Lowering Utility Costs in Electrified Buildings

Case Study: The Beacon

NYSERDA Buildings of Excellence Early Design Support Report

PAUL A.
CASTRUCCI,
ARCHITECTS
PASSIVE HOUSE DESIGN FIRM

NEW YORK STATE OF OPPORTUNITY. | NYSERDA

Authors

This report is written and presented by **Paul A. Castrucci, Architects, PLLC,** an architecture practice committed to sustainability, equity, and community. Primary authors of data analysis, narrative, data visualization, and design are Grayson Jordan and Ana Leopold. The firm was founded 30 years ago by architect and community advocate Paul A. Castrucci, R.A. to establish an architecture practice around craftsmanship, functionality, and the preservation of the environment. The firm's services are focused on new buildings that are Passive House and Net Zero certified where possible, as well as deeply sustainable rehabilitation of existing structures. We design buildings that will benefit generations to come, striving towards Net Zero buildings that are in sync with natural rhythms, solar access, shading and light, wind, and vegetative patterns. We strive to provide design solutions that integrate Passive House building techniques into the community fabric while maintaining a commitment to design excellence. Having completed NYC's first Passive House + Net Zero building (R-951 Residence), more than a dozen Passive House buildings, and a wide portfolio of projects for non-profit, and affordable housing units, we are recognized leaders in *affordable,* high efficiency building design. You can find us at *www.castrucciarchitect.com*.

Abbreviations and Terms

ACH50 – Air Changes per Hour at 50 Pascals
AEC – Architecture, Engineering and Construction
AHJ – Authority Having Jurisdiction
BEEx – Building Energy Exchange
BOE – Buildings of Excellence
Btu - British Thermal Unit
cEER – Combined Energy Efficiency Ratio
ci - Continuous Insulation
Con-Ed – Con-Edison (utility company)
COPH – Coefficient of Performance, Heat Pump
DHW – Domestic Hot Water
DHWr – Domestic Hot Water Recirculation
DOB - Department of Buildings of New York City
ERV – Energy Recovery Ventilator
°F – Degrees Fahrenheit
FDNY – Fire Department of New York
HPD - Housing Preservation Department of New York City
HVAC – Heating, Ventilation and Air Conditioning
kWh - kilowatt hours
kW - kilowatt
LBS - Pounds
LL - Local Law
NYC - New York City
NYCHA - New York City Housing Authority
NYSERDA - New York State Energy Research & Development Authority
MEP – Mechanical, Electrical and Plumbing
OTCR – New York City Office of Technical Certification and Research
PCA - Paul Castrucci, Architects
PH - Passive House
PTAC – Packaged Terminal Air Conditioning
PV – Photo Voltaic
SBS - Sentient Building Systems
SDA - Solar Design Associates
SHGC – Solar Heat Gain Coefficient
tCO2e - Tons of Carbon Dioxide Equivalent
Therm - 100,00 btu, kWh, therms etc
TOU – Time of Use
Utility Cost – In this report, the cost to power a building: to heat, cool, ventilate, light and power the outlets and equipment in a building, but NOT the cost of water, sewer, or internet. The cost of energy includes demand and supply, but may not include additional and regional fees set by fuel providers.
U-Value – Thermal Transmittance
UL – United Laboratories
UPVC - Unplasticized Polyvinyl Chloride
VRF – Variable Refrigerant Flow
WUFI – Warme Und Feuchte Instationar (energy software)
ZED - Zero Energy Design

Acknowledgments

We would like to thank the **New York State Energy Research & Development Authority (NYSERDA)** for providing funding for this and other projects through their Buildings of Excellence – Early Design Support Program, and for their support on this and other sustainability initiatives. NYSERDA's support and leadership in New York State across numerous programs is helping to lead us into a clean, resilient, and carbon neutral future - we are truly grateful. NYSERDA's Clean and Resilient Buildings programs support modernizing and upgrading our buildings to be more comfortable, healthier, and to save our residents and businesses money. Thank you especially to Kristin Graham, our Senior Project Manager from NYSERDA for funding the analysis associated with the results presented in this project.

Contributors
- Brightcore Energy, LLC - Geothermal feasibility analysis
- MaGrann Associates - eQuest Modeling
- Sentient Building Systems - Building Controls Feasibility Analysis
- Solar Design Associates - Solar and Solar Battery Feasibility Analysis
- ZeroEnergy Design - WUFI Energy Modeling, Embodied Carbon Modeling

The Beacon project team
- The Community Builders (TCB) - co-developer
- Ascendant Neighborhood Development (AND) - co-developer
- Paul A. Castrucci Architects – sustainability consultant, co-architect on residential building (design development and onward), architect on community facility
- Body Lawson Associates, Architects and Planners - co-architect on residential building (schematic design)
- WXY Studio - co-architect residential building (schematic design)
- Dagher Engineering - MEP engineer
- Robert Silman Associates - Structural engineer
- Con-Edison - Electric Utility provider

Additional Thanks
- Ryan Cassidy, former Director of Sustainability, Riseboro Community Partnership
- Meltek Inc.
- Legend Power Systems

Table of Contents

Authors i
Abbreviations and Terms i
Acknowledgements ii

Executive Summary 01
Overview 03

Residential Analysis and Results 13

ENVELOPE

Passive House + Gas DHW Strategy 15
Passive House + Electric Strategy 19
High Performance Strategy 23

RENEWABLES

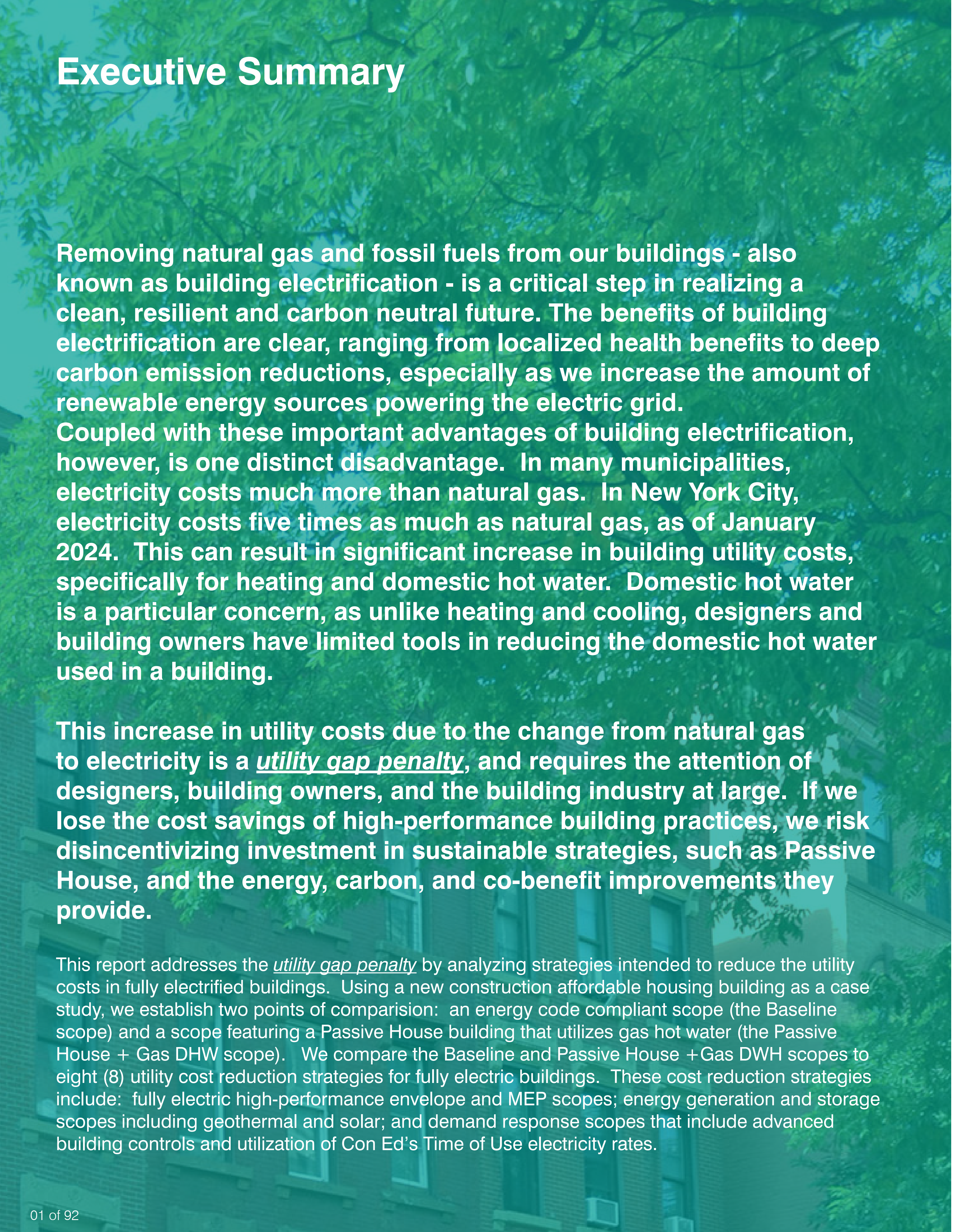
Rooftop Solar Photovoltaic 27
SIDEBAR: Challenges for the New Grid 30
Solar Batteries Strategy 33
Passive House + Geothermal Strategy 35

TOU + CONTROLS

Time of Use Rates Strategy 39
Building Controls and Energy Management 47
SIDEBAR: Resident Incentive Apps 58
Community Facility Analysis 65

Conclusions 73
Summary of Results 75
Conclusions and Recommendations 85

Tear Sheet 89
Footnotes and Citations 91



Executive Summary

Removing natural gas and fossil fuels from our buildings - also known as building electrification - is a critical step in realizing a clean, resilient and carbon neutral future. The benefits of building electrification are clear, ranging from localized health benefits to deep carbon emission reductions, especially as we increase the amount of renewable energy sources powering the electric grid.

Coupled with these important advantages of building electrification, however, is one distinct disadvantage. In many municipalities, electricity costs much more than natural gas. In New York City, electricity costs five times as much as natural gas, as of January 2024. This can result in significant increase in building utility costs, specifically for heating and domestic hot water. Domestic hot water is a particular concern, as unlike heating and cooling, designers and building owners have limited tools in reducing the domestic hot water used in a building.

This increase in utility costs due to the change from natural gas to electricity is a *utility gap penalty*, and requires the attention of designers, building owners, and the building industry at large. If we lose the cost savings of high-performance building practices, we risk disincentivizing investment in sustainable strategies, such as Passive House, and the energy, carbon, and co-benefit improvements they provide.

This report addresses the *utility gap penalty* by analyzing strategies intended to reduce the utility costs in fully electrified buildings. Using a new construction affordable housing building as a case study, we establish two points of comparision: an energy code compliant scope (the Baseline scope) and a scope featuring a Passive House building that utilizes gas hot water (the Passive House + Gas DHW scope). We compare the Baseline and Passive House +Gas DWH scopes to eight (8) utility cost reduction strategies for fully electric buildings. These cost reduction strategies include: fully electric high-performance envelope and MEP scopes; energy generation and storage scopes including geothermal and solar; and demand response scopes that include advanced building controls and utilization of Con Ed's Time of Use electricity rates.

The results of our analysis confirm the following:

1. The switch to fully electrified buildings can lead to significant utility cost increase if not thoughtfully addressed in the design phase. In some cases, the short-term effect could be to discourage implementation of deeply energy efficient design such as Passive House, leading to stacked losses to occupant health, comfort, and environmental justice.
2. Utility cost increases are due primarily to the switch from gas to electric powered domestic hot water systems. Buildings with high domestic hot water loads, such as multifamily residential, are especially susceptible to increased utility costs in electrified buildings.
3. The results of this study suggest that the most promising strategies to use in combination with Passive House principles are rooftop solar photovoltaic systems, geothermal systems, and advanced building controls combined with Con Edison Time of Use Rates.
4. In our case study, a solar photovoltaic array offset around 85% of the increased costs due to electic domestic hot water, reducing overall utility costs 42% from a baseline building and increasing the cost only 3.5% from a Passive House building with natural gas domestic hot water.
5. Combining geothermal heating and cooling with a Passive House envelope drives utility costs down 48% from the baseline and down 7% from the Passive House building with gas hot water, with room for further reduction if a solar photovoltaic array is added.
6. Combining a Passive House envelope with advanced building controls and Con Edison Time of Use Rates can reduce utility costs 43% from the baseline, and show a less than 1% increase from a Passive House building with gas hot water. Solar photovoltaic arrays savings increase using Time of Use Rates, pushing savings beneath the Passive House building with gas hot water. These strategies are each in different stages of market maturity, with some being easier, or less risky, to implement.

Finally, our research further highlights several ancillary strategies worth further research in active power management and resident savings sharing programs. We also note where further research, policy discussion, and industry wide information sharing is needed to improve our understanding of fully electric building performance. We encourage demonstration case studies of these tactics and the strategies above to progress implementation.

