VOL. 2

Commercial Baseline Study

Potential Study

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

Final Report

PREPARED FOR:

NEW YORK STATE ENERGY RESEARCH AND DEVELOPMENT AUTHORITY
Albany, New York

TRACEY DESIMONE
Project Manager

PATRICIA GONZALES
Senior Project Manager

VANESSA ULMER
Senior Advisor

PREPARED BY:

OPTIMAL ENERGY
Hinesburg, VT

OPINION DYNAMICS
Waltham, MA

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SECTION 1
Executive Summary

1 Executive Summary

Study Scope and Context

The Commercial Potential Study assesses the energy efficiency potential in New York State from the commercial buildings sector. The Potential Study is a component of the New York State Commercial Baseline Study and constitutes Volume 2 of this effort. Other components include a comprehensive statewide baseline study of the existing commercial market (Volume 1) as well as four market assessments that focus on specific technology or service markets of interest to NYSERDA (Volumes 3-6). This Potential Study was conducted by Optimal Energy, under subcontract to Opinion Dynamics.

Energy efficiency potential studies are an effective method for estimating what savings are technically possible, cost-effective (or economic), and achievable, as well as for determining the regions, measures, end uses, and building types offering the greatest opportunities for energy savings. In this case, the Study Team leverages the results of the baseline data collection in order to improve the accuracy of the potential estimate.

Specifically, the study looks at:

- All major fuel types (electricity, natural gas, fuel oil, and propane)
- Three geographic regions that align with the service territories of the seven New York investor-owned utilities:
    - Downstate – Con Edison territory
    - Long Island and Hudson Valley - PSEG Long Island, Central Hudson, and Orange & Rockland territories
    - Upstate - National Grid, New York State Electric and Gas Corporation (NYSEG), Rochester Gas & Electric (RG&E) territories
- A time horizon of 2020 through 2029, inclusive
- A broad range of energy efficiency technologies; however, the study does not include fuel switching or distributed generation

Note that while the Study Team expects the overall findings to apply proportionately to the entire commercial buildings sector, this study analyzes 60% of the commercial energy sales,[1] driven by the selected building types and sampling plan for the baseline study.

The study includes four different scenarios, under three primary headings:

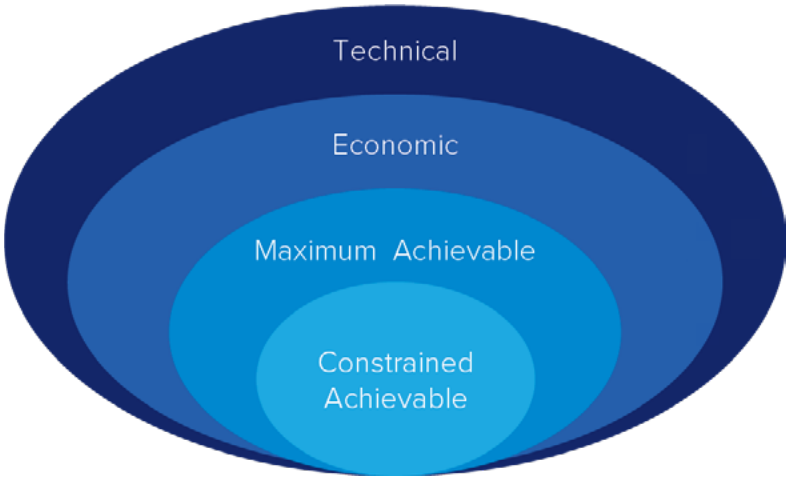
TECHNICAL POTENTIAL: includes all technically feasible efficiency opportunities that are generally available at the time of the study (one scenario)

ECONOMIC POTENTIAL: the subset of technical potential that passes a cost-effectiveness screening that is consistent with New York State standard practice (one scenario)

ACHIEVABLE POTENTIAL: the subset of economic potential that might be reasonably achievable, given financial and non-financial market barriers (two scenarios, maximum achievable and constrained achievable).

The graphic below shows these. As seen, technical potential represents the largest available savings, and each successive potential scenario is a subset of another scenario.

Figure 1 | Potential Scenarios



[1] Because utilities often distinguish commercial and industrial in different ways, and sometimes by energy sales rather than actual building uses, it is difficult to precisely determine the breakout. In addition, many multifamily residential buildings are often bundled in with commercial by utilities.

Methods

The analysis uses a top-down approach to estimate the total potential. This means that the analysis begins with the forecasted sales for each fuel, which are broken down to each building segment and ultimately into loads attributable to individual building equipment. The analysis then applies to each applicable load a series of percentage multipliers and factors developed to characterize the savings and costs of individual measures. This approach accurately estimates specific savings for each measure, while ensuring that the final savings are calibrated to the actual loads.

This study benefits from a rich set of primary baseline data on the actual building loads and sizes of buildings for eight commercial building types. It includes the types, sizes, efficiencies, and features of energy-using equipment currently installed in each building type and region in New York State. Because sample sizes are small, when disaggregated by both building type and region, the Study Team relies on the Statewide baseline data for estimates of equipment types and market shares. The rich set of baseline data allows for significantly improved estimates of the remaining opportunity for each measure.

This study takes a highly granular approach, looking at combinations of fuel type, efficiency technologies, markets, and building types. This granularity results in 5,476 total permutations.

Table 1 | **Unique Measures Included in Study**

Fuel Types	• Electricity • Natural gas • Fuel oil • Propane
Technologies[2]	• 141 different efficiency technologies
Markets	• Three types of market-driven measures (**New Construction, Major Renovation, and Lost Opportunity**) which are time-dependent and driven by the new construction and renovation forecasts and turnover rates for existing equipment. If they are not captured, then they are lost for the life of that building or equipment. In addition, the costs and savings reflect incremental costs and savings as compared to what baseline market-driven activity would have otherwise occurred. • **Retrofit measures**, which are time discretionary decisions to either retire functioning equipment early or to add a building or equipment feature that did not already exist such as wall insulation. Retrofit measure costs also reflect the entire cost of materials and labor for new equipment and removal of any existing equipment. Savings also initially reflect the full savings compared to the existing stock of equipment.
Building Types	1. Office/ Government 2. Retail 3. Food Service 4. Warehouse 5. Grocery/ Convenience 6. Health Services 7. Education 8. Lodging/ Hospitality
Total	• 5,476 total permutations

[2] In some cases, technologies are bundled and analyzed as a package of measures. For example, all specialized data center measures are bundled into a single package.

Results

Overall, the study finds a significant amount of electric, natural gas, oil, and propane potential remaining for the commercial sector in New York State. This section provides a summary of energy-efficiency potential estimates that represent opportunities from energy-efficiency measures that apply to end uses within each fuel type; the estimates do not include opportunities from converting from fossil fuel-based space and water heating equipment to electric heat pumps or vice versa.

The Study Team presents energy efficiency potentials throughout this report as savings at the customer site (i.e., at the meter).[3] Table 2 shows the cumulative energy savings in trillion British thermal units (TBtu) and the percentage reduction from forecasted energy sales in the technical and economic scenarios in the final year of the study.[4] Significant potential exists, with the economic scenario finding a 31% - 40% reduction in consumption compared to each fuel's baseline forecast over the 10-year study horizon. Fossil fuel potential is somewhat lower than electric opportunities.

Table 2 | **Cumulative Energy Efficiency Potential in 2029**

Fuel Type	2029 Sales Forecast (TBtu)	2029 Technical Potential (TBtu)	Technical Potential Percentage Reduction from Baseline Forecast	2029 Economic Potential (TBtu)	Economic Potential Percentage Reduction from Baseline Forecast
Electricity	165	78	47.3%	67	40.6%
Natural gas	197	84	42.5%	61	31.0%
Fuel oil	33	11	34.7%	10	31.4%
Propane	32	12	38.7%	10	31.0%

[3] Electric efficiency savings are converted to Btu directly when calculating site energy savings, using a conversion factor of 3,412 Btu/kWh, which is based on the energy content of a kWh.
[4] Note throughout the report the Study Team uses the term "cumulative" to refer to the entire savings observed in a future year from that year's efficiency plus all continuing savings from prior years' efficiency adoption. "Incremental" or "incremental annual" refers to the additional savings from the current year only. Cumulative is less than the sum of all incremental annual impacts each year because some measures are short lived and do not persist until the end of the study period.

Table 3 shows the average incremental annual savings as a percentage of forecast energy sales for each scenario. For electricity and natural gas, total average incremental savings sum to more than the total cumulative savings across the ten years, due to measures with expected useful lives of less than ten years. This is not the case for propane and fuel oil, due to the impact of efficient lighting installed in the electric scenario, which increases heating needs from reduced waste heat.

