiency as the gas system.

4.1. Targets Scenario 1. Gas & Electric Energy Use Reductions and Fuel-Switching

Scenario 1 utilizes the assumptions developed for Seattle's 2013 Climate Action Plan. In this scenario the overall 82% reduction in building related emission is achieved through a reduction in energy consumption of 63% in the residential sector and 45% in the commercial sector as well as an overall 63% reduction in the GHG intensity of building related fuels. Electric conservation under the CAP assumptions allows clean electricity to be made available for transportation and to offset fossil fuel use in other communities.

Scenarios 2 & 3 provide alternative approaches. Scenario 2 focuses on meeting just the 82% GHG reduction. Scenario 3 meets the GHG reduction while using no more electricity than in 2008. Both of these additional scenarios have less aggressive energy reductions than scenario 1. As a preview, scenario 3 reduces residential energy by 44% and commercial energy by 18%. Scenario 2 is only slightly different from Scenario 3, with 44% and 11%, respectively. Scenario 1 reduces residential energy by 63% and commercial energy by 45%, per the CAP goals.

Applying the commercial energy reduction goal from the CAP across the board to each building type in scenario 1 would create unrealistic targets for some building types. Instead, a more nuanced approach that takes into account which building types can best accommodate energy use reductions is needed. For example, if applied evenly without variation by building type, as seen in Table 9 and Table 10, the restaurant energy consumption becomes unrealistic given our current assumptions using only 12% of the energy current employed in this sector.

The EUI reductions in Table 11 are significant, using about one-third of the energy use on average compared to 2008 levels, and half the energy use projected by the BAU forecast in 2050.

Table 9. Scenario 1 2050 Target Forecast Energy and GHG Change Over 2008 Baseline

	kBtu Reduction	GHG Reduction
Multifamily (1-3)	-16%	26%
Multifamily (4-6)	41%	60%
Multifamily (7+)	54%	79%
Single Family	76%	84%
Dry Goods Retail	48%	93%
Grocery	57%	82%
Hospital	34%	95%
Hotel Motel	67%	80%
Office	37%	96%
Other Commercial	52%	89%
Restaurant	88%	31%
School	85%	90%
University	34%	95%
UW	-3%	100%
Warehouse	42%	94%
Residential	63%	81%
Commercial	45%	83%
Total	53%	82%

Table 10. Scenario 1 Target Forecast Energy Reductions by Fuel Type Over 2008 Baseline

	Target Change from 2008 Baseline				
	Gas	Elec	Oil	Stm	Bio
Multifamily (1-3)	-26%	30%	0%	0%	0%
Multifamily (4-6)	-59%	-34%	0%	-100%	100%
Multifamily (7+)	-77%	-46%	0%	-100%	100%
Single Family	-81%	-61%	-98%	0%	0%
Dry Goods Retail	-93%	-34%	0%	-100%	100%
Grocery	-82%	-48%	0%	0%	0%
Hospital	-89%	-31%	-98%	-100%	100%
Hotel Motel	-73%	-79%	0%	-100%	100%
Office	-94%	-27%	-98%	-100%	100%
Other Commercial	-85%	-39%	-98%	-100%	100%
Restaurant	-31%	-202%	0%	0%	0%
School	-89%	-83%	-98%	-100%	100%
University	-85%	-40%	0%	-100%	100%
UW	-83%	-2%	0%	-100%	100%
Warehouse	-94%	-22%	0%	0%	0%
Residential	-77%	-43%	-98%	-100%	100%
Commercial	-73%	-42%	-98%	-100%	100%
Total	-75%	-43%	-98%	-100%	100%

Table 11. Scenario 1 EUI by Building Type, Forecast Type, and Year (kBtu/Sq.Ft.)