Overview

In New York City and beyond, fully electrified buildings play a key role in achieving a clean, resilient, and carbon neutral future. To propel the industry forward in this regard, building electrification is the subject of several recent local laws, sustainability incentives, and institutional mandates. As part of a larger strategy to combat climate change, and in combination with a commitment to provide cleaner power sources for the electric grid, we are fully investing in the conversion from fossil fuel systems to highly efficient electric systems. As we make this transition, we need to account for the fact that electricity is nearly five times as expensive per unit power as natural gas. With their relatively high domestic hot water loads, multifamily buildings and *most especially* affordable housing buildings will bear the heaviest financial burden of increased utility costs.

This report addresses strategies on how to reduce the utility costs of fully electrified multifamily buildings below the threshold of hybrid gas and electric buildings.

As we seek to drive utility costs down, we also consider the following:

> *How can we maintain or increase the energy and carbon emission savings?*
>
> *What are the barriers in building codes, installation costs, and market readiness to implementing strategies that can reduce utility costs of fully electric buildings?*
>
> *What are additional opportunities and benefits of implementing these strategies?*

APPROACH

This report analyzes various strategies to reduce energy consumption and drive down utility costs. We seek to identify a feasible and replicable toolkit to make fully electric buildings more affordable than gas-powered and hybrid counterparts.

This report addresses utility costs in buildings, while still seeking improved energy efficiency in fully electrified buildings. In this report, when we refer to 'utility costs' we are referring to the costs to power a building. For example, when we refer to utility costs here, we mean the costs to heat, cool, ventilate, light and power the outlets and equipment in a building, but NOT the cost of water, sewer, or internet.

The strategies we studied for reducing utility costs are:

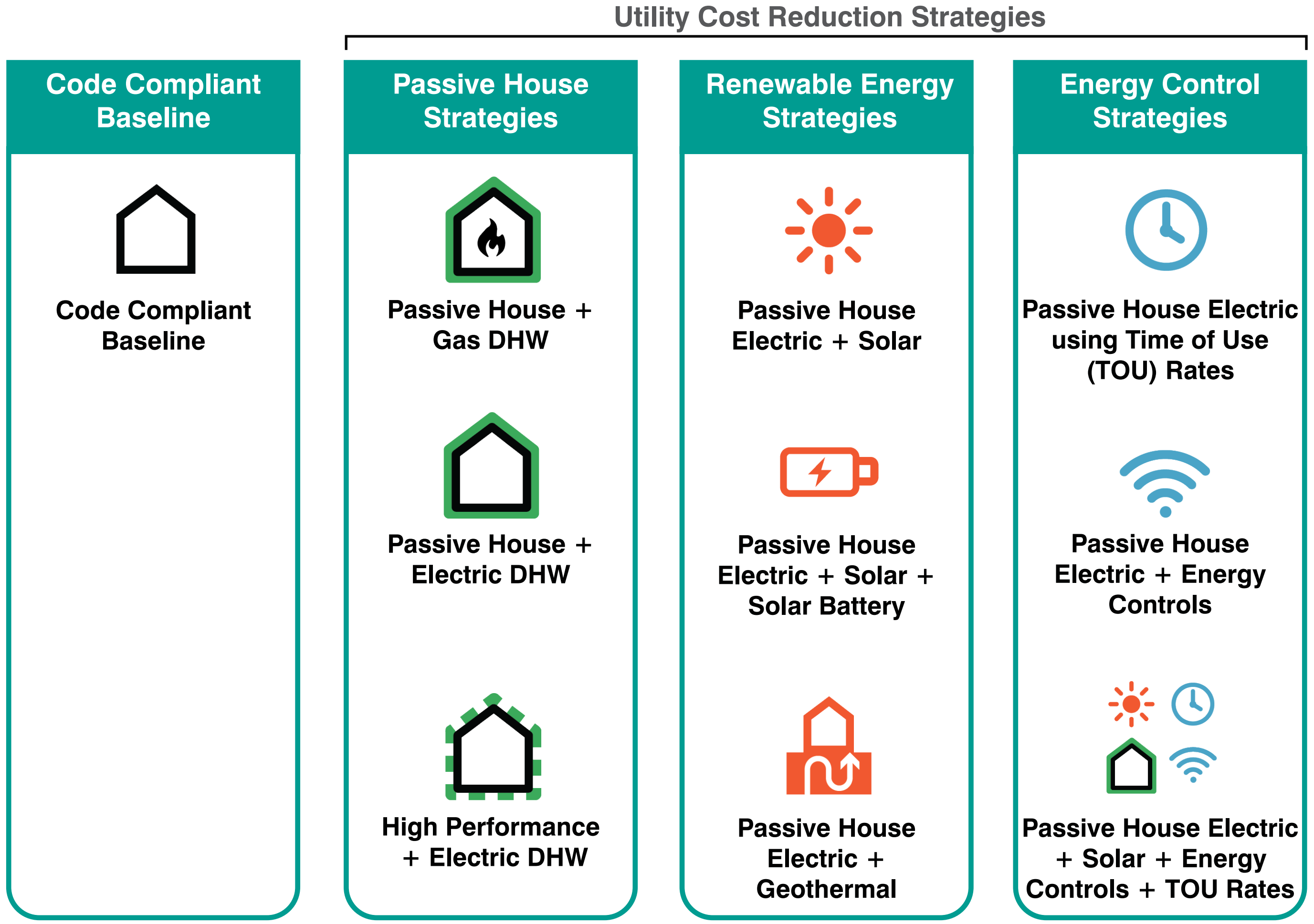


FIGURE 1 Diagram of scenarios studied for the residential building; one baseline and nine strategies for reducing utility costs.

As a case study to test each of these strategies, we have used the Beacon project, located in East Harlem, New York City. The Beacon project includes both a 21 story, new construction, affordable housing building and an adaptive re-use, deep energy retrofit of a five-story school building turned community facility. The Beacon is an excellent example project for testing the feasibility of optimization for a couple of reasons: 1) the dominant use on the project is multifamily affordable housing, which, as discussed below, is a typology that is especially sensitive to utility cost increases from electrification; 2) tight capital and resident budgets necessitate affordability in construction and ongoing utility costs; and 3) the different programs for each building on site lend themselves to investigating a different toolkit catered to each program. While this report focuses on affordability of utility costs in fully electric buildings, the Beacon is also the focal point of a *separate report investigating embodied carbon*. [1] A site with both new construction and adaptive re-use allows us to draw useful conclusions on embodied carbon.

In addition to informing the design approach for the Beacon, this study is intended for use by the industry at large. At PCA, we will use this analysis as the framework for advocating for fully electrified buildings, as well as a roadmap for finding cost-optimized solutions in these buildings that meet our clients' long-term performance and economic requirements. We hope that the findings of this work will assist other designers, builders, and developers in selecting the most effective strategies to optimize the design and cost of their electrified buildings. We also hope this report will be used by policymakers to fine tune electrification policy and streamline hurdles to implementation of the strategies studied for the Beacon.

THE COST OF ELECTRIFIED BUILDINGS IN NEW YORK CITY

The affordable housing industry has been one of the leaders in integrating Passive House and high energy performance strategies into residential buildings in New York City and the rest of the state. For over a decade, NYC affordable housing construction has delivered projects which have demonstrated that Passive House buildings significantly reduce energy use and operational carbon, provide superior occupant comfort and health, and reduce the ongoing utility costs of the building. The financing and tax structure of affordable housing makes the project type an ideal fit for Passive House, with the reduced heating, cooling and lighting costs representing a significant portion of the operating budget in these buildings. Utility costs should be reduced as much as possible in these buildings to create truly sustainable affordability for the building owners and residents.

As noted in Figure 1, graph below, utilities represent 25% of the operational budget of affordable housing, as compared to 10% for market rate housing. [2] Affordable housing typically has lower taxes than market rate, increasing utility cost as a percentage of total operating budget. While the proportion of utility costs increases in total budget, affordable housing owners are unable to increase rent to cover higher utility costs. The oversized impact of utilities on the overall operating expenses in affordable housing developments suggests that these typologies have the most to gain from lowering costs of electrification.

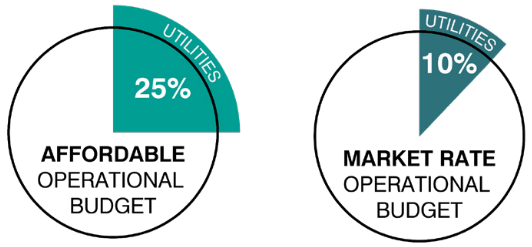


FIGURE 2 Proportion of utility cost to overall operational budget, market rate vs. affordable.

---

[1] Analyzing Embodied Carbon for Retrofit and New Construction, Paul A. Castrucci Architects, 2024.

[2] Data and insight courtesy of Ryan Cassidy of Riseboro Community Partnerships.

In PCA's experience, nearly all of the completed Passive House affordable housing buildings in New York City have been *mostly electric*. That is to say, these buildings have utilized electric heating and cooling (VRF) and ventilation (ERV) combined with energy efficient gas hot water heating (and often, clothes dryers). Fully electrified multifamily buildings can unintentionally but significantly increase utility costs of buildings without thoughtful systems intervention, serving as a disincentive to wide-spread electrification. The reluctance to switch to electric domestic hot water in the multifamily landscape has predominantly been because domestic hot water contributes more to total energy in these projects than any other typology (Up to ten times more than commercial buildings). This means that switching to a system that is more expensive per unit of energy is more cost prohibitive than any other typology. Because of the localized health benefits of eliminating gas combustion from our buildings, and because fully electrified buildings are a key component to a carbon neutral future, we see the necessity to overcome this cost hurdle as key to ensuring a future where buildings are increasingly fully electric.

Now we are seeing the first set of large scale, fully electrified, Passive House affordable housing projects being completed. In PCA's first electrified multifamily buildings, we expect to provide the health, comfort, carbon and total energy reduction benefits of fully electrified buildings, while maintaining the deep utility cost savings that our clients are accustomed to achieving. When we propose to electrify the hot water systems, we repeatedly run into a difficult and undeniable math problem: natural gas is significantly cheaper than electricity in New York City, meaning the increased cost of electrified DHW offsets a larger than desired portion of the savings from other holistic Passive House measures.

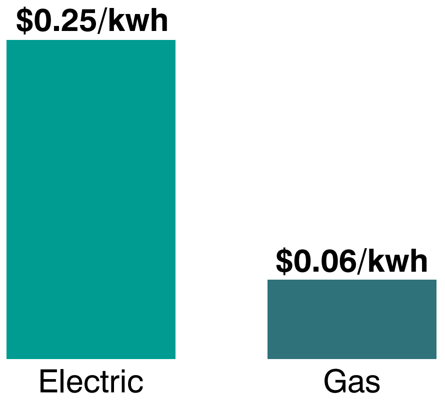


FIGURE 3 The utility gap penalty, where the cost per kWh of electricity is about five times as expensive as gas.

The gap in cost between gas and electric is a familiar challenge in our work. We call this problem the *utility gap penalty*, which is shorthand for saying that electricity is almost 5x more expensive than gas. Overcoming the utility gap penalty is key to making fully electric buildings affordable to use and operate. This utility cost market barrier is not new. We have been working in this context since our first experience with a New York City based Passive House in 2010. Our Passive House experience range from single family to large, mixed-use buildings, including both market rate and affordable housing multifamily projects. In previous projects, we addressed the utility gap penalty with three strategies:

1. Incorporating efficient heat pumps for space heating. Heat pump electric heating is often 2 to 3 times more efficient than gas heating systems. This covers a significant portion, but not all, of the utility gap penalty.
2. Significantly reducing the heating and cooling loads through the use of high-performance Passive House building envelopes. This offsets the additional cost of electricity by using less total energy to heat and cool the buildings.
3. Using high efficiency gas hot water heaters to meet domestic hot water needs. This avoids the utility gap penalty on the hot water energy load, which we have the least control over as designers.

When used together, these strategies have led to buildings with sufficient utility cost savings to incentivize building owners to build to Passive House standards. These buildings have not only enjoyed the cost savings that incentivize the use of Passive House, but also provide increased resiliency and important health, comfort and other environmental co-benefits.
Unfortunately, unlike heating and cooling loads that can be reduced with robust thermal envelopes, we have not historically had a toolbox for reducing the hot water load. The domestic hot water load in residential buildings is directly tied to resident behavior, which has been almost entirely outside of the designer's control.

In our fully electric projects, our concern is that the utility gap penalty associated with electric hot water will decrease the cost savings of Passive House and other deeply energy efficient design. As established above, utility savings is an important incentive driving Passive House implementation. If owners are dissuaded from implementing Passive House level design in fully electrified buildings due to this reduced incentive, there are cascading environmental, resident health, and thermal comfort losses. There is further concern that builders and developers may prioritize lower upfront cost electrification strategies (resistance heat hot water heating, for example), and lock in significantly higher utility costs for themselves and building residents. In addition to the direct environmental and health downsides of these less efficient options, they will lead to increased peak loads and increased reliance on the dirtier, localized generators called *"peaker plants*" that are used to meet high peak demands. These generators are often located in poorer neighborhoods, contributing to a larger environmental justice issue. In short, our interest in optimizing the utility cost performance of electrified hot water is based on significant financial, environmental, health and environmental justice concerns. [3] As building regulations increasingly mandate full building electrification, we seek to identify and employ proven solutions that continue to incentive owners to build deeply energy efficient and environmentally responsible buildings.

