Modeling the Impacts of Climate Change on Building Energy Performance in New York State

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School of Architecture and Planning

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Executive Summary

Buildings are one of the largest contributors to greenhouse gas emissions, responsible for 25-40% of emissions worldwide, 44.6% in the U.S., and 32% in New York State. By adapting design and occupancy habits, there is great potential to reduce emissions within the building sector.

Along with understanding how buildings impact the environment, it is important to understand how climate change will affect buildings. New York State has a large and widely varying building stock made up of more than five million buildings with several different building typologies. In order to increase the overall resilience in the State, it is crucial to gather as much data and analyze as many of these typologies as possible to understand how they currently operate and how they will operate as the climate continues to change. It is critical to improve energy performance statewide to maintain proper building operations during climate events, as both acute and prolonged events are predicted to become more extreme in future decades.

New York State's building stock can be broken down into five broad typologies, each playing a key protective role during hazardous climate events.

- Single family and multifamily residential buildings must allow occupants to shelter in place during extreme weather events. A heavy reliance on poorly performing HVAC systems could cause those same systems to fail, potentially leading to wider-spread health threats.
- Commercial buildings play a crucial role in recovery efforts from climate change and hazards.
- Industrial buildings are a large part of the economy in New York State.
- Educational buildings, along with providing communities with spaces for learning, often serve as emergency shelters. Improving the performance of HVAC systems in schools is not only critical to increasing the resiliency of the building stock, but to increasing the resiliency of communities.

While varying in program and location, the majority of New York State's building stock could improve its energy performance through a series of Energy Conservation Methods (ECMs) specifically selected for each building typology.

In this study, five different building typologies were modeled, each based on an existing building in New York State. The typologies selected for these case studies were a low-rise residential building, a multifamily residential building, a commercial building, an industrial building, and an education building. Each of these were modeled and tested with both baseline systems and upgraded systems following ECMs. The methodology used for this study is based on the Chartered Institution of Building Services Engineers (CIBSE) report “Climate change and the indoor environment: impacts and adaptation” and the New York State Energy and Development Authority (NYSERDA) New Construction Program Simulation Guidelines. Models were run in eQuest version 3.62 using the files originally created by L&S Energy Services for a 2008 Technical Assistance Study in Support of the New Construction Program (NCP 7074). After the energy conservation measures were modeled, tests were run to investigate the cumulative effect of the strategies on passive survivability, which is “a building's ability to maintain critical life-support conditions in the event of extended loss of power, heating fuel, or water, or in the event of extraordinary heat spells.” A final set of tests compared the baseline and upgraded buildings using four sets of meteorological data prepared by Weather Analytics.

Almost every energy conservation measure, across each of the five building typologies and seven ClimAID regions, showed reductions in energy use. Improved lighting design was particularly effective in reducing energy consumption across every case study. Improved insulation also created significant reductions across all externally load dominated buildings. These results help confirm the value of ECM implementation across the State and begin to show the potential these system upgrades can have in improving the resilience of our existing building stock.

Low-Rise Residential Building Case Study

GLENMORE GARDENS

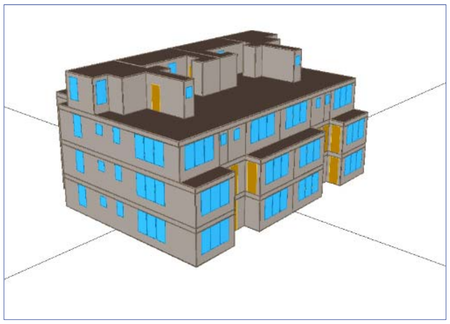


Figure 1: Screenshot of the building energy model in eQuest

In New York, there are approximately 4.75 million residential buildings, representing 90.1% of the total number of buildings in the State and 74.6% of the total floor area. The total value of the residential building stock is 1.71 trillion dollars, which accounts for 73.3% of the total value of the entire building stock.

Residential structures are particularly susceptible to climate change because they are externally load dominated, meaning that changes in solar radiation and outdoor temperature have greater impact on heating, ventilation, and air-conditioning (HVAC) system usage than other factors. In addition, because people spend significant amounts of time at home and may shelter in place there during periods of extreme weather, improving the performance of HVAC systems in residences is critical to increase the building stock resilience.

METHODOLOGY

The low-rise residential building energy model was based on a 12,700 square foot, 12-unit apartment complex built in Brooklyn, New York in 2008. The building is a four story, light gauge steel framed structure with a brick veneer finish, a flat roof, and a slab on grade foundation (Figure 1).

Each one of the apartments in the building has a natural gas fired forced hot air furnace for heating and a direct expansion air-conditioning system for cooling. The building sits on a street corner with a parking lot on its north side and neighbors to the north and east; these details were not included in the energy model. The long axis of the building is oriented east-west.

The methodology used for this study is based on the Chartered Institution of Building Services Engineers (CIBSE) report “Climate change and the indoor environment: impacts and adaptation” and the NYSERDA New Construction Program Simulation Guidelines. Models were run in eQuest version 3.62 using the files originally created by L&S Energy Services for a 2008 Technical Assistance Study in Support of the New Construction Program (NCP 7074).

Table 1: Energy Conservation Measures, System Descriptions, Effective Useful Life, and Incremental Costs

ECMs	Baseline System Description†	Upgraded System Description	EUL (years)	Cost ($)
Improved Insulation	R-20 continuous insulation in the roof.	R-30 continuous insulation in the roof.	50	$4,900
Upgraded Windows	Glazing with a solar heat gain coefficient of 0.50 and a U-value of 0.60.	Glazing with a solar heat gain coefficient of 0.28 and a U-value of 0.30.	30	$26,300
High Albedo Roof	The baseline design includes a dark roof with an absorptance value of 0.7.	The upgrade recommends installing an Energy Star qualified white roof with an absorptance value of 0.3.	20	$20,900
Interior Lighting	Standard efficiency lighting system that meets the Energy Conservation Construction Code maximums on a space by space basis. 1.00 watts/square foot.	Energy efficient fluorescent, compact fluorescent and incandescent lighting. The total lighting intensity of the building was calculated to be 0.47 watts/square foot.	15	$8,400
A/C Equipment	The baseline system consists of apartment split DX furnaces, with a SEER value of 10.	The proposed apartment split DX furnaces have SEER values of 14 for single story apartments and 17.2 for two story apartments.	15	$10,200

†The New York State Energy Conservation Code of 1999 was the baseline used for the analysis.

Using a package minus approach for the modeling, the building systems were downgraded in steps from the as-designed configuration to code compliant systems, starting first with the ECMs that have the longest effective useful life (EUL) as shown in Table 1. The building was modeled with the as-designed HVAC systems to understand the impact of design changes on energy usage, demand, operating costs, and SO_x/NO_X/CO_2 emissions.

After the energy conservation measures were modeled, the next set of runs investigated the cumulative effect of the strategies on passive survivability. Both the maximum interior temperature and the number of hours above 82.4°F were modeled; 82.4°F (28°C) is a threshold used by CIBSE as a proxy for high heat exposure.

Although the CIBSE study used future weather year data to investigate overheating for buildings in the United Kingdom, this study did not project results into the future because similar files are not currently available for New York State. In addition, changes in the average air temperature tend to have less impact on the operation of HVAC systems; the peak heating and cooling loads experienced during a heat wave or cold spell typically determine the size of a building system and its impact on energy demand.

To this end, for the third and final set of energy modeling runs, the baseline and upgraded buildings were compared using four sets of meteorological data prepared by Weather Analytics:

1) Typical Meteorological Year (TMY) Data:

    i. TMY, 1986 – 2015, 30 years
    ii. TMY, 2009 – 2015, 6 years

    TMY are data sets of hourly values of solar radiation and meteorological elements for a one-year period. They are typically used for computer simulations of solar or building HVAC systems. Because they represent typical rather than extreme conditions, they are not use for designing systems to meet the worst-case conditions occurring at a location. Although TMY are available from the National Renewable Energy Laboratory for most cities in the United States, these files cover the period 1991-2005 in New York State. Weather Analytics created custom TMY data for multiple sites across the State using more current data, specifically the period 1986 to 2015 and 2009 to 2015. This second set of files promotes understanding of how recent warming may impact building system performance.

2) eXtreme Meteorological Year (XMY) Data:

    i. XMY MAX, 2001 – 2015, 15 years
    ii. XMY MIN, 2001 – 2015, 15 years

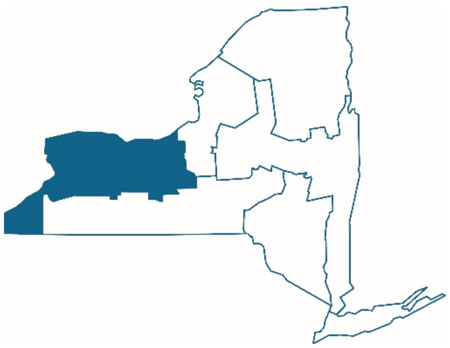
    Weather Analytics also created XMY files to examine the extreme cases occurring over the last 15 years. XMY files are created by using historical data to determine the maximum and minimum of a variable on a monthly basis. For example, if temperature is requested over a period of 15 years, the XMY MAX file will consist of the warmest months that occurred over the past 15 years, while the XMY MIN file will consist of the coolest (based on averages). Along with the extreme temperatures, the consequent data (e.g., solar radiation, wind speed) from the extreme month is also carried over to the XMY file, keeping consistency between each variable.

The results from this portion of the study indicate how weather variability may impact energy usage, demand, and operating costs. The number of hours the systems could not keep up with heating and cooling loads were also calculated, as well as the maximum interior temperature and number of hours above 82.4°F.

REGIONAL PROFILES

The following section outlines the results for each of the seven ClimAID regions. Following the profiles, a discussion of the statewide impacts for low-rise residential buildings is presented.

REGION 1: WESTERN NEW YORK AND THE GREAT LAKES PLAIN



As expected, the ECMs reduced the summer electrical peak (44.4%), the annual electricity use (27.7%), the winter electrical peak (8.6%), and the annual natural gas use (3.6%). These savings translated to a 13.1% reduction in utility costs, or $2,615 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 27.7%; carbon dioxide emissions were reduced by 5.3%. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 2: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	39,705	28.4	12.7	1,910.5	$17,419	5.4	13.5	121.0	N/A
Improved Insulation	39,783	28.6	12.7	1,931.7	$17,557	5.5	13.6	122.2	35.5
Upgraded Windows	41,639	32.7	12.8	1,981.5	$18,135	5.7	14.2	125.6	45.5
High Albedo Roof	41,662	32.7	12.8	1,981.2	$18,136	5.7	14.2	125.6	20,900.0
Interior Lighting	51,891	41.1	13.9	1,966.2	$19,581	7.1	17.7	127.1	5.8
A/C Equipment	54,911	51.0	13.9	1,966.2	$20,034	7.5	18.7	127.8	22.5
Reduction	27.7%	44.4%	8.6%	3.6%	13.1%	27.7%	27.7%	5.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 41.6% and 44.3%, annual energy use between 25.3% and 29.7%, winter peak between 8.1% and 8.7%, and annual natural gas use between 1.8% and 3.4%. These reductions in electricity and natural gas use resulted in an 11.6% to 14.1% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 69.1% and 70.6%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

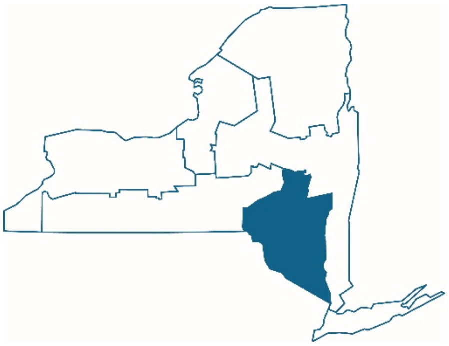
Table 3: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	54,911	51.0	13.9	1,966.2	$20,034	988	97.5	485
TMY, 1986-2015 (As-Designed)	39,705	28.4	12.7	1,910.5	$17,419	291	88.6	139
TMY, 2009-2015 (Baseline)	55,092	48.6	13.8	1,924.1	$19,808	878	94.4	394
TMY, 2009-2015 (As-Designed)	39,716	28.3	12.6	1,872.9	$17,195	259	86.0	104
Max. XMY (Baseline)	58,277	52.9	13.6	1,838.7	$19,774	1,004	102.4	802
Max. XMY (As-Designed)	40,991	30.9	12.5	1,806.1	$16,985	310	92.5	345
Min. XMY (Baseline)	50,897	41.4	14.1	2,112.5	$20,310	677	92.8	270
Min. XMY (As-Designed)	38,038	23.1	12.9	2,041.3	$17,954	199	84.2	27

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 97.5°F to 88.6°F. In addition, the ECMs reduced the total hours of exposure indoors from 485 hours to 139 hours, a 71.3% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs by between 8.5 and 9.9°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 57.0% and 90.0%.

REGION 2: CATSKILL MOUNTAINS AND WEST HUDSON RIVER VALLEY



As expected, the ECMs reduced the summer electrical peak (43.8%), the annual electricity use (28.5%), the winter electrical peak (2.3%), and the annual natural gas use (3.2%). These savings translated to a 13.7% reduction in utility costs, or $2,697 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 28.5%; carbon dioxide emissions were reduced by 5.2%. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 4: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	40,508	32.6	12.5	1,810.7	$16,940	5.5	13.8	115.3	N/A
Improved Insulation	40,619	32.9	12.6	1,831.6	$17,083	5.6	13.9	116.6	34.3
Upgraded Windows	42,579	37.0	12.8	1,871.0	$17,613	5.8	14.5	119.3	49.6
High Albedo Roof	42,609	37.1	12.8	1,870.6	$17,615	5.8	14.5	119.3	10,450.0
Interior Lighting	52,962	45.5	12.8	1,855.7	$19,078	7.3	18.1	120.8	5.7
A/C Equipment	56,689	57.9	12.8	1,855.7	$19,637	7.8	19.3	121.7	18.2
Reduction	28.5%	43.8%	2.3%	3.2%	13.7%	28.5%	28.5%	5.2%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 43.0% and 44.2%, annual energy use between 26.5% and 30.0%, winter peak between 8.0% and 8.8%, and annual natural gas use between 1.4% and 3.0%. These reductions in electricity and natural gas use resulted in a 12.3% to 14.4% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 67.8% and 70.6%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

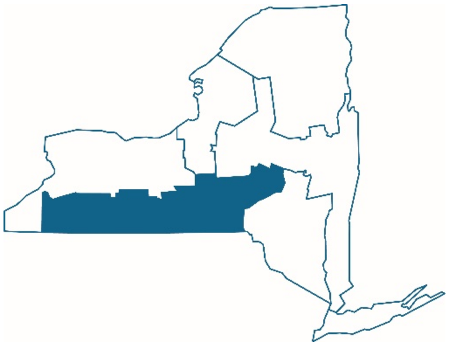
Table 5: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	56,689	57.9	13.7	1,855.7	$19,637	894	106.1	573
TMY, 1986-2015 (As-Designed)	40,508	32.6	12.6	1,810.7	$16,940	270	96.8	285
TMY, 2009-2015 (Baseline)	55,576	53.8	13.7	1,842.1	$19,389	961	103.5	582
TMY, 2009-2015 (As-Designed)	39,927	30.0	12.6	1,797.3	$16,773	299	95.0	238
Max. XMY (Baseline)	58,716	58.2	13.7	1,754.9	$19,336	950	102.6	864
Max. XMY (As-Designed)	41,099	32.5	12.5	1,730.1	$16,545	306	93.5	417
Min. XMY (Baseline)	52,579	46.7	14.0	1,996.0	$19,863	778	92.8	386
Min. XMY (As-Designed)	38,635	26.6	12.8	1,936.3	$17,413	229	85.6	52

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 106.1 to 96.8°F. In addition, the ECMs reduced the total hours of exposure indoors from 573 hours to 285 hours, a 50.3% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs by between 7.2 and 9.3°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 50.3% and 86.5%.

REGION 3: SOUTHERN TIER



As expected, the ECMs reduced the summer electrical peak (46.0%), the annual electricity use (26.7%), the winter electrical peak (8.6%), and the annual natural gas use (3.7%). These savings translated to a 12.5% reduction in utility costs, or $2,461 in annual savings. The ECMs also reduced air pollution associated with electricity generation. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 6: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	38,818	26.2	12.7	1,910.9	$17,288	5.3	13.2	120.8	N/A
Improved Insulation	38,905	26.5	12.7	1,933.3	$17,436	5.3	13.3	122.1	33.1
Upgraded Windows	40,467	30.6	12.8	1,983.4	$17,970	5.5	13.8	125.4	49.3
High Albedo Roof	40,489	30.6	12.8	1,983.1	$17,972	5.5	13.8	125.4	10,450.0
Interior Lighting	50,586	39.2	13.9	1,967.9	$19,395	6.9	17.2	126.9	5.9
A/C Equipment	52,945	48.5	13.9	1,967.9	$19,749	7.3	18.1	127.4	28.8
Reduction	26.7%	46.0%	8.6%	3.7%	12.5%	26.7%	26.7%	5.2%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 43.2% and 45.8%, annual energy use between 25.3% and 28.9%, winter peak between 8.5% and 8.7%, and annual natural gas use between 1.9% and 14.7%. These reductions in electricity and natural gas use resulted in an 11.7% to 13.6% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 65.2% and 69.5%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

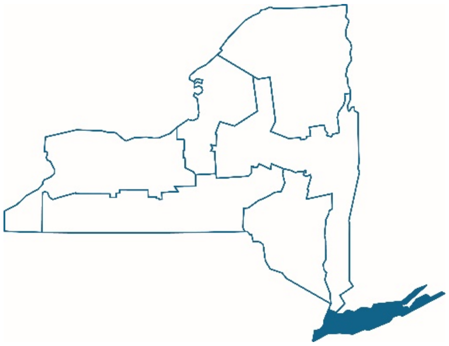
Table 7: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	52,945	48.5	13.9	1,967.9	$19,749	781	106.9	637
TMY, 1986-2015 (As-Designed)	38,818	26.3	12.7	1,910.9	$17,288	272	96.2	302
TMY, 2009-2015 (Baseline)	54,341	50.9	13.8	1,916.0	$19,647	654	97.7	406
TMY, 2009-2015 (As-Designed)	39,433	28.9	12.6	1,862.9	$17,092	206	88.7	102
Max. XMY (Baseline)	56,099	51.8	13.8	1,842.0	$19,467	885	100.8	813
Max. XMY (As-Designed)	39,891	29.4	12.6	1,807.2	$16,827	270	91.4	356
Min. XMY (Baseline)	51,425	41.4	14.1	2,118.0	$20,422	621	92.3	257
Min. XMY (As-Designed)	38,409	22.7	12.9	1,807.2	$18,032	199	85.6	21

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 106.9 to 96.2°F. In addition, the ECMs reduced the total hours of exposure indoors from 637 hours to 302 hours, a 52.6% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 6.7 and 10.7°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 52.6% and 91.8%.

REGION 4: NEW YORK CITY AND LONG ISLAND



As expected, the ECMs reduced the summer electrical peak (42.4%), the annual electricity use (29.0%), the winter electrical peak (8.8%), and the annual natural gas use (2.7%). These savings translated to a 13.5% reduction in utility costs, or $2,679 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 29.0%; carbon dioxide emissions were reduced by 4.8%. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 8: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	40,303	29.4	12.5	1,846.3	$17,123	5.5	13.7	117.4	N/A
Improved Insulation	40,388	29.6	12.6	1,864.6	$17,245	5.5	13.8	118.4	40.2
Upgraded Windows	42,386	33.0	12.7	1,897.0	$17,740	5.8	14.5	120.8	53.1
High Albedo Roof	42,413	33.1	12.7	1,896.7	$17,742	5.8	14.5	120.8	10,450.0
Interior Lighting	52,853	41.7	13.7	1,882.1	$19,221	7.2	18.0	122.4	5.7
A/C Equipment	56,725	51.1	13.7	1,882.1	$19,802	7.8	19.3	123.3	17.6
Reduction	29.0%	42.4%	8.8%	2.7%	13.5%	29.0%	29.0%	4.8%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 42.5% and 44.7%, annual energy use between 27.3% and 31.0%, winter peak between 8.6% and 8.8%, and annual natural gas use between 1.1% and 2.6%. These reductions in electricity and natural gas use resulted in a 12.7% to 15.3% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 71.6% and 74.7%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

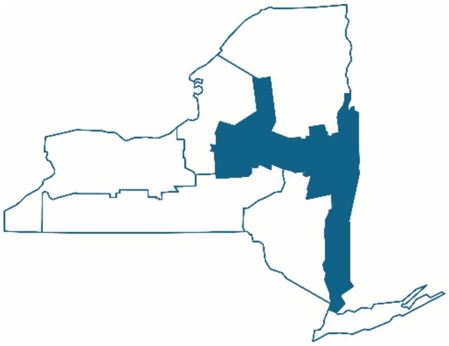
Table 9: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	56,725	51.1	13.7	1,882.1	$19,802	1,100	101.5	614
TMY, 1986-2015 (As-Designed)	40,303	29.4	12.5	1,846.3	$17,123	297	92.9	249
TMY, 2009-2015 (Baseline)	57,135	51.0	13.7	1,862.5	$19,746	984	100.4	612
TMY, 2009-2015 (As-Designed)	40,423	28.9	12.5	1,830.2	$17,045	279	91.9	239
Max. XMY (Baseline)	61,533	60.5	13.6	1,700.7	$19,434	1,105	101.1	938
Max. XMY (As-Designed)	42,439	33.8	12.4	1,682.8	$16,463	302	92.2	503
Min. XMY (Baseline)	53,641	47.9	13.9	1,929.3	$19,622	934	93.5	377
Min. XMY (As-Designed)	39,004	26.5	12.7	1,878.7	$17,123	236	84.8	81

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 101.5 to 92.9°F. In addition, the ECMs reduced the total hours of exposure indoors from 614 hours to 249 hours, a 59.4% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 8.5 and 8.8°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 46.4% and 78.5%.

REGION 5: EAST HUDSON AND MOHAWK RIVER VALLEYS



As expected, the ECMs reduced the summer electrical peak (44.8%), the annual electricity use (26.4%), the winter electrical peak (8.6%), and the annual natural gas use (3.9%). These savings translated to a 12.3% reduction in utility costs, or $2,463 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 26.4%; carbon dioxide emissions were reduced by 5.3%. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 10: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	38,910	27.4	12.8	1,945.1	$17,508	5.3	13.3	122.8	N/A
Improved Insulation	38,996	27.6	12.8	1,968.1	$17,658	5.3	13.3	124.2	32.7
Upgraded Windows	40,526	31.5	12.9	2,022.9	$18,216	5.6	13.8	127.7	47.1
High Albedo Roof	40,546	31.6	12.9	2,022.6	$18,218	5.6	13.8	127.7	10,450.0
Interior Lighting	50,609	39.9	14.0	2,007.2	$19,634	6.9	17.3	129.2	5.9
A/C Equipment	52,856	49.6	14.0	2,007.2	$19,971	7.2	18.0	129.7	30.3
Reduction	26.4%	44.8%	8.6%	3.9%	12.3%	26.4%	26.4%	5.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 42.7% and 47.0%, annual energy use between 25.3% and 29.1%, winter peak between 8.5% and 8.6%, and annual natural gas use between 2.0% and 3.6%. These reductions in electricity and natural gas use resulted in an 11.7% to 13.7% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 0.0% and 72.7%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

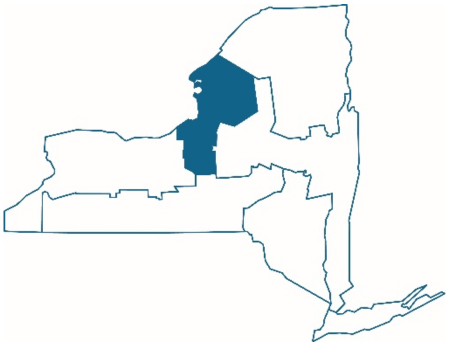
Table 11: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	52,856	49.6	14.1	2,007.2	$19,972	775	103.8	554
TMY, 1986-2015 (As-Designed)	38,910	27.4	12.9	1,945.1	$17,507	254	94.3	180
TMY, 2009-2015 (Baseline)	54,173	51.3	13.9	1,957.5	$19,871	658	97.8	350
TMY, 2009-2015 (As-Designed)	39,436	29.4	12.7	1,899.9	$17,315	213	88.8	75
Max. XMY (Baseline)	56,755	51.1	13.9	1,871.3	$19,741	902	101.3	830
Max. XMY (As-Designed)	40,258	28.5	12.7	1,833.8	$17,042	902	101.3	830
Min. XMY (Baseline)	51,514	44.9	14.1	2,156.7	$20,667	649	91.1	264
Min. XMY (As-Designed)	38,482	23.8	12.9	2,078.3	$18,242	177	84.7	36

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 103.8 to 94.3°F. In addition, the ECMs reduced the total hours of exposure indoors from 554 hours to 180 hours, a 67.5% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 0.0 and 9.5°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 0.0% and 86.4%.