Table 3 | **Average Incremental Annual Savings as a Percentage of Energy Sales Forecast, New York State, by Fuel and Scenario, 2029**

	Electric	Natural gas	Fuel oil	Propane
Technical Potential	5.3%	4.4%	3.3%	4.0%
Economic Potential	4.6%	3.3%	3.0%	3.3%

In addition to energy savings, the efficiency efforts would yield significant peak demand savings. Peak demand savings are reported in Table 4 in megawatts (MW), rather than as a percent of the forecast, to enable easier comparisons to the power generation that may be avoided through efficiency. Note that these numbers represent peak demand reductions at the customer site associated with the portion of the commercial load examined under the baseline study. It can be expected that savings for the entire sector would scale proportionally. As seen, by 2029, peak reduction in the economic scenario would reach 5,764 MW compared to the baseline forecast. For context, this compares to the 2017 NY Statewide peak at the meter (all sectors) of 28,273 MW.[5,6]

Table 4 | **Cumulative Peak Demand Reductions, New York State, by Scenario, in MW**

Scenario	2024	2029
Technical Potential	3,653	6,490
Economic Potential	3,273	5,764

[5] NY ISO. 2018 Power Trends. https://bit.ly/2RAWX3i
[6] Demand at generation is higher than demand at the customer site, due to electric losses through the transmission and distribution system. The magnitude of these losses increases as system load increases, so that marginal line losses are larger than average line losses. This study assumes a statewide average of 7.2% marginal line losses and average line losses 1.5 times smaller, or 4.8%. The number cited above is converted from a peak demand of 29,699 MW given in the document using a 4.8% line loss factor.

Table 5 shows the cumulative percentage savings relative to forecasted sales in 2029 for each region, and statewide, for the technical and economic potential scenarios. There is minor variation in the potential for each region. Because the Study Team relied primarily on Statewide primary equipment saturation data, the primary differences among the regions result from different climates, different avoided costs, and differences in the makeup of commercial building stock.

Table 5 | **Cumulative Percentage Reductions from Energy Sales Forecast, New York State, 2029, by Scenario, Region, and Fuel**

Scenario	Region	Electric	Natural gas	Fuel oil	Propane
Technical Potential	Downstate	47.3%	41.2%	32.1%	36.4%
	Long Island / Hudson Valley	47.1%	43.0%	35.1%	38.4%
	Upstate	47.6%	43.1%	36.6%	38.9%
	Statewide	47.3%	42.5%	34.7%	38.7%
Economic Potential	Downstate	42.9%	29.7%	28.7%	31.7%
	Long Island / Hudson Valley	37.8%	31.9%	32.4%	33.0%
	Upstate	39.1%	31.1%	33.1%	30.2%
	Statewide	40.6%	31.0%	31.4%	31.0%

Table 6 shows the economic impacts of the technical and economic potential scenarios. As can be seen, if New York achieves the full theoretical economic potential, $24 billion of net benefits would accrue. Since the technical potential includes measures that are not cost-effective, costs will significantly rise compared to the economic scenario, with comparatively modest additional benefits.

Table 6 | **Net Present Value Economic Impacts from Each Scenario, 2020-2029**

Scenario	Costs (million $)	Benefits (million $)	Net benefits (million $)	Benefit-Cost Ratio
Technical Potential	$22,995	$39,122	$16,127	1.70
Economic Potential	$8,930	$32,991	$24,061	3.69

The analysis also characterizes the nature of the available potential. Key observations include:

- Despite accelerating adoption of linear LED in recent years, a significant portion of existing buildings still have fluorescent lighting in their linear sockets, creating significant opportunity in indoor lighting.
- There is significant savings opportunity in replacing electric resistance heat with cold-climate heat pumps, especially as this technology becomes less expensive and more effective. The scope of this study did not include opportunities from converting from fossil fuel-based space and water heating equipment to efficient electric heat pumps, which warrants subsequent analysis.
- A large portion of the potential comes from controlling and optimizing energy use, as opposed to simply increasing the efficiency of current technologies.

SECTION 2
Introduction

2 Introduction

This study assesses the energy efficiency potential in New York State from the commercial buildings sector. Energy efficiency potential studies are an effective method for estimating what savings are technically possible, cost-effective (or economic), and achievable; and for determining the regions, measures, end uses, and building types offering the greatest opportunities for energy savings. For this study, the Study Team leverages the results of the baseline data collection in order to improve the accuracy of the potential estimate significantly.

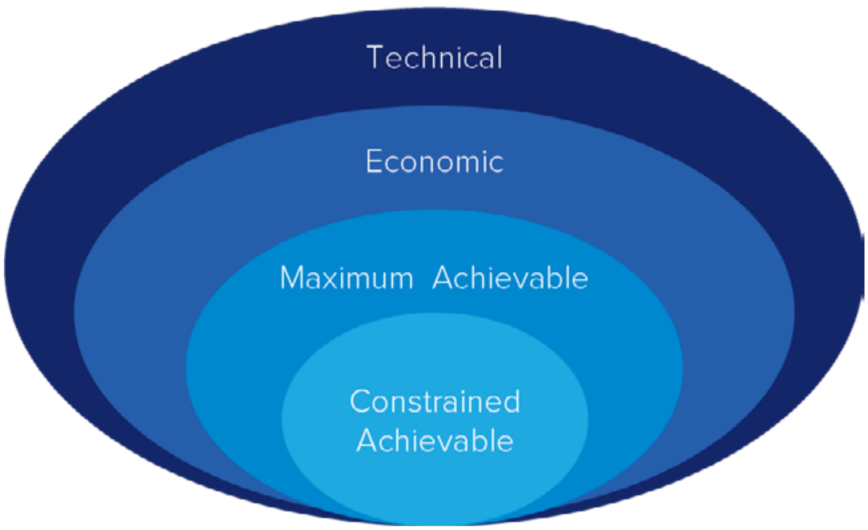
Specifically, the study looks at:

- All major fuel types (electricity, natural gas, fuel oil, and propane)
- Three geographic regions that align with the service territories of the seven New York investor-owned utilities:
    - Downstate – Con Edison Territory
    - Long Island and Hudson Valley - PSEG Long Island, Central Hudson, and Orange & Rockland territories
    - Upstate - National Grid, New York State Electric and Gas Corporation (NYSEG), Rochester Gas & Electric (RG&E) territories
- A time horizon of 2020 through 2029, inclusive
- A broad range of energy efficiency technologies; however, the study does not include fuel switching or distributed generation

Note that while the Study Team expects overall findings to apply proportionately to the entire commercial buildings sector, this study explicitly analyzes only a portion of the entire estimated commercial energy sales, driven by selected building types and sampling plan for the baseline study.

The Study Team estimates that the sales addressed in this study are approximately 60% of the entire commercial sector.[7] Potential studies typically assess a number of different scenarios, each a subset of the total available technical potential, as illustrated below.

Figure 2 | Potential Scenarios



[7] Because utilities often distinguish commercial and industrial in different ways, and sometimes by energy sales rather than actual building uses, it is difficult to precisely determine the breakout. In addition, many multifamily residential buildings are often bundled in with commercial by utilities.

The three primary categories of potential are:

TECHNICAL POTENTIAL: or all the technically feasible efficiency opportunities, ignoring all market barriers and assuming full adoption. Note that, as with virtually all studies, our Technical scenario does not attempt to estimate the entire technically possible universe of efficiency; for example, net-zero buildings are a technically feasible option which are excluded due to very limited adoption to date. Instead, the Study Team focused on those opportunities that are generally available and that the Study Team expect may be cost-effective at the time of the study.

ECONOMIC POTENTIAL: or the subset of technical potential that passes a cost-effectiveness screening. The Study Team determines cost-effectiveness using a total resource cost test (TRC) which accounts for the energy-related costs and benefits of efficiency measures from the perspective of the New York economy as a whole including the benefits associated with avoided carbon dioxide (CO2) emissions, consistent with New York State standard practice.[8]

ACHIEVABLE POTENTIAL: or the subset of economic potential that might be assumed to be reasonably achievable given financial and non-financial market barriers. As measured in potential studies, achievable potential can vary greatly based on penetration rates used to consider actual market barriers to achieving adoption. Achievable scenarios also look at the size of financial incentives (as a proxy for interventions to address market barriers, notably the higher upfront cost of energy-efficient compared to conventional technologies) and their impact on participation. This study looks at a maximum achievable scenario, with completely eliminated financial barriers, and a constrained achievable, where the customer is still responsible for 50% of the incremental cost of the measure. The scenarios recognize the uncertainty around customer adoption, which can change unpredictably over time.

[8] For each energy efficiency measure, the study structured the benefit/cost test as the ratio of net present values for the measure's benefits and costs, using the benefit and cost inputs following the NYS Public Service Commission's Benefit Cost Analysis Framework and subsequent New York Department of Public Service guidance. Measures with a benefit/cost ratio of 1.0 or greater were deemed cost-effective. Appendix 2A of this report includes a description of the benefits and costs considered.

Methodology

This section gives a brief overview of the methodology used to estimate potential. Appendix 2A provides a more detailed discussion.

The analysis uses a top-down approach to estimate the total potential. This means that the analysis begins with the actual, forecasted loads for each building segment, broken down to each building segment, and further into major end uses and ultimately into loads attributable to individual equipment. It then applies a series of percentage multipliers developed for each measure to determine the total savings. This is demonstrated by the following equation.