THE REGULATORY ENVIRONMENT: ELECTRIFICATION IN NEW YORK CITY

The timeline for electrifying NYC buildings has been accelerated by the enactment of two local laws, the influence of local building authorities, and by financial incentives encouraging building electrification.

Passed in 2019, *Local Law 97 (LL 97)* represented a significant step forward in energy efficiency for New York City buildings. This law requires most buildings over 25,000 sf to hit increasingly stringent emissions standards starting in 2024, with thresholds steadily lowering in the years 2030 and 2040, leading to carbon neutrality in 2050. While not specifically an electrification law, the requirement for carbon neutrality by 2050 highly favors fully electrified buildings.

Two years after passing LL 97, the NYC City Council formally required electrification in new construction buildings with *Local Law 154*. Phasing in between 2024 and 2028, based on building size and market sector, LL 154 applies to new construction, and effectively requires full electrification of buildings, importantly including domestic hot water systems. [4]

Within the local affordable housing industry, electrification of buildings is already strongly encouraged by NYC Housing Preservation Department (HPD). In response, developers and owners have increasingly proposed fully electrified affordable housing buildings, especially for projects awarded by highly competitive RFP processes.

At the same time, incentives for fully electric buildings have been on the rise. Programs such as the *Clean Heat Program* (NYSERDA), the *NYC Accelerator*, *Buildings of Excellence Competition* and *Early Design Support* (NYSERDA), *Empire Building Challenge* (NYSERDA), and the *HPD Electrification Pilot* (NYSERDA and HPD) all provide incentives for fully electrified buildings. [5]

Because of the regulatory and incentive environment described above, by the year 2035 we expect to see a transformational change in how our buildings are powered. In the long term, we predict that efforts to clean the grid will have the additional benefit of driving down the cost for using electricity. In the interim, we recognize an acute need for a toolkit of strategies to reduce the utility cost of these electrified buildings and prepare them to be carbon neutral.

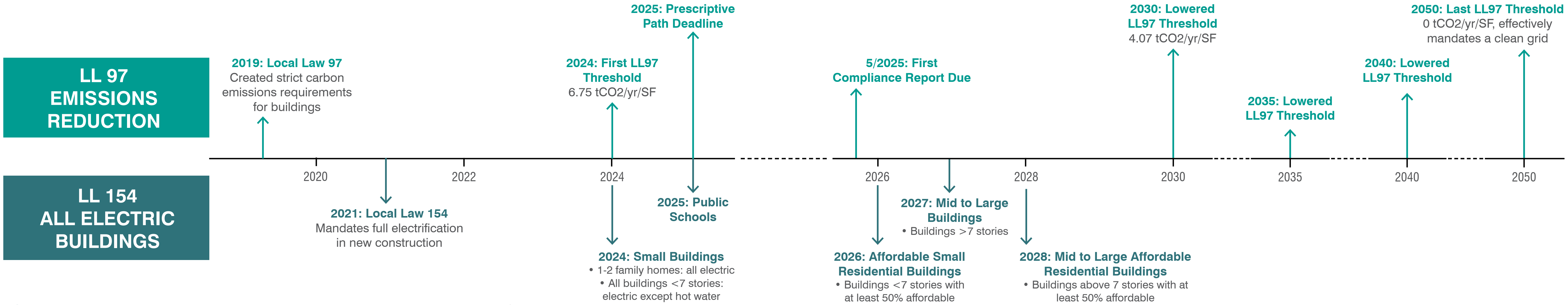


FIGURE 4 LL 97 and LL 154 timelines, the key laws that relate to carbon emissions and building electrification.

---

[3] Hudson Robbins, Shelley, "The Peaker Problem: An Overview of Peaker Power Plant Facts and Impacts in Boston, Philadelphia, and Detroit," *Clean Energy Group*, July 2022, https://www.cleanegroup.org/wp-content/uploads/The-Peaker-Problem.pdf (accessed January 18th, 2024)
"The Fossil Fuel End Game: A Frontline Vision to Retire New York City's Peaker Plants by 2030," *Peak Coalition*, March 2021, https://www.cleanegroup.org/publication/fossil-fuel-end-game/ (accessed February 20th, 2024)

[4] Local law 97: https://www.nyc.gov/site/sustainablebuildings/ll97/local-law-97.page
Local Law 154: https://www.nyc.gov/site/buildings/codes/building-electrification.page

THE CASE STUDY: ABOUT THE BEACON

The Beacon is an exciting project that combines much needed new affordable housing and the adaptive re-use of an existing school building into a Multi Service Center that will house a variety of local community groups. Located in East Harlem, a culturally rich and historic neighborhood in Upper Manhattan, the Beacon is within walking distance of a plethora of civic resources and to public transit. The site is in a predominantly residential neighborhood, nestled between both private and public multifamily housing, including NYCHA's Senator Robert F. Wagner ("Triborough Houses") to the East and Acacia Gardens to the West. Both buildings of the Beacon are situated in dialogue to the NYCHA campus, with entrances in the South, West, and North. The site is in a Disadvantaged Community, a Clean Energy Community (CEC), a NYS Department of Environmental Conservation (DEC) Potential Environmental Justice area, and is in a jurisdiction is committed to the NYS Energy Stretch Code 2020.

The residential portion of the project will be a new construction, 21 story building comprised of approximately 250 affordable housing units. The units are slated to be 30-80% AMI with 30% of units reserved for the homeless. The building is slated to be a poured concrete structure with metal panel facade. Located on the South side of the site, the adaptive re-use of the former school building includes a glazed rooftop greenhouse addition and a fully renovated interior for use as a Multi Service Center (MSC) for local community groups. This ambitious project is designed to the: PHIUS+ 2021 standard (new building) and the Enerphit standard (adaptive re-use), and will be seeking Enterprise Green Communities certification, and WELL certification.

At PCA, we are thrilled to be working with the development team of The Community Builders and Ascendant Neighborhood Development on the Beacon. Our role on the project is as lead energy and sustainability consultant for both buildings, as lead architect for the adaptive re-use and deep energy retrofit of the community facility building, and lead architect on the residential portion starting in design development. Body Lawson Associates, Architects and Planners and WXY Studio were the co-lead architects on the schematic design of the residential portion of the Beacon.

We see the residential building as an ideal case study for building electrification, Passive House, and strategies for optimizing long term energy and cost performance. The combination of the adaptive re-use building and new construction building on one site lends itself to a comparison between adaptive reuse and new construction buildings and a study on embodied carbon, which will be released as a *separate report*. [1]

---

[1] Analyzing Embodied Carbon for Retrofit and New Construction, Paul A. Castrucci Architects, 2024.

[5] Clean Heat Program: https://www.nyserda.ny.gov/All-Programs/Heat-Pump-Program
NYC Accelerator: https://accelerator.nyc/
Buildings of Excellence Competition: https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence
Empire Building Challenge: https://www.nyserda.ny.gov/All-Programs/Empire-Building-Challenge
HPD Retrofit Electrification Pilot: https://www.nyc.gov/site/hpd/services-and-information/hpd-nyserda-retrofit-electrification-pilot.page

OUR PROCESS

This report primarily focuses on the residential tower because the cost of electrified domestic hot water is most critical to utility cost and most difficult to control in affordable multifamily buildings. For the multifamily building, we identify the following strategies to reduce ongoing utility costs:

- Passive House design
- High Performance (not quite Passive House) design
- Rooftop Solar PV
- Solar Battery Storage
- Geothermal Heat Exchange
- Time-of-Use Utility Rates
- Energy Management Controls

We also study utility cost reduction in the existing Community Facility building, which has a much smaller domestic hot water load. We analyze Passive House, High Performance, and Rooftop Solar PV strategies to further demonstrate the viability of these strategies across building types. This analysis can be found in the 'Community Facility Analysis' section of this report.

Working with our consultant team in a series of integrated and iterative design meetings, we establish baseline buildings to compare both the new construction and existing buildings that make up the Beacon. The baseline residential building is as if it is built to the 2020 NYC Building Code, with electric hot water per code requirements.

The baseline existing community building is the same renovation scope, with the renovation meeting the 2020 NYC Energy Code requirements.

The baseline buildings is modeled using WUFI Passive and eQuest. Modeling in two softwares offers us the following advantages:

1. built-in verification of results,
2. multiple high level analytical data points,
3. granular data points on a per-hour basis, and
4. the ability to contextualize the results with over a decade of experience with high energy buildings using this software.

BASELINE PARAMETERS: CODE COMPLIANT SCOPE

THERMAL ENVELOPE

Slab on Grade: No Insulation
Foundation Walls: R-7.5 ci
Overhanging Floors: R-12.5 ci
Above Grade Walls: R-13.3 ci
Roof: R-30 ci
Windows: Metal casement, U-0.4 Operable, U-0.3 Fixed, SHGC 0.38
Storefront: Metal storefront, U-0.77 Doors, U-0.36 Fixed, SHGC 0.38
Air sealing: 3 ACH50

BUILDING SYSTEMS

Heating and Cooling: PTAC (3.7-(0.052xCap/100)/COPH Heating / 14.0-(0.30xCap/100)cEER
Domestic Hot Water: Resistance Electric Hot Water (0.3+ 27/Vm), %/h
Ventilation: Trickle Vents in Apartments / ERVs in Corridor Only (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None

Important modeling parameters that are used in both energy models are the heating and cooling setpoints. These setpoints are modeled using the Passive House standards of 68°F in heating and 77°F in cooling. For domestic hot water in the new construction building, we look at values for both Passive House usage patterns (12 gallons per day per person) and a more conservative usage pattern of 20 gallons per day per person based on our team's collective experience in New York City. Results expressed in this study are based on 20 gallons per day per person. Unless otherwise noted, these setpoints are used in all following strategy iterations.

Importantly, these same setpoints are used for the baseline case and all subsequent strategies.

The baseline buildings are used as our point of comparison for energy use and expected utility costs. Except for the Time-of-Use rates analysis, we assume $0.25 per kWh of electricity, and $1.845 per Therm of natural gas.

For the improvement strategies, we use the same WUFI and eQuest modeling software where possible, and our consultant's proprietary analytical tools for Solar Photovoltaic Panels, Solar Battery Storage, and Building Management Controls. Working with the development team's General Contractor and with our consultants, we identify logistical and regulatory barriers to implementation. Where appropriate, these barriers are discussed in the 'Conclusions' section of this report.

During this process, our research leads us to two additional promising strategies for reducing utility costs using previously untapped leverage points:

1. App-based demand response programs that allow residents to save money on their utility bills by lowering energy usage and
2. Power management systems that regulate and normalize the voltage of incoming electric service.

Because we don't yet have a framework within which to analyze these solutions, but find both to be potentially advantageous and worthy of future consideration, we have included discussions of each in the **SIDEBAR: CHALLENGES FOR THE NEW GRID** and **SIDEBAR: RESIDENT INCENTIVE APPS** sections that follow.

We believe that the analysis and research that follows offers a robust understanding of the performance of each improvement strategy. We are thrilled to share the results covered in the following pages, and summarized under recommendations, with our fellow designers, builders, building owners, developers and policy makers.

[6] Standardized modeling parameters for Passive House certification and energy code are helpful tools to provide a one-to-one comparison across projects. In our decades of experience across new construction and retrofits, New York usage patterns for energy and hot water are usually significantly elevated above Passive House standard criteria. In our office, we provide additional calculations for client-decision making based on more realistic temperature set-points and hot water usage. We are still refining these set points, and further research is needed for a best practice of realistic usage parameters. This report is intended as an applicable tool for addressing hot water costs in electrified buildings, requiring our team to elevate water usage parameters above Passive House standards based on our experience in New York City.