REGION 6: TUG HILL PLATEAU



As expected, the ECMs reduced the summer electrical peak (44.9%), the annual electricity use (27.0%), the winter electrical peak (8.7%), and the annual natural gas use (3.9%). These savings translated to a 12.7% reduction in utility costs, or $2,564 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 27.0%; carbon dioxide emissions were reduced by 5.4%. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 12: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	39,434	27.0	12.6	1,963.8	$17,698	5.4	13.4	124.0	N/A
Improved Insulation	39,522	27.2	12.7	1,986.9	$17,850	5.4	13.5	125.4	32.2
Upgraded Windows	41,210	31.3	12.8	2,043.3	$18,441	5.6	14.1	129.1	44.5
High Albedo Roof	41,231	31.3	12.8	2,043.0	$18,443	5.6	14.1	129.1	10,450.0
Interior Lighting	51,351	39.6	13.8	2,027.3	$19,867	7.0	17.5	130.5	5.9
A/C Equipment	53,988	49.0	13.8	2,027.3	$20,262	7.4	18.4	131.1	25.8
Reduction	27.0%	44.9%	8.7%	3.9%	12.7%	27.0%	27.0%	5.4%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 41.8% and 44.9%, annual energy use between 25.3% and 29.0%, winter peak between 8.6% and 8.7%, and annual natural gas use between 2.2% and 3.7%. These reductions in electricity and natural gas use resulted in an 11.7% to 13.7% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 66.3% and 69.6%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

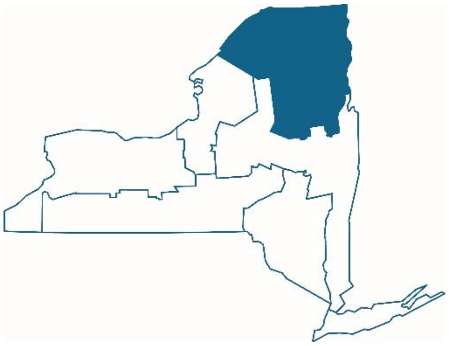
Table 13: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	53,988	49.0	13.9	2,027.3	$20,262	836	99.4	456
TMY, 1986-2015 (As-Designed)	39,434	27.0	12.7	1,963.8	$17,698	271	90.1	116
TMY, 2009-2015 (Baseline)	53,950	55.7	13.9	1,980.6	$19,976	753	90.0	367
TMY, 2009-2015 (As-Designed)	39,278	31.1	12.7	1,922.3	$17,426	252	85.0	80
Max. XMY (Baseline)	57,341	53.4	13.8	1,903.1	$20,020	922	102.6	857
Max. XMY (As-Designed)	40,739	31.1	12.6	1,861.8	$17,281	311	92.3	367
Min. XMY (Baseline)	51,509	42.7	14.0	2,176.4	$20,785	622	95.1	304
Min. XMY (As-Designed)	38,458	24.5	12.8	2,095.7	$18,343	189	86.3	50

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 99.4 to 90.1°F. In addition, the ECMs reduced the total hours of exposure indoors from 456 hours to 116 hours, a 74.6% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 5.0 and 10.3°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 57.2% and 83.6%.

REGION 7: ADIRONDACK MOUNTAINS



As expected, the ECMs reduced the summer electrical peak (45.0%), the annual electricity use (27.2%), the winter electrical peak (8.0%), and the annual natural gas use (3.6%). These savings translated to a 12.8% reduction in utility costs, or $2,541 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 27.2%; carbon dioxide emissions were reduced by 5.3%. All the ECMs, except interior lighting and insulation improvements, have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 14: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	39,310	28.5	12.6	1,893.1	$17,255	5.4	13.4	119.9	N/A
Improved Insulation	39,402	28.7	12.6	1,916.1	$17,407	5.4	13.4	121.2	32.2
Upgraded Windows	41,108	33.0	12.7	1,963.9	$17,949	5.6	14.0	124.4	48.5
High Albedo Roof	41,131	33.0	12.7	1,963.5	$17,951	5.6	14.0	124.4	10,450.0
Interior Lighting	51,289	41.4	13.7	1,948.7	$19,385	7.0	17.5	125.9	5.9
A/C Equipment	54,025	51.7	13.7	1,948.7	$19,796	7.4	18.4	126.5	24.8
Reduction	27.2%	45.0%	8.0%	3.6%	12.8%	27.2%	27.2%	5.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 43.1% and 44.9%, annual energy use between 26.0% and 29.7%, winter peak between 8.0% and 8.7%, and annual natural gas use between 1.9% and 3.3%. These reductions in electricity and natural gas use resulted in a 12.0% to 14.3% decrease in total annual energy cost. In all cases, the ECMs also reduced the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 59.1% and 70.3%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

Table 15: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	54,025	51.7	14.0	1,948.7	$19,796	849	105.0	648
TMY, 1986-2015 (As-Designed)	39,310	28.5	12.8	1,893.1	$17,255	268	95.1	216
TMY, 2009-2015 (Baseline)	54,173	48.2	13.7	1,858.0	$19,274	770	94.8	495
TMY, 2009-2015 (As-Designed)	39,189	26.6	12.6	1,813.4	$16,759	229	86.5	123
Max. XMY (Baseline)	58,420	55.2	13.8	1,819.5	$19,680	1,009	102.8	993
Max. XMY (As-Designed)	41,070	31.2	12.6	1,785.3	$16,872	308	92.6	498
Min. XMY (Baseline)	52,096	46.6	14.0	2,084.7	$20,323	604	93.4	327
Min. XMY (As-Designed)	38,561	26.5	12.8	2,016.3	$17,882	247	84.9	34

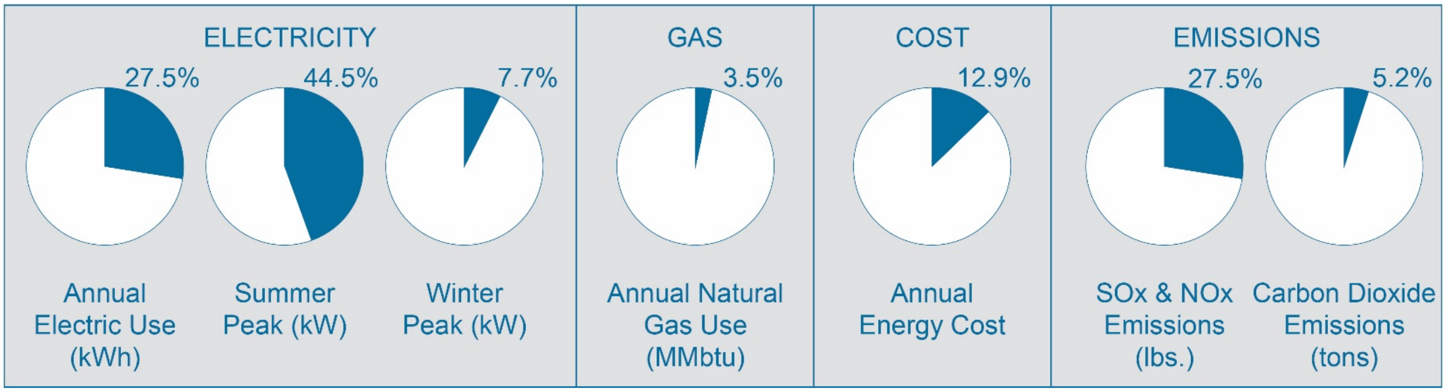
PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 105.0 to 95.1°F. In addition, the ECMs reduced the total hours of exposure indoors from 648 hours to 216 hours, a 66.7% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 8.2 and 10.3°F; the number of total hours where the interior temperature was over 82.4°F was reduced by between 49.8% and 89.6%.

STATEWIDE IMPACTS FOR LOW-RISE RESIDENTIAL BUILDINGS

The following tables take the average reductions in energy use from the baseline and upgraded systems and averages them across all seven ClimAID regions. The first section measures the reductions in statewide energy use, demand, cost and emissions. The second shows the difference in weather variability impact on energy use, demand, cost, and operations. Reductions for the first two sections are shown as a percentage in blue. The final section shows the difference in passive survivability impacts, with the baseline design represented in white and the upgraded design in blue.

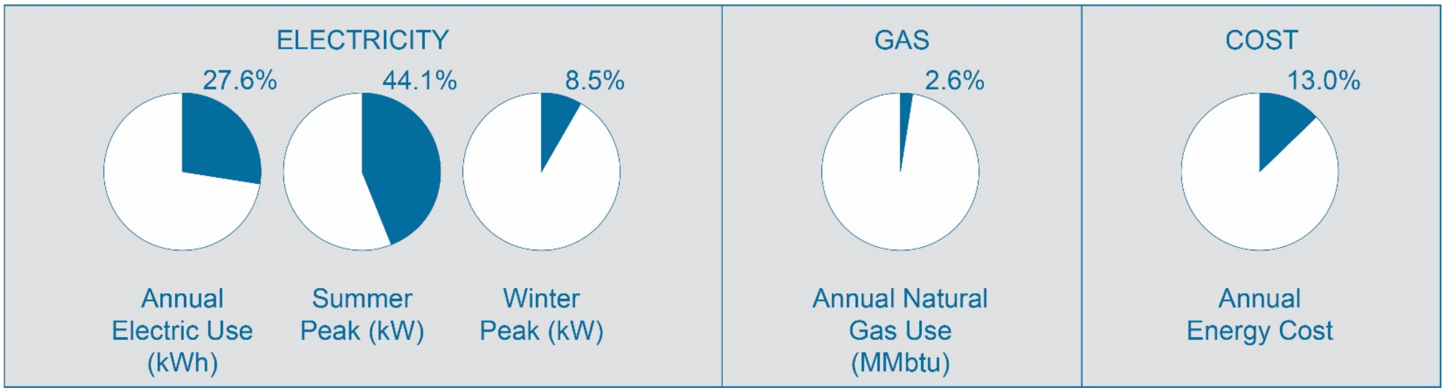
REDUCTIONS IN STATEWIDE ENERGY USE, DEMAND, COST, AND EMISSIONS IMPACTS



ECMs have positive impacts on energy use and cost across the State. Reductions are seen in every category, averaging at 27.5% for annual electric use, 44.5% for summer peak, 7.7% for winter peak, 3.5% for annual natural gas use, 12.9% for cost, 27.5% for air pollution from electrical generation, and 5.2% for carbon dioxide emissions.

While each ECM contributes to enhancing building performance, interior lighting improvements make the biggest difference among each ClimAID region. This measure alone reduces annual electric use by an average of 10,209 kWh and annual energy cost by an average of $1,441 per region for low-rise residential building types.

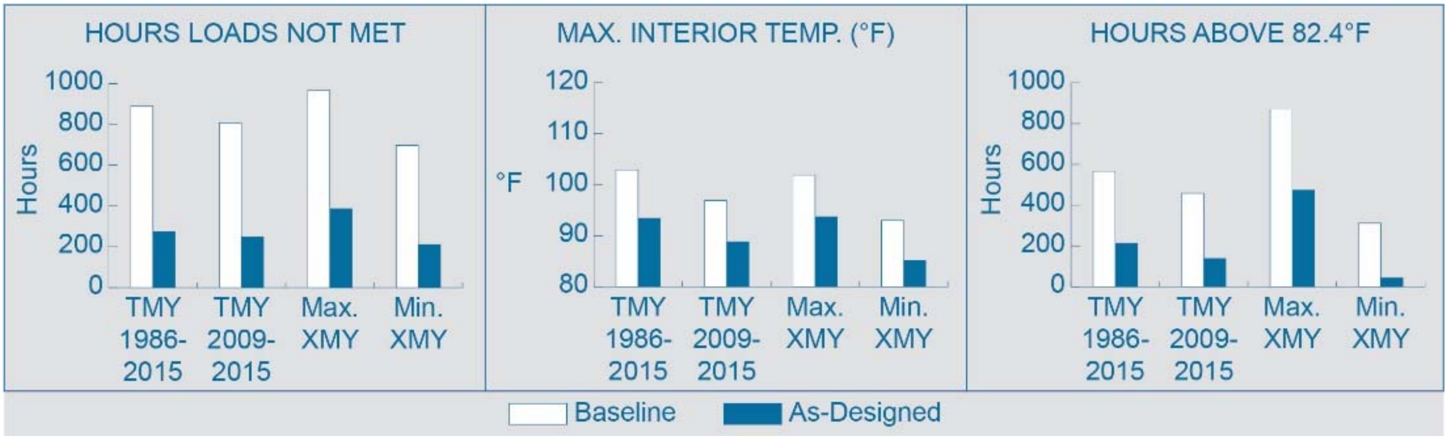
WEATHER VARIABILITY IMPACT ON ENERGY USE, DEMAND, COST, AND OPERATIONS



All four data sets show that ECMs improve energy performance in all seven ClimAID regions. While reductions are seen in every category investigated - 27.6% for annual energy use, 44.1% for summer peak, 8.5% for winter peak, 2.6% for annual fuel use, and 13.0% for annual energy cost, on average – the greatest seen across the State is in the hours of loads not met at a 66.8% reduction, on average.

Among all regions, the ECMs are particularly beneficial to energy performance during extreme temperature events, as seen in the comparison of the baseline and upgraded building for both the maximum and minimum XMY. Annual energy use and annual energy cost were reduced by averages of 29.6% and 14.2%, respectively, in every region during extreme warm temperatures. Annual fuel use was reduced by 4.9% on average during extreme cold temperatures. ClimAID Region 3 was exceptionally high in this category, with a reduction in annual fuel use during cold temperatures by 14.7%.

STATEWIDE PASSIVE SURVIVABILITY IMPACTS



All regions showed positive effects in passive survivability from ECMs. The maximum interior temperature saw a reduction of 9.3%, on average across the state. The greatest improvements over the baseline for maximum interior temperatures in Regions 1, 2, 6, and 7 were seen in the analysis of extreme warm temperatures (XMY).

In every region, there was a greater reduction in the number of hours that the interior temperature exceeded 82.4°F between 2009 and 2015 compared to that between 1986 and 2015. For example, with the application of ECMs, the number of hours over 82.4°F in Region 5 dropped from 554 to 180 (67.5%) from 1986 to 2015 while they dropped from 350 to 75 (78.6%) from 2009 to 2015 - an improvement of 11.1%. On average, reductions improved between the two time periods by 8.3%.

Multifamily Residential Building Case Study

In New York, there are approximately 705,260 multifamily residential buildings; they represent 13.4% of the total number of buildings in the State and 0.029% of the total floor area. The total value of the residential building stock is 1.71 trillion dollars; this is 73.3% of the total value of the entire building stock.

Because residential structures are externally load dominated, meaning that changes in solar radiation and outdoor temperature have greater impact on heating, ventilation, and air-conditioning (HVAC) system usage than other factors, they are particularly susceptible to climate change. In addition, because people spend significant time at home, and may shelter in place there during periods of extreme weather, improving the performance of HVAC systems in residences is critical to increase the resilience of the building stock.

GLENDALE HOMES

Figure 2: Screenshot of the building energy model in eQuest

METHODOLOGY

The multifamily residential building energy model was based on a 151,853 square foot in-patient nursing facility in Glenville, New York. The three story building has a steel frame and concrete plank structural system. It functions as both residential, with sleeping, dining, and living areas, as well as commercial space with common areas and offices.

Offices, common areas, and sleeping units are serviced by packaged variable volume rooftop units with energy recovery wheels, dining areas by constant volume air-handlers, and stairwells by cabinet unit's heaters. Spatial temperatures are controlled by programmable thermostats. The building sits in between three parking lots, one each to the north, east, and west sides; these details were not included in the energy model. The long axis of the building is oriented north-south.

The methodology used for this study is based on the Chartered Institution of Building Services Engineers (CIBSE) report "Climate change and the indoor environment: impacts and adaptation" and the NYSERDA New Construction Program Simulation Guidelines. Models were run in eQuest version 3.61 using the files originally created by L&S Energy Services for a 2008 Technical Assistance Study in Support of the New Construction Program (NCP 10341).

Table 16: Energy Conservation Measures, System Descriptions, Effective Useful Life, and Incremental Costs

ECMs	Baseline System Description†	Upgraded System Description	EUL (years)	Cost ($)
High Performance Envelope	R-20 continuous insulation in the roof and R-13 insulation in the walls.	R-40 continuous insulation in the roof and R-26.9 insulation in the walls.	50	$200,900
High Performance Glazing	Glazing with a solar heat gain coefficient of 0.40 and a U-value of 0.55.	Glazing with a solar heat gain coefficient of 0.25 and a U-value of 0.28.	30	$65,800

†The New York State Energy Conservation Code of 1999 was the baseline used for the analysis.

Using a package minus approach for the modeling, the building systems were downgraded in steps from the as-designed configuration to code compliant systems, starting first with the energy conservation measures (ECMs) that have the longest effective useful life (EUL) (Table 16). The building was modeled with the as-designed HVAC systems to understand the impact of design changes on energy usage, demand, operating costs, and $SO_x/NO_X/CO_2$ emissions.

After the energy conservation measures were modeled, the next set of runs investigated the cumulative effect of the strategies on passive survivability. Both the maximum interior temperature and the number of hours above 82.4°F were modeled; 82.4°F (28°C) is a threshold used by CIBSE as a proxy for high heat exposure.

Although the CIBSE study used future weather year data to investigate overheating for buildings in the United Kingdom, this study did not project results into the future because similar files are not currently available for New York State. In addition, changes in the average air temperature tend to have less impact on the operation of HVAC systems; the peak heating and cooling loads experienced during a heat wave or cold spell typically determine the size of a building system and its impact on energy demand.

To this end, for the third and final set of energy modeling runs, the baseline and upgraded buildings were compared using four sets of meteorological data prepared by Weather Analytics:

1) Typical Meteorological Year (TMY) Data:

   i. TMY, 1986 – 2015, 30 years
   ii. TMY, 2009 – 2015, 6 years

   TMY are data sets of hourly values of solar radiation and meteorological elements for a one-year period. They are typically used for computer simulations of solar or building HVAC systems. Because they represent typical rather than extreme conditions, they are not useful for designing systems to meet the worst-case conditions occurring at a location. Although TMY are available from the National Renewable Energy Laboratory for most cities in the United States, these files cover the period 1991-2005 in New York State. Weather Analytics created custom TMY data for multiple sites across the State using more current data, specifically the period 1986 to 2015 and 2009 to 2015. This second set of files promotes understanding of how recent warming may impact building system performance.

2) eXtreme Meteorological Year (XMY) Data:

   i. XMY MAX, 2001 – 2015, 15 years
   ii. XMY MIN, 2001 – 2015, 15 years

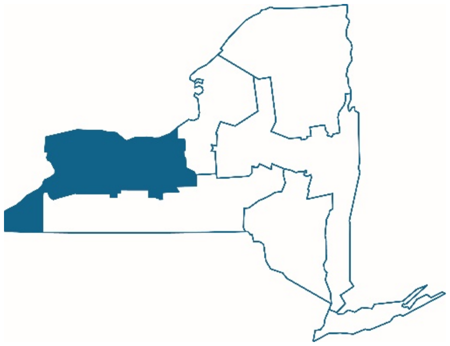
   Weather Analytics also created XMY files to examine the extreme cases occurring over the last 15 years. XMY files are created by using historical data to determine the maximum and minimum of a variable on a monthly basis. For example, if temperature is requested over a period of 15 years, the XMY MAX file will consist of the warmest months that occurred over the past 15 years, while the XMY MIN file will consist of the coolest (based on averages). Along with the extreme temperatures, the consequent data (e.g., solar radiation, wind speed) from the extreme month is also carried over to the XMY file, keeping consistency between each variable.

The results from this portion of the study indicate how weather variability may impact energy usage, demand, and operating costs. The number of hours the systems could not keep up with heating and cooling loads were also calculated, as well as the maximum interior temperature and number of hours above 82.4°F.

REGIONAL PROFILES

The following section outlines the results for each of the seven ClimAID regions. Following the profiles, a discussion of the statewide impacts for low-rise residential buildings is presented.

REGION 1: WESTERN NEW YORK AND THE GREAT LAKES PLAIN



As expected, the ECMs reduced the summer electrical peak (3.4%), the annual electricity use (0.2%), the winter electrical peak (5.1%), and the annual natural gas use (9.6%). These savings translated to a 1.4% reduction in utility costs, or $4,748 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.2%; carbon dioxide emissions were reduced by 4.8%. Unlike glazing improvements, high-performance envelope improvements have a payback period longer than its expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 17: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,945,926	440.0	293.8	6,546.6	$331,169	266.6	663.6	834.5	N/A
High Performance Envelope	1,946,702	444.6	297.0	6,818.0	$332,913	266.7	663.8	850.5	115.2
High Performance Glazing	1,949,724	455.5	309.5	7,243.0	$335,917	267.1	664.9	876.1	21.9
Reduction	0.2%	3.4%	5.1%	9.6%	1.4%	0.2%	0.2%	4.8%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 2.3% and 3.7%, annual energy use between 0.1% and 0.4%, and annual natural gas use between 90.9% and 91.0%. The winter peak was increased in all four sets of data by between 0.2% and 0.4%. These reductions in electricity and natural gas use resulted in a 1.3% to 1.4% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

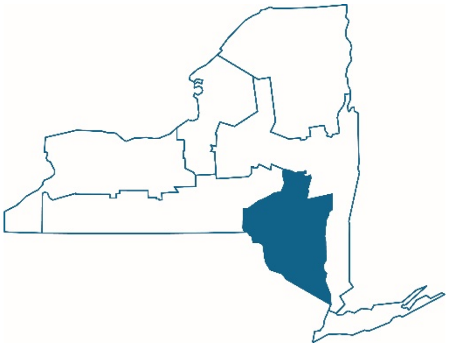
Table 18: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,949,724	455.5	304.6	72,430.0	$335,917	0	86.0	175
TMY, 1986-2015 (As-Designed)	1,945,926	440.1	305.5	6,546.6	$331,169	0	86.0	76
TMY, 2009-2015 (Baseline)	1,949,978	434.0	304.5	69,194.0	$334,013	0	86.0	199
TMY, 2009-2015 (As-Designed)	1,946,182	420.5	305.5	6,254.0	$329,452	0	85.6	96
Max. XMY (Baseline)	2,010,022	483.1	304.2	53,077.0	$333,349	0	86.7	341
Max. XMY (As-Designed)	2,001,372	465.2	305.3	4,801.7	$329,016	0	86.0	203
Min. XMY (Baseline)	1,908,524	418.5	304.9	85,532.0	$337,598	0	85.7	37
Min. XMY (As-Designed)	1,907,147	409.0	305.6	7,772.2	$332,705	0	83.1	7

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs did not change the maximum interior temperature, which stayed at 86.0°F, but reduced the total hours of exposure indoors from 175 hours to 76 hours, a 56.6% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 0.0 and 2.6°F; the total number of hours where the interior temperature was over 82.4°F was reduced by between 40.5% and 81.1%.