Measure savings = Segment / end-use / year kWh sales X Applicability factor X Feasibility factor X Turnover factor (replacement only) X Not complete factor (retrofit only) X Savings fraction X Penetration rate

The Study Team has defined the equation terms and their related factors as follows:

- **APPLICABILITY FACTOR** is the fraction of the end use energy sales (from the sales disaggregation) for each building type and year that is attributable to equipment that could be replaced by the high-efficiency measure. For example, for replacing office interior linear fluorescent lighting with a higher efficiency LED technology, the Study Team uses the portion of total office building interior lighting electrical load consumed by linear fluorescent lighting.
- **FEASIBILITY FACTOR** is the fraction of applicable end use sales for which it is technically feasible to install the efficiency measure. Numbers below 100% reflect engineering or other technical barriers that are likely to preclude the adoption of the measure. The Study Team did not reduce feasibility for economic or behavioral barriers that would affect penetration estimates. Rather, it reflects technical or physical constraints that would make measure adoption impossible or ill-advised, e.g., efficient lighting technology that cannot be used in certain low-temperature applications.
- **TURNOVER FACTOR** is the percentage of existing equipment that will be naturally replaced each year due to failure, remodeling, or renovation. This applies to the lost opportunity (planned or replaced when the equipment fails) and renovation markets only. It is generally assumed that turnover factors are to be one divided by the baseline equipment measure life (for example, the Study Team assumes that 5% or 1 / 20th of the existing stock of equipment is replaced each year for a measure with a 20 year estimated life).
- **NOT COMPLETE FACTOR** is the percentage of existing equipment that already represents the high-efficiency option. This applies only to retrofit markets. For example, if 30% of current buildings already have connected thermostats, then the not-complete factor for connected thermostats would be 70% (100% - 30%), reflecting that only 70% of the total potential from thermostats remains.

- **SAVINGS FRACTION** represents the percent savings (compared to either existing stock for retrofit markets, or new baseline equipment for non-retrofit markets) of the high efficiency technology. The Study Team bases savings fractions on individual measure data and assumptions about existing stock efficiency, standard practice for new purchases, and high-efficiency options.
    - *Baseline adjustments* refer to savings fractions' downward adjustments in future years for early retirement retrofit measures. This accounts for the fact that newer, standard equipment efficiencies are higher than older, existing stock efficiencies. The Study Team assumes average existing equipment being replaced for a retrofit measure is at 60% of its estimated useful life. The baseline adjustment also comes with a cost credit to reflect the value of deferring investment in standard equipment that the participant would have had to install to replace the failed unit.
- **ANNUAL PENETRATIONS** are the difference between the base case measure penetrations and the assumed measure penetrations for an economic potential scenario. For the economic potential, the Study Team assumes that 100% penetration of cost-effective measures is captured for all markets, with retrofit measures generally being phased in to reflect resource constraints such as contractor availability. For the achievable scenarios, the Study Team base penetrations in part on the baseline data survey questions about "awareness" and "willingness to adopt."

The Study Team develops these factors for each measure, building type, and market (retrofit, lost opportunity, and new construction). The product of all these factors results in the total potential for each measure permutation.

Once total savings are determined, the Study Team applies a cost-per-unit saved factor for each technology and building type permutation. Then each measure is screened for cost-effectiveness, to determine its inclusion in the economic potential, or just the technical potential. The total potential is the sum of the potential for all measures, after accounting for adjustments such as mutual exclusivity, stock adjustments, and interactions.

This study benefits from a rich set of primary baseline data on the actual building loads and sizes of buildings for eight building types. It includes the types, sizes, efficiencies, and features of energy-using equipment currently installed in each building type and region in New York State. Because sample sizes are small when disaggregated by both building type and region, the Study Team relies on the Statewide data for estimates of equipment types and market shares. The rich set of baseline data allows for a significantly improved estimate of the remaining opportunity for each measure.

This study took a highly granular approach, looking at combinations of fuel type, efficiency technologies, markets, and building types. The granularity resulted in 5,476 total permutations.

Table 7 | **Unique Measures Included in Study**

Fuel Types	• Electricity • Natural gas • Fuel oil • Propane
Technologies[9]	• 141 different efficiency technologies
Lease Structures	• Three types of market-driven measures (**New Construction, Major Renovation, and Lost Opportunity**) which are time-dependent and driven by the new construction and renovation forecasts and turnover rates for existing equipment. If they are not captured, then they are lost for the life of that building or equipment. In addition, the costs and savings reflect incremental costs and savings as compared to what baseline market-driven activity would have otherwise occurred. • **Retrofit measures**, which are time discretionary decisions to either retire functioning equipment early or to add a building or equipment feature that did not already exist such as wall insulation. Retrofit measure costs also reflect the entire cost of materials and labor for new equipment and removal of any existing equipment. Savings also initially reflect the full savings compared to the existing stock of equipment.
Building Types	1. Office/ Government 2. Retail 3. Food Service 4. Warehouse 5. Grocery/ Convenience 6. Health Services 7. Education 8. Lodging/ Hospitality
Total	• 5,476 total permutations

[9] In some cases, technologies are bundled and analyzed as a package of measures. For example, all specialized data center measures are bundled into a single package.

SECTION 3

Aggregate Results

3 Aggregate Results

Overall, the study finds a significant amount of electric, natural gas, oil, and propane efficiency potential remaining for the commercial sector. New efficiency opportunities continue to emerge, even as the baseline improves because efficient technologies improve and costs come down. This report presents energy efficiency potential estimates that represent opportunities from energy efficiency measures that apply to equipment within each fuel type; the estimates do not include opportunities from converting from fossil fuel-based space and water heating equipment to electric heat pumps or vice versa.

The Study Team presents energy efficiency potentials throughout this report as savings at the customer site (i.e., at the meter), or as a percent reduction in consumption compared to each fuel's baseline forecast.

Figure 3 shows the baseline forecast for statewide commercial electric use for 2020-2029 (i.e., for the portion of the commercial energy sales analyzed in this study). The figure compares the baseline forecast with what energy sales would be like under the Economic Potential and the two achievable scenarios. As expected, sales would decline significantly under efficiency scenarios. This represents electricity that would not be consumed if the given scenario is followed. Figure 4 through Figure 6 provide the analogous figures for each fossil fuel. While the efficiency potential is lower for fossil fuels, it is still significant. Overall, the cumulative potential reduction in the forecasts in 2029 from the economic base case scenario are 41.7%, 31.0%, 31.4% and 31.0%, respectively for electricity, gas, oil, and propane.

Figure 3 | **Electric Energy Savings, Relative to the Sales Forecast, New York State, 2020-2029**

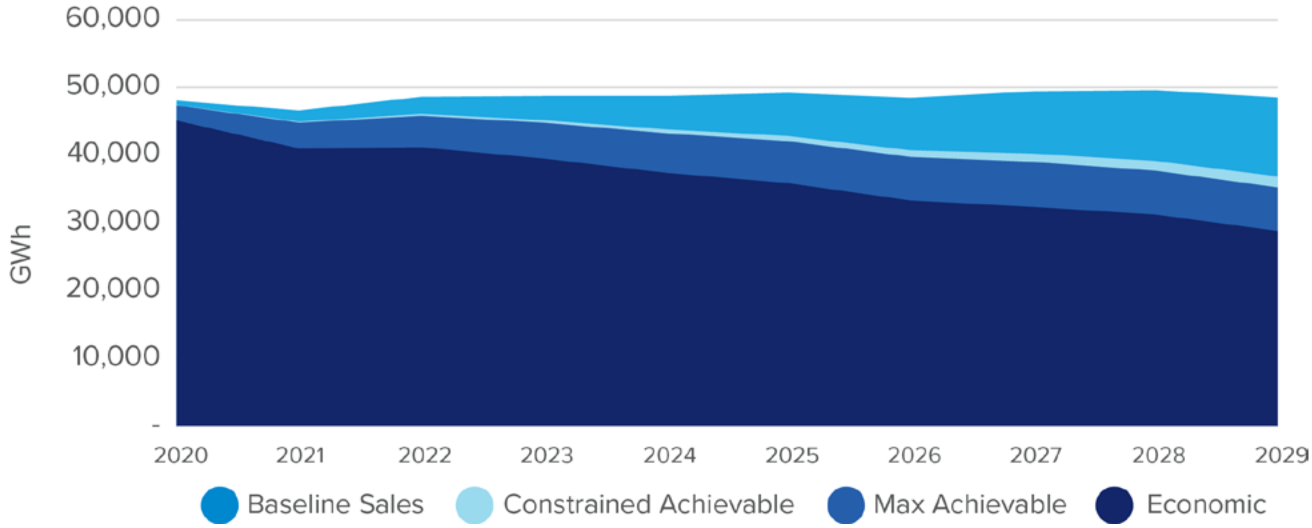


Figure 4 | **Gas Energy Savings, Relative to the Sales Forecast, New York State, 2020-2029**