Residential Analysis and Results

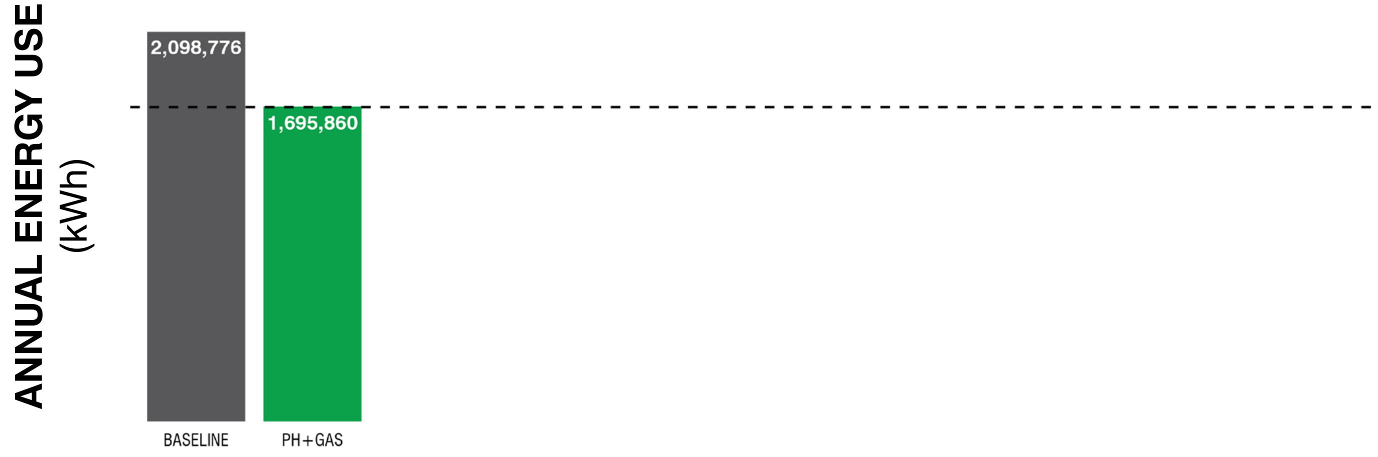
Passive House + Gas DHW

OVERVIEW

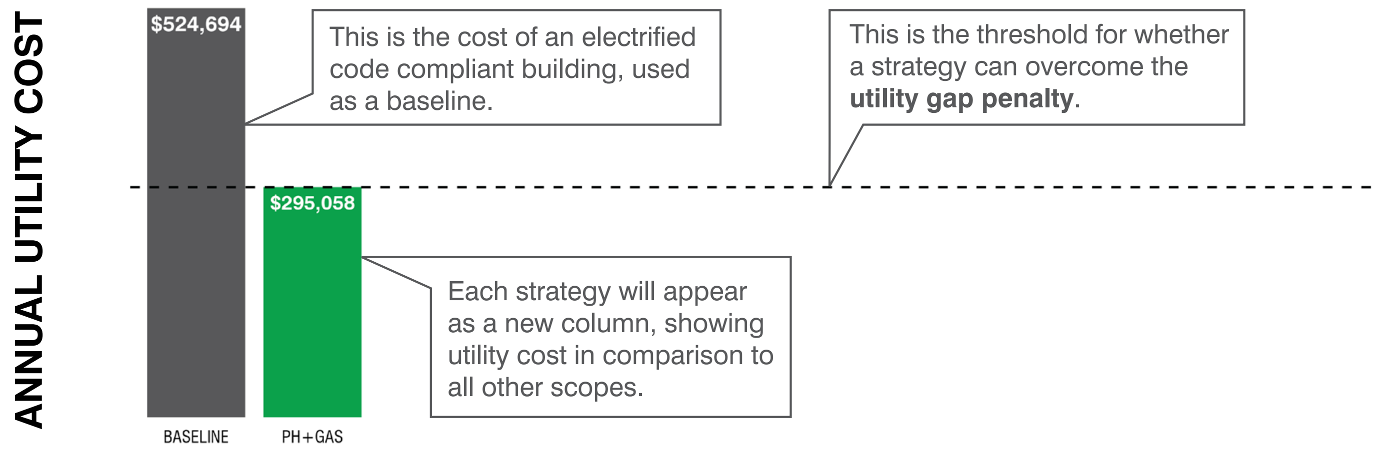
Passive House design with high efficiency gas domestic hot water heating is the current industry standard scope for multifamily affordable housing in NYC. These projects integrate fully electric heating, cooling and ventilation systems with gas-fired domestic hot water heating systems. This hybrid approach has been the most common configuration of PCA's affordable, multifamily housing Passive House projects. Passive House design with high efficiency gas domestic hot water heating results in deep energy and carbon reductions, with corresponding cost savings.

PROCESS

This iteration's scope is modeled to a fully electric Passive House scope which then has a gas domestic hot water system substituted. A Passive House compliant scope is established using a heat pump domestic hot water system which is then modeled in WUFI Passive to confirm that the design meets the Passive House criteria and to simulate heating, cooling and total site energy loads. This same scope is modeled in eQuest to check the modeling results and to generate granular data on the time of energy use. Using eQuest, a second model is created with the same scope elements, but with a high efficiency gas hot water heating system swapped in for the electric heat pump. The results from this eQuest model are expressed on the following pages.



Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.

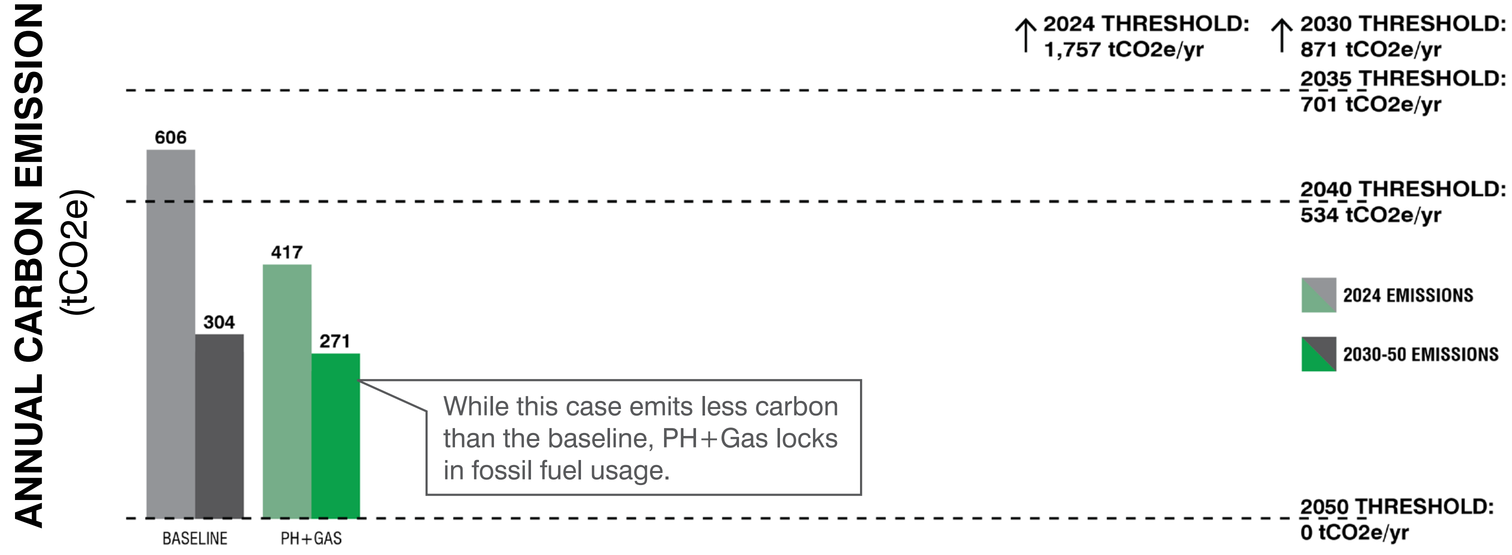


This is the cost of an electrified code compliant building, used as a baseline.

This is the threshold for whether a strategy can overcome the **utility gap penalty**.

Each strategy will appear as a new column, showing utility cost in comparison to all other scopes.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



While this case emits less carbon than the baseline, PH+Gas locks in fossil fuel usage.

Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

Throughout NYC, this approach has demonstrated energy savings of up to 85% (NYPH) and corresponding utility cost savings, while delivering constant, filtered fresh air through energy recovery ventilation and increasing thermal comfort with robust thermal envelope design. However, **gas domestic hot water locks in GHG emissions and fails to meet carbon-neutral ready standards.** Many new buildings may not be able to install gas systems and if they do, may not be able to meet LL97 2050 standards. This common approach illustrates the utility gap penalty by acting as the utility cost baseline that we strive to meet or outperform in our fully electric Passive House buildings. When we are electrifying our domestic hot water systems, **this hybrid approach is our most salient point of comparison.**

ANNUAL PERFORMANCE

Energy Use: **1,695,860 kWh**	**-19%** Reduction from Baseline
Utility Cost: **$295,058**	**-44%** Reduction from Baseline
Carbon Emissions: **417 tCO2e/yr**	**-31%** Reduction from Baseline

THERMAL ENVELOPE

Slab on Grade: 2” EPS ci (R10)
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: 4” mineral wool ci (R18)
Roof: 6” polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: *Gas Condensing (95% Efficient)*
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: Standard

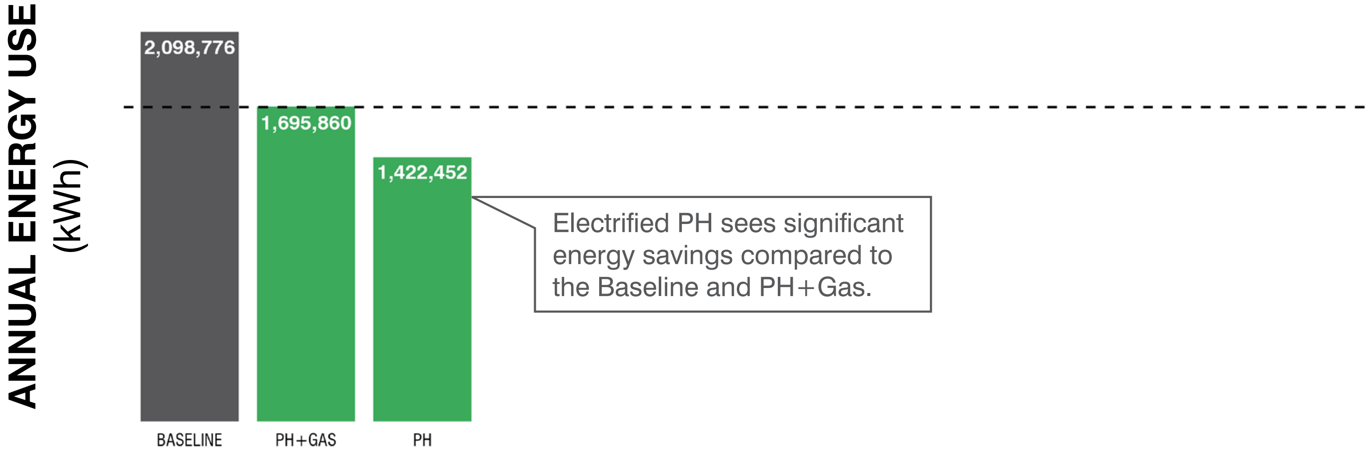
Passive House + Electric DHW

OVERVIEW

The Passive House + Electric DHW (PH+Electric) design is the first fully electrified optimization strategy that we study. This strategy reduces energy use and relies on the Passive House approach to control utility costs through significant heating, cooling and lighting reductions. In this iteration, we use an electric high-performance heat pump hot water heating. This strategy will fully comply with Local Law 154, is carbon-neutral ready, and will further reduce the building's carbon emissions output as required by Local Law 97. However, this case incurs the utility gap penalty when compared to the Passive House + Gas DHW strategy, which is a hurdle to implementation. While utility costs are below a Code Compliant Baseline, they are significantly higher than a hybrid gas/electric building. Our research uses this scope as a jumping off point for improvements.

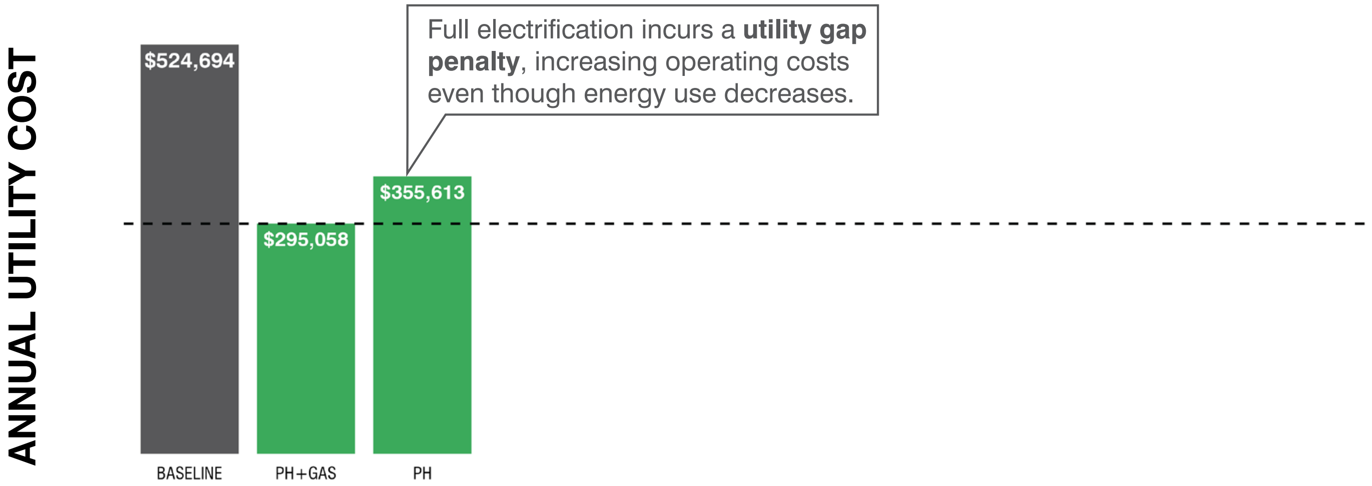
PROCESS

This iteration starts with a Passive House compliant scope being established with an electric heat pump hot water heater. This scope is modeled in WUFI Passive to confirm that it meets the Passive House criteria, and to simulate heating, cooling and total site energy loads. This same scope is modeled in eQuest to check the modeling results and to generate granular data on the time of energy use. The results from this eQuest model are expressed on the following pages.