REGION 2: CATSKILL MOUNTAINS AND WEST HUDSON RIVER VALLEY



As expected, the ECMs reduced the summer electrical peak (3.3%), the annual electricity use (0.2%), the winter electrical peak (9.7%), and the annual natural gas use (9.1%). These savings translated to a 1.3% reduction in utility costs, or $4,311 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.2%; carbon dioxide emissions were reduced by 4.3%. Unlike glazing improvements, high performance envelope improvements have a payback period longer than its expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 19: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,978,172	461.0	281.6	6,196.8	$333,907	271.0	674.6	821.5	N/A
High Performance Envelope	1,979,588	465.9	282.6	6,455.3	$335,670	271.2	675.0	836.9	114.0
High Performance Glazing	1,982,221	476.9	312.0	6,814.2	$338,218	271.6	675.9	858.5	25.8
Reduction	0.2%	3.3%	9.7%	9.1%	1.3%	0.2%	0.2%	4.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 4.1% and 1.7%, annual energy use between 0.1% and 0.3%, and annual natural gas use between 90.8% and 90.9%. The winter peak increased in all four sets of data by between 0.3% and 0.4%. These reductions in electricity and natural gas use resulted in a 0.9% to 1.3% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

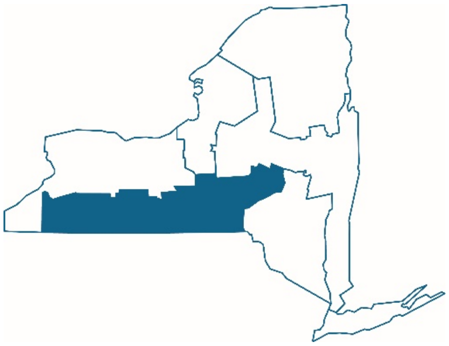
Table 20: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,982,221	476.9	304.4	68,142.0	$338,218	0	87.2	239
TMY, 1986-2015 (As-Designed)	1,978,172	461.4	305.5	6,196.8	$333,906	0	85.9	128
TMY, 2009-2015 (Baseline)	1,982,243	481.0	304.5	67,865.0	$338,055	0	85.7	172
TMY, 2009-2015 (As-Designed)	1,977,248	463.8	305.5	6,177.3	$333,651	0	86.0	82
Max. XMY (Baseline)	2,037,209	530.5	304.0	50,795.0	$336,058	0	88.0	352
Max. XMY (As-Designed)	2,034,873	508.8	305.3	4,634.4	$333,038	0	85.9	199
Min. XMY (Baseline)	1,926,014	405.6	304.9	82,707.0	$338,526	0	85.6	91
Min. XMY (As-Designed)	1,924,969	398.8	305.7	7,605.2	$334,376	0	85.2	36

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 87.2 to 85.9°F. In addition, the ECMs reduced the total hours of exposure indoors from 239 hours to 128 hours, a 46.4% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 0.5 and 2.1°F; the total number of hours where the interior temperature was over 82.4°F was reduced by between 43.5% and 60.4%.

REGION 3: SOUTHERN TIER



As expected, the ECMs reduced the summer electrical peak (2.1%), the annual electricity use (0.2%), the winter electrical peak (1.8%), and the annual natural gas use (9.2%). These savings translated to a 1.4% reduction in utility costs, or $4,656 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.2%; carbon dioxide emissions were reduced by 4.6%. Unlike glazing improvements, high performance envelope improvements have a payback period longer than its expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 21: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,927,290	437.4	300.9	6,721.8	$329,424	264.0	657.2	840.4	N/A
High Performance Envelope	1,930,981	440.0	299.9	7,008.8	$331,700	264.5	658.5	858.0	88.3
High Performance Glazing	1,931,222	446.9	305.5	7,399.6	$334,080	264.6	658.5	880.9	27.6
Reduction	0.2%	2.1%	1.8%	9.2%	1.4%	0.2%	0.2%	4.6%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 1.9% and 3.4% and annual natural gas use between 90.9% and 91.0%. For the 30-year TMY analysis (1986-2015) and the Weather Analytics “Max” XMY data, annual energy use reduced by 0.2%, while for the seven-year TMY analysis (2009-2015) and the Weather Analytics “Min” XMY data, annual energy use increased by between 0.01% and o.3%. For all four sets of weather data, the ECMs increased winter peak by between 0.2% and o.3%. These reductions in electricity and natural gas use resulted in a 1.0% to 1.4% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

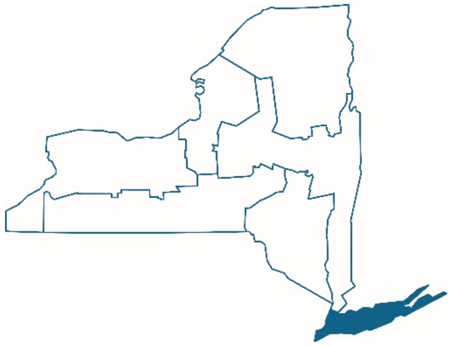
Table 22: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,931,222	446.9	304.5	73,996.0	$334,080	0	85.8	126
TMY, 1986-2015 (As-Designed)	1,927,290	437.6	305.5	6,721.8	$329,425	0	85.6	60
TMY, 2009-2015 (Baseline)	1,956,623	475.3	304.7	71,206.0	$336,216	0	85.8	153
TMY, 2009-2015 (As-Designed)	1,961,797	466.4	305.6	6,456.4	$333,008	0	85.8	70
Max. XMY (Baseline)	1,999,384	495.5	304.2	54,081.0	$332,357	0	85.6	169
Max. XMY (As-Designed)	1,994,594	478.5	305.2	4,887.0	$328,511	0	86	46
Min. XMY (Baseline)	1,905,887	408.5	304.9	88,208.0	$338,808	0	85.6	46
Min. XMY (As-Designed)	1,906,103	398.5	305.6	8,031.4	$334,104	0	83.2	6

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 85.8 to 85.6°F. In addition, the ECMs reduced the total hours of exposure indoors from 126 hours to 60 hours, a 52.4% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 0.0 and 2.4°F; the total number of hours where the interior temperature was over 82.4°F was reduced by between 52.4% and 87.0%.

REGION 4: NEW YORK CITY AND LONG ISLAND



As expected, the ECMs reduced the summer electrical peak (3.5%), the annual electricity use (0.3%), the winter electrical peak (0.8%), and the annual natural gas use (9.2%). These savings translated to a 1.3% reduction in utility costs, or $4,330 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.3%; carbon dioxide emissions were reduced by 4.2%. Unlike glazing improvements, high performance envelope improvements have a payback period longer than its expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 23: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,988,936	433.1	305.9	5,467.6	$331,146	272.5	678.2	781.3	N/A
High Performance Envelope	1,990,136	437.1	308.2	5,696.8	$332,701	272.6	678.6	795.0	129.2
High Performance Glazing	1,995,632	448.8	306.9	6,021.9	$335,476	273.4	680.5	815.3	23.7
Reduction	0.3%	3.5%	0.8%	9.2%	1.3%	0.3%	0.3%	4.2%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 2.9% and 4.5%, annual energy use between 0.3% and 0.9%, and annual natural gas use by 90.9%. The winter peak increased in all four sets of data by between 0.3% and 0.4%. The reductions in electricity and natural gas use resulted in a 1.3% to 1.8% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

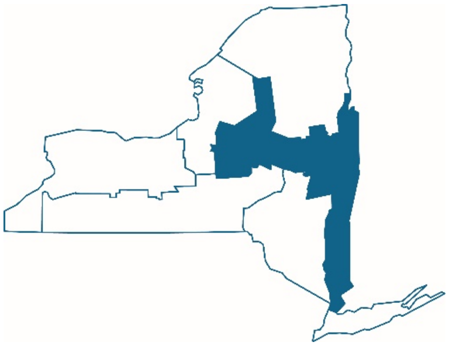
Table 24: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,995,632	448.8	304.3	60,219.0	$335,476	0	85.8	241
TMY, 1986-2015 (As-Designed)	1,988,936	433.2	305.4	5,467.6	$331,146	0	86.0	120
TMY, 2009-2015 (Baseline)	2,020,761	478.4	304.4	59,218.0	$338,645	0	85.8	182
TMY, 2009-2015 (As-Designed)	2,001,572	456.7	305.4	5,379.6	$332,513	0	85.9	101
Max. XMY (Baseline)	2,080,674	495.6	304.1	42,823.0	$337,795	0	97.2	2,628
Max. XMY (As-Designed)	2,064,719	477.8	305.3	3,907.9	$333,155	0	93.5	2,300
Min. XMY (Baseline)	1,953,007	433.8	304.7	72,470.0	$336,433	0	85.8	107
Min. XMY (As-Designed)	1,946,348	421.2	305.5	6,593.6	$331,514	0	85.4	47

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs increased the maximum interior temperature from 85.8°F to 86.0°F and reduced the total hours of exposure indoors from 241 hours to 120 hours, a 50.2% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total number of hours where the interior temperature was over 82.4°F was reduced by between 12.5% and 56.1%. The maximum interior temperature only saw significant reductions in the maximum XMY data set, reducing exposure to high temperatures from 97.2 to 93.5°F, a 3.8% reduction.

REGION 5: EAST HUDSON AND·MOHAWK RIVER VALLEYS



As expected, the ECMs reduced the summer electrical peak (2.3%), the annual electricity use (0.05%), the winter electrical peak (0.1%), and the annual natural gas use (9.9%). These savings translated to a 1.3% reduction in utility costs, or $4,374 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.05%; carbon dioxide emissions were reduced by 4.9%. Unlike glazing improvements, high performance envelope improvements have a payback period longer than its expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 25: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,929,339	441.4	305.8	6,735.7	$329,815	264.3	657.9	841.7	N/A
High Performance Envelope	1,929,698	442.4	306.0	7,038.6	$331,687	264.4	658.0	859.5	107.3
High Performance Glazing	1,928,791	451.9	306.0	7,478.3	$334,189	264.2	657.7	885.0	26.3
Reduction	0.05%	2.3%	0.1%	9.9%	1.3%	0.05%	0.05%	4.9%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 2.3% and 3.7% and annual natural gas use between 90.9% and 91.0%. For the 30-year TMY analysis (1986-2015), annual energy use increased by 0.03%. In the other three cases, annual energy use decreased by between 0.09% and 0.4%. The winter peak increased in all four sets of data by 0.3%. These reductions in electricity and natural gas use resulted in a 1.3% to 1.7% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

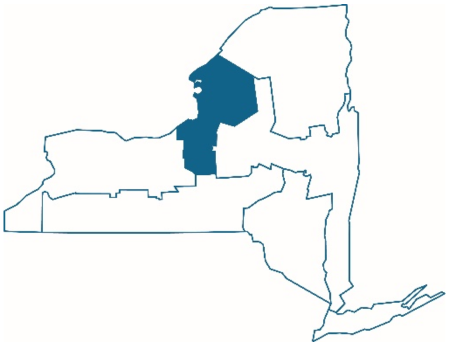
Table 26: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,928,787	451.9	304.7	74,783.0	$334,188	0	85.1	104
TMY, 1986-2015 (As-Designed)	1,929,339	441.7	305.5	6,735.7	$329,815	0	85.8	34
TMY, 2009-2015 (Baseline)	1,946,186	455.9	304.8	72,135.0	$335,209	0	86.0	131
TMY, 2009-2015 (As-Designed)	1,944,458	442.2	305.8	6,517.8	$330,775	0	85.8	59
Max. XMY (Baseline)	1,990,118	489.9	304.3	55,581.0	$331,867	0	90.0	557
Max. XMY (As-Designed)	1,984,550	471.7	305.3	5,002.6	$327,698	0	87.1	332
Min. XMY (Baseline)	1,910,157	402.1	305.0	89,724.0	$340,358	0	85.3	45
Min. XMY (As-Designed)	1,902,829	391.0	305.9	8,200.2	$334,626	0	84.2	6

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs increased the maximum interior temperature from 85.1 to 85.8°F and reduced the total hours of exposure indoors from 104 hours to 34 hours, a 67.3% improvement over the baseline, code compliant building. For all four sets of weather data, the hours where the interior temperature was over 82.4°F was reduced by between 40.4% and 86.7%. The total exposure to high temperature was reduced in all data sets, besides the 30-year TMY analysis, by between 0.2 and 2.9°F.

REGION 6: TUG HILL PLATEAU



As expected, the ECMs reduced the summer electrical peak (3.0%), the annual electricity use (0.03%), the winter electrical peak (2.3%), and the annual natural gas use (9.4%). These savings translated to a 1.4% reduction in utility costs, or $4,654 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.03%; carbon dioxide emissions were reduced by 4.8%. Unlike glazing improvements, high performance envelope improvements have a payback period longer than its expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 27: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,937,667	435.0	299.8	7,315.1	$334,541	265.5	660.7	877.5	N/A
High Performance Envelope	1,938,321	437.3	300.5	7,608.2	$336,397	265.5	661.0	894.8	108.2
High Performance Glazing	1,938,303	448.3	307.0	8,075.0	$339,195	265.5	661.0	922.1	23.5
Reduction	0.03%	3.0%	2.3%	9.4%	1.4%	0.03%	0.03%	4.8%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 2.1% and 3.7% and annual natural gas use between 90.9% and 91.0%. For the Weather Analytics “Min” XMY data, annual energy use increased by 0.01%. In the other three cases, annual energy use decreased by between 0.03% and 0.3%. The winter peak increased in all four sets of data by between 0.2% and 0.4%. These reductions in electricity and natural gas use resulted in a 1.3% to 1.5% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

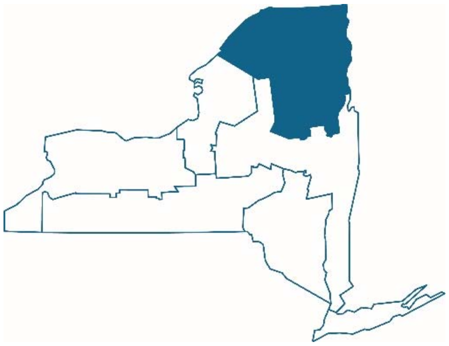
Table 28: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,938,303	448.3	304.7	80,750.0	$339,195	0	85.9	119
TMY, 1986-2015 (As-Designed)	1,937,667	435.1	305.5	7,315.1	$334,541	0	85.5	51
TMY, 2009-2015 (Baseline)	1,954,020	504.6	304.6	77,695.0	$339,720	0	85.9	114
TMY, 2009-2015 (As-Designed)	1,951,728	485.7	305.5	7,051.0	$335,065	0	85.5	53
Max. XMY (Baseline)	1,999,222	485.3	304.2	60,461.0	$336,160	0	87.2	402
Max. XMY (As-Designed)	1,993,070	467.4	305.3	5,468.1	$331,769	0	86.1	209
Min. XMY (Baseline)	1,904,985	407.7	305.1	95,049.0	$342,777	0	85.8	57
Min. XMY (As-Designed)	1,905,104	399.3	305.7	8,670.9	$337,791	0	85.7	12

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 85.9 to 85.5°F. In addition, the ECMs reduced the total hours of exposure indoors from 119 hours to 51 hours, a 57.1% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 0.1 and 1.1°F; the total number of hours where the interior temperature was over 82.4°F was reduced by between 48.0% and 78.9%.

REGION 7: ADIRONDACK MOUNTAINS



As expected, the ECMs reduced the summer electrical peak (2.9%), the annual electricity use (0.2%), the winter electrical peak (0.3%), and the annual natural gas use (8.9%). These savings translated to a 1.1% reduction in utility costs, or $3,869 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 0.2%; carbon dioxide emissions were reduced by 4.4%. Both ECMs have payback periods longer than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 29: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,948,489	454.3	305.7	7,197.8	$335,460	266.9	664.4	873.1	N/A
High Performance Envelope	1,949,313	456.4	305.7	7,488.6	$337,328	267.1	664.7	890.3	107.5
High Performance Glazing	1,946,228	467.7	306.7	7,899.2	$339,329	266.6	663.7	913.6	32.9
Reduction	0.2%	2.9%	0.3%	8.9%	1.1%	0.2%	0.2%	4.4%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 2.7% and 4.2% and annual natural gas use by 90.9%. For the Weather Analytics “Max” XMY data, the annual energy use reduced by 0.4%. For the other three sets of data, the annual energy use increased by between 0.02% and 0.7%. The winter peak increased in all four sets of data by between 0.3% and 0.4%. These reductions in electricity and natural gas use resulted in a 0.5% to 1.4% decrease in total annual energy cost. In all four sets of data, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment remained at zero for both the baseline and as-designed building models.

Table 30: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,946,228	467.7	304.6	78,992.0	$339,329	0	87.0	171
TMY, 1986-2015 (As-Designed)	1,948,489	454.6	305.5	7,197.8	$335,460	0	85.9	73
TMY, 2009-2015 (Baseline)	1,937,427	446.5	304.8	72,203.0	$333,936	0	85.9	133
TMY, 2009-2015 (As-Designed)	1,950,964	434.7	305.8	6,598.4	$332,235	0	85.7	61
Max. XMY (Baseline)	2,018,881	504.7	304.2	58,013.0	$337,640	0	88.6	497
Max. XMY (As-Designed)	2,010,807	483.5	305.4	5,282.5	$333,316	0	86.0	278
Min. XMY (Baseline)	1,916,305	422.6	304.9	93,131.0	$343,324	0	85.8	87
Min. XMY (As-Designed)	1,916,769	410.8	305.8	8,515.5	$338,608	0	85.6	32

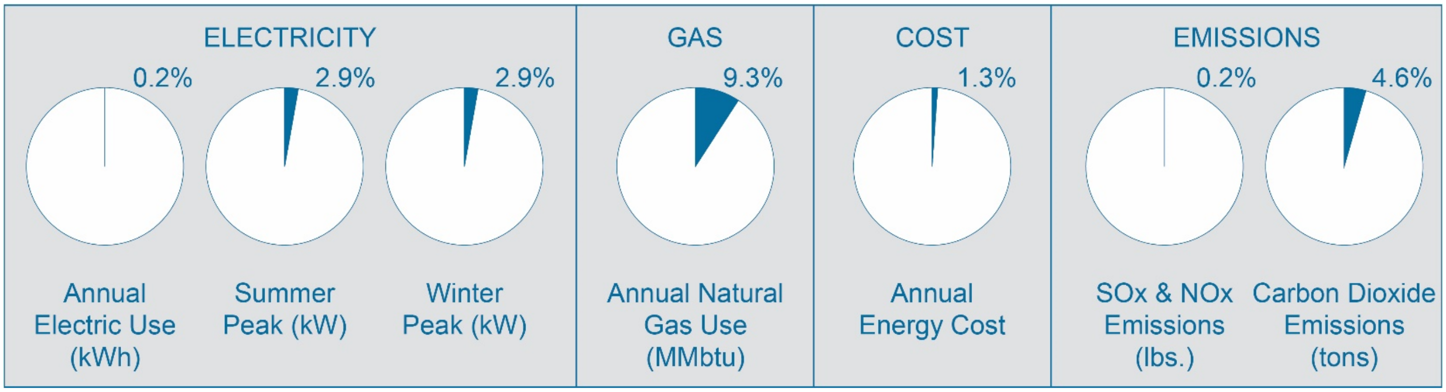
PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 87.0 to 85.9°F. In addition, the ECMs reduced the total hours of exposure indoors from 171 hours to 73 hours, a 57.3% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 0.2 and 2.6°F; the total number of hours where the interior temperature was over 82.4°F was reduced by between 44.1% and 63.2%.

STATEWIDE IMPACTS FOR MULTIFAMILY RESIDENTIAL BUILDINGS

The following tables take the average reductions in energy use from the baseline and upgraded systems and averages them across all seven ClimAID regions. The first section measures the reductions in statewide energy use, demand, cost and emissions. The second shows the difference in weather variability impact on energy use, demand, cost, and operations. Reductions for the first two sections are shown as a percentage in blue. The final section shows the difference in passive survivability impacts, with the baseline design represented in white and the upgraded design in blue.

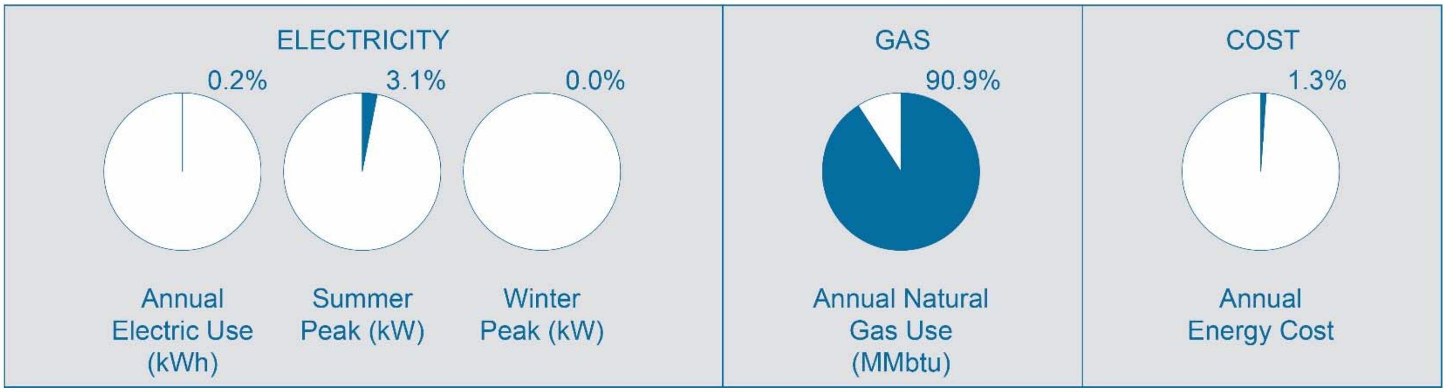
REDUCTIONS IN STATEWIDE ENERGY USE, DEMAND, COST, AND EMISSIONS IMPACTS



ECMs had positive impacts on energy use and cost across the State. Reductions are seen in every category, averaging at 0.2% for annual electric use, 2.9% for summer peak, 2.9% for winter peak, 9.3% for annual natural gas use, 1.3% for cost, 0.2% for air pollution from electrical generation, and 4.6% for carbon dioxide emissions.

While each ECM contributes to enhancing building performance, the addition of high-performance glazing made the biggest difference among each ClimAID region. This measure alone reduced annual electric use by an average of 2,200 kWh, annual fuel use by an average of 403 MMbtu, and annual energy cost by an average of $2,573 per region for multifamily residential building types.

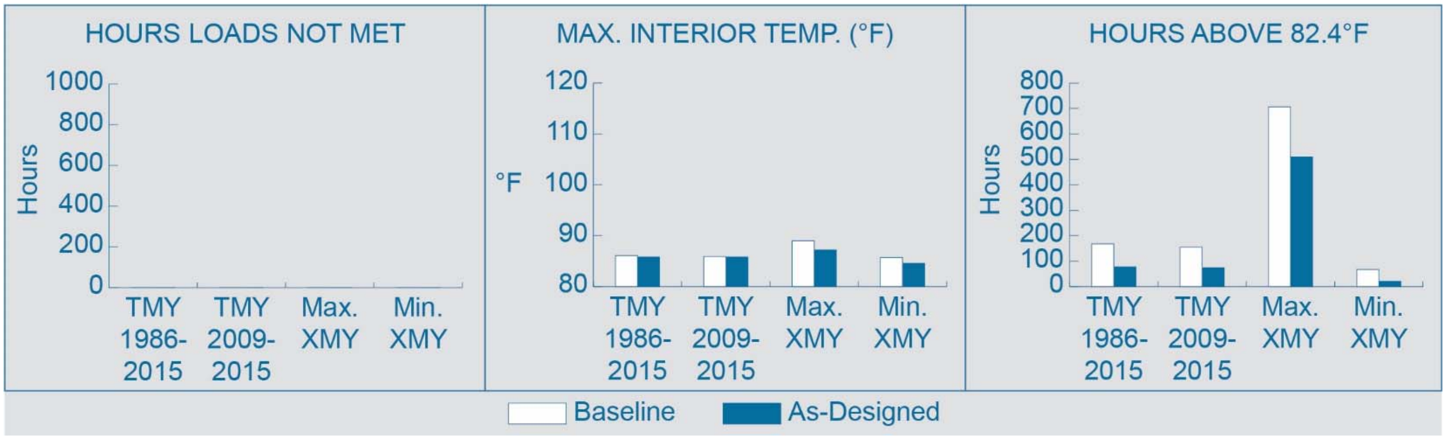
WEATHER VARIABILITY IMPACT ON ENERGY USE, DEMAND, COST, AND OPERATIONS



All four data sets show that ECMs improve energy performance in all seven ClimAID regions. While reductions are seen in most of the categories investigated – 0.2% for annual energy use, 3.1% for summer peak, and 1.3% for annual energy cost, on average – the greatest seen across the State was a reduction of 90.9% for annual fuel use, on average. The ECMs caused a slight increase in winter peak, by an average of 0.3%.