	BAU EUIs		Target EUI
	2008	2050	2050
Multifamily (1-3)	39.5	20.6	14.1
Multifamily (4-6)	35.8	20.8	13.4
Multifamily (7+)	48.0	27.3	17.5
Single Family	42.9	23.8	9.8
Dry Goods Retail	74.6	49.1	25.3
Grocery	208.7	140.6	71.5
Hospital	198.6	152.6	81.2
Hotel Motel	100.0	79.9	20.9
Office	76.3	52.7	37.9
Other Commercial	74.2	58.1	26.6
Restaurant	305.7	269.8	24.9
School	59.1	43.0	6.6
University	131.3	98.7	57.6
UW	106.9	76.0	73.6
Warehouse	39.6	30.3	16.3
Residential	42.2	23.1	11.8
Commercial	94.7	72.5	37.7
Total	59.7	40.0	20.6

Table 12. Scenario 1 GHG Intensity by Building Type, Forecast Type, and Year ($MgCO_2e/TBtu$)

	BAU GHG Intensity		Target GHG Int.	Intensity Reduction Over 2008	
	2008	2050	2050	2050 BAU	2050 Target
Multifamily (1-3)	12,632	18,731	8,024	48%	-36%
Multifamily (4-6)	14,483	20,623	9,829	42%	-32%
Multifamily (7+)	19,816	23,746	9,232	20%	-53%
Single Family	36,042	36,861	23,073	2%	-36%
Dry Goods Retail	13,116	17,377	1,774	32%	-86%
Grocery	13,578	18,629	5,736	37%	-58%
Hospital	35,868	28,682	2,491	-20%	-93%
Hotel Motel	31,109	31,663	18,445	2%	-41%
Office	11,114	11,671	742	5%	-93%
Other Commercial	23,250	22,468	5,236	-3%	-77%
Restaurant	35,499	40,714	198,308	15%	459%
School	26,259	30,765	18,483	17%	-30%
University	39,205	29,903	2,817	-24%	-93%
UW	37,609	22,796	178	-39%	-100%
Warehouse	14,728	16,563	1,620	12%	-89%
Residential	30,501	30,287	15,663	-1%	-49%
Commercial	23,340	23,650	7,214	1%	-69%
Total	26,712	26,165	10,378	-2%	-61%

4.2. Targets Scenario 2. Fuel-Switching Only

This scenario does not include any energy efficiency adjustments other than the increase in efficiency that comes from using a heat pump to replace a natural gas system used in HVAC (space heating) and DHW; the energy column in Table 13 reflects only those fuel conversion efficiency improvements. Reduction in load beyond the equipment efficiency (e.g., residential weatherization, commercial building mechanical system design) is not considered in this scenario. This isolates the fossil fuel reduction required to meet the CAP building emission targets, while showing the additional electricity that would be required to implement the electrification in absence of any additional strategies for mitigating impacts to electric loads.

Table 13. Scenario 2 2050 Target Forecast Energy and GHG Change Over 2008 Baseline

	kBtu Reduction	GHG Reduction
Multifamily (1-3)	-58%	26%
Multifamily (4-6)	11%	60%
Multifamily (7+)	40%	79%
Single Family	59%	84%
Dry Goods Retail	21%	93%
Grocery	30%	82%
Hospital	-1%	95%
Hotel Motel	2%	80%
Office	23%	96%
Other Commercial	15%	89%
Restaurant	-16%	31%
School	35%	90%
University	5%	95%
UW	-6%	100%
Warehouse	13%	94%
Residential	44%	81%
Commercial	11%	83%
Total	26%	82%

Table 14 shows the reduction in fuel use for each energy source over 2008 levels based on Scenario 2. The natural gas reduction in this table is the energy reduction required to meet the overall GHG target. Table 15 shows the resulting EUIs for each building type based on the BAU forecast and the additional reductions necessary in the Scenario 2 forecast. Finally, Table 16 Shows the overall reduction in GHG intensity required for each building type and for each sector to meet the GHG emissions for this scenario.