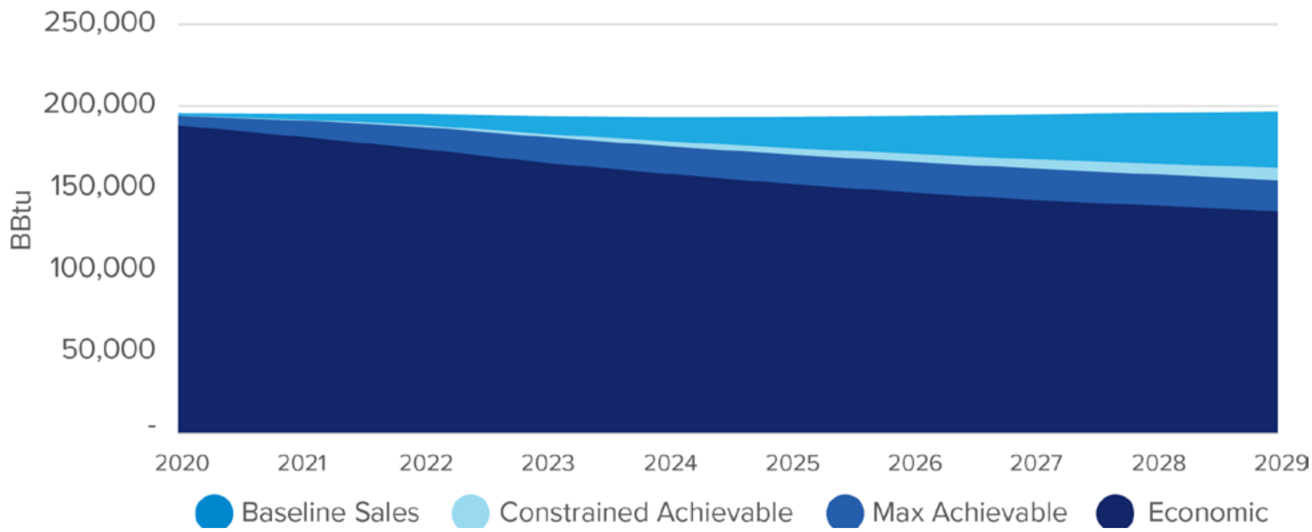


Figure 5 | **Oil Energy Savings, Relative to the Sales Forecast, New York State, 2020-2029**

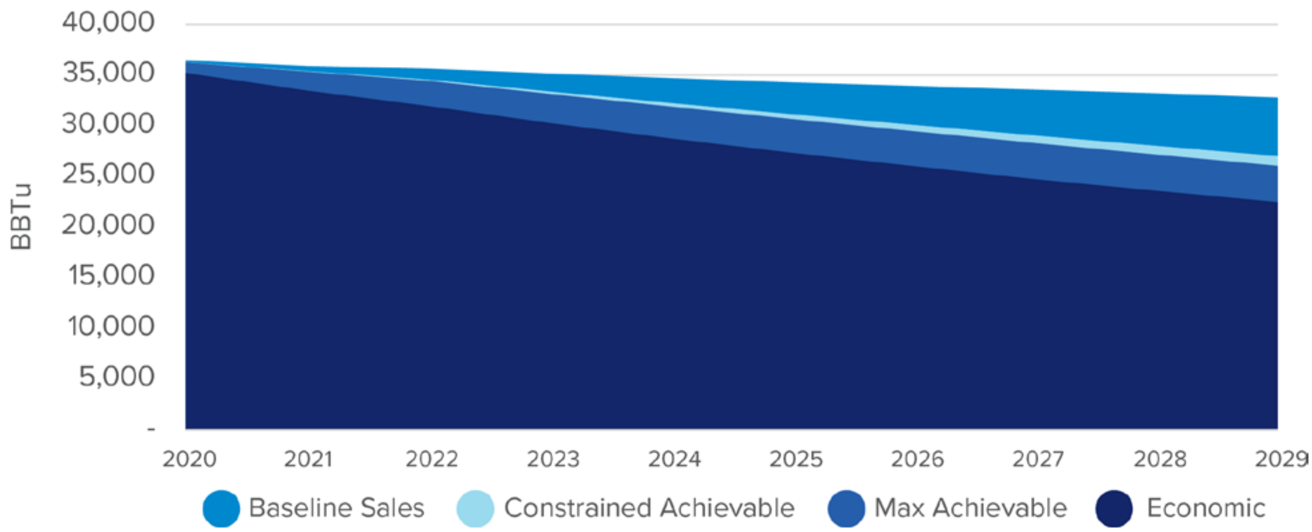


Figure 6 | **Propane Energy Savings, Relative to the Sales Forecast, New York State, 2020-2029**

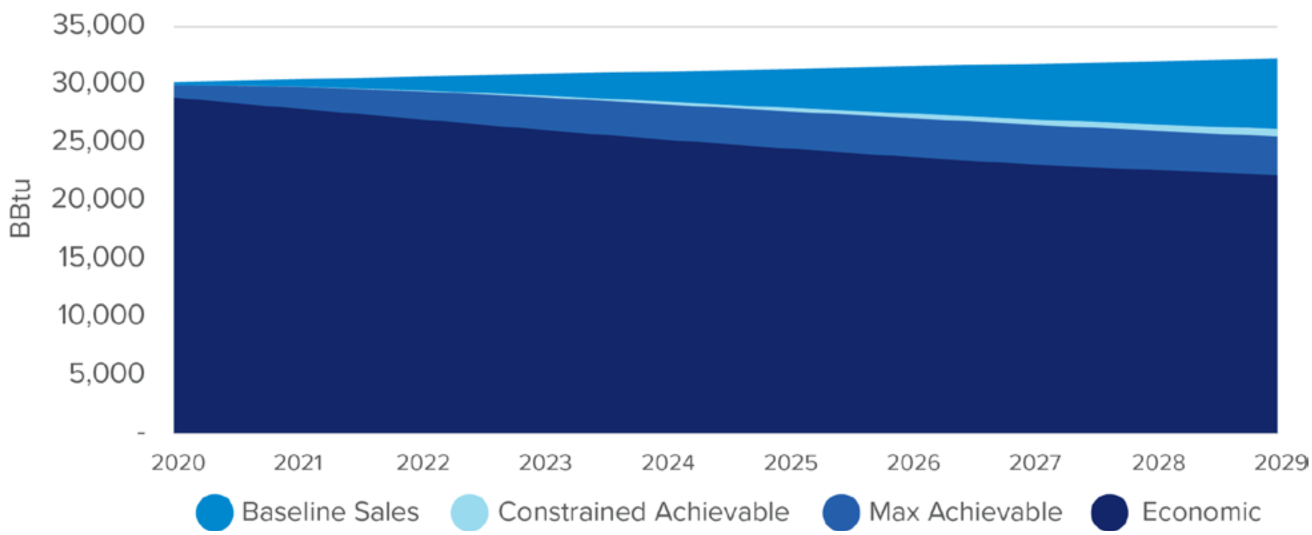


Table 8 shows the cumulative percentage reduction from each of the scenarios in Year 5 and Year 10.[10] Significant potential exists, and even the Constrained Achievable scenario would see a 17% to 25% reduction in consumption compared to each fuel's baseline forecast over the 10-year study horizon. Fossil fuel potential is somewhat lower than electric opportunities.

Table 8 | **Cumulative Percentage Reductions from Baseline Sales Forecast, New York State, by Scenario, Fuel, and Year**

		Electric	Natural gas	Fuel oil	Propane
2024	Technical Potential	27.0%	25.0%	18.9%	23.6%
	Economic Potential	23.3%	18.0%	17.1%	18.8%
	Maximum Achievable	11.3%	9.2%	8.1%	9.1%
	Constrained Achievable	10.1%	7.7%	7.1%	8.3%
2029	Technical Potential	47.3%	42.5%	34.7%	38.7%
	Economic Potential	40.6%	31.0%	31.4%	31.0%
	Maximum Achievable	27.4%	21.4%	20.6%	20.7%
	Constrained Achievable	24.1%	17.6%	17.6%	18.8%

Table 9 shows the average incremental annual savings for each scenario. For electricity and gas, total average incremental savings sum to more than the total cumulative savings across the ten years, due to measures with expected useful lives of less than ten years. This is not the case for propane and fuel oil due to the impact of efficient lighting installed in the electric scenario, which increases heating needs from reduced waste.

Table 9 | **Average Incremental Annual Savings, in Percentage Reductions from Baseline Sales Forecast, New York State, by Fuel and Scenario**

	Electric	Natural gas	Fuel oil	Propane
Technical Potential	5.3%	4.4%	3.3%	4.0%
Economic Potential	4.6%	3.3%	3.0%	3.3%
Maximum Achievable	2.9%	2.2%	2.0%	2.2%
Constrained Achievable	2.6%	1.8%	1.7%	2.0%

[10] Note throughout the report the Study Team uses the term "cumulative" to refer to the entire savings observed in a future year from that year's efficiency plus all continuing savings from prior years' efficiency adoption. "Incremental" or "incremental annual" refers to the additional savings from the current year only. Cumulative is less than the sum of all incremental annual impacts each year because some measures are short lived and do not persist until the end of the study period.

In addition to energy savings, the efficiency efforts would yield significant peak demand savings. Peak demand savings are reported in Table 10 in megawatts (MW), rather than as a percent of the forecast, to enable easier comparisons to the power generation that may be avoidable through efficiency. Note that these numbers represent peak demand reductions at the customer site associated with the portion of the commercial load examined under the baseline study. It can be expected that savings for the entire sector would scale proportionally. As seen, by 2029, peak reduction in the economic scenario will reach 5,764 MW compared to the baseline forecast. For context, this compares to the 2017 NY Statewide peak at the meter (all sectors) of 28,273 MW.[11,12]

Table 10 | **Cumulative Peak Demand Reductions, New York State, by Scenario, in MW**

Scenario	2024	2029
Technical Potential	3,653	6,490
Economic Potential	3,273	5,764
Maximum Achievable	1,681	3,902
Constrained Achievable	1,486	3,393

[11] NY ISO. 2018 Power Trends. https://bit.ly/2tddMlm

[12] Demand at generation is higher than demand at the customer site, due to electric losses through the transmission and distribution system. The magnitude of these losses increases as system load increases, so that marginal line losses are larger than average line losses. This study assumes a statewide average of 7.2% marginal line losses and average line losses 1.5 times smaller, or 4.8%. The number cited above is converted from a peak demand of 26,699 MW given in the document uing a 4.8% line loss factor.