Among all regions, the ECMs are particularly beneficial to energy performance during extreme temperature events, as seen in the comparison of the baseline and upgraded building for both the maximum and minimum XMY. Summer electrical peak and annual energy use were reduced by averages of 3.8% and 0.3%, respectively, during extreme warm temperatures. Annual energy cost saw the greatest improvement during the minimum XMY analysis, with a 1.5% average reduction.

STATEWIDE PASSIVE SURVIVABILITY IMPACTS



All regions showed positive effects in passive survivability from ECMs. The maximum interior temperature saw a reduction of 0.9%, on average across the state. The greatest improvements over the baseline for maximum interior temperatures in Regions 2, 4, 5, 6, and 7 were seen in the analysis of extreme warm temperatures (XMY), reducing by an average 2.7%.

All regions, except Region 3, saw significant reductions in the number of hours exceeding an interior temperature of 82.4°F, reducing statewide by an average of 43.8%. The greatest improvements over the baseline building were seen in the minimum XMY data set where the number of total hours of exposure indoors was reduced by 73.3%, on average.

Commercial Building Case Study

In New York, there are approximately 322,549 commercial buildings; they represent 6.11% of the total number of buildings in the State and 0.016% of the total floor area. Commercial buildings play a crucial function in recovery efforts from climate change and hazards.

PRICE CHOPPER MADISON

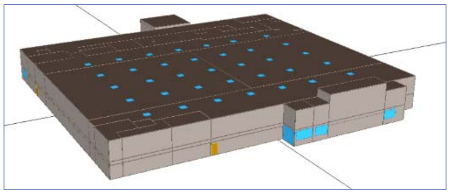


Figure 3: Screenshot of the building energy model in eQuest

METHODOLOGY

The commercial building energy model was based on a 37,094 square foot supermarket built in Madison, New York in 2009. The single-story building uses tilt-up concrete construction for the building shell. The roof consists of a metal frame and a metal deck covered with standard seam roofing.

Packaged rooftop air conditioners will meet most of the building's heating and cooling needs. The building's lighting system is comprised of T5 and T8 fixtures, compact fluorescents, LEDs, incandescent, and metal halides, and sensors are used to reduce the reliance on artificial light during daytime hours. The building will operate as a supermarket 24/7 with the bakery and food service area operating under a 6am to 9pm schedule.

The methodology used for this study is based on the Chartered Institution of Building Services Engineers (CIBSE) report "Climate change and the indoor environment: impacts and adaptation" and the NYSERDA New Construction Program Simulation Guidelines. Models were run in eQuest version 3.62 using the files originally created by L&S Energy Services for a 2008 Technical Assistance Study in Support of the New Construction Program (NCP 8234).

Table 31: Energy Conservation Measures, System Descriptions, Effective Useful Life, and Incremental Costs

ECMs	Baseline System Description†	Upgraded System Description	EUL (years)	Cost ($)
Above Code Insulation	Steel-framed walls U=0.84, and roofs with insulation entirely above deck U=0.063.	Above code insulation in the exterior walls and roof.	50	$19,600
Daylighting and Lighting Controls	Occupancy sensors in classrooms, conference/meeting rooms, and break rooms. Lighting timers were installed.	Daylighting and lighting controls	30	$5,100
Above Code Glazing	Glazing for all sides has a U-value of 0.57 and a solar heat gain coefficient (SHGC) of 0.49.	Glazing with a U-value of 0.29 and a solar heat gain coefficient (SHGC) of 0.43.	30	$500
Energy Efficient HVAC System	Standard efficiency HVAC system	Energy-efficient HVAC system	15	$3,000
Energy Efficient Lighting Design	Standard efficiency lighting fixtures with a LPD of 1.49 w/sf.	High efficiency lighting fixtures with a LPD of 1.09 w/sf.	15	$42,000
Premium Efficiency Motors	Standard efficiency motors	Premium efficiency motors	15	$900

†The New York State Energy Conservation Code of 1999 was the baseline used for the analysis.

Using a package minus approach for the modeling, the building systems were downgraded in steps from the as-designed configuration to code compliant systems, starting first with the energy conservation measures (ECMs) that have the longest effective useful life (EUL) (Table 1). The building was modeled with the as-designed HVAC systems to understand the impact of design changes on energy usage, demand, operating costs, and $SO_x/NO_X/CO_2$ emissions.

After the energy conservation measures were modeled, the next set of runs investigated the cumulative effect of the strategies on passive survivability. Both the maximum interior temperature and the number of hours above 82.4°F were modeled; 82.4°F (28°C) is a threshold used by CIBSE as a proxy for high heat exposure.

Although the CIBSE study used future weather year data to investigate overheating for buildings in the United Kingdom, this study did not project results into the future because similar files are not currently available for New York State. In addition, changes in the average air temperature tend to have less impact on the operation of HVAC systems; the peak heating and cooling loads experienced during a heat wave or cold spell typically determine the size of a building system and its impact on energy demand.

To this end, for the third and final set of energy modeling runs, the baseline and upgraded buildings were compared using four sets of meteorological data prepared by Weather Analytics:

1) Typical Meteorological Year (TMY) Data:

   i. TMY, 1986 – 2015, 30 years
   ii. TMY, 2009 – 2015, 6 years

   TMY are data sets of hourly values of solar radiation and meteorological elements for a 1-year period. They are typically used for computer simulations of solar or building HVAC systems. Because they represent typical rather than extreme conditions, they are not use for designing systems to meet the worst-case conditions occurring at a location. Although TMY are available from the National Renewable Energy Laboratory for most cities in the United States, these files cover the period 1991-2005 in New York State. Weather Analytics created custom TMY data for multiple sites across the state using more current data, specifically the period 1986 to 2015 and 2009 to 2015. This second set of files promotes understanding of how recent warming may impact building system performance.

2) eXtreme Meteorological Year (XMY) Data:

   i. XMY MAX, 2001 – 2015, 15 years
   ii. XMY MIN, 2001 – 2015, 15 years

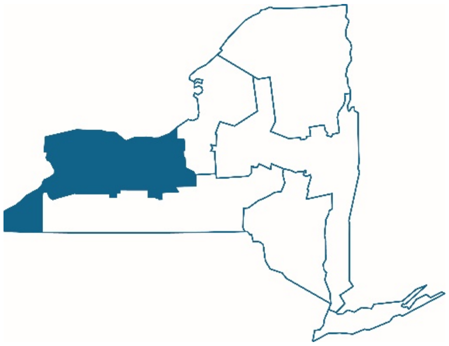
   Weather Analytics also created XMY files to examine the extreme cases occurring over the last 15 years. XMY files are created by using historical data to determine the maximum and minimum of a variable on a monthly basis. For example, if temperature is requested over a period of 15 years, the XMY MAX file will consist of the warmest months that occurred over the past 15 years, while the XMY MIN file will consist of the coolest (based on averages). Along with the extreme temperatures, the consequent data (e.g., solar radiation, wind speed) from the extreme month is also carried over to the XMY file, keeping consistency between each variable.

The results from this portion of the study indicate how weather variability may impact energy usage, demand, and operating costs. The number of hours the systems could not keep up with heating and cooling loads were also calculated, as well as the maximum interior temperature and number of hours above 82.4°F.

REGIONAL PROFILES

The following section outlines the results for each of the seven ClimAID regions. Following the profiles, a discussion of the statewide impacts for commercial buildings is presented.

REGION 1: WESTERN NEW YORK AND THE GREAT LAKES PLAIN



As expected, the ECMs reduced the summer electrical peak (19.9%), the annual electricity use (16.1%), the winter electrical peak (17.3%), and the annual natural gas use (3.7%). These savings translated to a 14.2% reduction in utility costs, or $32,841 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 16.1%; carbon dioxide emissions were reduced by 9.1%. With the exception of glazing improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 32: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,111,135	183.6	140.1	5,411.2	$199,137	152.2	378.9	574.3	N/A
Above Code Insulation	1,114,912	186.5	140.3	5,526.6	$200,397	152.7	380.2	582.0	15.6
Daylighting and Lighting Controls	1,165,576	200.0	148.1	5,489.3	$207,772	159.7	397.5	591.5	0.7
Above Code Glazing	1,165,585	200.1	148.1	5,491.1	$207,785	159.7	397.5	591.7	38.5
Energy Efficient HVAC System	1,177,908	215.7	151.5	5,491.1	$209,633	161.4	401.7	594.5	1.6
Energy Efficient Lighting Design	1,288,566	224.1	165.1	5,618.0	$226,993	176.5	439.4	627.6	2.4
Premium Efficiency Motors	1,324,495	229.2	169.4	5,550.7	$231,978	181.5	451.7	632.0	0.2
Reduction	16.1%	19.9%	17.3%	3.7%	14.2%	16.1%	16.1%	9.1%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 23.0% and 26.0%, annual energy use between 16.0% and 16.6%, winter peak between 16.0% and 20.2%, and annual natural gas use between 1.9% and 3.8%. These reductions in electricity and natural gas use resulted in a 13.8% to 15.1% decrease in total annual energy cost. The number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from zero to four hours for the maximum XMY data set. In the three other cases, the number of hours where loads were not met remained at zero hours from the baseline to the as-designed building.

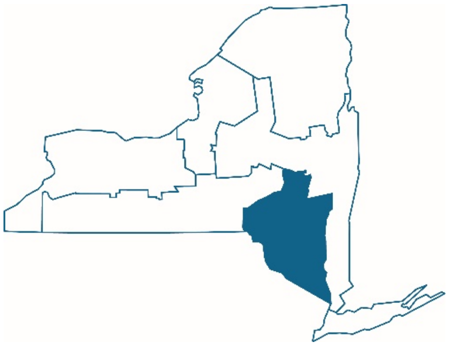
Table 33: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,324,495	247.6	170.0	5,550.7	$231,978	0	87.1	884
TMY, 1986-2015 (As-Designed)	1,111,135	190.6	140.1	5,411.2	$199,137	0	86.5	840
TMY, 2009-2015 (Baseline)	1,328,464	242.4	175.6	5,351.4	$231,378	0	86.9	867
TMY, 2009-2015 (As-Designed)	1,113,633	186.2	140.1	5,224.9	$198,394	0	86.3	841
Max. XMY (Baseline)	1,363,613	264.7	176.6	4,747.8	$233,029	0	85.6	342
Max. XMY (As-Designed)	1,136,683	200.5	142.1	4,566.2	$197,900	4	85.2	313
Min. XMY (Baseline)	1,294,447	226.0	166.5	6,201.1	$231,373	0	87.3	1,339
Min. XMY (As-Designed)	1,087,054	167.2	139.9	6,081.4	$199,547	0	86.7	1,253

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 87.1 to 86.5°F. In addition, the ECMs reduced the total hours of exposure indoors from 884 hours to 840 hours, a 5.0% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.5% and 0.7%, and the total hours where the interior temperature was over 82.4°F decreased by between 3.0% and 8.5%.

REGION 2: CATSKILL MOUNTAINS AND WEST HUDSON RIVER VALLEY



As expected, the ECMs reduced the summer electrical peak (20.2%), the annual electricity use (16.2%), the winter electrical peak (21.0%), and the annual natural gas use (3.8%). These savings translated to a 14.3% reduction in utility costs, or $33,574 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 16.2%; carbon dioxide emissions were reduced by 9.4%. With the exception of glazing improvements, all of the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 34: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,125,036	193.0	140.0	5,304.2	$200,580	154.1	383.6	571.3	N/A
Above Code Insulation	1,128,912	196.1	140.4	5,373.7	$201,579	154.7	385.0	576.3	19.6
Daylighting and Lighting Controls	1,179,154	209.7	152.5	5,349.6	$208,971	161.5	402.1	586.5	0.7
Above Code Glazing	1,179,167	209.7	152.5	5,351.4	$208,983	161.5	402.1	586.6	41.7
Energy Efficient HVAC System	1,195,036	228.0	157.0	5,351.4	$211,363	163.7	407.5	590.3	1.3
Energy Efficient Lighting Design	1,306,491	236.5	172.4	5,514.1	$229,059	179.0	445.5	625.7	2.4
Premium Efficiency Motors	1,342,938	241.7	177.2	5,452.1	$234,154	184.0	457.9	630.5	0.2
Reduction	16.2%	20.2%	21.0%	3.8%	14.3%	16.2%	16.2%	9.4%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 18.7% and 23.5%, annual energy use between 16.2% and 16.7%, winter peak between 19.7% and 23.7%, and annual natural gas use between 2.0% and 3.8%. These reductions in electricity and natural gas use resulted in a 13.9% to 15.2% decrease in total annual energy cost. For the 30-year TMY, the seven-year TMY, and the maximum XMY data sets, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from zero to 12 hours, 0 to one hour, and zero to 40 hours, respectively.

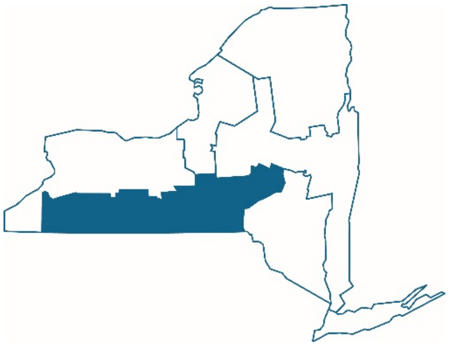
Table 35: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,342,938	244.7	183.5	5,452.1	$234,153	0	86.7	729
TMY, 1986-2015 (As-Designed)	1,125,036	193.4	140.0	5,304.2	$200,581	12	86.0	723
TMY, 2009-2015 (Baseline)	1,340,424	253.8	174.4	5,373.9	$233,307	0	86.9	667
TMY, 2009-2015 (As-Designed)	1,122,403	195.5	140.1	5,210.1	$199,621	1	86.1	645
Max. XMY (Baseline)	1,375,580	255.3	192.4	4,661.5	$234,306	0	85.3	219
Max. XMY (As-Designed)	1,145,243	207.5	148.2	4,485.1	$198,697	40	84.7	204
Min. XMY (Baseline)	1,314,030	235.0	181.7	6,166.3	$234,102	0	87.0	1,206
Min. XMY (As-Designed)	1,101,578	179.8	140	6,043.9	$201,500	0	86.7	1,143

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 86.7 to 86.0°F. In addition, the ECMs reduced the total hours of exposure indoors from 729 hours to 723 hours, a 0.8% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.3% and 0.9%, and the total hours where the interior temperature was over 82.4°F decreased by between 3.3% and 6.8%.

REGION 3: SOUTHERN TIER



As expected, the ECMs reduced the summer electrical peak (20.0%), the annual electricity use (16.2%), the winter electrical peak (18.4%), and the annual natural gas use (3.6%). These savings translated to a 14.2% reduction in utility costs, or $32,790 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 16.2%; carbon dioxide emissions were reduced by 9.0%. With the exception of glazing improvements, all of the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 36: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO$_x$ (lbs.)	NO$_x$ (lbs.)	CO$_2$ (tons)	
As-Designed Building	1,102,942	185.2	140.0	5,543.1	$198,700	151.1	376.1	580.2	N/A
Above Code Insulation	1,106,408	188.5	140.3	5,683.5	$200,062	151.6	377.3	589.2	14.4
Daylighting and Lighting Controls	1,156,605	202.0	150.5	5,644.6	$207,359	158.5	394.4	598.6	0.7
Above Code Glazing	1,156,611	202.0	150.5	5,646.6	$207,372	158.5	394.4	598.7	38.5
Energy Efficient HVAC System	1,166,598	218.2	153.9	5,646.6	$208,870	159.8	397.8	601.0	2.0
Energy Efficient Lighting Design	1,280,194	226.1	167.3	5,749.8	$226,528	175.4	436.5	633.4	2.4
Premium Efficiency Motors	1,315,911	231.5	171.5	5,683.8	$231,490	180.3	448.7	637.8	0.2
Reduction	16.2%	20.0%	18.4%	3.6%	14.2%	16.2%	16.2%	9.0%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs reduced summer peak between 17.3% and 25.9%, annual energy use between 16.0% and 16.5%, and winter peak between 16.7% and 21.2%. For the Weather Analytics “Min” XMY data, annual natural gas use increased by 2.6%, but for the other three sets of weather data it was reduced between 2.5% and 3.7%. These reductions use resulted in a 13.8% to 14.9% decrease in total annual energy cost. The number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from zero to five hours for the maximum XMY data set but remained at zero for the three other cases.

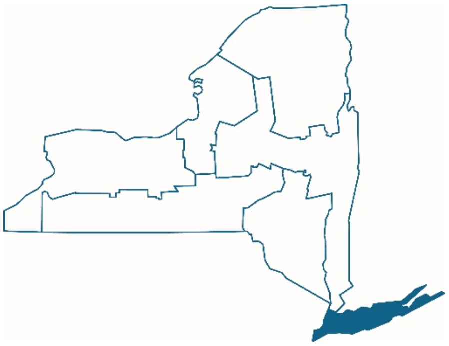
Table 37: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,315,911	238.6	171.6	5,683.8	$231,489	0	87.0	935
TMY, 1986-2015 (As-Designed)	1,102,942	186.5	140.0	5,543.1	$198,700	0	86.4	887
TMY, 2009-2015 (Baseline)	1,325,347	230.8	168.1	5,566.2	$232,199	0	87.0	819
TMY, 2009-2015 (As-Designed)	1,113,428	190.8	140.0	5,413.4	$199,495	0	86.3	774
Max. XMY (Baseline)	1,353,371	267.1	181.8	4,763.4	$231,586	0	85.8	393
Max. XMY (As-Designed)	1,130,138	198.0	143.3	4,586.2	$197,038	5	85.3	371
Min. XMY (Baseline)	1,298,693	213.2	175.7	6,451.6	$233,514	0	87.0	1,415
Min. XMY (As-Designed)	1,088,045	171.8	140	6,617.5	$201,300	0	86.9	1,322

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 87.0 to 86.4°F. In addition, the ECMs reduced the total hours of exposure indoors from 935 hours to 887 hours, a 5.1% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.1% and 0.8%, and the total hours where the interior temperature was over 82.4°F decreased by between 5.1% and 6.6%.

REGION 4: NEW YORK CITY AND LONG ISLAND



As expected, the ECMs reduced the summer electrical peak (21.8%), the annual electricity use (16.5%), the winter electrical peak (20.5%), and the annual natural gas use (5.0%). These savings translated to a 14.8% reduction in utility costs, or $34,787 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 16.5%; carbon dioxide emissions were reduced by 10.3%. With the exception of glazing improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 38: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,135,789	187.6	140.5	4,857.3	$199,512	155.6	387.3	547.7	N/A
Above Code Insulation	1,142,045	194.0	140.3	4,903.4	$200,728	156.5	389.4	551.8	16.1
Daylighting and Lighting Controls	1,192,405	207.5	151.9	4,885.8	$208,176	163.4	406.6	562.5	0.7
Above Code Glazing	1,192,417	207.5	152.0	4,887.3	$208,187	163.4	406.6	562.6	45.5
Energy Efficient HVAC System	1,211,579	224.5	156.6	4,887.3	$211,061	166.0	413.1	567.0	1.0
Energy Efficient Lighting Design	1,323,139	234.5	172.3	5,108.5	$229,122	181.3	451.2	605.8	2.3
Premium Efficiency Motors	1,360,073	239.8	176.6	5,048.1	$234,299	186.3	463.8	610.9	0.2
Reduction	16.5%	21.8%	20.5%	5.0%	14.8%	16.5%	16.5%	10.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 20.6% and 25.8%, annual energy use between 16.1% and 16.9%, winter peak between 12.8% and 23.7%, and annual natural gas use between 2.3% and 3.9%. These reductions in electricity and natural gas use resulted in a 14.1% to 15.3% decrease in total annual energy cost. The number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from two to 63 hours for the maximum XMY data set. In the three other cases, the number of hours where loads were not met remained at zero hours from the baseline to the as-designed building.

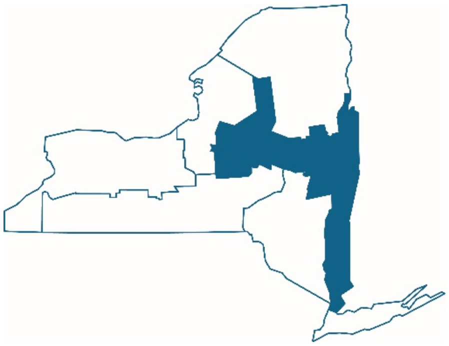
Table 39: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,360,073	265.5	178.8	5,048.1	$234,299	0	86.0	448
TMY, 1986-2015 (As-Designed)	1,135,789	197.0	140.5	4,857.3	$199,512	0	85.7	431
TMY, 2009-2015 (Baseline)	1,358,884	252.4	160.6	4,965.7	$233,627	0	85.9	437
TMY, 2009-2015 (As-Designed)	1,138,041	193.1	140.0	4,774.4	$199,352	0	85.6	416
Max. XMY (Baseline)	1,409,171	268.3	210.8	4,308.6	$237,227	2	84.3	43
Max. XMY (As-Designed)	1,170,396	212.9	168	4,211.3	$200,827	63	83.8	34
Min. XMY (Baseline)	1,328,879	242.3	183.4	5,556.3	$232,670	0	86.9	872
Min. XMY (As-Designed)	1,115,024	180.1	140.0	5,429.6	$199,831	0	86.3	850

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 86.0 to 85.7°F. In addition, the ECMs reduced the total hours of exposure indoors from 448 hours to 431 hours, a 3.8% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.4% and 0.7%, and the total hours where the interior temperature was over 82.4°F decreased by between 2.5% and 20.9%.

REGION 5: EAST HUDSON AND MOHAWK RIVER VALLEYS



As expected, the ECMs reduced the summer electrical peak (18.4%), the annual electricity use (16.1%), the winter electrical peak (18.3%), and the annual natural gas use (14.6%). These savings translated to a 15.1% reduction in utility costs, or $35,314 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 16.1%; carbon dioxide emissions were reduced by 8.6%. With the exception of glazing improvements, all of the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 40: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,102,674	189.8	140.0	5,597.3	$198,985	151.1	376.0	583.3	N/A
Above Code Insulation	1,105,783	191.5	140.3	5,726.1	$200,224	151.5	377.1	591.5	15.8
Daylighting and Lighting Controls	1,155,042	204.5	150.2	5,680.6	$207,340	158.2	393.9	600.3	0.7
Above Code Glazing	1,155,041	204.6	150.2	5,682.7	$207,352	158.2	393.9	600.4	41.7
Energy Efficient HVAC System	1,164,783	221.5	153.5	5,682.7	$208,813	159.6	397.2	602.7	2.1
Energy Efficient Lighting Design	1,277,995	227.1	167.2	5,783.4	$226,400	175.1	435.8	634.8	2.4
Premium Efficiency Motors	1,313,814	232.6	171.4	5,048.1	$234,299	180.0	448.0	600.1	0.1
Reduction	16.1%	18.4%	18.3%	14.6%	15.1%	16.1%	16.1%	8.6%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 18.6% and 27.4%, annual energy use between 16.1% and 16.6%, winter peak between 18.4% and 24.2%, and annual natural gas use between 1.7% and 3.0%. These reductions in electricity and natural gas use resulted in a 13.8% to 14.9% decrease in total annual energy cost. The number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from zero to one hour for the maximum XMY data set. In the three other cases, the number of hours where loads were not met remained at zero hours from the baseline to the as-designed building.