Table 14. Scenario 2 Target Forecast Energy Reductions by Fuel Type Over 2008 Baseline

	Target Change from 2008 Baseline				
	Gas	Elec	Oil	Stm	Bio
Multifamily (1-3)	-26%	84%	0%	0%	0%
Multifamily (4-6)	-59%	7%	0%	-100%	100%
Multifamily (7+)	-77%	-22%	0%	-100%	100%
Single Family	-81%	-16%	-98%	0%	0%
Dry Goods Retail	-93%	3%	0%	-100%	100%
Grocery	-82%	-12%	0%	0%	0%
Hospital	-89%	40%	-98%	-100%	100%
Hotel Motel	-73%	56%	0%	-100%	100%
Office	-94%	-10%	-98%	-100%	100%
Other Commercial	-85%	22%	-98%	-100%	100%
Restaurant	-31%	112%	0%	0%	0%
School	-89%	14%	-98%	-100%	100%
University	-85%	24%	0%	-100%	100%
UW	-83%	2%	0%	-100%	100%
Warehouse	-94%	17%	0%	0%	0%
Residential	-77%	0%	-98%	-100%	100%
Commercial	-73%	13%	-98%	-100%	100%
Total	-75%	7%	-98%	-100%	100%

Table 15. Scenario 2 EUI by Building Type, Forecast Type, and Year (kBtu/Sq.Ft.)

	BAU EUIs		Target EUI
	2008	2050	2050
Multifamily (1-3)	39.5	20.6	19.1
Multifamily (4-6)	35.8	20.8	20.1
Multifamily (7+)	48.0	27.3	23.2
Single Family	42.9	23.8	16.3
Dry Goods Retail	74.6	49.1	38.9
Grocery	208.7	140.6	115.3
Hospital	198.6	152.6	123.1
Hotel Motel	100.0	79.9	61.4
Office	76.3	52.7	46.4
Other Commercial	74.2	58.1	46.9
Restaurant	305.7	269.8	233.7
School	59.1	43.0	29.3
University	131.3	98.7	83.4
UW	106.9	76.0	75.2
Warehouse	39.6	30.3	24.3
Residential	42.2	23.1	18.0
Commercial	94.7	72.5	61.2
Total	59.7	40.0	32.8

Table 16. Scenario 2 GHG Intensity by Building Type, Forecast Type, and Year ($MgCO_2e/TBtu$)

	BAU GHG Intensity		Target GHG Int.	Intensity Reduction Over 2008	
	2008	2050	2050	2050 BAU	2050 Target
Multifamily (1-3)	12,632	18,731	5,915	48%	-53%
Multifamily (4-6)	14,483	20,623	6,541	42%	-55%
Multifamily (7+)	19,816	23,746	6,954	20%	-65%
Single Family	36,042	36,861	13,809	2%	-62%
Dry Goods Retail	13,116	17,377	1,155	32%	-91%
Grocery	13,578	18,629	3,556	37%	-74%
Hospital	35,868	28,682	1,643	-20%	-95%
Hotel Motel	31,109	31,663	6,279	2%	-80%
Office	11,114	11,671	607	5%	-95%
Other Commercial	23,250	22,468	2,967	-3%	-87%
Restaurant	35,499	40,714	21,097	15%	-41%
School	26,259	30,765	4,150	17%	-84%
University	39,205	29,903	1,946	-24%	-95%
UW	37,609	22,796	174	-39%	-100%
Warehouse	14,728	16,563	1,088	12%	-93%
Residential	30,501	30,287	10,261	-1%	-66%
Commercial	23,340	23,650	4,444	1%	-81%
Total	26,712	26,165	6,539	-2%	-76%