Table 11 shows the cumulative percentage savings in 2029 for each region, and statewide, for each scenario. There is minor variation in the potential for each region. This is in alignment with the sensitivity analyses (described below) that show that the available potential is not significantly sensitive to the avoided costs. Because the Study Team relies largely on Statewide primary equipment saturation data from the baseline study, the main differences among the regions result from different climates, different avoided costs, and differences in the makeup of commercial building stock.

Table 11 | **Cumulative Percentage Reductions from Baseline Sales Forecast, New York State, 2029, by Scenario, Region, and Fuel**

Scenario	Region	Electric	Natural gas	Fuel oil	Propane
Technical Potential	Downstate	47.3%	41.2%	32.1%	36.4%
	Long Island / Hudson Valley	47.1%	43.0%	35.1%	38.4%
	Upstate	47.6%	43.1%	36.6%	38.9%
	Statewide	47.3%	42.5%	34.7%	38.7%
Economic Potential	Downstate	42.9%	29.7%	28.7%	31.7%
	Long Island / Hudson Valley	37.8%	31.9%	32.4%	33.0%
	Upstate	39.1%	31.1%	33.1%	30.2%
	Statewide	40.6%	31.0%	31.4%	31.0%
Maximum Achievable	Downstate	28.3%	20.7%	19.0%	22.5%
	Long Island / Hudson Valley	26.6%	22.1%	21.4%	22.3%
	Upstate	26.7%	21.3%	21.4%	20.0%
	Statewide	27.4%	21.4%	20.6%	20.7%
Constrained Achievable	Downstate	24.7%	16.7%	15.8%	20.2%
	Long Island / Hudson Valley	23.7%	18.3%	18.5%	20.2%
	Upstate	23.4%	17.7%	18.5%	18.1%
	Statewide	24.1%	17.6%	17.6%	18.8%

Table 12 shows the economic impacts of each primary scenario. As can be seen, if New York achieved the full theoretical economic potential, $24 billion of net benefits would accrue to the Statewide economy. Capturing all of the maximum achievable potential would provide over $15 billion in net benefits. All economic and achievable scenarios are highly cost-effective, yielding between $3.65 and $3.93 in benefits per dollar invested.

Table 12 | **Net Present Value Economic Impacts from Each Scenario, 2020-2029**

Scenario	Costs (million 2020$)	Benefits (million 2020$)	Net benefits (million 2020$)	TRC Benefit-Cost Ratio
Technical Potential	$22,995	$39,122	$16,127	1.70
Economic Potential	$ 8,930	$ 32,991	$ 24,061	3.69
Maximum Achievable	$ 5,664	$ 20,697	$ 15,033	3.65
Constrained Achievable	$ 4,577	$ 17,971	$ 13,394	3.93

The analysis also characterizes the nature of the available potential. Key observations include:

- There is significant savings opportunity in replacing electric resistance heat with cold-climate heat pumps, especially as this technology becomes less expensive and more effective. The scope of this study did not include opportunities from converting from fossil fuel-based space and water heating end uses to efficient electric heat pumps, which warrants subsequent analysis.
- A large portion of the potential comes from controlling and optimizing energy use, as opposed to simply increasing the efficiency of current technologies.
- Despite accelerating adoption of linear LED in recent years, a significant portion of existing buildings still have fluorescent lighting in their linear sockets, creating significant opportunity in indoor lighting.

Sensitivity Analysis

The study includes a sensitivity analysis, with two additional economic scenarios defined to determine how significantly the potential might vary with different avoided costs. A high avoided cost economic scenario reflects avoided costs 25% higher than in the economic base scenario; and a second sensitivity excludes the societal value of avoided CO2 emissions, resulting in lower avoided costs relative to the base economic scenario of roughly 25% lower for electricity, 36% lower for gas, 15% lower for oil, and 10% lower for propane. The Study Team finds that the amount of potential is not very sensitive to medium-sized swings in avoided costs.

Depending on the market, region, and building type, only a handful of measures typically drop out between the economic scenario with high avoided costs and the scenario that excludes the avoided costs of CO2 emissions. Overall, there is only a 6% swing in economic potential between these two economic sensitivity scenarios. Fuel oil and propane have even lower sensitivity, with swings of 0.5% and 2.2%, respectively. This is largely because avoided costs per MMBtu saved for these fuels are much higher than that for natural gas (reflecting low forecasted natural gas costs in the 2018 Congestion Assessment and Resource Integration Study (CARIS) 2 model, the forecast used for this study) so that most of the examined measures for fuel oil and propane pass the cost-effectiveness test even without including the value of avoided CO2 emissions. It should be noted that many measures are characterized based on average savings and costs by market and building type. Therefore, it is likely that for many of the measures that do fail the cost-effectiveness screen there still may be some significant cost-effective opportunities, depending on the specific existing and new efficiency levels, sizes, and ease of application.

SECTION 4

Economic Potential

4 Economic Potential

Electric Results

Table 13 shows for each year of the study the incremental and the cumulative percentage reduction from the baseline electric sales forecast, electric energy savings in GWh, and the total peak reduction in MW, reported at the customer site. The incremental annual savings for this scenario start high at 6% of forecast sales in 2020 and slowly drop to 4% in 2029. This is because as the equipment stock turns over and is replaced by efficient equipment, there is less and less available to be retrofitted. By 2029, much lower retrofit savings are available, because the efficient measure has already replaced most of the equipment as part of the natural replacement cycle.

Table 13 | **Statewide Incremental and Cumulative Electric Energy and Peak Reduction by Year in the Economic Base Case**

	Incremental			Cumulative		
	Electric Energy (% of sales fore-cast)	Electric Energy (GWh)	Peak Reduction (MW)	Electric Energy (% of sales forecast)	Electric Energy (GWh)	Peak Reduction (MW)
2020	6.0%	2,929	841	6.0%	2,929	841
2021	5.8%	2,700	780	12.1%	5,628	1,620
2022	4.7%	2,283	658	15.4%	7,477	2,147
2023	4.5%	2,199	637	19.0%	9,254	2,659
2024	4.3%	2,113	614	23.3%	11,366	3,273
2025	4.2%	2,083	609	27.1%	13,316	3,855
2026	4.2%	2,010	590	31.3%	15,196	4,418
2027	4.1%	2,007	592	34.4%	17,023	4,935
2028	4.1%	2,007	587	37.0%	18,377	5,358
2029	4.0%	1,960	570	40.6%	19,716	5,764

Figure 7 shows the cumulative 2029 electric energy savings by end use. Over one-quarter of the total comes from interior lighting measures, with building level measures such as energy management systems, demand control ventilation, and retro-commissioning, making up another quarter of available potential. Ventilation and refrigeration together make up another 27% of the total potential, with the rest of the end uses rounding out the remaining available potential. This distribution is fairly typical of commercial potential studies. For example, the 2014 Energy Efficiency and Renewable Energy Potential Study of New York State shows 32% of the total savings coming from interior lighting. This is similar to but slightly higher than the 27% savings found in this study, likely because of improved code and baseline efficiency in terms of lighting.

Figure 7 | **Statewide Electric Cumulative Energy Savings by End Use Under the Economic Base Case, 2029**

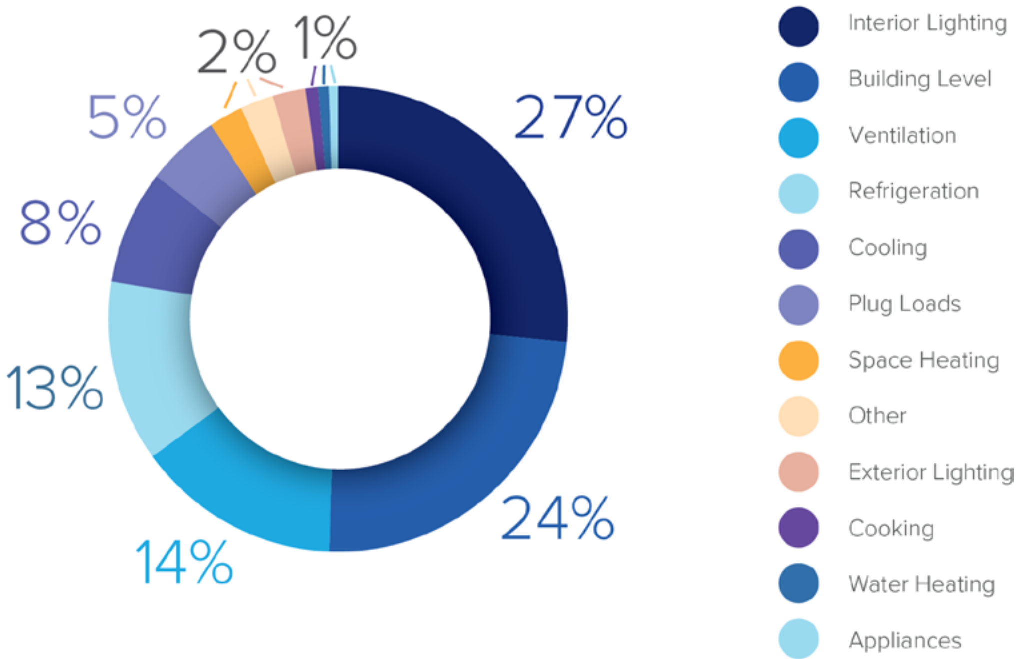


Figure 8 shows potential electric savings by building type. The largest contributor of potential savings is the office and government sector at 37%. Retail (13%), education (12%), health service/hospital (10%), and warehouses (9%) are all also large contributors.