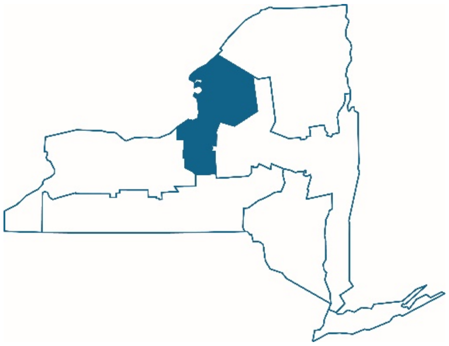
Table 41: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,313,814	233.5	171.6	5,717.1	$231,375	0	86.9	1,080
TMY, 1986-2015 (As-Designed)	1,102,674	190.0	140.0	5,597.3	$198,985	0	86.2	1,036
TMY, 2009-2015 (Baseline)	1,319,845	234.6	172.7	5,564.2	$231,362	0	86.9	1,012
TMY, 2009-2015 (As-Designed)	1,106,446	188.4	140.1	5,444.3	$198,633	0	86.6	968
Max. XMY (Baseline)	1,353,460	262.8	190.7	4,825.0	$231,969	0	85.6	494
Max. XMY (As-Designed)	1,128,945	190.7	144.5	4,679.4	$197,418	1	85.2	460
Min. XMY (Baseline)	1,297,522	218.5	175.7	6,512.5	$233,703	0	87.0	819
Min. XMY (As-Designed)	1,087,400	171.3	140.0	6,404.3	$201,536	0	86.3	774

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 86.9 to 86.2°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,080 hours to 1,036 hours, a 4.1% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.3% and 0.8%, and the total hours where the interior temperature was over 82.4°F decreased by between 4.1% and 6.9%.

REGION 6: TUG HILL PLATEAU



As expected, the ECMs reduced the summer electrical peak (25.3%), the annual electricity use (18.6%), the winter electrical peak (20.7%), and the annual natural gas use (23.2%). These savings translated to a 14.0% reduction in utility costs, or $32,876 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 18.6%; carbon dioxide emissions were reduced by 9.3%. With the exception of glazing improvements, all of the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 42: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,107,621	179.2	140.0	5,880.0	$201,423	151.7	377.7	601.0	N/A
Above Code Insulation	1,110,299	179.6	140.3	6,054.5	$202,872	152.1	378.6	611.8	13.5
Daylighting and Lighting Controls	1,160,326	193.1	150.1	4,885.8	$208,176	159.0	395.7	555.0	1.0
Above Code Glazing	1,192,417	207.5	152.0	4,887.3	$208,187	163.4	406.6	562.6	45.5
Energy Efficient HVAC System	1,211,579	224.5	156.6	4,887.3	$211,061	166.0	413.1	567.0	1.0
Energy Efficient Lighting Design	1,323,139	234.5	172.3	5,108.5	$229,122	181.3	451.2	605.8	2.3
Premium Efficiency Motors	1,360,073	239.8	176.6	5,048.1	$234,299	186.3	463.8	610.9	0.2
Reduction	18.6%	25.3%	20.7%	23.2%	14.0%	18.6%	18.6%	9.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 21.1% and 26.9%, annual energy use between 16.1% and 16.4%, winter peak between 12.2% and 21.6%, and annual natural gas use between 1.8% and 3.1%. These reductions in electricity and natural gas use resulted in a 13.6% to 14.7% decrease in total annual energy cost. The number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from zero to six hours for the maximum XMY data set. In the three other cases, the number of hours where loads were not met remained at zero hours from the baseline to the as-designed building.

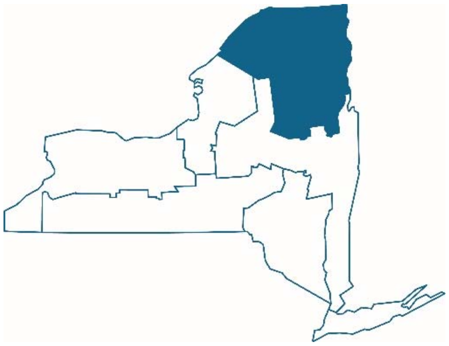
Table 43: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,320,451	237.3	178.5	6,018.6	$234,179	0	86.9	1,115
TMY, 1986-2015 (As-Designed)	1,107,621	187.3	140.0	5,880.0	$201,423	0	86.7	1,067
TMY, 2009-2015 (Baseline)	1,318,423	248.9	168.3	5,842.9	$232,821	0	86.9	1,047
TMY, 2009-2015 (As-Designed)	1,105,270	186.4	140.0	5,727.2	$200,154	0	86.9	992
Max. XMY (Baseline)	1,353,726	265.4	183.6	5,048.0	$233,347	0	86.0	549
Max. XMY (As-Designed)	1,131,947	200.0	144.9	4,891.5	$199,141	6	85.8	524
Min. XMY (Baseline)	1,298,094	233.1	159.4	6,807.5	$235,559	0	87.6	1,492
Min. XMY (As-Designed)	1,089,450	170.3	139.9	6,686.7	$203,538	0	87.3	1,371

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 86.9 to 86.7°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,115 hours to 1,067 hours, a 4.3% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.0% and 0.3%, and the total hours where the interior temperature was over 82.4°F decreased by between 4.3% and 8.1%.

REGION 7: ADIRONDACK MOUNTAINS



As expected, the ECMs reduced the summer electrical peak (19.9%), the annual electricity use (16.1%), the winter electrical peak (21.0%), and the annual natural gas use (18.9%). These savings translated to a 14.2% reduction in utility costs, or $33,352 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 16.1%; carbon dioxide emissions were reduced by 8.7%. With the exception of glazing improvements, all of the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 44: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,107,060	183.6	140.0	5,814.6	$200,947	151.7	377.5	597.0	N/A
Above Code Insulation	1,110,488	185.4	140.3	5,964.2	$202,358	152.1	378.7	606.6	13.9
Daylighting and Lighting Controls	1,160,721	199.0	153.5	5,920.7	$209,632	159.0	395.8	615.7	0.7
Above Code Glazing	1,160,730	199.0	153.5	5,922.6	$209,646	159.0	395.8	615.8	35.7
Energy Efficient HVAC System	1,171,871	214.7	158.0	5,922.6	$211,317	160.5	399.6	618.4	1.8
Energy Efficient Lighting Design	1,284,029	223.8	173.1	6,002.5	$228,619	175.9	437.9	649.1	2.4
Premium Efficiency Motors	1,320,035	229.1	177.3	5,048.1	$234,299	180.8	450.1	601.6	0.2
Reduction	16.1%	19.9%	21.0%	18.9%	14.2%	16.1%	16.1%	8.7%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 20.3% and 24.6%, annual energy use between 16.1% and 16.5%, winter peak between 19.3% and 22.8%, and annual natural gas use between 1.7% and 3.5%. These reductions in electricity and natural gas use resulted in a 13.7% to 14.8% decrease in total annual energy cost. . For the 30-year TMY and the maximum XMY data sets, the number of hours where heating and cooling loads were not able to be met by the HVAC equipment increased from zero to one hour and zero to 17 hours, respectively.

Table 45: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,320,035	242.4	180.9	5,934.7	$233,613	0	87.1	1,052
TMY, 1986-2015 (As-Designed)	1,107,060	186.5	140.0	5,814.6	$200,947	1	86.5	1,003
TMY, 2009-2015 (Baseline)	1,320,612	236.2	174.9	5,592.0	$231,644	0	86.7	880
TMY, 2009-2015 (As-Designed)	1,107,686	188.3	141.2	5,482.0	$199,045	0	86.2	867
Max. XMY (Baseline)	1,359,702	269.4	185.7	4,969.8	$233,774	0	86.0	455
Max. XMY (As-Designed)	1,135,186	203.2	143.4	4,797.2	$199,061	17	85.3	442
Min. XMY (Baseline)	1,298,948	242.1	170.8	6,727.1	$235,205	0	87.6	1,405
Min. XMY (As-Designed)	1,088,505	182.8	140.0	6,609.4	$202,932	0	87.1	1,317

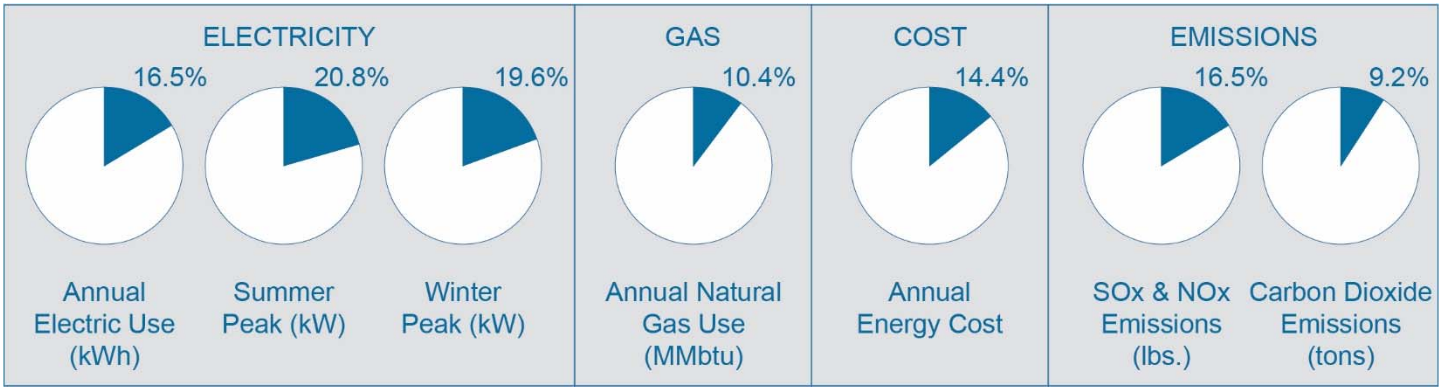
PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 87.1 to 86.5°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,052 hours to 1,003 hours, a 4.7% improvement over the baseline, code compliant building. For the other three sets of weather data, the total exposure to high temperature decreased by between 0.6% and 0.8%, and the total hours where the interior temperature was over 82.4°F decreased by between 1.5% and 6.3%.

STATEWIDE IMPACTS FOR COMMERCIAL BUILDINGS

The following tables take the average reductions in energy use from the baseline and upgraded systems and averages them across all seven ClimAID regions. The first section measures the reductions in statewide energy use, demand, cost and emissions. The second shows the difference in weather variability impact on energy use, demand, cost, and operations. Reductions for the first two sections are shown as a percentage in blue. The final section shows the difference in passive survivability impacts, with the baseline design represented in white and the upgraded design in blue.

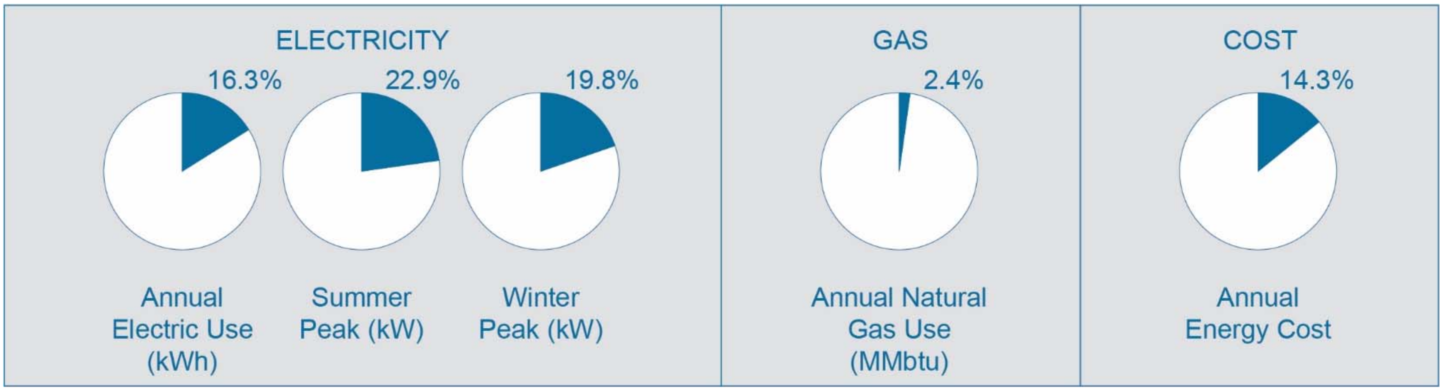
REDUCTIONS IN STATEWIDE ENERGY USE, DEMAND, COST, AND EMISSIONS IMPACTS



ECMs have positive impacts on energy use and cost across the State. Reductions are seen in every category, averaging at 16.5% for annual electric use, 20.8% for summer peak, 19.6% for winter peak, 10.4% for annual natural gas use, 14.4% for cost, 16.5% for air pollution from electrical generation, and 9.2% for carbon dioxide emissions.

While each ECM contributes to enhancing building performance, the addition of an energy efficient lighting design made the biggest difference among each ClimAID region. This measure alone reduced annual electric use by an average of 112,028 kWh, annual fuel use by an average of 145 MMbtu, and annual energy cost by an average of $17,675 per region for commercial building types.

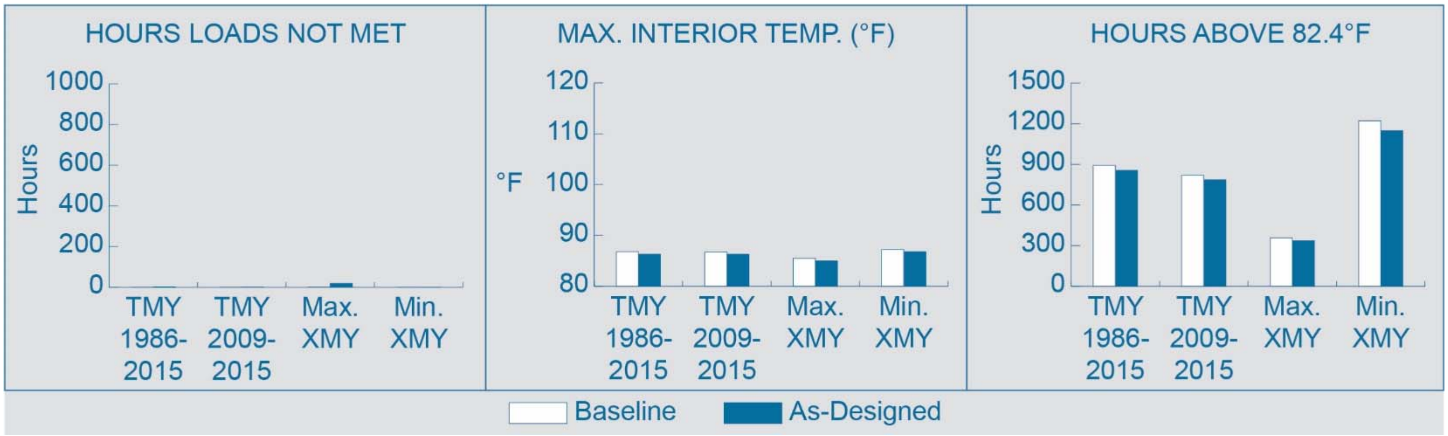
WEATHER VARIABILITY IMPACT ON ENERGY USE, DEMAND, COST, AND OPERATIONS



All four data sets show that ECMs improve energy performance in all seven ClimAID regions. While reductions are seen in most of the categories investigated – 16.3% for annual energy use, 22.9% for summer peak, 19.8% for winter peak, 2.4% for annual fuel use, and 14.3% for annual energy cost, on average.

Among all regions, the ECMs are particularly beneficial to energy performance during extreme temperature events, as seen in the comparison of the baseline and upgraded building for the maximum XMY. Annual energy use, annual fuel use, and annual energy cost were reduced by averages of 16.6%, 3.3%, and 15.0%, respectively, in every region during extreme warm temperatures. Conversely, annual fuel use and annual energy cost reduced the least, 1.3% and 13.8%, respectively, for the extreme cold temperature data set.

STATEWIDE PASSIVE SURVIVABILITY IMPACTS



All regions showed positive effects in passive survivability from ECMs. The maximum interior temperature saw an increase of 0.5% on average across the State. While all changes were positive, all the data sets showed minimal reductions, with none reaching above a 0.9%.

The number of hours that the interior temperature exceeded 82.4°F decreased statewide by an average of 5.4%. The greatest improvements were seen in the data sets for extreme warm and cold temperatures. Regions 1, 2, 4, and 5 improved the most in the maximum XMY analysis, and Regions 3, 6, and 7 improved the most in the minimum XMY analysis. New York City saw reductions in the exposure to high temperatures indoors within the maximum XMY analysis that exceeded the statewide average, reducing by 20.9%.

Industrial Building Case Study

SEPSA

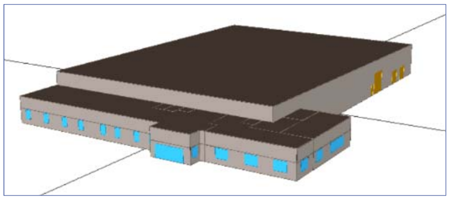


Figure 4: Screenshot of the building energy model in eQuest

In New York, there are approximately 90,544 industrial buildings; they represent 1.72% of the total number of buildings in the State and 0.004% of the total floor area.

Industrial buildings are a large part of the economy in New York State. Improving the energy performance of this building group is critical to increasing the resilience of the building stock.

METHODOLOGY

The industrial building energy model was based on a single story 36,000 square foot built in Ballston Spa, New York. The building includes offices and manufacturing space, and its envelope characteristics will exceed the requirements of the ASHRAE Standard 90.1-2007 (Figure 1).

The office space is conditioned with split condensers and outside air supplied by an energy recovery unit, and the manufacturing area uses infrared radiant heaters and outside air supplied through an energy recovery unit with duct heater reheat.

The methodology used for this study is based on the Chartered Institution of Building Services Engineers (CIBSE) report “Climate change and the indoor environment: impacts and adaptation” and the NYSERDA New Construction Program Simulation Guidelines. Models were run in eQuest version 3.64 using the files originally created by L&S Energy Services for a 2008 Technical Assistance Study in Support of the New Construction Program (NCP 9249).

Table 46: Energy Conservation Measures, System Descriptions, Effective Useful Life, and Incremental Costs

ECMs	Baseline System Description†	Upgraded System Description	EUL (years)	Cost ($)
Above Code Building Envelope Improvements	R-20 continuous insulation in the roof and R-13 insulation in the walls.	R-30 continuous insulation in the roof and R-31 insulation in the walls.	50	$26,100
Above code Lighting Design	Baseline lighting design uses a total of 56.25 kW.	Improved lighting design uses a total of 29.53 kW.	15	$19,500
HVAC Equipment	Variable Speed Drive of supply fan	Constant speed fans	15	N/A
Occupancy Control of Lighting	Occupancy sensors in classrooms, conference rooms and break rooms per section 9.4.1.2. Controlled wattage = 1.27 kW.	Occupancy sensors in Conference Spc, Women Spc, Men Spc, Server Spc, Shower Spc, Women's Toilet Spc, Men's Toilet Spc. Controlled wattage = 2.96 kW.	15	$2,010
Demand Control of Ventilation	Not required	Static plate, enthalpy	15	N/A
Energy Management and Control	Optimum Start Controls	Optimum Start Controls	15	N/A

†The New York State Energy Conservation Code of 1999 was the baseline used for the analysis.

Using a package minus approach for the modeling, the building systems were downgraded in steps from the as-designed configuration to code compliant systems, starting first with the ECMs that have the longest effective useful life (EUL) as shown in Table 46. The building was modeled with the as-designed HVAC systems to understand the impact of design changes on energy usage, demand, operating costs, and $SO_x/NO_X/CO_2$ emissions.

After the energy conservation measures were modeled, the next set of runs investigated the cumulative effect of the strategies on passive survivability. Both the maximum interior temperature and the number of hours above 82.4°F were modeled; 82.4°F (28°C) is a threshold used by CIBSE as a proxy for high heat exposure.

Although the CIBSE study used future weather year data to investigate overheating for buildings in the United Kingdom, this study did not project results into the future because similar files are not currently available for New York State. In addition, changes in the average air temperature tend to have less impact on the operation of HVAC systems; the peak heating and cooling loads experienced during a heat wave or cold spell typically determine the size of a building system and its impact on energy demand.

To this end, for the third and final set of energy modeling runs, the baseline and upgraded buildings were compared using four sets of meteorological data prepared by Weather Analytics:

1) Typical Meteorological Year (TMY) Data:

    i. TMY, 1986 – 2015, 30 years
    ii. TMY, 2009 – 2015, 6 years

    TMY are data sets of hourly values of solar radiation and meteorological elements for a 1-year period. They are typically used for computer simulations of solar or building HVAC systems. Because they represent typical rather than extreme conditions, they are not use for designing systems to meet the worst-case conditions occurring at a location. Although TMY are available from the National Renewable Energy Laboratory for most cities in the United States, these files cover the period 1991-2005 in New York State. Weather Analytics created custom TMY data for multiple sites across the state using more current data, specifically the period 1986 to 2015 and 2009 to 2015. This second set of files promotes understanding of how recent warming may impact building system performance.

2) eXtreme Meteorological Year (XMY) Data:

    i. XMY MAX, 2001 – 2015, 15 years
    ii. XMY MIN, 2001 – 2015, 15 years

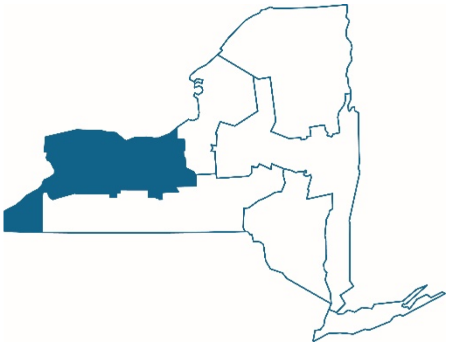
    Weather Analytics also created XMY files to examine the extreme cases occurring over the last 15 years. XMY files are created by using historical data to determine the maximum and minimum of a variable on a monthly basis. For example, if temperature is requested over a period of 15 years, the XMY MAX file will consist of the warmest months that occurred over the past 15 years, while the XMY MIN file will consist of the coolest (based on averages). Along with the extreme temperatures, the consequent data (e.g., solar radiation, wind speed) from the extreme month is also carried over to the XMY file, keeping consistency between each variable.

The results from this portion of the study indicate how weather variability may impact energy usage, demand, and operating costs. The number of hours the systems could not keep up with heating and cooling loads were also calculated, as well as the maximum interior temperature and number of hours above 82.4°F.

REGIONAL PROFILES

The following section outlines the results for each of the seven ClimAID regions. Following the profiles, a discussion of the statewide impacts for industrial buildings is presented.