4.3. Targets Scenario 3. Fuel-Switching plus Electric Use Reductions

In this scenario, since the residential sector is already below 2008 electricity consumption in the BAU forecast, only the commercial sector is adjusted. The commercial sector is adjusted so the total electric energy for both sectors combined is equal to the electric energy use in 2008 of both sectors combined. This scenario shows the level electric energy use that would effectively neutralize the impact of the electrification of fossil fuel end uses in the previous scenario. Such a goal would be achieved with a combination of incremental improvements in the electric efficiency of the end uses that are electric. This would include the HVAC and hot water loads that had been converted to electricity but it would also include incremental improvements to lighting, refrigeration and other process loads. Table 17 shows the overall reduction in energy use by building type and sector. Overall, the scenario would require an additional 7% energy savings across the commercial sector when compared to Scenario 1 summarized in Table 13.

Table 18 shows the distribution in reductions across all fuel types and building types. The table is essentially the same as Table 14 in the previous scenario, except the additional electric savings are distributed proportionately among the commercial sector building types. Table 19 and Table 20 show the reduction in overall EUI required to accomplish these goals in each building type and the overall GHG intensity achieved in this scenario.

Table 17. Scenario 3 2050 Target Forecast Energy and GHG Change Over 2008 Baseline

	kBtu Reduction	GHG Reduction
Multifamily (1-3)	-58%	26%
Multifamily (4-6)	11%	60%
Multifamily (7+)	40%	79%
Single Family	59%	84%
Dry Goods Retail	27%	93%
Grocery	36%	82%
Hospital	7%	95%
Hotel Motel	17%	80%
Office	26%	96%
Other Commercial	23%	89%
Restaurant	7%	31%
School	46%	90%
University	11%	95%
UW	-5%	100%
Warehouse	20%	94%
Residential	44%	81%
Commercial	18%	83%
Total	30%	82%

Table 18. Scenario 3 Target Forecast Energy Reductions by Fuel Type Over 2008 Baseline

	Target Change from 2008 Baseline				
	Gas	Elec	Oil	Stm	Bio
Multifamily (1-3)	-26%	84%	0%	0%	0%
Multifamily (4-6)	-59%	7%	0%	-100%	100%
Multifamily (7+)	-77%	-22%	0%	-100%	100%
Single Family	-81%	-16%	-98%	0%	0%
Dry Goods Retail	-93%	-5%	0%	-100%	100%
Grocery	-82%	-20%	0%	0%	0%
Hospital	-89%	24%	-98%	-100%	100%
Hotel Motel	-73%	26%	0%	-100%	100%
Office	-94%	-14%	-98%	-100%	100%
Other Commercial	-85%	8%	-98%	-100%	100%
Restaurant	-31%	41%	0%	0%	0%
School	-89%	-7%	-98%	-100%	100%
University	-85%	10%	0%	-100%	100%
UW	-83%	1%	0%	-100%	100%
Warehouse	-94%	8%	0%	0%	0%
Residential	-77%	0%	-98%	-100%	100%
Commercial	-73%	0%	-98%	-100%	100%
Total	-75%	0%	-98%	-100%	100%

Table 19. Scenario 3 EUI by Building Type, Forecast Type, and Year (kBtu/Sq.Ft.)

	BAU EUIs		Target EUI
	2008	2050	2050
Multifamily (1-3)	39.5	20.6	19.1
Multifamily (4-6)	35.8	20.8	20.1
Multifamily (7+)	48.0	27.3	23.2
Single Family	42.9	23.8	16.3
Dry Goods Retail	74.6	49.1	35.9
Grocery	208.7	140.6	105.5
Hospital	198.6	152.6	113.7
Hotel Motel	100.0	79.9	52.3
Office	76.3	52.7	44.5
Other Commercial	74.2	58.1	42.3
Restaurant	305.7	269.8	186.8
School	59.1	43.0	24.2
University	131.3	98.7	77.6
UW	106.9	76.0	74.9
Warehouse	39.6	30.3	22.5
Residential	42.2	23.1	18.0
Commercial	94.7	72.5	55.9
Total	59.7	40.0	31.0