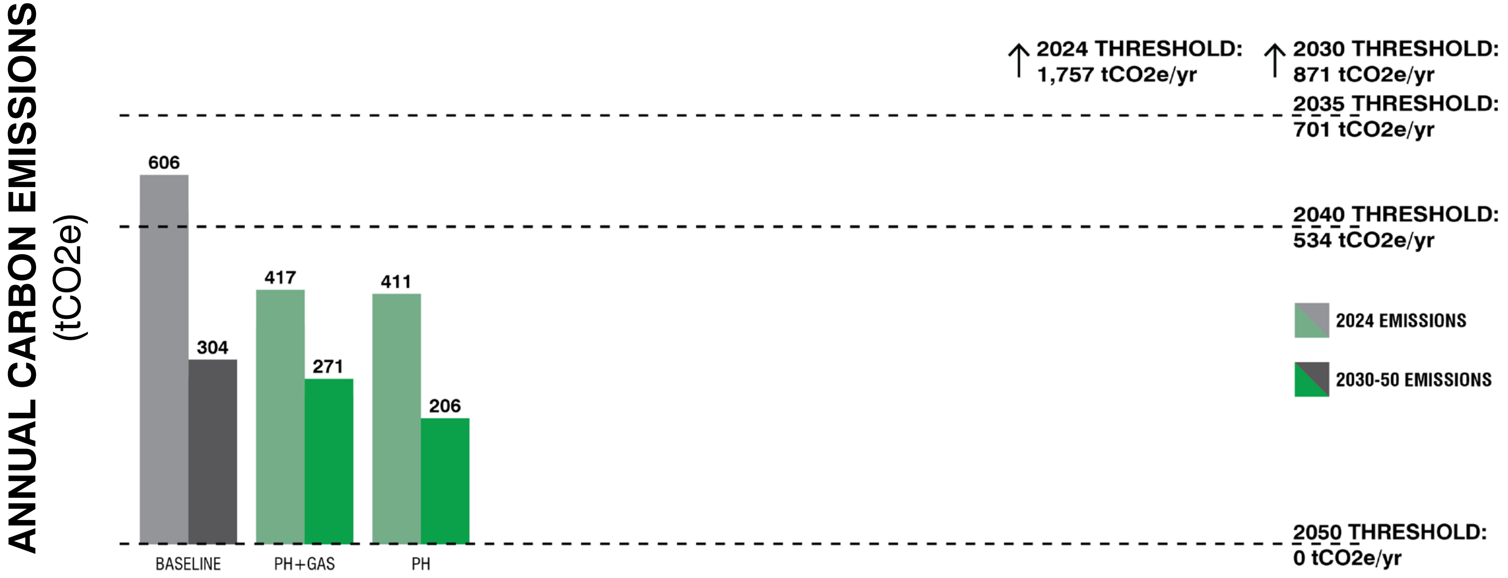
Electrified PH sees significant energy savings compared to the Baseline and PH+Gas.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Full electrification incurs a **utility gap penalty**, increasing operating costs even though energy use decreases.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

The PH+Electric design, which is a fully electric building meeting Passive House standards, shows a divergence of performance between energy, carbon, and utility cost savings. **While these saving categories are often tightly correlated in affordable housing Passive House buildings, this scope sees energy and carbon savings increase, while utility cost savings decrease, compared to the PH+Gas case. The utility penalty gap is responsible for this divergence, attributed to switching to fully electrified hot water. This puts the priorities of the building owner's bottom line at odds with larger sustainability and climate goals.** This is the impetus of this study and something we are keen to address on the Beacon specifically and for high efficiency, affordable housing projects throughout NYC.

ANNUAL PERFORMANCE

Energy Use: **1,422,452 kWh**	**-32%** Reduction from Baseline	**-16%** Reduction from PH+Gas
Utility Cost: **$355,613**	**-32%** Reduction from Baseline	**+21%** Increase from PH+Gas
Carbon Emissions: **411 tCO2e/yr**	**-32%** Reduction from Baseline	**-1.4%** Reduction from PH+Gas

THERMAL ENVELOPE

Slab on Grade: 2" EPS ci (R10)
Foundation Walls: 3" EPS ci (R13)
Overhanging Floors: 4" polyiso ci (R26)
Above Grade Walls: 4" mineral wool ci (R18)
Roof: 6" polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: *Air to Water Heat Pump (0.38 COP)*
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: Standard
Building Management Systems: None

High Performance + Electric DWH

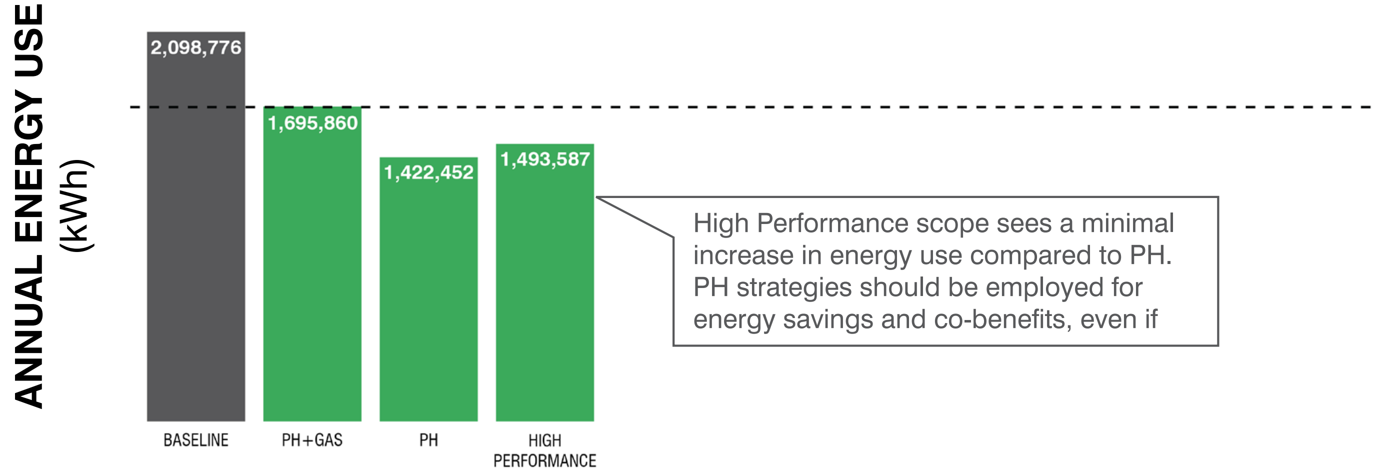
OVERVIEW

Where possible, we encourage certification to the Passive House standard as a way to provide third party checks and balances on the construction process. We think that designing and building to the Passive House Standard is equally as important, even if the project is not certified. Where budget is an issue, as often is the case in affordable housing, we seek to provide the highest possible performance within the budget, using Passive House as a tool to find the most impactful sustainability solutions. We can call this approach, which is a thoughtful value engineered Passive House design, the *High Performance* approach. We seek to capture most of the energy and non-energy benefits of the Passive House approach, at a reduced installation cost.

For the Beacon project, the High Performance design is defined as a fully electrified design, with high performance through wall terminal package units for heating and cooling. Additionally, we make modifications to the thermal envelope, specifically in targeting windows with the best balance of performance and cost. By making these changes, we expect to cut the construction costs for the Beacon by nearly 2 million dollars.

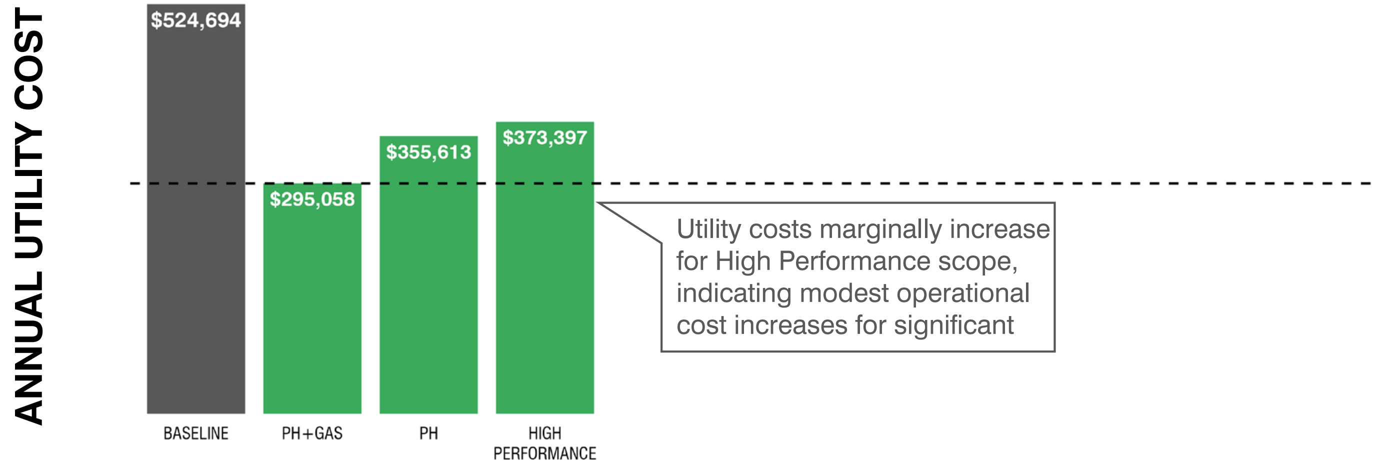
PROCESS

This iteration uses the same scope preparation and modeling methodology as the PH+Electric, but with the value engineered changes described above.



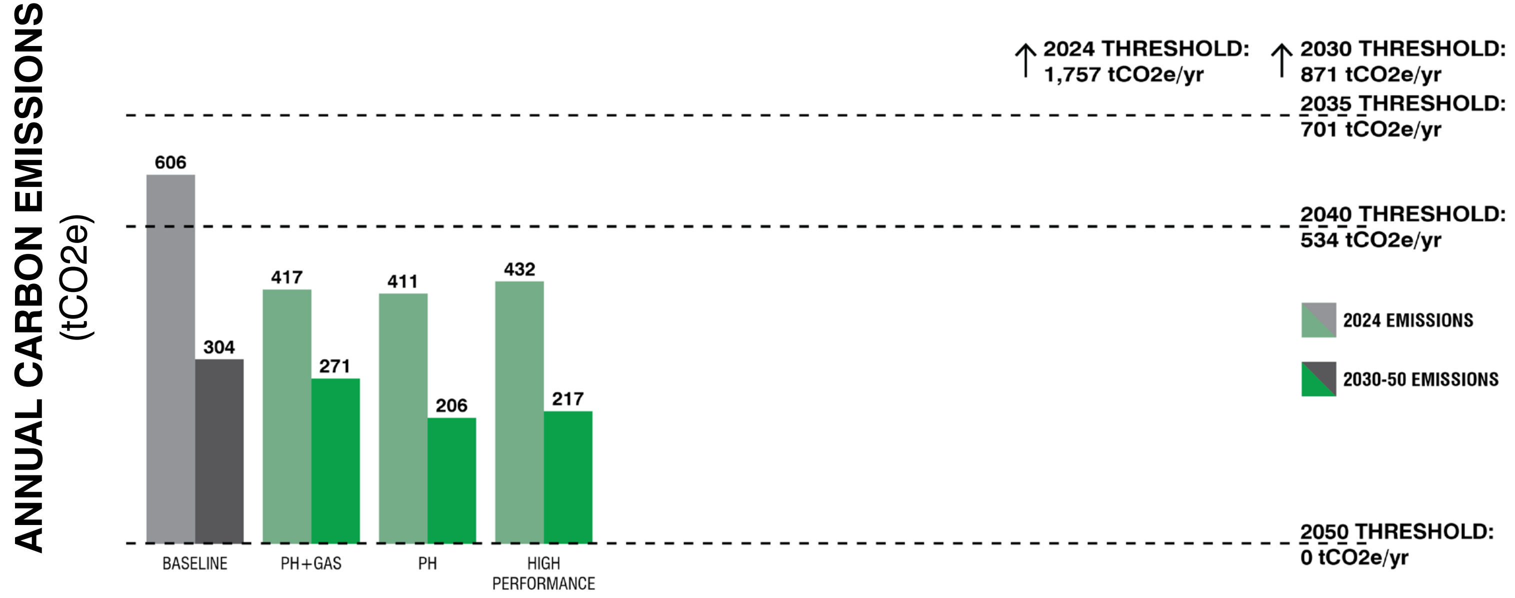
High Performance scope sees a minimal increase in energy use compared to PH. PH strategies should be employed for energy savings and co-benefits, even if

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Utility costs marginally increase for High Performance scope, indicating modest operational cost increases for significant

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

The High Performance strategy performs well, with **minimized utility cost and performance reduction compared to the PH+Electric scope, especially when considering the nearly $2 million dollars in installation cost savings**. Both energy and cost increase approximately 5% from the PH+Electric scope. There is a roughly 12% decrease in total energy use from PH+Gas, but a 27% increase in annual utility cost.