REGION 1: WESTERN NEW YORK AND THE GREAT LAKES PLAIN



As expected, the ECMs reduced the summer electrical peak (30.1%), the annual electricity use (39.6%), the winter electrical peak (33.6%), and the annual natural gas use (28.8%). These savings translated to a 38.9% reduction in utility costs, or $23,764 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 39.6%; carbon dioxide emissions were reduced by 36.4%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 47: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	230,281	79.6	58.9	457.4	$37,286	31.5	78.5	80.2	N/A
Above Code Building Envelope	260,707	91.8	66.1	587.4	$42,631	35.7	88.9	94.8	4.9
Above code Lighting Design	372,403	112.7	86.9	501.1	$58,867	51.0	127.0	115.7	1.2
Variable Speed Drives	371,235	112.5	86.6	503.5	$58,706	50.9	126.6	115.6	-
Occupancy Control of Lighting	373,864	113.3	87.5	499.2	$59,075	51.2	127.5	115.9	5.4
Demand Control of Ventilation	379,349	113.7	87.3	610.9	$60,567	52.0	129.4	123.8	-
Energy Management and Control	381,284	113.9	88.6	642.8	$61,050	52.2	130.0	126.1	-
Reduction	39.6%	30.1%	33.6%	28.8%	38.9%	39.6%	39.6%	36.4%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 29.6% and 31.6%, annual energy use between 39.2% and 41.1%, winter peak between 33.7% and 34.3%, and annual natural gas use between 26.8% and 28.9%. These reductions in electricity and natural gas use resulted in a 38.8% to 39.9% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

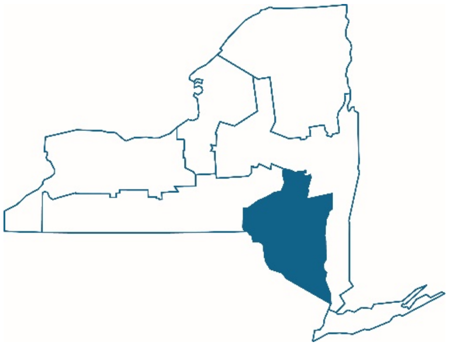
Table 48: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	381,284	114.2	73.9	643.0	$61,049	0	86.7	104
TMY, 1986-2015 (As-Designed)	230,281	79.9	49.0	457.0	$37,286	47	88.3	140
TMY, 2009-2015 (Baseline)	376,863	109.6	73.0	594.0	$60,095	0	86.7	104
TMY, 2009-2015 (As-Designed)	226,180	77.2	48.2	427.0	$36,490	47	88.3	140
Max. XMY (Baseline)	393,299	120.0	74.7	365.0	$61,186	0	86.7	104
Max. XMY (As-Designed)	238,967	82.1	49.4	267.0	$37,444	47	88.3	140
Min. XMY (Baseline)	360,514	100.5	71.4	870.0	$59,298	0	86.7	104
Min. XMY (As-Designed)	212,439	69.9	46.9	630.0	$35,648	47	88.3	140

PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

REGION 2: CATSKILL MOUNTAINS AND WEST HUDSON RIVER VALLEY



As expected, the ECMs reduced the summer electrical peak (29.1%), the annual electricity use (39.1%), the winter electrical peak (33.8%), and the annual natural gas use (29.4%). These savings translated to a 38.6% reduction in utility costs, or $23,667 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 39.1%; carbon dioxide emissions were reduced by 36.5%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 49: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	234,866	82.2	57.3	403.6	$37,651	32.2	80.1	78.1	N/A
Above Code Building Envelope	265,344	93.7	63.4	515.0	$42,892	36.4	90.5	91.7	5.0
Above code Lighting Design	377,121	114.5	85.3	432.6	$59,164	51.7	128.6	112.8	1.2
Variable Speed Drives	375,901	114.3	85.1	435.0	$58,995	51.5	128.2	112.7	-
Occupancy Control of Lighting	378,536	115.1	85.9	430.8	$59,365	51.9	129.1	113.0	5.4
Demand Control of Ventilation	383,907	116.0	85.4	541.7	$60,836	52.6	130.9	120.8	-
Energy Management and Control	385,934	115.9	86.6	571.3	$61,318	52.9	131.6	123.0	-
Reduction	39.1%	29.1%	33.8%	29.4%	38.6%	39.1%	39.1%	36.5%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 28.4% and 31.8%, annual energy use between 38.2% and 40.3%, winter peak between 33.3% and 34.1%, and annual natural gas use between 27.1% and 29.2%. These reductions in electricity and natural gas use resulted in a 37.9% to 39.4% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

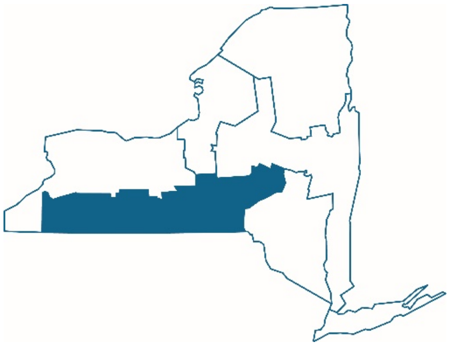
Table 50: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	385,934	116.0	74.1	571.0	$61,318	0	86.7	104
TMY, 1986-2015 (As-Designed)	234,866	82.3	49.2	404.0	$37,651	47	88.3	140
TMY, 2009-2015 (Baseline)	390,552	119.7	74.8	551.0	$61,889	0	86.7	104
TMY, 2009-2015 (As-Designed)	235,317	81.6	49.4	392.0	$37,649	47	88.3	140
Max. XMY (Baseline)	405,049	124.4	76.2	328.0	$62,723	0	86.7	104
Max. XMY (As-Designed)	250,234	89.1	50.8	239.0	$38,969	47	88.3	140
Min. XMY (Baseline)	381,068	110.3	74.2	808.0	$62,007	0	86.7	104
Min. XMY (As-Designed)	227,446	75.2	48.9	577.0	$37,577	47	88.3	140

PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

REGION 3: SOUTHERN TIER



As expected, the ECMs reduced the summer electrical peak (30.1%), the annual electricity use (40.2%), the winter electrical peak (34.0%), and the annual natural gas use (28.3%). These savings translated to a 39.4% reduction in utility costs, or $23,549 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 40.2%; carbon dioxide emissions were reduced by 36.4%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 51: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	221,854	75.0	48.0	491.7	$36,228	30.4	75.7	80.2	N/A
Above Code Building Envelope	250,342	85.4	52.2	629.3	$41,327	34.3	85.4	94.9	5.1
Above Code Lighting Design	361,866	106.1	70.6	538.4	$57,510	49.6	123.4	115.5	1.2
Variable Speed Drives	360,693	105.9	70.4	540.8	$57,349	49.4	123.0	115.3	-
Occupancy Control of Lighting	363,317	106.7	71.1	536.5	$57,717	49.8	123.9	115.7	5.5
Demand Control of Ventilation	369,446	107.0	72.8	653.0	$59,335	50.6	126.0	123.9	-
Energy Management and Control	371,064	107.3	72.8	686.1	$59,777	50.8	126.5	126.2	-
Reduction	40.2%	30.1%	34.0%	28.3%	39.4%	40.2%	40.2%	36.4%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 28.3% and 31.9%, annual energy use between 38.9% and 41.1%, winter peak between 33.6% and 34.5%, and annual natural gas use between 27.3% and 28.3%. These reductions in electricity and natural gas use resulted in a 38.5% to 39.9% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

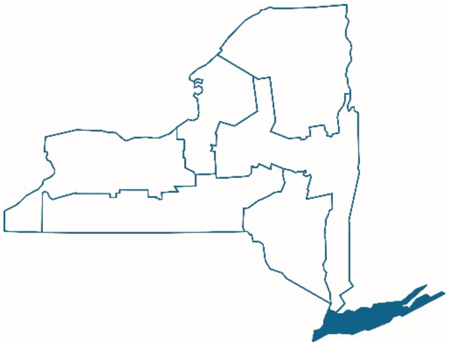
Table 52: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	371,064	107.3	72.8	686.0	$59,776	0	86.7	104
TMY, 1986-2015 (As-Designed)	221,854	75.1	48.0	492.0	$36,228	47	88.3	140
TMY, 2009-2015 (Baseline)	381,771	116.9	73.8	623.0	$61,006	0	86.7	104
TMY, 2009-2015 (As-Designed)	229,006	81.4	48.8	447.0	$37,035	47	88.3	140
Max. XMY (Baseline)	396,643	121.5	75.5	388.0	$61,826	0	86.7	104
Max. XMY (As-Designed)	242,333	87.1	50.1	282.0	$38,044	47	88.3	140
Min. XMY (Baseline)	368,396	102.9	72.8	925.0	$60,812	0	86.7	104
Min. XMY (As-Designed)	216,977	70.1	47.7	670.0	$36,566	47	88.3	140

PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

REGION 4: NEW YORK CITY AND LONG ISLAND



As expected, the ECMs reduced the summer electrical peak (29.3%), the annual electricity use (39.1%), the winter electrical peak (33.8%), and the annual natural gas use (29.4%). These savings translated to a 38.7% reduction in utility costs, or $23,836 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 39.1%; carbon dioxide emissions were reduced by 36.9%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 53: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	239,064	85.5	49.5	319.0	$37,776	32.8	81.5	74.1	N/A
Above Code Building Envelope	273,158	98.4	54.3	401.0	$43,379	37.4	93.1	86.8	4.7
Above code Lighting Design	385,358	119.7	71.2	330.0	$59,785	52.8	131.4	108.7	1.2
Variable Speed Drives	384,106	119.5	71.0	333.0	$59,611	52.6	131.0	108.6	-
Occupancy Control of Lighting	386,749	120.3	71.7	329.0	$59,984	53.0	131.9	109.0	5.4
Demand Control of Ventilation	390,477	120.8	74.8	424.0	$61,114	53.5	133.2	115.4	-
Energy Management and Control	392,680	120.9	74.8	452.0	$61,612	53.8	133.9	117.5	-
Reduction	39.1%	29.3%	33.8%	29.4%	38.7%	39.1%	39.1%	36.9%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 28.9% and 31.1%, annual energy use between 37.9% and 40.6%, winter peak between 33.8% and 34.5%, and annual natural gas use between 22.6% and 29.4%. These reductions in electricity and natural gas use resulted in a 37.6% to 39.8% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

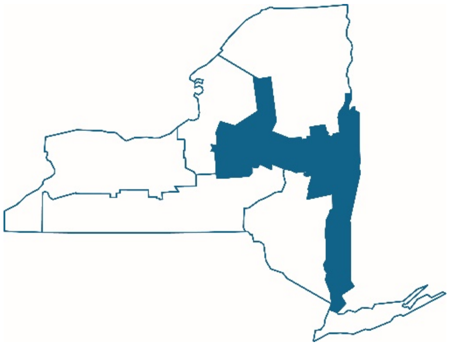
Table 54: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	392,680	120.9	74.8	452.0	$61,612	0	86.7	104
TMY, 1986-2015 (As-Designed)	239,064	85.5	49.5	319.0	$37,776	47	88.3	140
TMY, 2009-2015 (Baseline)	386,841	115.0	73.8	436.0	$60,640	0	86.7	104
TMY, 2009-2015 (As-Designed)	234,619	80.4	48.6	310.0	$37,052	47	88.3	140
Max. XMY (Baseline)	414,308	131.2	76.8	230.0	$63,524	0	86.7	104
Max. XMY (As-Designed)	257,236	93.3	50.8	178.0	$39,651	47	88.3	140
Min. XMY (Baseline)	376,859	106.7	73.3	644.0	$60,391	0	86.7	104
Min. XMY (As-Designed)	224,036	73.5	48.0	456.0	$36,341	47	88.3	140

PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

REGION 5: EAST HUDSON AND MOHAWK RIVER VALLEYS



As expected, the ECMs reduced the summer electrical peak (30.2%), the annual electricity use (40.1%), the winter electrical peak (33.8%), and the annual natural gas use (27.9%). These savings translated to a 39.3% reduction in utility costs, or $23,600 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 40.1%; carbon dioxide emissions were reduced by 36.1%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 55: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	222,785	76.6	48.2	514.2	$36,503	30.5	76.0	81.8	N/A
Above Code Building Envelope	250,521	86.7	52.3	661.0	$41,544	34.3	85.4	96.8	5.2
Above Code Lighting Design	362,140	107.9	69.3	569.4	$57,738	49.6	123.5	117.3	1.2
Variable Speed Drives	360,961	107.7	69.1	571.8	$57,575	49.5	123.1	117.2	-
Occupancy Control of Lighting	363,597	108.6	69.8	567.6	$57,945	49.8	124.0	117.6	5.4
Demand Control of Ventilation	370,526	109.1	72.9	680.0	$59,659	50.8	126.3	125.7	-
Energy Management and Control	372,175	109.7	72.9	712.9	$60,103	51.0	126.9	128.1	-
Reduction	40.1%	30.2%	33.8%	27.9%	39.3%	40.1%	40.1%	36.1%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 29.7% and 32.1%, annual energy use between 39.4% and 40.8%, winter peak between 33.7% and 34.2%, and annual natural gas use between 27.0% and 27.9%. These reductions in electricity and natural gas use resulted in a 38.9% to 39.5% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

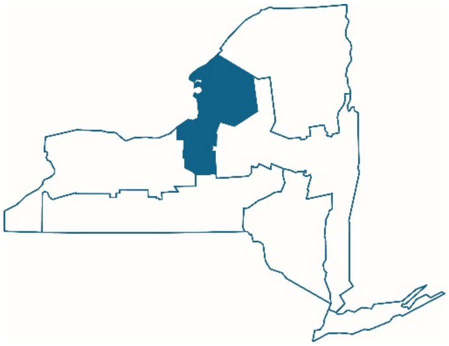
Table 56: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	372,175	109.7	72.9	713.0	$60,103	0	86.7	104
TMY, 1986-2015 (As-Designed)	222,785	76.7	48.2	514.0	$36,503	47	88.3	140
TMY, 2009-2015 (Baseline)	381,790	111.8	74.0	659.0	$61,220	0	86.7	104
TMY, 2009-2015 (As-Designed)	228,497	77.3	48.9	447.0	$37,136	47	88.3	140
Max. XMY (Baseline)	389,264	119.6	74.1	426.0	$60,945	0	86.7	104
Max. XMY (As-Designed)	235,817	81.2	49.1	308.0	$37,219	47	88.3	140
Min. XMY (Baseline)	367,423	101.9	72.5	968.0	$60,921	0	86.7	104
Min. XMY (As-Designed)	217,505	71.6	47.7	707.0	$36,865	47	88.3	140

PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

REGION 6: TUG HILL PLATEAU



As expected, the ECMs reduced the summer electrical peak (29.7%), the annual electricity use (39.8%), the winter electrical peak (37.0%), and the annual natural gas use (29.0%). These savings translated to a 39.0% reduction in utility costs, or $23,698 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 39.8%; carbon dioxide emissions were reduced by 36.1%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 57: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	225,033	75.5	48.4	548.4	$37,046	30.8	76.7	84.3	N/A
Above Code Building Envelope	252,545	86.0	52.4	702.1	$42,095	34.6	86.1	99.7	5.2
Above Code Lighting Design	364,484	106.6	76.1	610.5	$58,336	49.9	124.3	120.3	1.2
Variable Speed Drives	363,274	106.4	75.9	613.0	$58,169	49.8	123.9	120.1	-
Occupancy Control of Lighting	365,912	107.2	76.7	608.7	$58,539	50.1	124.8	120.5	5.4
Demand Control of Ventilation	372,287	107.3	75.4	739.6	$60,281	51.0	126.9	129.6	-
Energy Management and Control	374,046	107.5	76.8	772.8	$60,744	51.2	127.5	132.0	-
Reduction	39.8%	29.7%	37.0%	29.0%	39.0%	39.8%	39.8%	36.1%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 29.2% and 31.0%, annual energy use between 39.0% and 41.1%, winter peak between 33.6% and 34.5%, and annual natural gas use between 27.6% and 29.2%. These reductions in electricity and natural gas use resulted in a 38.5% to 39.8% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

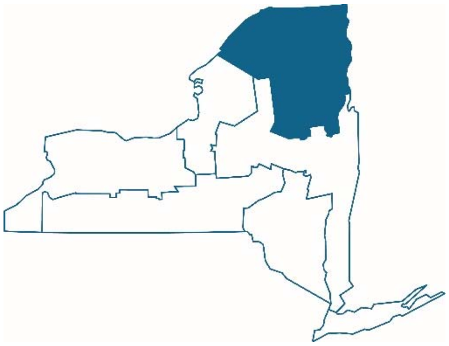
Table 58: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	374,046	107.6	73.0	773.0	$60,744	0	86.7	104
TMY, 1986-2015 (As-Designed)	225,033	75.8	48.4	548.0	$37,046	47	88.3	140
TMY, 2009-2015 (Baseline)	368,611	106.0	72.1	725.0	$59,642	0	86.7	104
TMY, 2009-2015 (As-Designed)	219,575	74.5	47.6	513.0	$36,017	47	88.3	140
Max. XMY (Baseline)	388,708	113.2	74.3	468.0	$61,117	0	86.7	104
Max. XMY (As-Designed)	237,225	80.2	49.3	333.0	$37,582	47	88.3	140
Min. XMY (Baseline)	363,993	102.2	72.1	1,013.0	$60,675	0	86.7	104
Min. XMY (As-Designed)	214,295	70.5	47.2	733.0	$36,540	47	88.3	140

PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

REGION 7: ADIRONDACK MOUNTAINS



As expected, the ECMs reduced the summer electrical peak (30.6%), the annual electricity use (40.1%), the winter electrical peak (33.1%), and the annual natural gas use (29.1%). These savings translated to a 39.3% reduction in utility costs, or $24,078 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 40.1%; carbon dioxide emissions were reduced by 36.5%. All the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 59: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO$_x$ (lbs.)	NO$_x$ (lbs.)	CO$_2$ (tons)	
As-Designed Building	227,393	77.4	56.7	520.0	$37,299	31.2	77.5	83.2	N/A
Above Code Building Envelope	258,793	88.4	62.0	658.9	$42,772	35.5	88.2	98.6	4.7
Above Code Lighting Design	370,476	109.5	83.6	568.6	$58,982	50.8	126.3	119.2	1.2
Variable Speed Drives	369,229	109.3	83.4	571.1	$58,811	50.6	125.9	119.1	-
Occupancy Control of Lighting	371,878	110.2	84.2	566.8	$59,183	50.9	126.8	119.4	5.4
Demand Control of Ventilation	377,533	110.7	83.7	701.7	$60,840	51.7	128.7	128.6	-
Energy Management and Control	379,363	111.5	84.8	733.6	$61,307	52.0	129.4	130.9	-
Reduction	40.1%	30.6%	33.1%	29.1%	39.3%	40.1%	40.1%	36.5%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 28.6% and 31.2%, annual energy use between 39.2% and 41.0%, winter peak between 33.9% and 34.4%, and annual natural gas use between 27.9% and 29.2%. These reductions in electricity and natural gas use resulted in a 38.8% to 39.7% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment from zero to 47 hours.

Table 60: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	379,363	111.8	73.7	734.0	$61,306	0	86.7	104
TMY, 1986-2015 (As-Designed)	227,393	77.5	48.6	520.0	$37,229	47	88.3	140
TMY, 2009-2015 (Baseline)	377,954	109.2	73.4	624.0	$60,436	0	86.7	104
TMY, 2009-2015 (As-Designed)	226,481	75.2	48.5	442.0	$36,625	47	88.3	140
Max. XMY (Baseline)	390,953	115.2	74.3	424.0	$61,185	0	86.7	104
Max. XMY (As-Designed)	237,807	82.2	49.1	300.0	$37,471	47	88.3	140
Min. XMY (Baseline)	369,957	106.0	72.9	959.0	$61,247	0	86.7	104
Min. XMY (As-Designed)	218,427	72.9	47.8	691.0	$36,909	47	88.3	140

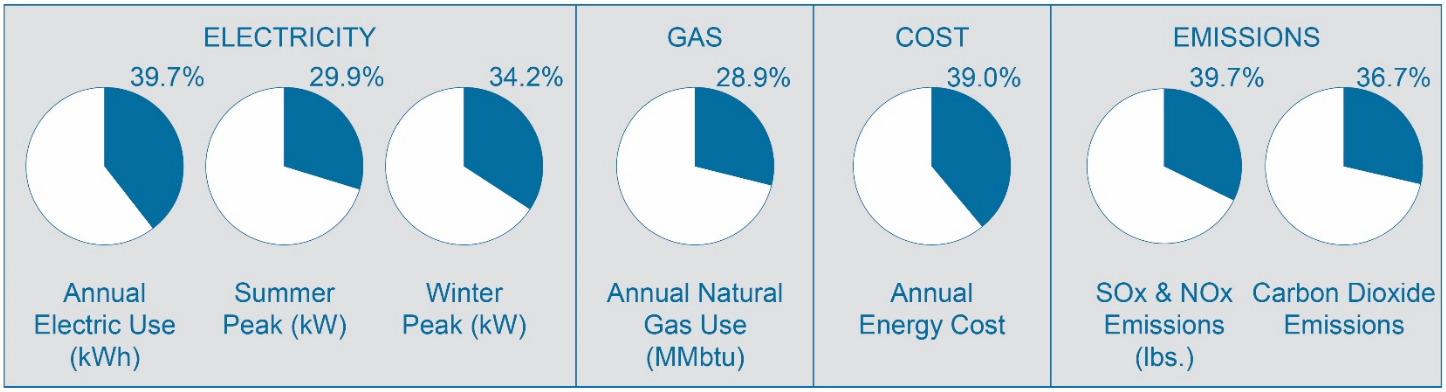
PASSIVE SURVIVABILITY

For all data sets, the ECMs increased the maximum interior temperature from 86.7 to 88.3°F. In addition, the ECMs increased the total hours of exposure indoors from 104 hours to 140 hours, a 34.6% increase over the baseline, code compliant building.

STATEWIDE IMPACTS FOR INDUSTRIAL BUILDINGS

The following tables take the average reductions in energy use from the baseline and upgraded systems and averages them across all seven ClimAID regions. The first section measures the reductions in statewide energy use, demand, cost and emissions. The second shows the difference in weather variability impact on energy use, demand, cost, and operations. Reductions for the first two sections are shown as a percentage in blue. The final section shows the difference in passive survivability impacts, with the baseline design represented in white and the upgraded design in blue.

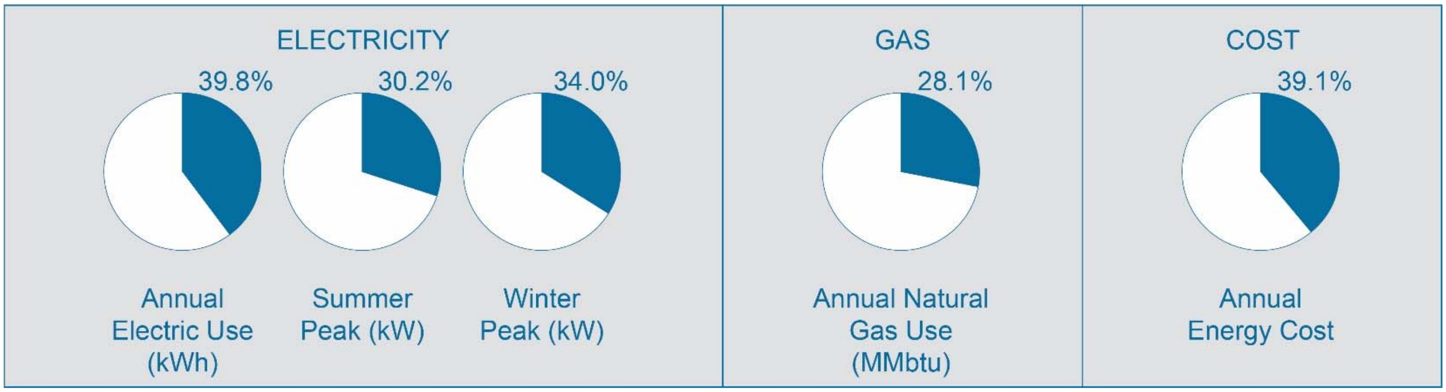
REDUCTIONS IN STATEWIDE ENERGY USE, DEMAND, COST, AND EMISSIONS IMPACTS



ECMs have positive impacts on energy use and cost across the State. Reductions are seen in every category, averaging at 39.7% for annual electric use, 29.9% for summer peak, 34.2% for winter peak, 28.9% for annual natural gas use, 39.0% for cost, 39.7% for air pollution from electrical generation, and 36.7% for carbon dioxide emissions.

While each ECM contributes to enhancing building performance, lighting improvements in uncovered parking areas made the biggest difference among each ClimAID region. This measure alone reduces annual electric use by an average of 111,777 kWh, annual fuel use by an average of 86 MMbtu, and annual energy cost by an average of $16,249 per region for commercial building types.