Figure 8 | **Statewide Electric Cumulative Energy Savings by Building Type Under the Economic Base Case, 2029**

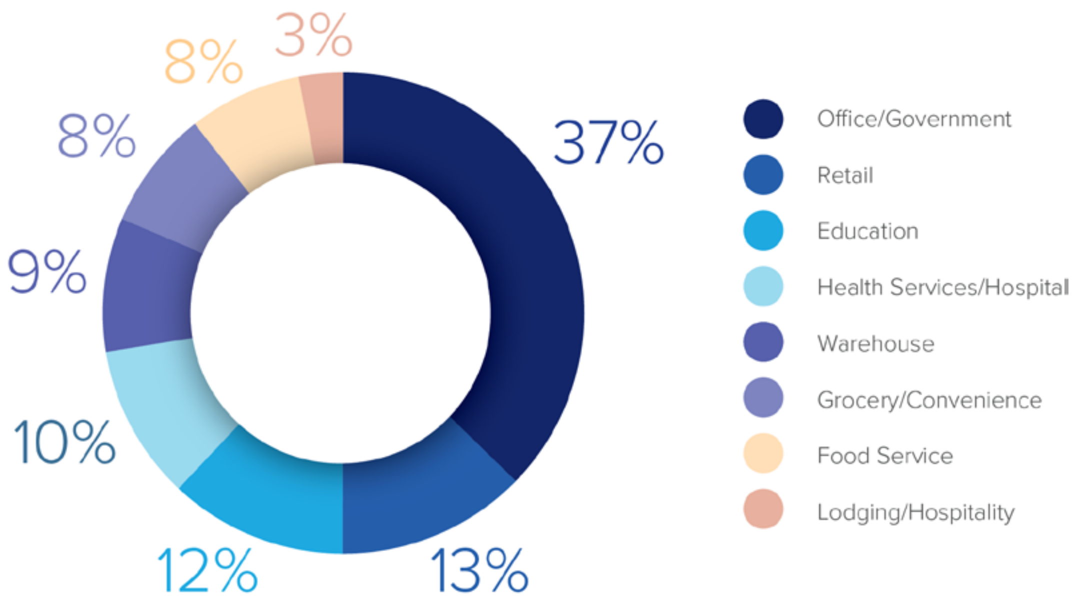


Table 14 shows the measures that contribute to the greatest statewide savings in electricity over the 10-year period. In total, these ten measures consist of about 55% of the total potential. No single measure completely dominates, although LED tubes and interior lighting controls combine to form 20% of the total potential. It is important to note that the distribution of savings by measure is somewhat driven by choice of method relating to the selection of mutually exclusive measures and the order in which measures are assumed to be adopted in the model for calculating interactions between measures. Actual realized potential might differ significantly from economic potential. For the Economic Potential scenarios, the Study Team assumed 100% of savings come from the measure that offers the greatest total savings from within whichever group of mutually exclusive measures to which it applies. For interactions, if a measure is considered to be installed only after other measures that will interact with it, savings for that measure will appear lower than if it was assumed to be installed without the other interacting measures.[14] Therefore, for example, if retro-commissioning is assumed to address all end uses and save 10%, then it would reduce the opportunity for savings from all subsequent measures by 10%.[15]

Table 14 | **Top Electric Energy Saving Measures, Economic Base Case, 2029**

Measure	Percent of total
LED Tube Replacement	13%
Interior Lighting Controls	7%
Data Center	7%
Energy management system - building level, fossil fuel-heated	7%
Variable frequency drives on HVAC system - ventilation	6%
Retro-commissioning - building level, fossil fuel-heated building	4%
Energy management system - building level, electric-heated	3%
Evaporator fan motor replacement	3%
Chiller Systems	3%
Tier 2 Power Strips	3%
Total	**55%**

[14] As an example of interactions, if one assumes installation of insulation first, and then a more efficient heating system, the latter will save less energy because of the reduced heating load resulting from the former measure.
[15] Note that cost-effectiveness at the measure level is not impacted by the interaction adjustments so that each measure's cost-effectiveness is assessed independently.

LED tube replacements are the most dominant source of savings, with 13% of the total. Other important measures are building level controls (such as energy management systems and retro-commissioning), variable frequency drives, evaporator fan motor replacements on refrigeration systems, and Tier 2 power strips as the primary measure affecting plug loads.

Table 15 shows the measures that contribute the greatest savings in electricity peak demand over the 10-year period. Similar to the projection for electricity savings, no single measure dominates in reducing electricity demand, with the highest contribution being 15% for LED tube replacements. As compared to the top energy-saving measures reported in Table 14, the list of measures in Table 15 is focused more on cooling and ventilation. Significant contributions come from duct sealing, Wi-Fi thermostats, and mini-split ductless heat pumps.

Table 15 | **Top Electric Peak Demand Saving Measures Under the Economic Base Case, 2029**

Measure	Percent of total
LED Tube Replacement	15%
Duct sealing – ventilation, fossil fuel-heated building	8%
Interior Lighting Controls	8%
Variable frequency drives on HVAC system - ventilation	6%
Energy management system - building level, fossil fuel-heated building	5%
Wi-Fi thermostats - cooling, fossil fuel-heated building	3%
Retro-commissioning - building level, fossil fuel-heated building	3%
Duct sealing - cooling, fossil fuel-heated building	3%
Mini-split ductless heat pump – cooling	3%
Demand Control Ventilation - ventilation, fossil fuel-heated building	3%
Total	**57%**

Natural Gas Results

Table 16 shows the incremental and cumulative natural gas savings by year as a percent of the baseline sales forecast and in billion British thermal units (BBtu). The percent reduction is significantly lower than for electricity. This is due to both natural constraints on the efficiency of heating equipment, and fairly low avoided costs (based on the 2018 CARIS 2 forecasted prices used for this study) that cause many envelope measures that would lower heating load to be not cost-effective. In addition, interior lighting offers high cost-effective savings and is an end-use that does not apply to gas.

Table 16 | **Statewide Incremental and Cumulative Natural Gas Potential by Year, Under the Economic Base Case**

	Incremental		Cumulative	
	% of sales forecast	BBtu	% of sales forecast	BBtu
2020	3.7%	7,139	3.7%	7,139
2021	3.5%	6,790	7.1%	13,928
2022	3.6%	6,945	10.9%	21,284
2023	3.4%	6,679	14.6%	28,316
2024	3.3%	6,450	18.0%	34,723
2025	3.2%	6,226	21.1%	40,899
2026	3.1%	6,050	24.1%	46,739
2027	3.0%	5,914	26.8%	52,119
2028	3.0%	5,813	28.9%	56,691
2029	2.9%	5,710	31.0%	61,035

[14] As an example of interactions, if one assumes installation of insulation first, and then a more efficient heating system, the latter will save less energy because of the reduced heating load resulting from the former measure.
[15] Note that cost-effectiveness at the measure level is not impacted by the interaction adjustments so that each measure's cost-effectiveness is assessed independently.

Figure 9 shows natural gas savings by end use. Since natural gas is predominantly used for space heating, space heating measures make up the largest portion of the available potential. In this case, building-level measures, which make up 25% of the total potential, would largely save energy from the space heating end use as well. Water heating, cooking, and other end uses make up less than one-quarter of the total potential.

Figure 9 | **Statewide Natural Gas Cumulative Savings by End Use Under the Economic Base Case, 2029**