ANNUAL PERFORMANCE

Energy Use: **1,493,587 kWh**	**-29%** Reduction from Baseline	**-12%** Reduction from PH+Gas	**+5%** Increase from PH+Electric
Utility Cost: **$373,397**	**-29%** Reduction from Baseline	**+27%** Increase from PH+Gas	**+5%** Increase from PH+Electric
Carbon Emissions: **432 tCO2e/yr**	**-29%** Reduction from Baseline	**+4%** Increase from PH+Gas	**+5%** Increase from PH+Electric

THERMAL ENVELOPE

Slab on Grade: *No Insulation*
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: *4” EPS ci (R16)*
Roof: 6” polyiso ci (R38)
Windows: *UPVC casement, U-0.25, SHGC 0.38 (double pane)*
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: *0.8 ACH50*

BUILDING SYSTEMS

Heating and cooling: *High Performance Package Unit (Ephocha)*
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% latent eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: Standard
Building Management Systems: None

Solar

OVERVIEW

With current installation costs and available incentives, rooftop solar photovoltaics (PV) is often a highly viable energy improvement option for NYC buildings. Solar PV directly reduces the building's utility costs. This is an especially important consideration where the electricity cost is a significant driver of ongoing budgets. In this urban context, there is limited available area for PV. Maximizing solar capacity requires navigating New York City's Fire Department roof access requirements, competing rooftop requirements such as mechanical equipment and recreational terraces, and localized shading conditions.

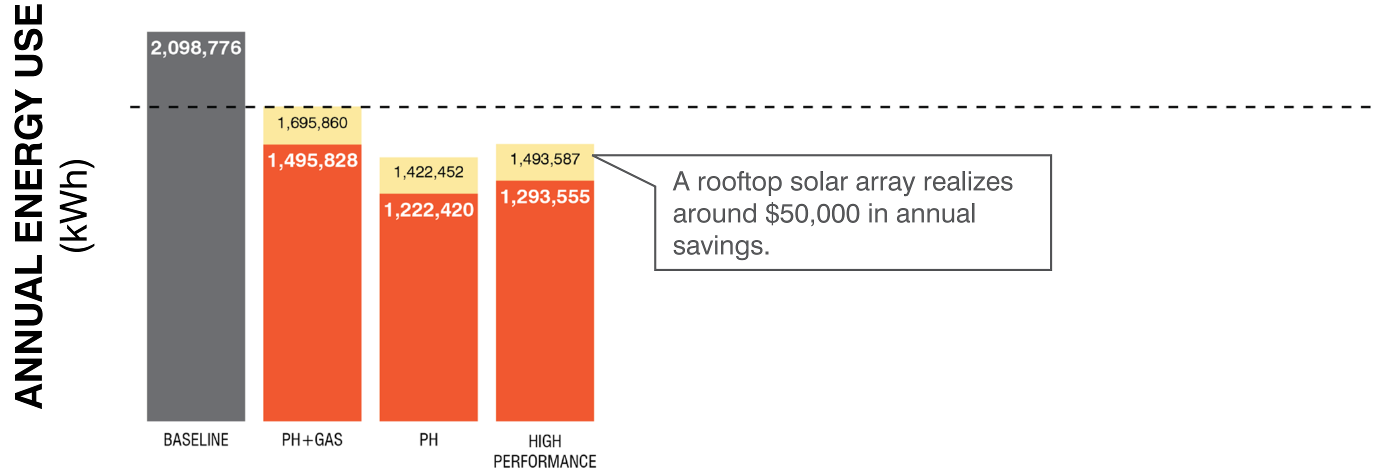
PROCESS

For the residential building, the design team fully maximizes the available roof area by proposing solar PV on an elevated canopy. This canopy eliminates any roof conflicts, and because of the height of the main massing of the project, there is no shading from the adjacent buildings.

For the initial solar analysis of the Beacon, we are working with Solar Design Associates through Schematic Design for solar and solar battery design. The Solar Design Associates team's analysis includes the proposed solar layout, and optimized design and the estimated monthly performance.

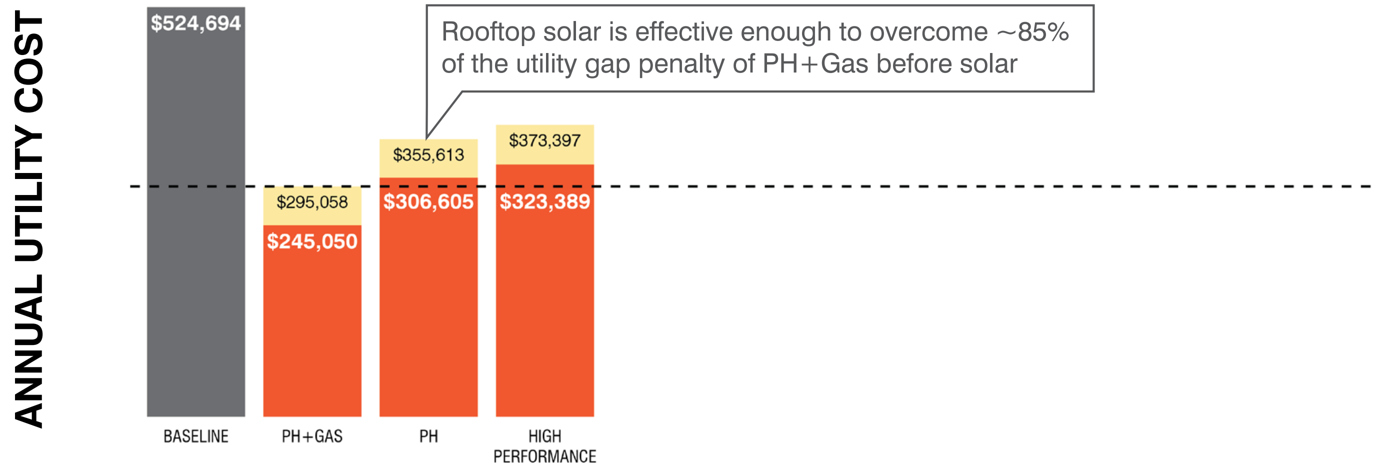
SOLAR PV SYSTEM

Residential: 168 kWdc **(200,032 kWh annual production)**



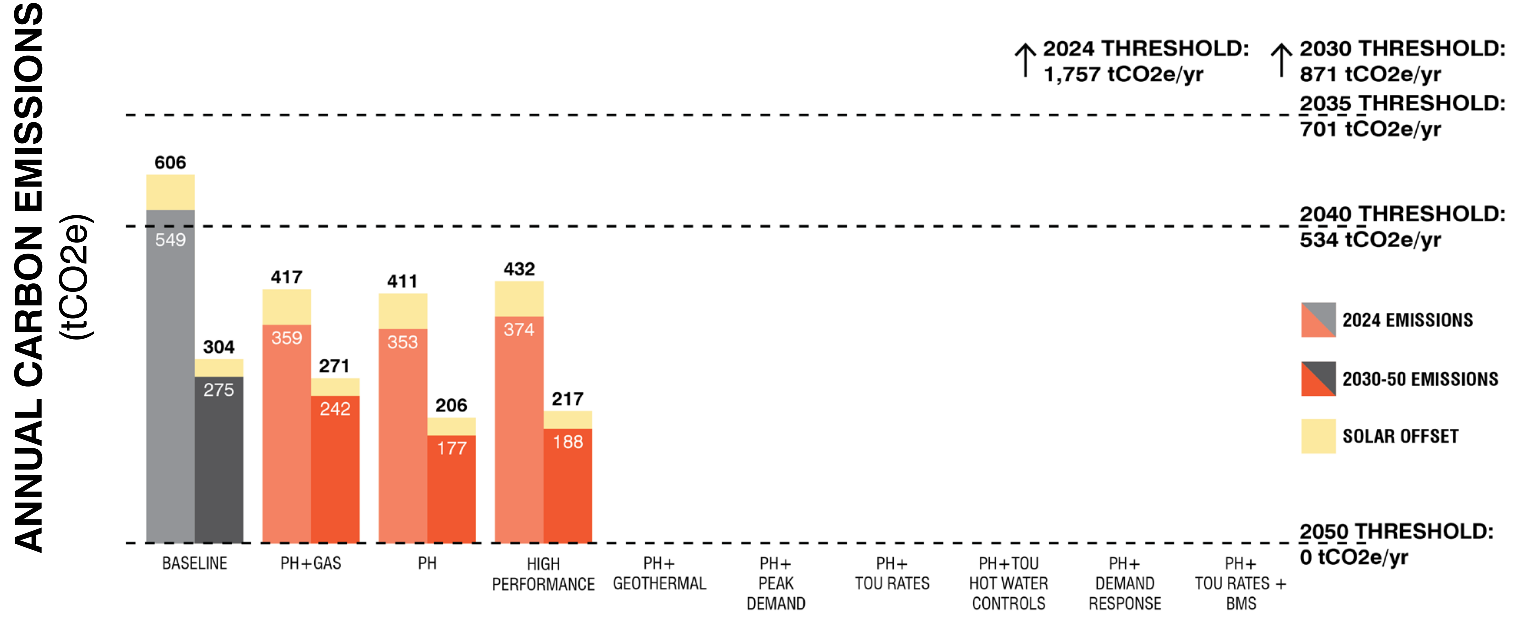
A rooftop solar array realizes around $50,000 in annual savings.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Rooftop solar is effective enough to overcome ~85% of the utility gap penalty of PH+Gas before solar

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

For the residential building, the solar is expected to generate 200,032 kWh per year, resulting in approximately $50,000 annual savings. This equates to about 14% of the total building electric load and 49% of the domestic hot water cost for the PH+Electric scenario. **Importantly, this also nearly makes up for the difference in cost between a high efficiency gas hot water heater and electrified heat pump hot water heater** (reducing the cost from $101,275 per year to $50,008 per year, versus $42,596 for the gas hot water).

ANNUAL PERFORMANCE

Solar Savings:
$50,008/yr

14%
of building utility costs

85%
of DHW utility costs

SIDEBAR

CHALLENGES FOR THE NEW GRID

In order to rise to the challenge of a carbon free future, our grid is becoming increasingly electric, and increasingly reliant on renewable energy. At the same time, our buildings are using fully electrified equipment, while implementing sophisticated controls to optimize performance (see Building Controls and Energy Management section). As the grid transforms into a distributed system with a greater percentage of renewable energy, the reliability of the *grid frequency stability* decreases[7] Smart Gate estimates that the grid frequency reliability index of the US power grid will decrease from 7.6 today (a score on the threshold between 'good' and 'caution') to 4.7 (a score in the 'critical' range) in the next eight years. Our electric equipment, which is increasingly sophisticated in controls but sensitive to variation in the electric frequency, is designed to operate at constant, known voltage levels. Power delivered at inconsistent voltage levels leads to loss of energy efficiency, increased ongoing maintenance and reduced equipment lifespan.

In our research, we have been introduced to the concept of active power management. This building management strategy addresses the problems with the increasing voltage variability in the power grid. The system is installed on the incoming electric service, analyzing and correcting the power entering the building to a stable voltage. The Legend Power Systems SmartGATE system provides voltage adjustment up to +/- 8%. As our buildings become more energy efficient and sophisticated, Active Power Management is a strategy worthy of building owners' and designers' consideration.

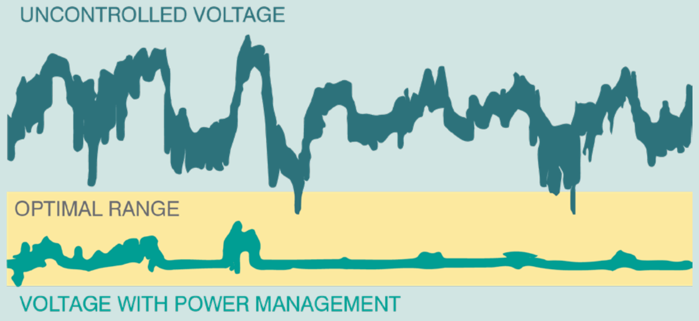


FIGURE 5 Voltage stabilization through management, adapted from Legend Systems.

---

[7] Muelaner, Jody. "Grid Frequency Stability and Renewable Power." Engineering.Com, WTWH Media, LLC, 5 Feb. 2021, www.engineering.com/story/grid-frequency-stability-and-renewable-power.