Table 20. Scenario 3 GHG Intensity by Building Type, Forecast Type, and Year ($MgCO_2e/TBtu$)

	BAU GHG Intensity		Target GHG Int.	Intensity Reduction Over 2008	
	2008	2050	2050	2050 BAU	2050 Target
Multifamily (1-3)	12,632	18,731	5,915	48%	-53%
Multifamily (4-6)	14,483	20,623	6,541	42%	-55%
Multifamily (7+)	19,816	23,746	6,954	20%	-65%
Single Family	36,042	36,861	13,809	2%	-62%
Dry Goods Retail	13,116	17,377	1,253	32%	-90%
Grocery	13,578	18,629	3,887	37%	-71%
Hospital	35,868	28,682	1,779	-20%	-95%
Hotel Motel	31,109	31,663	7,371	2%	-76%
Office	11,114	11,671	632	5%	-94%
Other Commercial	23,250	22,468	3,287	-3%	-86%
Restaurant	35,499	40,714	26,394	15%	-26%
School	26,259	30,765	5,025	17%	-81%
University	39,205	29,903	2,091	-24%	-95%
UW	37,609	22,796	175	-39%	-100%
Warehouse	14,728	16,563	1,174	12%	-92%
Residential	30,501	30,287	10,261	-1%	-66%
Commercial	23,340	23,650	4,863	1%	-79%
Total	26,712	26,165	6,921	-2%	-74%

5. Conclusions & Recommendations

The model provides a valuable tool for identifying the scope of change required to meet the City's carbon reduction goal and for predicting the energy use and GHG emissions reductions of potential City policies. The forecast emissions and reduction targets by building type provide metrics that are relevant for individual building owners and provide a means to understand how their building's performance (both EUI and GHG) compares to the City's goals.

The results of policy impact analyses can be used to assess a range of options and prioritize those expected to yield the greatest impact, as well as to communicate the need for particular strategies.

The EUI and GHG targets, at 5–15 year intervals through 2050, also provide a key tracking tool for the City. Performance by building type, from annual building energy benchmarking data and from building stock assessments, can be compared against the targets to assess whether reductions are on track. In addition, future point-in-time comprehensive energy use and GHG emissions inventories, especially as new data become available, can be compared to the targets and used to re-calibrate the model.

Lastly, projected energy and GHG savings for policies that are implemented (e.g., mandatory tune-ups) can be evaluated against measured results to further refine the predictive assumptions and recalibrate the modeled impact.

5.1. Policy Implications

Base-year and BAU forecasts can be used to identify which building types have the biggest opportunity for emission reductions, and where to focus policy development. For instance:

- Single-family buildings are often not considered a priority, as the return per building is small. However, the model has revealed that due to high saturations of gas space and water heating, and the overall size of the single-family market, single-family buildings are responsible for nearly half of Seattle's 2015 GHG emissions from residential and commercial buildings combined (Table 7). According to the BAU forecast the ratio will drop to about 30% of total emissions by 2050, but this is still a large component of the total building emissions. Therefore, any policy strategy to achieve a carbon-neutral City will need to address these homes.
- SCL and PSE conservation potential assessments project that new construction for some building types will include high ratios of gas fueled end uses. For example, low-rise multifamily units are forecast to increase by 84,000 units by 2050 with an associated increase of about 20,000 $MgCO_2e$. Multifamily buildings are typically all-electric. An important strategy for the City is to ensure specific building types like this do not trend toward gas-fueled end uses in new construction.
- Restaurants and hospitals have high EUIs, high energy use, and high emissions on average for each building and in aggregate. These building types have process loads that often preclude deep efficiencies. However, these building types and their process loads must be addressed seriously in order to meet the building level reductions required to meet the CAP emissions goals.