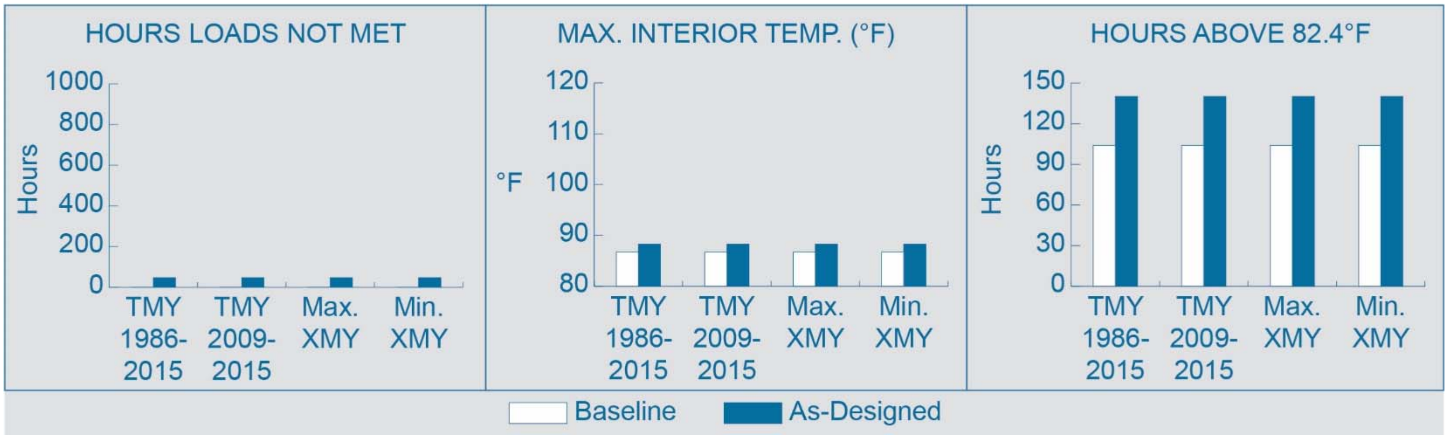
WEATHER VARIABILITY IMPACT ON ENERGY USE, DEMAND, COST, AND OPERATIONS



All four data sets show that ECMs improve energy performance in all seven ClimAID regions. While reductions are seen in every category investigated – 39.8% for annual energy use, 30.2% for summer peak, 34.0% for winter peak, 28.1% for annual fuel use, and 39.1% for annual energy cost, on average.

Among all regions, the ECMs are particularly beneficial to energy performance during extreme temperature events, as seen in the comparison of the baseline and upgraded building for both the maximum and minimum XMY. Annual energy use and annual energy cost were reduced by averages of 40.9% and 39.7%, respectively, in every region during extreme warm temperatures. Summer electrical peak and winter electrical peak saw reductions of 31.4% and 34.4%, respectively, on average during extreme cold temperatures. Annual fuel use was reduced most for the 30-year TMY data set, by an average of 28.9%.

STATEWIDE PASSIVE SURVIVABILITY IMPACTS



All regions showed negative effects in passive survivability from ECMs. The maximum interior temperature saw an increase of 1.8%, on average across the State. The number of hours that the interior temperature exceeded 82.4°F increased statewide in all data sets by an average of 34.6%.

Educational Building Case Study

CAYUGA – ONODAGA BOCES VOCATIONAL SCHOOL

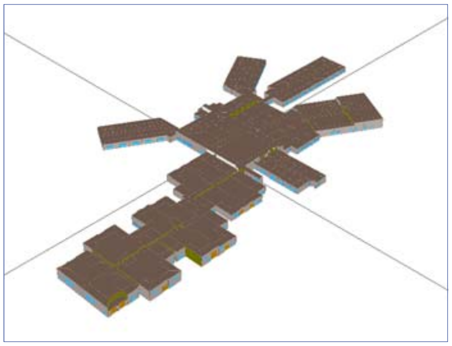


Figure 5: Screenshot of the building energy model in eQuest

In New York, there are approximately 13,944 educational buildings; they represent 0.26% of the total number of buildings in the State and 0.0001% of the total floor area.

Along with providing communities with spaces for learning, educational buildings often serve as emergency shelters. Because of this, improving the performance of HVAC systems in schools is critical to increasing the resilience of the building stock as well as the resiliency of communities.

METHODOLOGY

The educational building energy model was based on a 192,000 square foot, single story educational facility built in Auburn, New York in 2007. The building has a steel structural skeleton, consisting of insulated six inch metal studs, with brick cladding and a flat roof (Figure 5).

Classroom and office spaces are conditioned by a heat pump-based system, and trade areas are conditioned by heat only ventilation systems with heat recovery and a radiant floor. The building has parking lots on all sides and is surrounded by fields and farmland; these details were not included in the energy model. The long axis of the building is oriented east-west.

The methodology used for this study is based on the Chartered Institution of Building Services Engineers (CIBSE) report “Climate change and the indoor environment: impacts and adaptation” and the NYSERDA New Construction Program Simulation Guidelines. Models were run in eQuest version 3.62 using the files originally created by L&S Energy Services for a 2008 Technical Assistance Study in Support of the New Construction Program (NCP 5088).

Table 61: Energy Conservation Measures, System Descriptions, Effective Useful Life, and Incremental Costs

ECMs	Baseline System Description†	Upgraded System Description	EUL (years)	Cost ($)
Improved Insulation	Designed to code insulation value for the walls and roof.	Additional insulation in the walls and roof.	50	$34,100
High Efficiency Lighting	A lighting intensity of 0.7 to 2.2 watts per square foot was modeled, depending upon the space type. The baseline lighting averaged 1.38 watts per square foot.	The lighting intensity was calculated using the indoor fixtures as specified in the design drawings. The installed lighting averaged 0.87 watts per square foot.	15	$298,400
VSDs in Pumping Systems	Constant speed on the pumping systems.	Variable speed drivers (VSDs) on pumping systems.	15	$8,300
Lighting Controls	Lighting timers	Occupancy sensors.	15	$16,300
Energy Recovery Units	No energy recovery units.	Energy recovery units.	15	$63,700

†The New York State Energy Conservation Code of 1999 was the baseline used for the analysis.

Using a package minus approach for the modeling, the building systems were downgraded in steps from the as-designed configuration to code compliant systems, starting first with the ECMs that have the longest effective useful life (EUL) as shown in table 61. The building was modeled with the as-designed HVAC systems to understand the impact of design changes on energy usage, demand, operating costs, and $SO_x/NO_X/CO_2$ emissions.

After the energy conservation measures were modeled, the next set of runs investigated the cumulative effect of the strategies on passive survivability. Both the maximum interior temperature and the number of hours above 82.4°F were modeled; 82.4°F (28°C) is a threshold used by CIBSE as a proxy for high heat exposure.

Although the CIBSE study used future weather year data to investigate overheating for buildings in the United Kingdom, this study did not project results into the future because similar files are not currently available for New York State. In addition, changes in the average air temperature tend to have less impact on the operation of HVAC systems; the peak heating and cooling loads experienced during a heat wave or cold spell typically determine the size of a building system and its impact on energy demand.

To this end, for the third and final set of energy modeling runs, the baseline and upgraded buildings were compared using four sets of meteorological data prepared by Weather Analytics:

1) Typical Meteorological Year (TMY) Data:

    i. TMY, 1986 – 2015, 30 years
    ii. TMY, 2009 – 2015, 6 years

    TMY are data sets of hourly values of solar radiation and meteorological elements for a one-year period. They are typically used for computer simulations of solar or building HVAC systems. Because they represent typical rather than extreme conditions, they are not use for designing systems to meet the worst-case conditions occurring at a location. Although TMY are available from the National Renewable Energy Laboratory for most cities in the United States, these files cover the period 1991-2005 in New York State. Weather Analytics created custom TMY data for multiple sites across the state using more current data, specifically the period 1986 to 2015 and 2009 to 2015. This second set of files promotes understanding of how recent warming may impact building system performance.

2) eXtreme Meteorological Year (XMY) Data:

    i. XMY MAX, 2001 – 2015, 15 years
    ii. XMY MIN, 2001 – 2015, 15 years

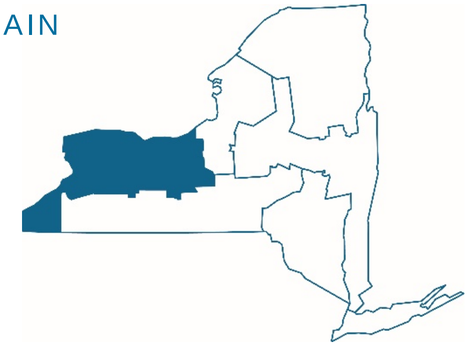
    Weather Analytics also created XMY files to examine the extreme cases occurring over the last 15 years. XMY files are created by using historical data to determine the maximum and minimum of a variable on a monthly basis. For example, if temperature is requested over a period of 15 years, the XMY MAX file will consist of the warmest months that occurred over the past 15 years, while the XMY MIN file will consist of the coolest (based on averages). Along with the extreme temperatures, the consequent data (e.g., solar radiation, wind speed) from the extreme month is also carried over to the XMY file, keeping consistency between each variable.

The results from this portion of the study indicate how weather variability may impact energy usage, demand, and operating costs. The number of hours the systems could not keep up with heating and cooling loads were also calculated, as well as the maximum interior temperature and number of hours above 82.4°F.

REGIONAL PROFILES

The following section outlines the results for each of the seven ClimAID regions. Following the profiles, a discussion of the statewide impacts for low-rise residential buildings is presented.

REGION 1: WESTERN NEW YORK AND THE GREAT LAKES PLAIN



As expected, the ECMs reduced the summer electrical peak (25.0%), the annual electricity use (23.4%), the winter electrical peak (23.7%), and the annual natural gas use (6.6%). These savings translated to a 17.8% reduction in utility costs, or $46,000 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 23.4%; carbon dioxide emissions were reduced by 11.5%. With the exception of insulation improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 62: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,012,737	405.1	506.1	10,008.3	$211,961	138.7	345.3	820.5	N/A
Improved Insulation	1,016,441	405.1	506.1	10,053.9	$212,965	139.3	346.6	824.0	34.0
High Efficiency Lighting	1,193,956	405.6	507.7	9,907.3	$238,713	163.6	407.1	856.6	11.6
VSDs on Pumping Systems	1,239,765	497.8	590.9	9,907.3	$245,585	169.8	422.8	867.2	1.2
Lighting Controls	1,277,254	532.2	618.3	9,921.6	$251,118	175.0	435.5	876.7	2.6
Energy Recovery Units	1,322,584	540.2	663.1	10,604.7	$257,961	181.2	451.0	927.2	9.3
Reduction	23.4%	25.0%	23.7%	6.6%	17.8%	23.4%	23.4%	11.5%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 23.5% and 24.8%, annual energy use between 22.7% and 24.2%, and winter peak between 23.7% and 24.6%. For all four sets of data, annual natural gas use increased by 0.8%. These reductions in electricity use resulted in a 16.8% to 19.0% decrease in total annual energy cost. In all cases, the ECMs decreased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 8.7% and 73.8%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

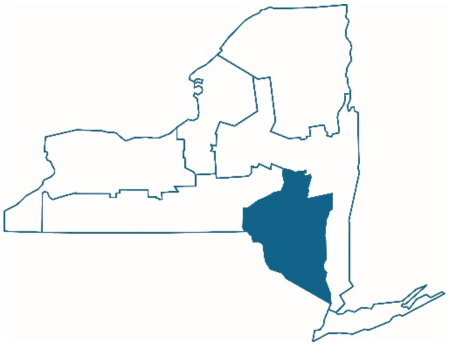
Table 63: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,322,585	540.2	663.1	9,928.9	$257,961	254	104.8	1,717
TMY, 1986-2015 (As-Designed)	1,012,737	406.3	506.1	10,008.3	$211,960	193	100.4	1,382
TMY, 2009-2015 (Baseline)	1,300,571	537.8	650.8	9,626.4	$252,844	237	103.3	1,661
TMY, 2009-2015 (As-Designed)	994,635	404.2	496.3	9,701.4	$207,403	193	98.7	1,333
Max. XMY (Baseline)	1,226,338	592.4	625.3	7,955.7	$231,685	201	106.2	1,710
Max. XMY (As-Designed)	929,752	445.6	476.2	8,016.2	$187,560	184	101.3	964
Min. XMY (Baseline)	1,380,343	538.6	673.6	11,457.0	$275,793	1,069	104.1	1,756
Min. XMY (As-Designed)	1,067,350	411.9	507.7	11,552.6	$229,418	280	99.8	1,425

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 104.8 to 100.4°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,717 hours to 1,382 hours, a 19.5% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.3 and 4.9°F; total hours where the interior temperature was over 82.4°F were reduced between 18.9% and 43.6%.

REGION 2: CATSKILL MOUNTAINS AND WEST HUDSON RIVER VALLEY



As expected, the ECMs reduced the summer electrical peak (25.1%), the annual electricity use (23.8%), the winter electrical peak (24.0%), and the annual natural gas use (1.7%). These savings translated to an 18.3% reduction in utility costs, or $46,404 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 23.8%; carbon dioxide emissions were reduced by 7.9%. With the exception of insulation improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 64: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO$_x$ (lbs.)	NO$_x$ (lbs.)	CO$_2$ (tons)	
As-Designed Building	1,002,906	418.9	499.8	9,483.7	$207,515	137.4	342.0	787.5	N/A
Improved Insulation	1,006,523	419.6	501.4	9,555.0	$208,485	137.9	343.2	792.5	35.2
High Efficiency Lighting	1,185,060	512.2	583.5	9,410.8	$234,401	162.4	404.1	825.5	11.5
VSDs on Pumping Systems	1,231,546	522.6	592.4	9,410.8	$241,374	168.7	420.0	836.3	1.2
Lighting Controls	1,269,577	547.1	611.4	9,398.2	$247,003	173.9	432.9	844.3	2.9
Energy Recovery Units	1,315,393	559.0	657.6	9,405.5	$253,919	180.2	448.5	855.4	9.2
Reduction	23.8%	25.1%	24.0%	1.7%	18.3%	23.8%	23.8%	7.9%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 24.7% and 26.4%, annual energy use between 23.1% and 24.5%, and winter peak between 23.8% and 24.3%. For all four sets of data, annual natural gas use increased by 0.8%. These reductions in electricity use resulted in a 17.4% to 19.5% decrease in total annual energy cost. In all cases, the ECMs decreased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 3.8% and 33.3%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

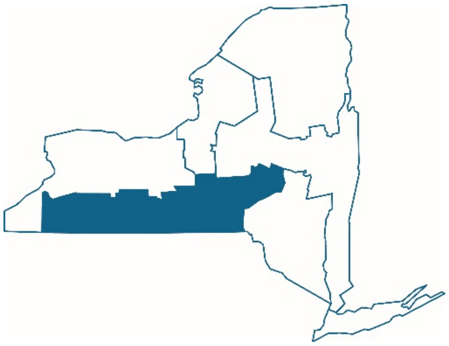
Table 65: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,315,393	559.0	657.6	9,435.0	$253,919	228	105.0	1,722
TMY, 1986-2015 (As-Designed)	1,002,906	421.1	499.8	9,513.2	$207,515	219	100.5	1,405
TMY, 2009-2015 (Baseline)	1,308,824	602.5	653.6	9,280.2	$252,005	201	106.1	1,740
TMY, 2009-2015 (As-Designed)	997,451	444.5	496.7	9,357.0	$205,760	193	101.7	1,408
Max. XMY (Baseline)	1,230,638	602.3	618.4	7,600.4	$230,198	175	106.1	1,778
Max. XMY (As-Designed)	929,593	450.0	468	7,662.7	$185,415	158	101.3	1,443
Min. XMY (Baseline)	1,395,924	578.3	684.6	11,084.5	$275,896	237	105.7	1,882
Min. XMY (As-Designed)	1,072,893	425.7	521.5	11,172.9	$227,971	158	101.5	1,603

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 105.0 to 100.5°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,722 hours to 1,405 hours, an 18.4% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.2 and 4.8°F; total hours where the interior temperature was over 82.4°F were reduced between 14.9% and 19.1%.

REGION 3: SOUTHERN TIER



As expected, the ECMs reduced the summer electrical peak (25.5%), the annual electricity use (23.0%), the winter electrical peak (23.6%), and the annual natural gas use (1.7%). These savings translated to a 17.4% reduction in utility costs, or $45,542 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 23.0%; carbon dioxide emissions were reduced by 7.3%. With the exception of insulation improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 66: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,026,362	400.1	506.2	10,261.7	$215,524	140.6	350.0	838.4	N/A
Improved Insulation	1,030,189	400.5	507.6	10,339.6	$216,566	141.1	351.3	843.9	32.7
High Efficiency Lighting	1,205,642	493.3	591.3	10,179.5	$241,923	165.2	411.1	875.2	11.8
VSDs on Pumping Systems	1,251,672	503.0	598.9	10,179.5	$248,828	171.5	426.8	885.9	1.2
Lighting Controls	1,288,959	527.7	618.5	10,166.1	$254,341	176.6	439.5	893.8	3.0
Energy Recovery Units	1,333,514	537.1	662.3	10,173.0	$261,066	182.7	454.7	904.5	9.5
Reduction	23.0%	25.5%	23.6%	1.7%	17.4%	23.0%	23.0%	7.3%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 23.6% and 26.0%, annual energy use between 22.6% and 24.1%, and winter peak between 21.6% and 24.7%. For all four sets of data, annual natural gas use increased by 0.8%. These reductions in electricity use resulted in a 16.8% to 18.9% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 4.8% and 66.7%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

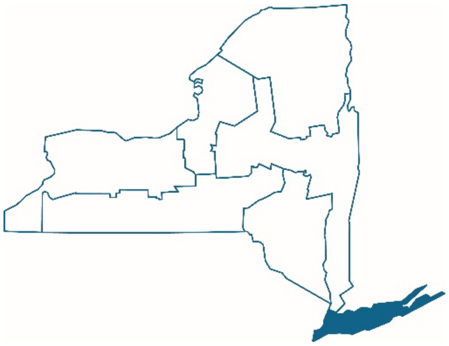
Table 67: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,333,516	549.0	662.3	10,173.0	$261,066	385	104.1	1,704
TMY, 1986-2015 (As-Designed)	1,026,362	419.2	506.2	10,261.7	$215,524	166	99.7	1,345
TMY, 2009-2015 (Baseline)	1,336,053	570.5	656.0	9,819.1	$259,323	210	105.5	1,703
TMY, 2009-2015 (As-Designed)	1,022,200	422.4	500.3	9,897.8	$212,717	184	101.2	1,406
Max. XMY (Baseline)	1,238,525	582.6	598.4	8,028.2	$233,948	184	105.3	1,677
Max. XMY (As-Designed)	940,582	436.1	469.0	8,089.2	$189,622	175	100.3	1,332
Min. XMY (Baseline)	1,426,672	566.3	696.9	11,805.5	$284,834	526	104.5	1,802
Min. XMY (As-Designed)	1,104,008	431.7	524.6	11,896.9	$236,983	175	100.3	1,500

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 104.1 to 99.7°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,704 hours to 1,345 hours, a 21.1% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.2 and 5.0°F; total hours where the interior temperature was over 82.4°F were reduced between 16.8% and 21.1%.

REGION 4: NEW YORK CITY AND LONG ISLAND



As expected, the ECMs reduced the summer electrical peak (24.9%), the annual electricity use (24.1%), the winter electrical peak (24.1%), and the annual natural gas use (2.2%). These savings translated to an 18.7% reduction in utility costs, or $44,990 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 24.1%; carbon dioxide emissions were reduced by 8.6%. With the exception of insulation improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 68: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	955,584	427.9	480.8	8,651.7	$195,248	130.9	325.9	727.8	N/A
Improved Insulation	958,710	428.5	482.2	8,711.1	$196,073	131.3	326.9	732.0	41.3
High Efficiency Lighting	1,138,291	523.3	563.0	8,588.3	$222,273	155.9	388.2	766.5	11.4
VSDs on Pumping Systems	1,180,468	533.5	572.1	8,588.3	$228,600	161.7	402.5	776.3	1.3
Lighting Controls	1,218,874	558.9	590.8	8,774.0	$234,296	167.0	451.6	796.1	2.9
Energy Recovery Units	1,258,213	569.5	633.6	8,584.3	$240,238	172.4	429.1	794.1	10.7
Reduction	24.1%	24.9%	24.1%	2.2%	18.7%	24.1%	24.1%	8.6%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 24.0% and 25.0%, annual energy use between 23.4% and 24.8%, and winter peak between 23.9% and 24.5%. For all four sets of data, annual natural gas use increased by between 0.7% and 0.8%. These reductions in electricity use resulted in a 17.8% to 20.0% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 10.0% and 44.7%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

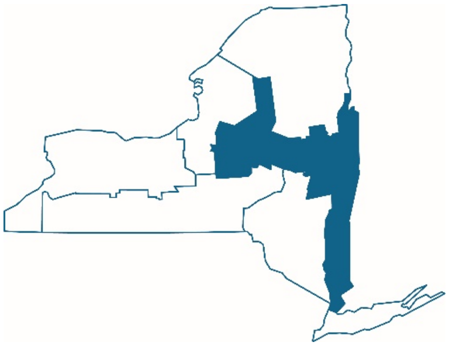
Table 69: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,258,213	569.5	633.6	8,584.3	$240,238	219	105.7	1,704
TMY, 1986-2015 (As-Designed)	955,584	427.9	480.8	8,651.7	$195,248	193	100.9	1,385
TMY, 2009-2015 (Baseline)	1,244,271	577.2	630.9	8,478.1	$237,510	219	105.6	1,782
TMY, 2009-2015 (As-Designed)	945,463	432.7	479.9	8,542.7	$193,076	193	100.8	1,454
Max. XMY (Baseline)	1,199,640	613.3	598.4	6,943.7	$221,608	175	106.5	1,805
Max. XMY (As-Designed)	901,588	460.0	451.7	6,991.3	$177,186	158	101.5	1,489
Min. XMY (Baseline)	1,309,719	537.2	654.4	9,990.5	$256,401	333	106	1,803
Min. XMY (As-Designed)	1,002,632	408.3	497.4	10,065.5	$210,788	184	101.2	1,481

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 105.7 to 100.9°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,704 hours to 1,385 hours, an 18.8% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.4 and 5.0°F; total hours where the interior temperature was over 82.4°F were reduced between 17.5% and 18.8%.

REGION 5: EAST HUDSON AND MOHAWK RIVER VALLEYS



As expected, the ECMs reduced the summer electrical peak (25.0%), the annual electricity use (23.0%), the winter electrical peak (23.7%), and the annual natural gas use (1.8%). These savings translated to a 17.4% reduction in utility costs, or $46,100 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 23.0%; carbon dioxide emissions were reduced by 7.2%. With the exception of insulation improvements, all the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 70: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,043,025	389.2	508.1	10,466.1	$219,428	142.9	355.7	854.3	N/A
Improved Insulation	1,046,982	389.6	509.5	10,548.1	$220,512	143.4	357.0	860.0	31.5
High Efficiency Lighting	1,223,445	480.7	594.0	10,377.1	$245,956	167.6	417.2	890.9	11.7
VSDs on Pumping Systems	1,270,909	490.2	601.5	10,377.1	$253,075	174.1	433.4	901.9	1.2
Lighting Controls	1,308,144	514.4	621.1	10,362.0	$258,571	179.2	446.1	909.7	3.0
Energy Recovery Units	1,354,237	518.9	665.7	10,369.2	$265,528	185.5	461.8	920.8	9.2
Reduction	23.0%	25.0%	23.7%	1.8%	17.4%	23.0%	23.0%	7.2%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 23.7% and 26.0%, annual energy use between 22.5% and 24.0%, and winter peak between 23.6% and 24.8%. For all four sets of data, annual natural gas use increased by 0.8% to 0.9%. These reductions in electricity use resulted in a 16.7% to 18.9% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 8.3% and 7.2%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

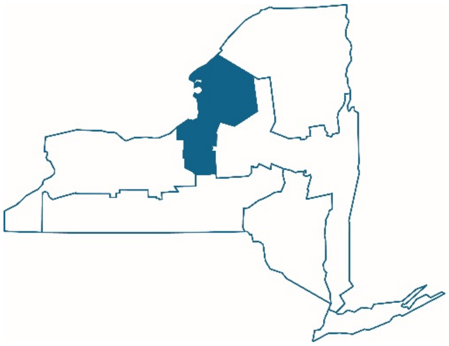
Table 71: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,354,237	553.5	665.7	10,398.7	$265,528	675	103.7	1,603
TMY, 1986-2015 (As-Designed)	1,043,025	420.6	508.1	10,495.6	$219,428	193	99.4	1,282
TMY, 2009-2015 (Baseline)	1,347,047	562.0	670.7	9,959.3	$261,813	307	104.4	1,654
TMY, 2009-2015 (As-Designed)	1,033,718	416.1	512.6	10,047.0	$215,340	201	100.2	1,341
Max. XMY (Baseline)	1,254,279	595.9	620.0	8,158.8	$237,094	210	105.7	1,708
Max. XMY (As-Designed)	953,610	445.4	471.7	8,220.7	$192,365	193	100.9	1,387
Min. XMY (Baseline)	1,444,892	558.6	669.0	11,983.7	$288,636	1,349	104.2	1,810
Min. XMY (As-Designed)	1,120,255	426.4	525.6	12,076.8	$240,499	307	100.1	1,491

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 103.7 to 99.4°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,603 hours to 1,282 hours, a 20.0% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.1 and 4.8°F; total hours where the interior temperature was over 82.4°F were reduced between 17.6% and 20.0%.