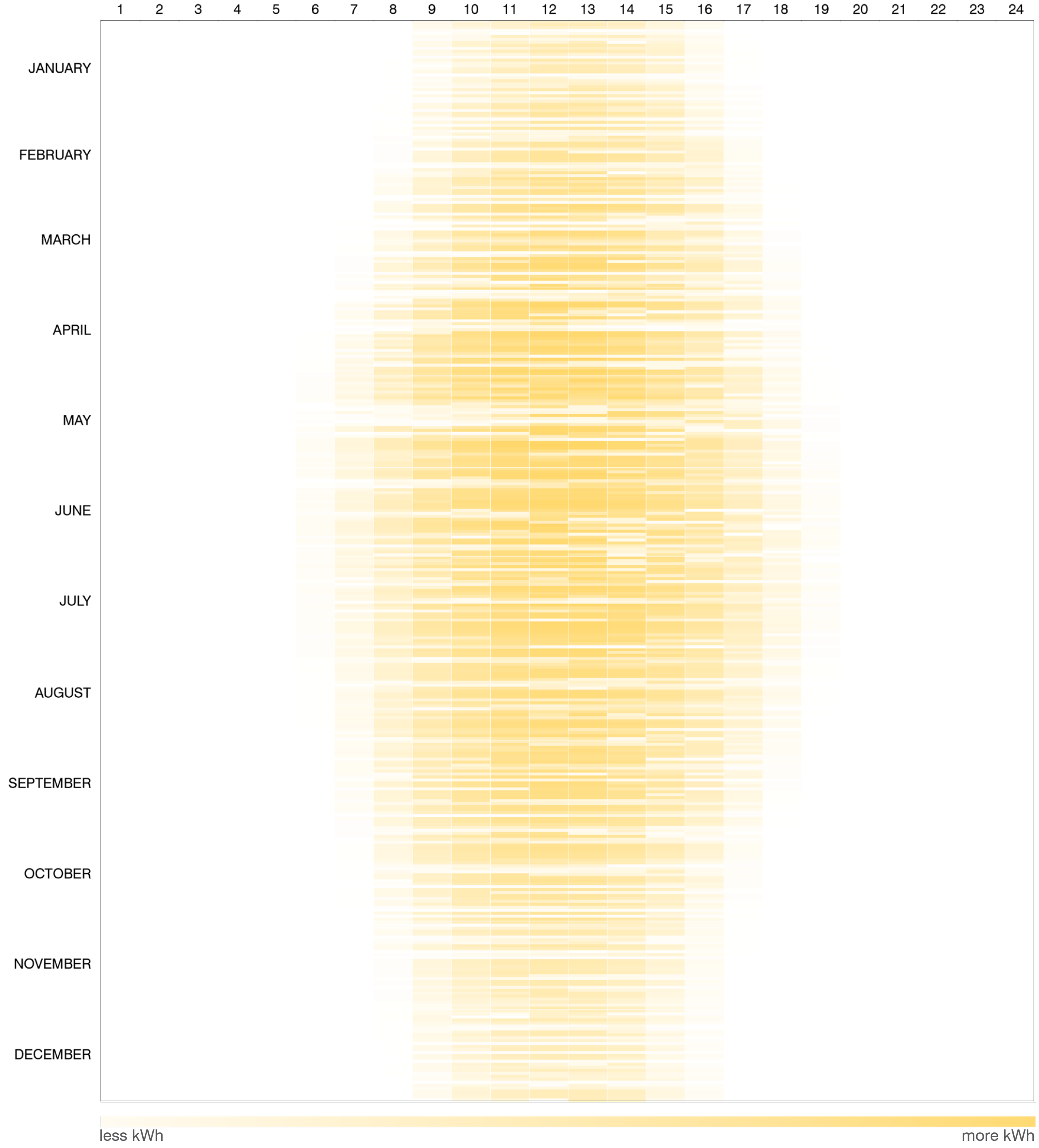
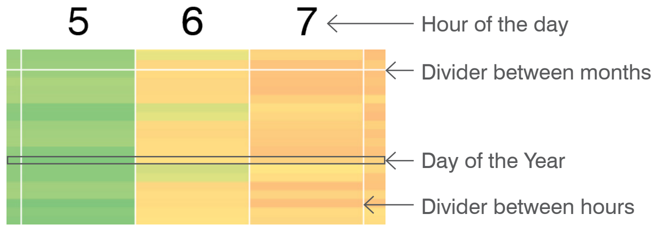


FIGURE 6 **Solar output heat map**

HOW TO READ A HEAT MAP

These heat maps show every hour of every day of the year, allowing us to visualize the hourly energy data generated by eQuest and accurately apply Time of Use rates.

On the left (y-axis) is every day of the year, divided by months. Each horizontal rectangle represents a calendar day. At the top (x-axis) you will see hours 1 - 24, representing the hours of each calendar day.



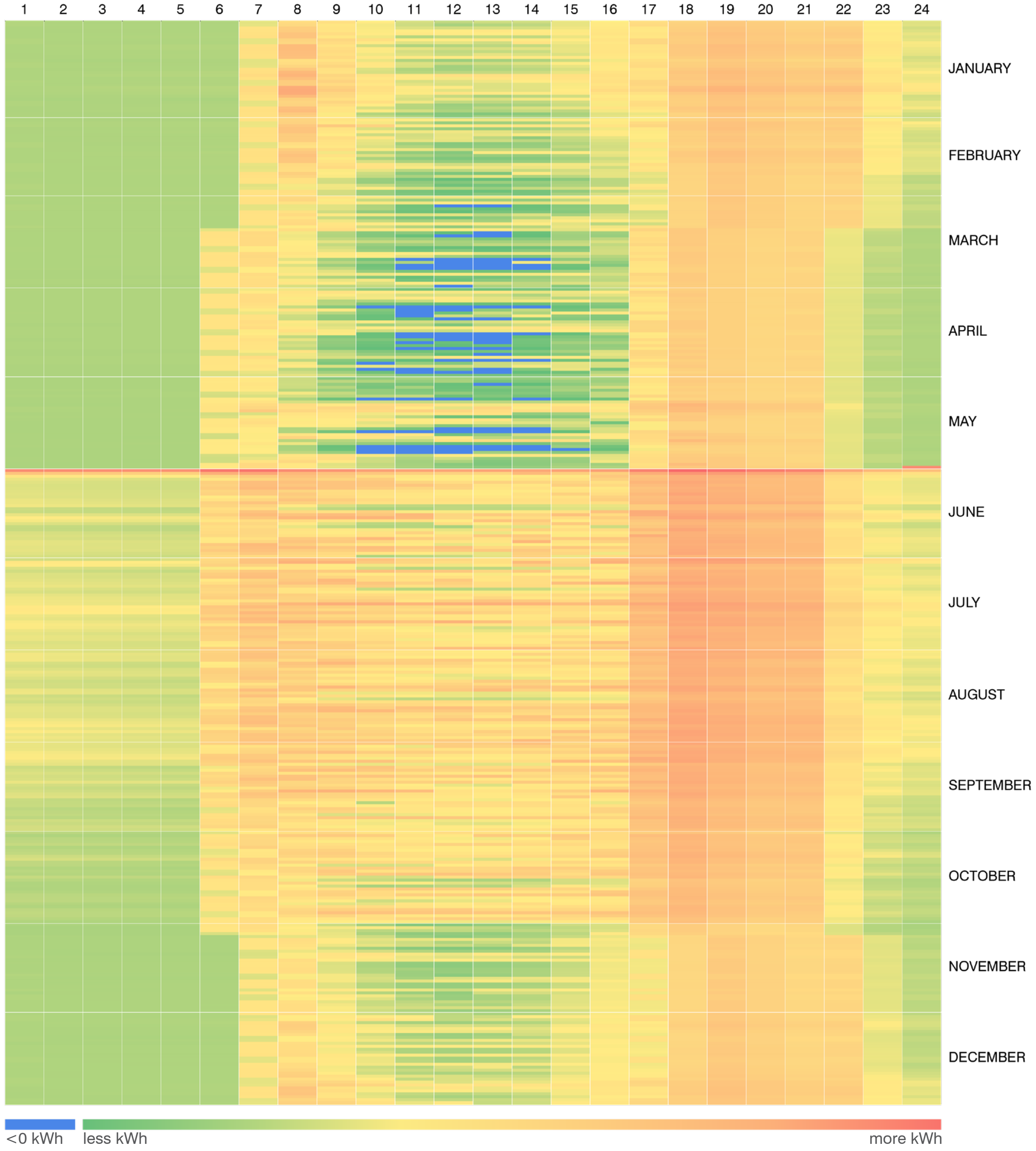


FIGURE 7 **Heat map total energy after solar output is deducted**

Solar offsets energy use in the middle of the day, lowering the peaks in the summer and even completely covering building loads in the winter.

Solar Batteries

To fully wean our buildings from natural gas and oil, we will need an electrified solution for emergency backup power. The residential NYC Building Code requires emergency power for the Beacon, and many other buildings in NYC. Currently, using solar batteries in lieu of gas backup generators is prohibitively difficult due to installation cost increases and regulatory barriers discussed below.

For the Beacon, a 600 kW rooftop solar battery that weighs approximately 3000 lbs would be proposed. Providing structural support for this is inexpensive if planned for in new construction (especially of this construction typology), but can be more difficult to implement in existing buildings (especially with roof structures not sized for additional loads).

The more difficult hurdle for implementation is fire safety and Authority Having Jurisdiction (AHJ) approvals. The battery must be UL 9540 certified, while also having undergone UL 9540A testing. The installation has to be approved by Con-Ed, Department of Buildings (DOB), New York City's Fire Department (FDNY), and the Office of Technical Certification and Research (OTCR). It also requires electrical and construction permits from DOB, and a sign off from FDNY and Con-Ed before the system can be used.

While test fitting the solar batteries on the Beacon site, navigating alternatives to rooftop placement and fire safety requirements limits the areas on site these batteries could be placed. The fire safety requirements discourage indoor placement, and limited outdoor areas in dense urban typologies like the Beacon site, mean the solar batteries would eat into limited outdoor recreation areas for tenants. The spatial considerations from regulatory requirements remain an issue for solar battery implementation on sites with limited outdoor area.

Another significant barrier to implementation is installation cost. The market for solar batteries in NYC is nascent, and finding experienced installers is difficult - the market is not currently robust enough to enjoy competitive pricing. This is compounded by the fact that, for the Beacon and many buildings in NYC, the daily solar production is much smaller than the total load. The ability to use a solar battery to reduce costs through Time of Use or Peak Demand programs is ineffective because there isn't enough solar production to fill the solar batteries. The hours of solar production coincide with the peak electric costs in these programs, and there is no way to 'set aside' power in the battery during times of cheaper electric rates.

To accelerate the use of solar batteries in NYC, significant policy changes are required. The solar battery approval and permitting process needs to be significantly streamlined, and the implementation should be concurrently incentivized through state and city energy programs. Further research should be dedicated to solar battery enclosures and placement to identify safer ways for solar batteries to be placed indoors or adjacent to occupiable areas.

Passive House + Geothermal

OVERVIEW

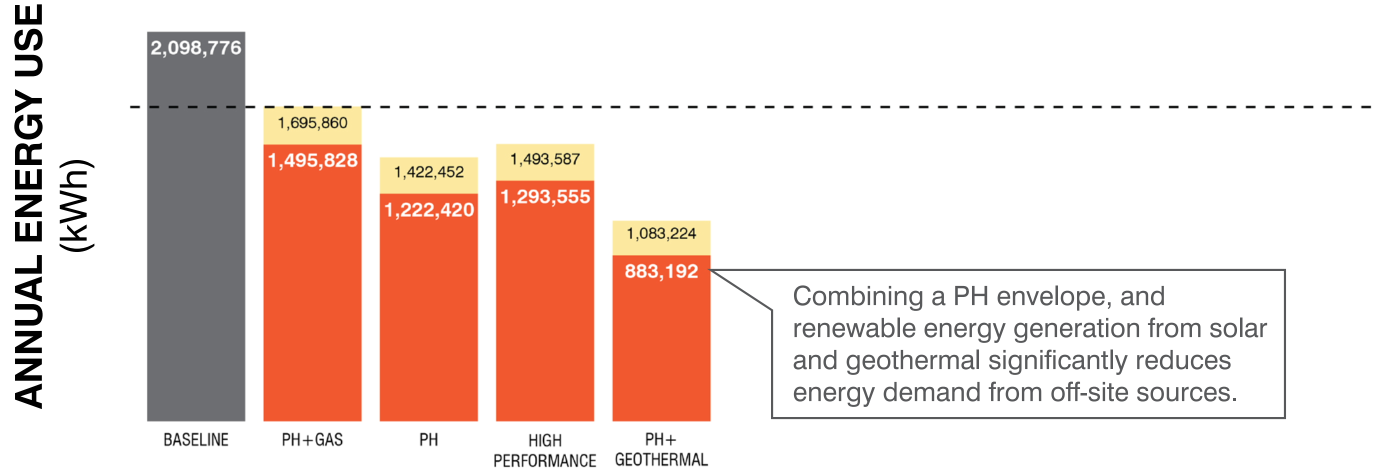
Geothermal energy combines water source heat pumps and domestic hot water (DHW) on the building interior with an exterior ground-loop heat exchanger to take advantage of the stable temperatures underground and provide cost-effective, deeply sustainable heating, cooling and DHW. This strategy is being increasingly implemented in NYC, as incentives for the technology create a compelling financial case for geothermal.

PROCESS

To assess the suitability of geothermal for the Beacon, we are working with Brightcore Building Energy Performance. Their scope includes the review of the underlying geology, existing buildings to remain, and proposed foundations. Using their propriety analytical tools, they can estimate the energy performance of the Beacon with geothermal heating, cooling and domestic hot water (for both the residential and community facility buildings), and compare it to the PH+Electric energy modeling results. Finally, Brightcore use the available incentives for geothermal and heat pumps, installation costs of both systems, and ongoing maintenance costs to provide a full cost and performance picture of the geothermal proposal.