- The BAU forecasts depend on assumptions from the CPAs that a significant amount of conservation in both new and existing buildings will stabilize energy use and emissions at near 2015 levels through 2050. However, this conservation cannot be taken for granted. The support for and effectiveness of these BAU actions remains critical and must be considered part of overall efforts, along with programs focused on incremental reductions, to dramatically reduce emissions below the 2008 reference year.

5.2. Applicability to Other Cities

The model developed for the City of Seattle utilizes almost two decades of baseline studies that characterized the City's building stock. As a result, data about EUIs and fuel saturations could be used in this model with confidence that these represented the actual Seattle building stock. It is our belief that other cities could use this approach, but in most cases a set of estimates would be required that would bridge the gap between the anecdotal building type and energy end use distributions maintained by utilities or the Chambers of Commerce and the details needed to generate a model similar to that created for Seattle. Understanding the details of a particular city requires experience in that locality.

Generalized models that could be applied across jurisdictions could be valuable, but only after a credible estimate of the building floor areas, number of residential units, building types, and building end uses in each locale can be made. Benchmarking can be an important part of that process and provide building and energy use information for a subset of a jurisdiction's building stock, but the baseline distribution of all of the buildings and building end uses is also important and would need to be developed.

5.3. Next Steps for Policy Analysis

The main value of the model is that it provides a comprehensive platform for understanding the current and forecast Seattle building stock at the granular level of building type, end use, and fuel type. These are the key inputs that are necessary for determining the carbon impact of various policies.

To fully leverage the model for policy analysis, as a next step we recommend an in-depth analysis of the model results. Profiles of each building type that summarize and interpret the forecasts by end use, fuel types, and population changes can be used to brainstorm the direct technical mechanisms for reducing emissions and energy for specific end uses in specific building types. Then policy frameworks can be developed around these mechanisms. This approach will allow the model to be used as a bottom-up strategy for designing effective policies, where the structure of the policy is directly informed by the technical mechanisms required to reduce emissions. The model can then be used to analyze the impact of the policies based on clear performance metrics.

We also recommend further exploring opportunities for collaboration with other cities or organizations to support model refinements, analysis, and maintenance.

6. References

City of Seattle. 2011. “Resolution 31312: A RESOLUTION adopting new climate protection and adaptation goals for Seattle and outlining the process for updating the Seattle Climate Action Plan to provide a roadmap for achieving those goals.” clerk.seattle.gov/~scripts/nph-brs.exe?d=RESF&s1=31312.resn.&Sect6=HITOFF&l=20&p=1&u=/~public/resny.htm&r=1&f=G

DPD (Seattle Department of Planning and Development). 2015. “A Comprehensive Plan for Managing Growth 2015-2035: Draft.” www.seattle.gov/dpd/cs/groups/pan/@pan/documents/web_informational/p2294968.pdf

Ecotope. 2014. Residential Building Stock Assessment. neea.org/resource-center/regional-data-resources

Navigant. 2015. Commercial Building Stock Assessment. neea.org/resource-center/regional-data-resources

OSE (Seattle Office of Sustainability & Environment). 2013. “Seattle Climate Action Plan.” www.seattle.gov/Documents/Departments/OSE/2013_CAP_20130612.pdf

OSE and EMI Consulting. 2015. Seattle Building Energy Benchmarking Analysis Report 2013 Data. www.seattle.gov/Documents/Departments/OSE/EBR-2013-report.pdf

OSE and SEI (Stockholm Environmental Institute). 2011. “Getting to Zero: A Pathway to a Carbon Neutral Seattle.” www.seattle.gov/Documents/Departments/OSE/CN_Seattle_Report_May_2011.pdf

OSE and SEI. 2014. “2012 Seattle Community Greenhouse Gas Emissions Inventory.” www.seattle.gov/Documents/Departments/OSE/2012%20GHG%20inventory%20report_final.pdf

SCL (Seattle City Light) with Cadmus. 2015. Conservation Potential Assessment. www.seattle.gov/light/conserve/cv5_pub.htm