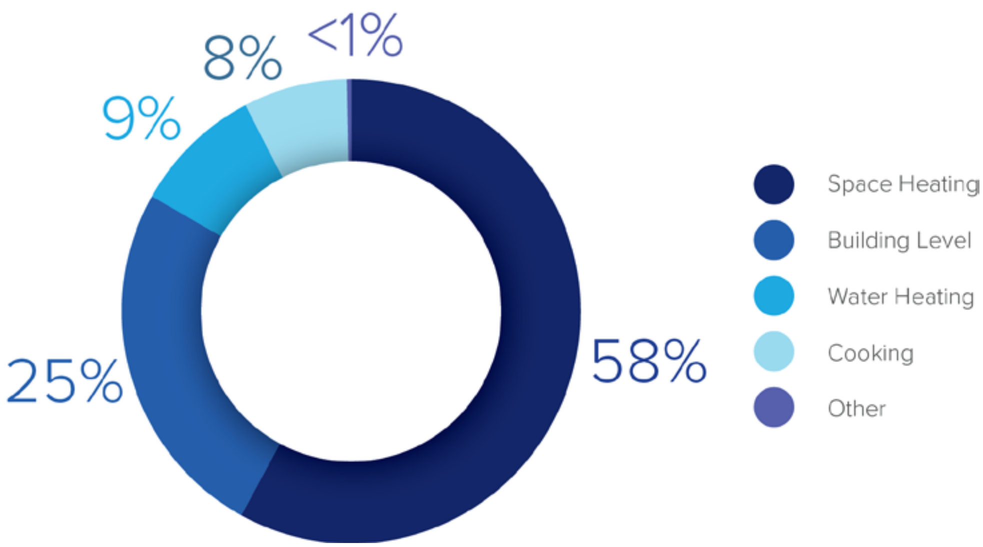
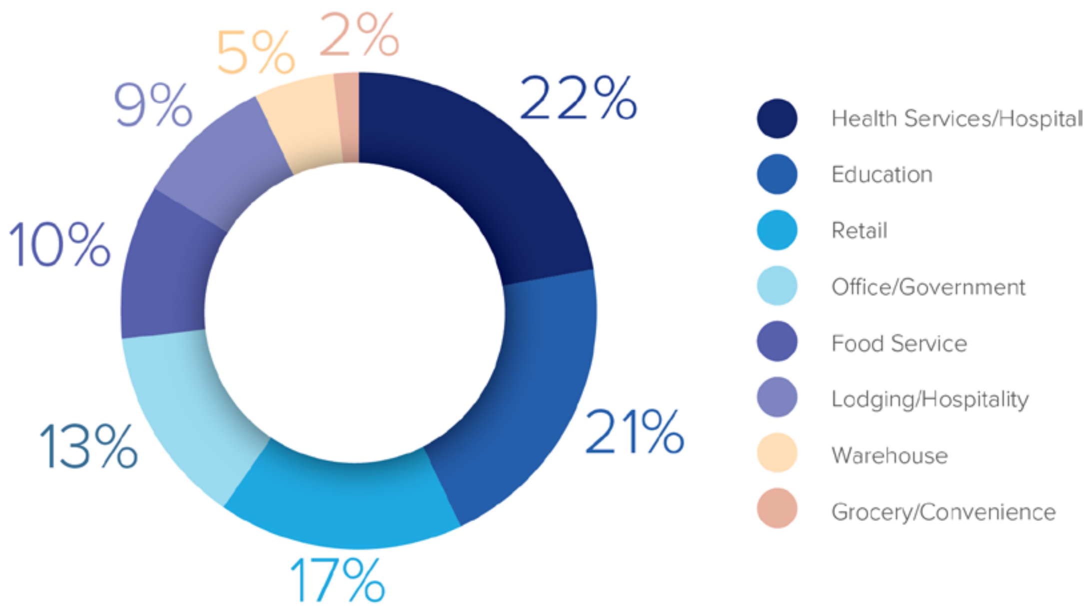


Figure 10 shows potential natural gas savings by building type. Although there is no single dominant segment, the top segments that can provide the largest natural gas savings are health services/hospitals (22%), education (21%), and retail (17%). This contrasts from electric efficiency, where the office/governmental building type has the greatest share of the potential. This is likely related to larger office/governmental buildings typically being “cooling dominant” because of large internal heat gains and less surface area compared to volume. Many large buildings may use cooling for most of the year and have minimal heating loads. In addition, the large potential to install efficient interior lighting in office/governmental buildings results in a reduction in waste heat, and as an interactive effect, in heating demand increases and in turn, a reduction in the gas savings potential

Figure 10 | **Natural Gas Savings by Building Type Under the Economic Base Case, 2029**



Just as there are few end uses that comprise the savings for natural gas, Table 17 shows that there is a more concentrated set of measures providing the bulk of natural gas savings. The top ten measures provide 76% of the projected natural gas savings over ten years. The top measures are dominated by controls and optimization measures, such as energy management systems, demand control ventilation, and energy recovery ventilators, rather than by replacements of actual heating equipment (furnaces and boilers). Efficient furnaces and boilers already benefit from relatively high market penetration and share of the existing building stock, and limited efficiency gains.

Table 17 | **Top Electric Energy Saving Measures, Economic Base Case, 2029**

Measure	Cumulative BBtu	Percent of total
Energy management system - building level, gas-heated building	9,093	14%
Demand control ventilation - building level, gas-heated building	8,680	13%
Energy recovery ventilator	7,580	12%
Boilers	3,666	6%
Retro-commissioning - building level, gas-heated building	3,666	6%
Furnace	3,195	5%
Duct sealing, gas-heated building	3,288	5%
Boiler modifications	3,156	5%
Optimized unitary AC system, gas-heated building	2,638	4%
Instantaneous water heater	1,540	2%
Total	**61,035**	**71%**

Fuel Oil Results

Table 18 shows the incremental and cumulative fuel oil savings by year as a percent of the baseline sales forecast and in BBtu. The reduction for fuel oil is very similar to the reduction for natural gas, largely due to similar measures in this case. Note that the incremental annual savings in this case sum to less than the 2029 cumulative number. This is due to interactions between fuel oil measures, which predominately impact space heating, with heating demand increases that result from lower waste heat from lighting efficiency measures. These interactions are especially noticeable in the fuel oil and propane potential results.

Table 18 | **Statewide Incremental and Cumulative Fuel Oil Potential by Year, Under the Economic Base Case**

	Incremental		Cumulative	
	% of sales forecast	BBtu	% of sales forecast	BBtu
2020	3.4%	1,244	3.4%	1,244
2021	3.2%	1,163	6.7%	2,407
2022	3.3%	1,184	10.3%	3,673
2023	3.2%	1,126	13.9%	4,878
2024	3.1%	1,071	17.1%	5,949
2025	3.0%	1,016	20.3%	6,961
2026	2.9%	969	23.3%	7,919
2027	2.8%	930	26.3%	8,838
2028	2.7%	894	28.9%	9,589
2029	2.6%	861	31.4%	10,299

Like natural gas, the use of oil is almost exclusively for the heating of buildings. Further, oil is not used in cooking, and only typically used for water heating when it is already an indirect system running from a boiler that is also used for space heating. Savings are therefore almost entirely from space heating. This is reflected in Figure 11, which shows that space heating accounts for nearly three-quarters of the savings, with building-level measures comprising nearly all of the remainder. In the case of oil, building-level measures effectively obtain virtually all savings from the space heating end use as well, since there is very little other consumption.

Figure 11 | **Statewide Fuel Oil Savings by End Use Under the Economic Base Case, 2029**

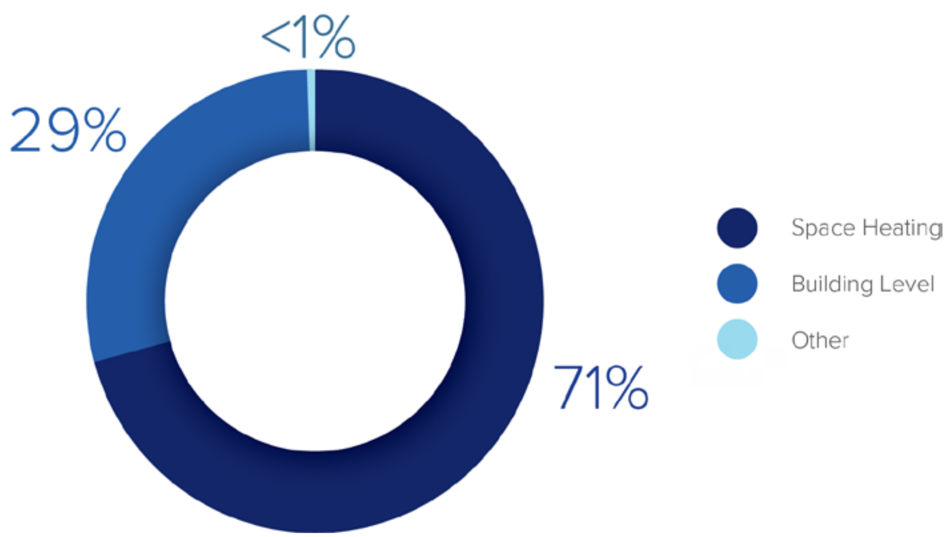
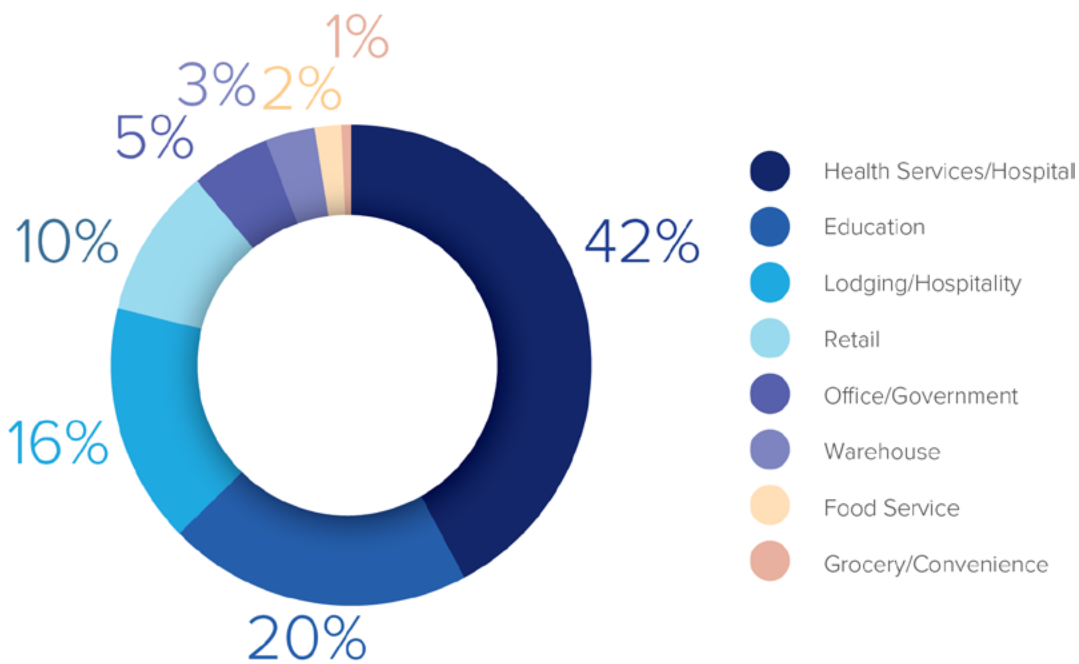


Figure 12 provides potential oil savings by building type. The largest contributor is the health services/hospital segment at 42%, similar to natural gas, followed by education at 20%, and lodging/hospitality at 16%. This tends to reflect which building types are the predominant oil consumers, rather than demonstrating that those buildings types are particularly inefficient. It also should be noted that fuel oil and propane (or unregulated fuel) potential resides predominantly in more rural areas of the state without natural gas available.