REGION 6: TUG HILL PLATEAU



As expected, the ECMs reduced the summer electrical peak (25.1%), the annual electricity use (22.9%), the winter electrical peak (25.2%), and the annual natural gas use (3.9%). These savings translated to a 16.9% reduction in utility costs, or $45,811 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 22.9%; carbon dioxide emissions were reduced by 5.6%. With the exception of interior lighting improvements, all the ECMs have payback periods shorter than their expected useful life. However, this cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 72: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO$_x$ (lbs.)	NO$_x$ (lbs.)	CO$_2$ (tons)	
As-Designed Building	1,061,369	410.5	524.2	11,016.2	$225,481	145.4	361.9	890.7	N/A
Improved Insulation	1,238,507	411.2	525.9	10,860.8	$251,120	169.7	422.3	922.7	1.3
High Efficiency Lighting	1,287,944	502.8	611.3	10,860.8	$258,536	176.4	439.2	934.2	40.2
VSDs on Pumping Systems	1,324,530	513.4	618.7	10,845.4	$263,931	181.5	451.7	941.8	1.5
Lighting Controls	1,324,528	537.4	638.5	10,875.3	$263,932	181.5	451.7	943.5	16,300.0
Energy Recovery Units	1,376,797	547.8	701.3	10,604.7	$271,292	188.6	469.5	939.8	8.7
Reduction	22.9%	25.1%	25.2%	3.9%	16.9%	22.9%	22.9%	5.6%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 23.8% and 25.3%, annual energy use between 22.6% and 24.0%, and winter peak between 23.9% and 25.3%. For all four sets of data, annual natural gas use increased by 0.7% to 0.8%. These reductions in electricity use resulted in a 16.6% to 18.6% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 10.0% and 66.7%. Therefore, ECMs would help mechanical equipment to keep up with the expected and extreme heating or cooling loads, reducing the potential for HVAC system failure during extreme temperature events and decreasing strain on the electrical grid.

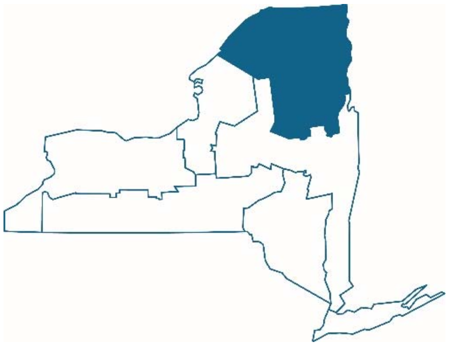
Table 73: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,376,799	567.4	701.3	10,882.0	$271,812	263	104.3	1,806
TMY, 1986-2015 (As-Designed)	1,057,276	432.1	524.2	10,964.3	$224,377	184	100.1	1,475
TMY, 2009-2015 (Baseline)	1,346,454	549.9	697.7	10,551.5	$265,277	587	103.9	1,781
TMY, 2009-2015 (As-Designed)	1,033,021	418.4	523.9	10,636.5	$218,772	228	99.5	1,469
Max. XMY (Baseline)	1,265,029	563.2	640.8	8,708.4	$242,005	175	105.3	1,821
Max. XMY (As-Designed)	962,025	420.6	487.5	8,771.4	$196,932	158	100.7	1,519
Min. XMY (Baseline)	1,453,217	563.7	710.1	12,513.2	$293,062	762	104.2	1,841
Min. XMY (As-Designed)	1,125,509	428.7	532.9	12,604.8	$244,455	254	99.9	1,564

PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 104.3 to 100.1°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,806 hours to 1,475 hours, an 18.3% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.2 and 4.6°F; total hours where the interior temperature was over 82.4°F were reduced between 15.1% and 18.3%.

REGION 7: ADIRONDACK MOUNTAINS



As expected, the ECMs reduced the summer electrical peak (25.2%), the annual electricity use (23.0%), the winter electrical peak (25.2%), and the annual natural gas use (1.6%). These savings translated to a 17.4% reduction in utility costs, or $46,459 in annual savings. The ECMs also reduced air pollution associated with electricity generation for the building by 23.0%; carbon dioxide emissions were reduced by 6.7%. With the exception of interior lighting and lighting control improvements, all of the ECMs have payback periods shorter than their expected useful life. This cost-benefit calculation does not include savings from electrical demand charges, put a value on carbon dioxide emissions, or consider the potential health-related impacts of air pollution.

Table 74: Energy Conservation Measure Impacts on Use, Demand, Cost, and Emissions

Energy Conservation Measures	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Annual Emissions			ECM Simple Payback (years)
						SO_x (lbs.)	NO_x (lbs.)	CO_2 (tons)	
As-Designed Building	1,047,820	403.0	518.9	10,766.8	$221,282	143.6	357.3	873.0	N/A
Improved Insulation	1,225,372	403.6	520.3	10,610.3	$247,434	167.9	417.9	905.0	1.3
High Efficiency Lighting	1,273,936	495.0	605.5	10,610.3	$254,834	174.5	434.4	916.3	40.3
VSDs on Pumping Systems	1,311,489	505.2	613.1	10,598.0	$260,312	179.7	447.2	924.3	1.5
Lighting Controls	1,311,487	529.4	632.9	10,598.0	$261,324	179.7	447.2	924.3	16.1
Energy Recovery Units	1,360,748	538.9	694.0	10,604.7	$267,741	186.4	464.0	936.1	9.9
Reduction	23.0%	25.2%	25.2%	1.6%	17.4%	23.0%	23.0%	6.7%	N/A

WEATHER VARIABILITY IMPACTS

For all four sets of weather data, the ECMs have a positive impact on energy performance, reducing summer peak between 24.1% and 26.2%, annual energy use between 22.7% and 24.3%, and winter peak between 24.0% and 25.2%. For all four sets of data, annual natural gas use increased by between 0.8% and 0.9%. These reductions resulted in a 16.8% to 19.0% decrease in total annual energy cost. In all cases, the ECMs increased the number of hours where heating and cooling loads were not able to be met by the HVAC equipment by between 4.5% and 74.4%.

Table 75: Weather Variability Impacts on Use, Demand, Cost, and Passive Survivability

Weather Data	Annual Electric Use (kWh)	Summer Peak (kW)	Winter Peak (kW)	Annual Natural Gas Use (MMbtu)	Annual Energy Cost	Hours Loads Not Met	Max. Interior Temp. (°F)	Hours >82.4°F
TMY, 1986-2015 (Baseline)	1,360,750	553.9	694.0	10,604.7	$267,741	298	104.4	1,841
TMY, 1986-2015 (As-Designed)	1,043,946	420.2	518.9	10,684.9	$220,701	184	100.2	1,537
TMY, 2009-2015 (Baseline)	1,321,476	549.8	670.3	9,883.6	$257,523	228	104.2	1,744
TMY, 2009-2015 (As-Designed)	1,009,755	416.1	509.3	9,967.9	$211,271	175	99.8	1,431
Max. XMY (Baseline)	1,257,592	607.8	629.5	8,323.9	$238,582	193	105.9	1,774
Max. XMY (As-Designed)	952,486	448.7	478.0	8,388.9	$193,206	184	101.2	1,461
Min. XMY (Baseline)	1,438,159	563.4	712.4	12,192.7	$288,880	1,437	105.5	1,945
Min. XMY (As-Designed)	1,111,118	426.5	535.0	12,286.1	$240,385	368	101.5	1,710

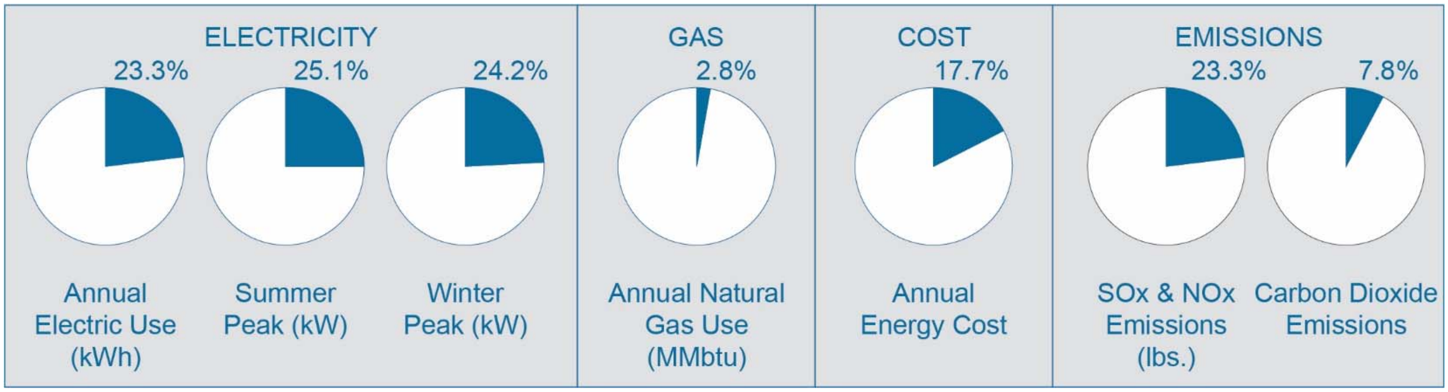
PASSIVE SURVIVABILITY

For the 30-year TMY analysis (1986-2015), the ECMs reduced the maximum interior temperature from 104.4 to 100.2°F. In addition, the ECMs reduced the total hours of exposure indoors from 1,841 hours to 1,537 hours, a 16.5% improvement over the baseline, code compliant building. Similar results were observed for all four sets of weather data; the total exposure to high temperature was reduced by the ECMs between 4.0 and 4.7°F; total hours where the interior temperature was over 82.4°F was reduced by between 12.1% and 18.0%.

STATEWIDE IMPACTS FOR EDUCATIONAL BUILDINGS

The following tables take the average reductions in energy use from the baseline and upgraded systems and averages them across all seven ClimAID regions. The first section measures the reductions in statewide energy use, demand, cost and emissions. The second shows the difference in weather variability impact on energy use, demand, cost, and operations. Reductions for the first two sections are shown as a percentage in blue. The final section shows the difference in passive survivability impacts, with the baseline design represented in white and the upgraded design in blue.

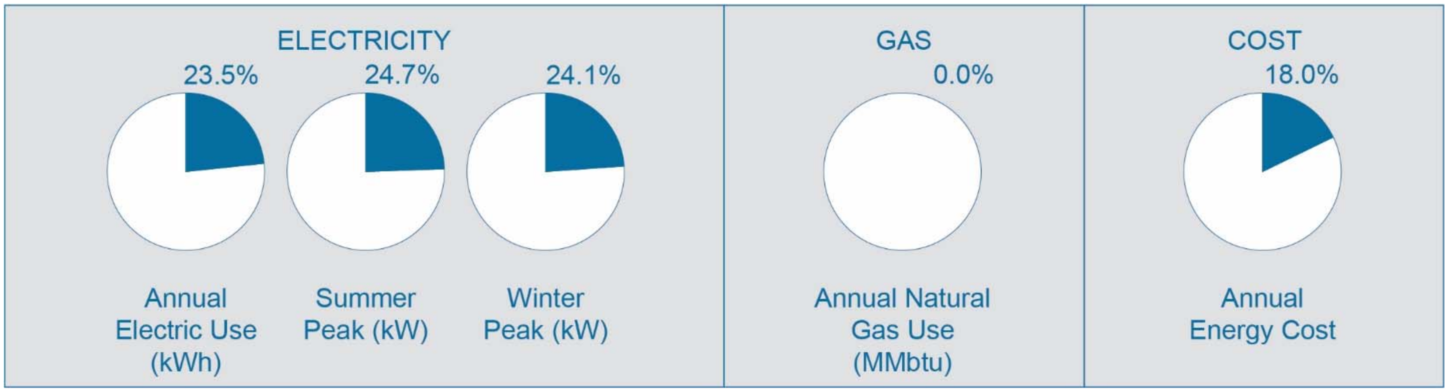
REDUCTIONS IN STATEWIDE ENERGY USE, DEMAND, COST, AND EMISSIONS IMPACTS



ECMs have positive impacts on energy use and cost across the State. Reductions are seen in every category, averaging at 23.3% for annual electric use, 25.1% for summer peak, 24.2% for winter peak, 2.8% for annual natural gas use, 17.7% for cost, 23.3% for air pollution from electrical generation, and 7.8% for carbon dioxide emissions.

While each ECM contributes to enhancing building performance, interior lighting improvements made the biggest difference among each ClimAID region. This measure alone reduces annual electric use by an average of 140,793 kWh, annual fuel use by an average of 106 MMbtu, and annual energy cost by an average of $20,497 per region for educational building types.

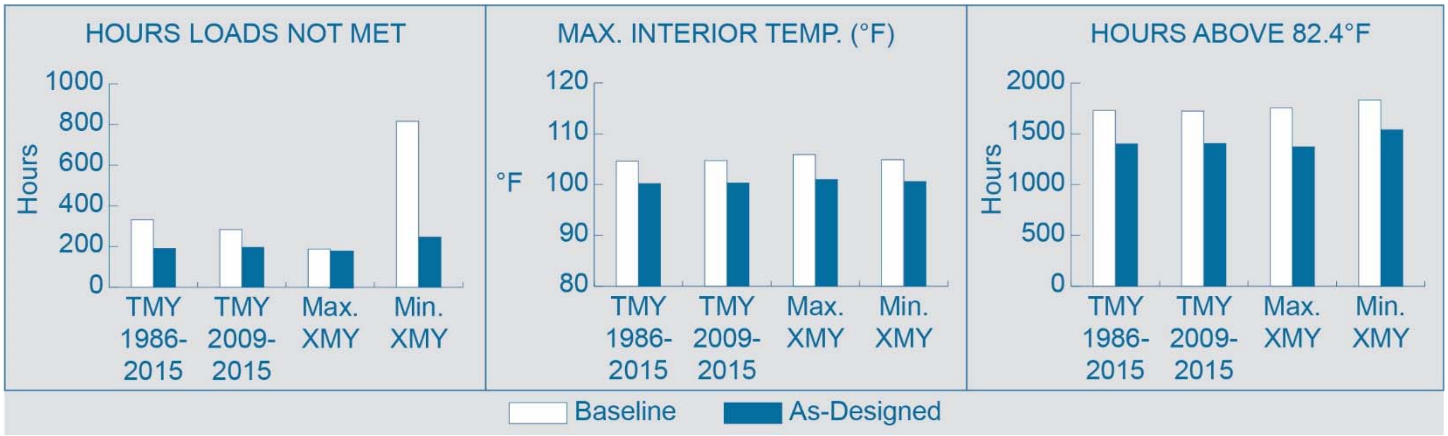
WEATHER VARIABILITY IMPACT ON ENERGY USE, DEMAND, COST, AND OPERATIONS



All four data sets show that ECMs improve energy performance in all seven ClimAID regions. While reductions are seen in most of the categories investigated – 23.5% for annual energy use, 24.7% for summer peak, 24.1% for winter peak, and 18.0% for annual energy cost, on average, annual fuel use and the number of hours of loads not met both increased by averages of 0.8% and 32.0%, respectively.

Among all regions, the ECMs are particularly beneficial to energy performance during extreme temperature events, as seen in the comparison of the baseline and upgraded building for the maximum XMY. Annual energy use and annual energy cost were reduced by averages of 24.3% and 19.1%, respectively, in every region during extreme warm temperatures. The number of hours where heating and cooling loads were not able to be met by the HVAC equipment was reduced by 62.4% on average during extreme cold temperatures.

STATEWIDE PASSIVE SURVIVABILITY IMPACTS

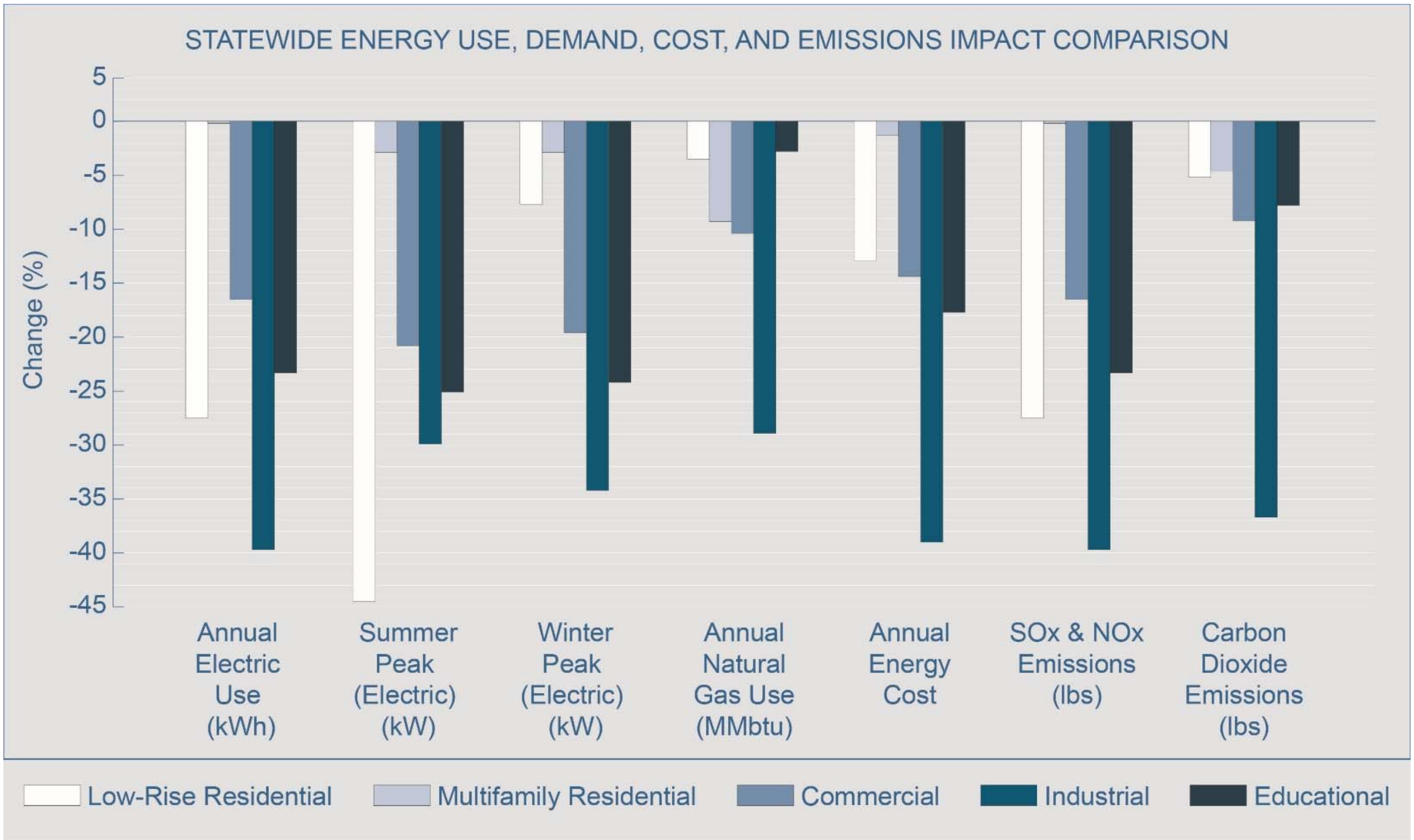


All regions showed positive effects in passive survivability from ECMs. The maximum interior temperature saw a reduction of 4.3% on average across the state. The greatest improvements over the baseline for maximum interior temperatures were seen in the analysis of extreme warm temperatures (XMY), which showed an average reduction of 4.5% statewide.

The number of hours that the interior temperature exceeded 82.4°F was reduced statewide by an average of 18.9%. While for most of the cases in each region the number of hours were reduced by between 12.1% and 21.1%, the data from the maximum XMY analysis in Region 1 showed a reduction of 43.6%.

Discussion of Statewide Impacts

In general, the ECMs improved the energy performance of all the different building typologies throughout all regions. The industrial building study seemed to have the most reductions among the different categories, with its lowest still being over a 25% reduction in annual natural gas use. The ECM that had the greatest impact on the industrial building was the introduction of above code lighting, which brought the baseline usage of 56.25kW down to an improved usage of 29.53 kW. The industrial building was only surpassed by low-rise residential for reductions in summer peak electricity use, which reached 44.5%. The multifamily residential building study came in with the lowest reductions across the board; the average statewide reductions never exceeded 10%, and more often than not fell closer to the 1-5% range. Both annual electric use and SO_x & NO_x emissions saw average reductions of only 0.2%. It is important to continue exploring how to keep improving these reductions because residential buildings, both low-rise and multifamily, are more susceptible to climate change and more crucial to resilience efforts.



Within the weather variability and passive survivability study, there were more significant variations within the statewide data. The low-rise residential building saw a broad range of reduction values, from a 2.6% reduction in annual natural gas use to a 70.3% reduction in the number of hours exceeding 82.4°F. Similarly to the previous section, the multifamily residential building saw consistently low reduction values, all falling between 0.0% and 3.1% except for annual natural gas use and the number of hours exceeding 82.4°F. These values were exceptionally high, coming in at 90.9% and 43.9%, respectively. The commercial building consistently fell within the middle ground among the other typologies, mostly staying within 14% - 23% reduction range. The outliers of this range, annual natural gas use, the number of hours where the loads were not met, the maximum interior temperature, and the number of hours exceeding 82.4°F, all fell between 0.0% - 5.4%. The educational building saw similar results to the commercial, ranging from 18% to 25% reductions in five out of the eight categories. Annual natural gas use and maximum interior temperature fell well below this range, only reducing by 0.0% and 4.3%, respectively. The number of hours of the loads not met exceeded this range with a 32%

reduction. The industrial building saw a trend of higher reduction values for electric and gas use and cost, ranging between 28% - 40% in reductions. However, this typology saw increases in maximum interior temperature, by 1.8%, and the number of hours above 82.4°F, by 34.6%. Due to the typical use of the industrial building, particularly in that they typically are not used for shelter in place, these increases do not severely impact these structures in terms of passive survivability.


WEATHER VARIABILITY AND PASSIVE SURVIVABILITY IMPACT COMPARISON
Change (%)
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
-45
-50
-55
-60
-65
-70
-75
-80
-85
-90
-95
Annual Electric Use (kWh)
Summer Peak (Electric) (kW)
Winter Peak (Electric) (kW)
Annual Natural Gas Use (MMbtu)
Annual Energy Cost
Hours Loads Not Met
Max. Interior Temp. (°F)
Hours > 82.4°F
Low-Rise Residential
Multifamily Residential
Commercial
Industrial
Educational

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