Figure 12 | **Statewide Fuel Oil Savings by Building Type Under the Economic Base Case, 2029**



The top ten measures for fuel oil savings are shown in Table 19, accounting for 92% of the savings, with most of them attributable to the building and mechanical systems. This fraction is significantly higher than that of natural gas and electricity, largely due to the more limited applications for fuel oil (i.e., it is not typically used for cooking or water heating).

Table 19 | **Top Statewide Fuel Oil Saving Measures Under the Economic Base Case, 2029**

Measure	Percent of total
Demand control ventilation - building level, oil-heated building	17%
Furnace	15%
Energy management system - building level, oil-heated building	15%
Energy recovery ventilator	14%
Retro-commissioning - building level, oil-heated building	6%
Duct sealing, oil-heated building	6%
Optimized oil heating system	6%
Kitchen exhaust demand control ventilation, oil-heated building	5%
Guest room energy management, oil-heated building	4%
Wi-Fi thermostats – oil-heated building	4%
Total	**92%**

Propane Results

Table 20 shows the incremental and cumulative propane savings by year as a percent of the baseline sales forecast and in BBtu. As seen, the percent reduction in propane sales is very similar to the reductions for natural gas and fuel oil, and somewhat lower than the reduction in electric usage.

Table 20 | **Statewide Incremental and Cumulative Propane Potential by Year, Under the Economic Base Case**

	Incremental		Cumulative	
	% of sales forecast	BBtu	% of sales forecast	BBtu
2020	4.4%	1,316	4.4%	1,316
2021	4.0%	1,217	8.3%	2,532
2022	3.8%	1,169	12.1%	3,713
2023	3.6%	1,108	15.6%	4,825
2024	3.4%	1,049	18.8%	5,868
2025	3.2%	994	21.8%	6,853
2026	3.0%	945	24.7%	7,790
2027	2.9%	907	27.2%	8,665
2028	2.7%	873	29.2%	9,351
2029	2.6%	839	31.0%	9,997

Figure 13 shows propane savings by end use. More than half of the savings are from space heating measures, with building level and water heating providing the next two largest shares, at 25% and 20% of the total, respectively. As would be expected, propane breaks out by end use similarly to natural gas. However, the customer mix and climate weighting vary somewhat because unregulated fuels are predominant in rural areas without natural gas available.

Figure 13 | **Propane Savings by End Use Under the Economic Base Case, 2029**

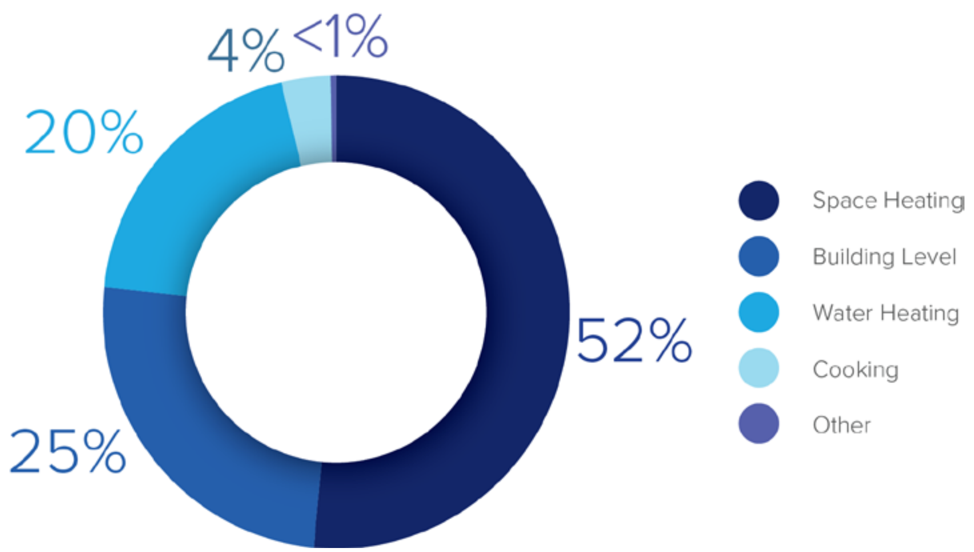
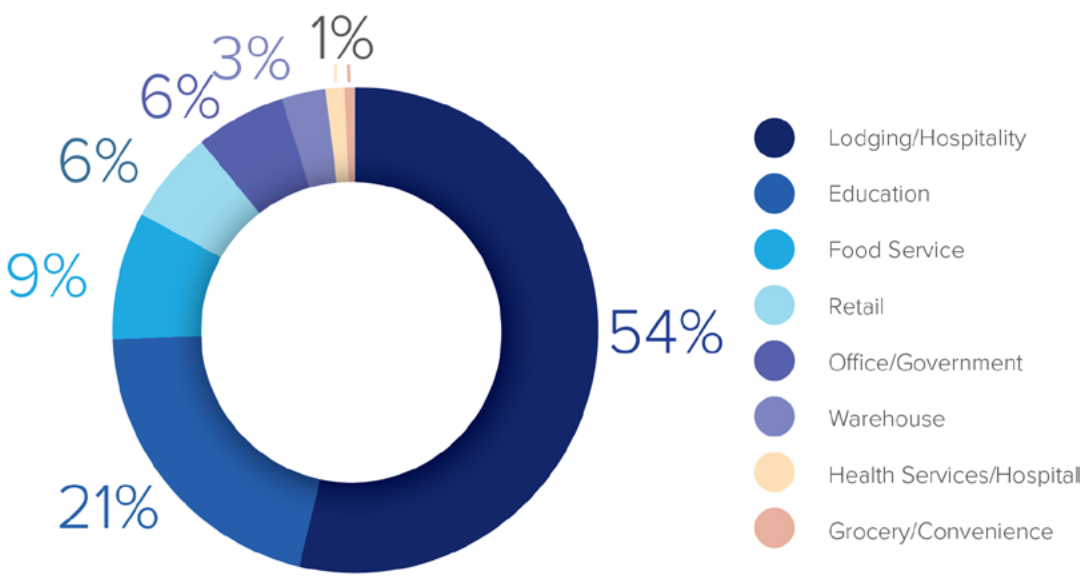


Figure 14 provides potential propane savings by building type, with lodging/hospitality showing the greatest potential at 54%. Education facilities are another large source at 21% of potential propane savings.

As with oil, available savings by building type are more a function of which building types have greater penetration of propane than any variations in baseline equipment efficiency or equipment types.

Figure 14 | **Propane Savings by Building Type Under the Economic Base Case, 2029**



Among the top ten measures for propane savings are a wider range of measures compared to oil (Table 21), which together represent 69% of the economic potential. This is because propane is often used for end uses beyond space heating, such as water heating, cooking, and laundry. In fact, the Study Team sees significant savings from ozone laundry and water heaters, which have not appeared on the list of top saving measures for other fuels.

Table 21 | **Top Propane Saving Measures Under the Economic Base Case, 2029**

Measure	Cumulative BBtu	Percent of total
Energy management system - building level, propane-heated building	1,426	14%
Ozone laundry	1,063	11%
Unit heater	742	7%
Energy recovery ventilator	728	7%
Storage water heater	571	6%
Demand control ventilation - building level, propane-heated building	540	5%
Guest room energy management, propane-heated building	533	5%
Retro-commissioning - building level, propane-heated building	518	5%
Boilers	507	5%
Instantaneous water heater	289	3%
Total	**11,765**	**69%**

SECTION 5

Conclusion

5 Conclusion

This study finds significant potential for economic and achievable energy efficiency remains in New York State. Total economic potential reaches over 40% of the baseline sales forecast for electricity, and about 31% of the baseline sales forecast for natural gas, fuel oil, and propane. Further, this potential is highly cost-effective, bringing a net present value of $24 billion to New York State in avoided electric generation expenses, avoided capacity investments, avoided purchases of natural gas and unregulated fuels, and avoided CO2 emissions. This represents almost $4 in benefits for every $1 spent on the efficiency measures.