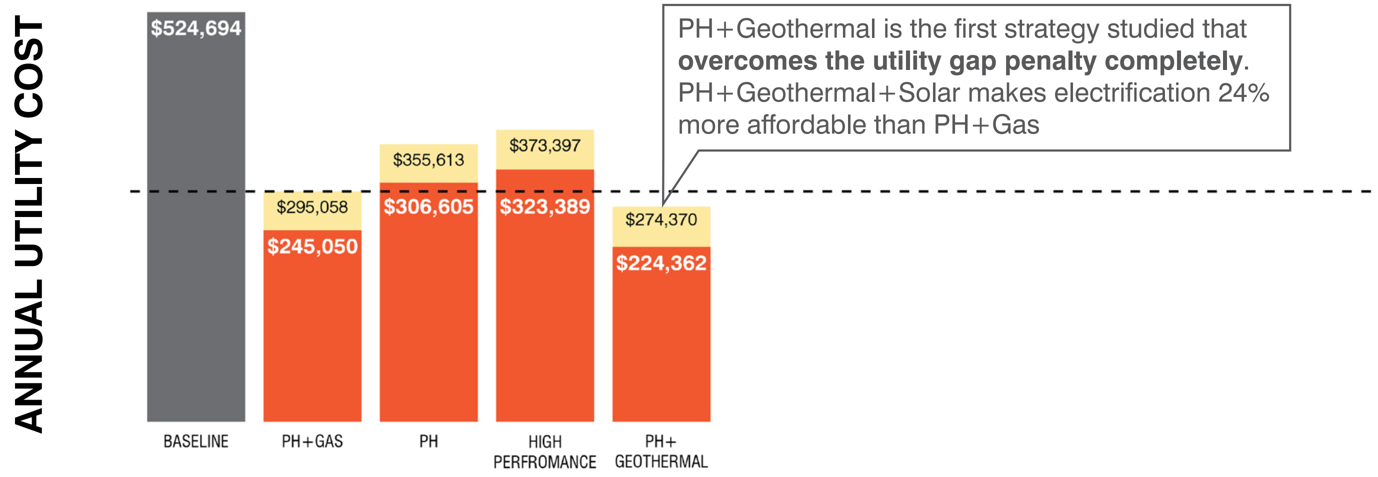
GEOTHERMAL SYSTEM

Residential: Grounds heat exchanger with interior HVAC **(122 ton capacity)**



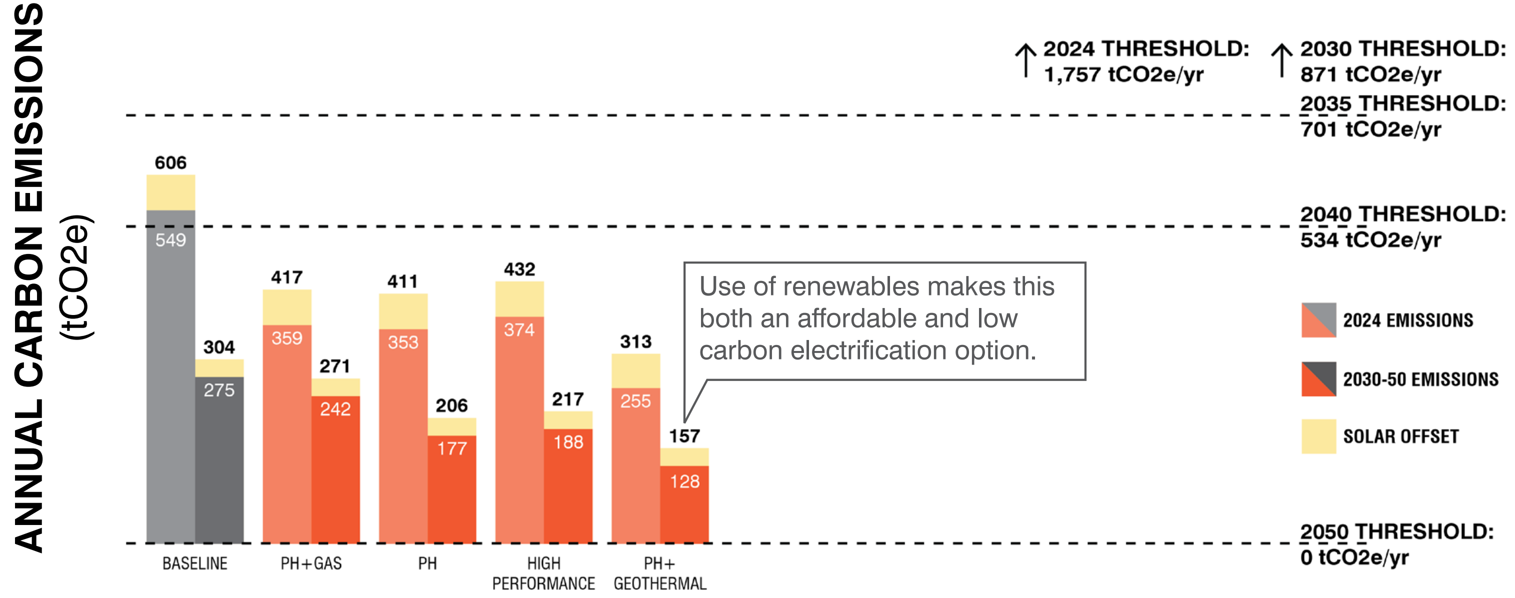
Combining a PH envelope, and renewable energy generation from solar and geothermal significantly reduces energy demand from off-site sources.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



PH+Geothermal is the first strategy studied that **overcomes the utility gap penalty completely**. PH+Geothermal+Solar makes electrification 24% more affordable than PH+Gas

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Use of renewables makes this both an affordable and low carbon electrification option.

Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

The geothermal system covers 100% of the heating, cooling and hot water load for both the residential and community facility buildings. **This strategy, combined with Passive House, has the highest energy performance and is one of the top performers in terms of utility cost and carbon emissions.** Importantly, this strategy costs 10% less to operate than the traditional Passive House + Gas Hot Water approach. Implementing this approach faces spatial hurdles and reluctance from a developer-builder standpoint because it is a new technology. Our client's past experience with geothermal systems included unreliable systems and a need to duplicate thermal systems in case of geothermal failure. **These implementation hurdles may be minimized with changing technology, but past experiences can prevent building owners from continuing to adopt new technology.**

ANNUAL PERFORMANCE

Energy Use: **1,083,224 kWh**	**-48%** Reduction from Baseline	**-36%** Reduction from PH+Gas	**-24%** Reduction from PH+Electric
Utility Cost: **$274,370**	**-48%** Reduction from Baseline	**-7%** Reduction from PH+Gas	**-23%** Reduction from PH+Electric
with solar: $224,362	-57% Reduction from Baseline	-24% Reduction from PH Gas	-37% Reduction from PH Electric
Carbon Emissions: **313 tCO2e/yr**	**-48%** Reduction from Baseline	**-25%** Reduction from PH+Gas	**-24%** Reduction from PH+Electric

THERMAL ENVELOPE

Slab on Grade: 2” EPS ci (R10)
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: 4” mineral wool ci (R18)
Roof: 6” polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: *Ground heat exchanger with interior HVAC (122 ton capacity)*
Rate Structure: Standard
Building Management Systems: None

Time of Use Rates

OVERVIEW

While previous strategies are designed to decrease utility costs by lowering energy loads, Time of Use Rates reduce utility costs by adjusting the rate per unit of energy. After maximizing energy and cost savings through optimized thermal envelope and advanced MEP solutions, we seek new strategies to optimize energy and cost performance. Con-Ed offers optional Time of Use Rates (TOU) for residential buildings, which incentivize using less energy during peak times. In addition to potential cost savings, this strategy incentivizes decreased peak loads and the associated reliance on “peaker” plants used to meet temporary peak loads.

PROCESS

Using hourly energy modeling from eQuest, we apply the respective utility rate to each hour of every day for a year to yield the total utility cost.

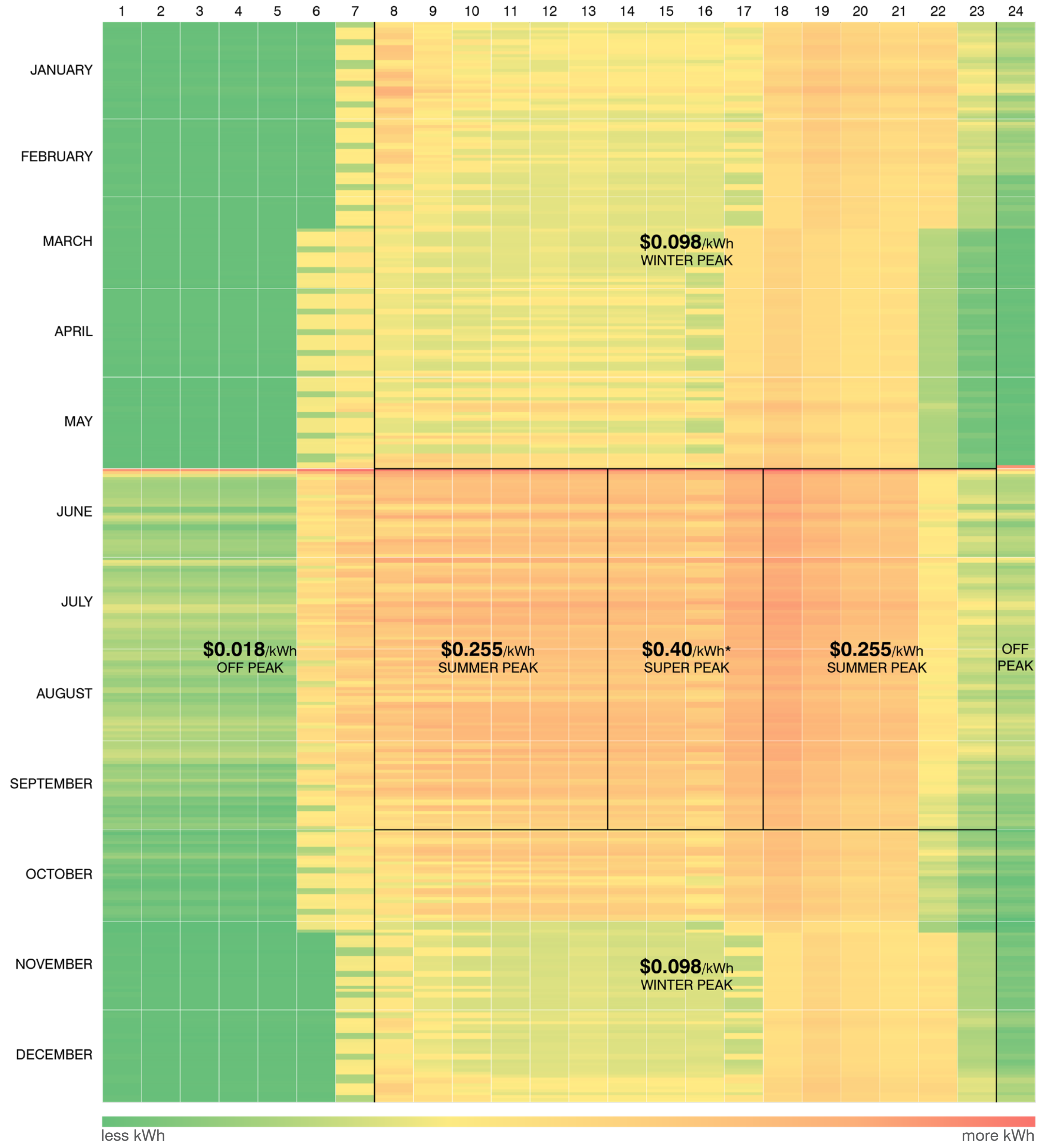


FIGURE 8 **Hourly energy use heat map with time of use rate overlay.**

Energy use increases (orange and red) at the time of highest energy rates. This reflects the high cooling loads that occur in the middle of the day in the middle of the summer.

DELIVERY RATES

Below are the Time of Use demand rates supplied by Con-Ed. Total rate includes the variable demand rate plus a standard delivery rate of 12.73 cents/kWh.

RATE TYPE	MONTH	HOURS	DEMAND RATE
OFF PEAK	ALL MONTHS	MIDNIGHT - 8AM	$0.018/kWh
WINTER PEAK	OCTOBER - MAY	8AM - MIDNIGHT	$0.098/kWh
SUMMER PEAK	JUNE - SEPTEMBER	8AM - 2-M, 6PM - MIDNIGHT	$0.255/kWh
SUPER PEAK	JUNE - SEPTEMBER	2PM - 6PM	$0.40/kWh *

STANDARD	ALL MONTHS	ALL HOURS	$0.12/kWh

* Unknown, assumed $0.40/kWh based on available information.

NOTE: Total rate is demand (listed above) + supply ($0.123/kWh)

NOTE ON SUPER PEAK SUPPLY

From 2 pm to 6 pm on weekdays of peak months (June 1 to Sept 30th), Con-Ed charges ‘Super Peak’ supply rates. Con-Ed does not provide the cost of Super-Peak, but characterizes it as significantly higher than standard rates. There is no clarity offered by Con-Ed on these rates, and in general, Con-Ed provides very little guidance on the practical implementation of Time of Use Rates. Based on cost data shared from our consultants, we have increased the total cost for electricity during these times to 52 cents per kWh, significantly higher than the standard rate charge of 25 per kWh. For buildings considering opting into Time of Use rates, we recommend having Con-Ed provide detailed guidance on these rates before committing. We believe that once the building has a Con-Ed account, obtaining this detail will be less difficult. If TOU is to be implemented at scale in NYC, industry wide advocacy work should be done with Con-Ed to increase access to these rates.

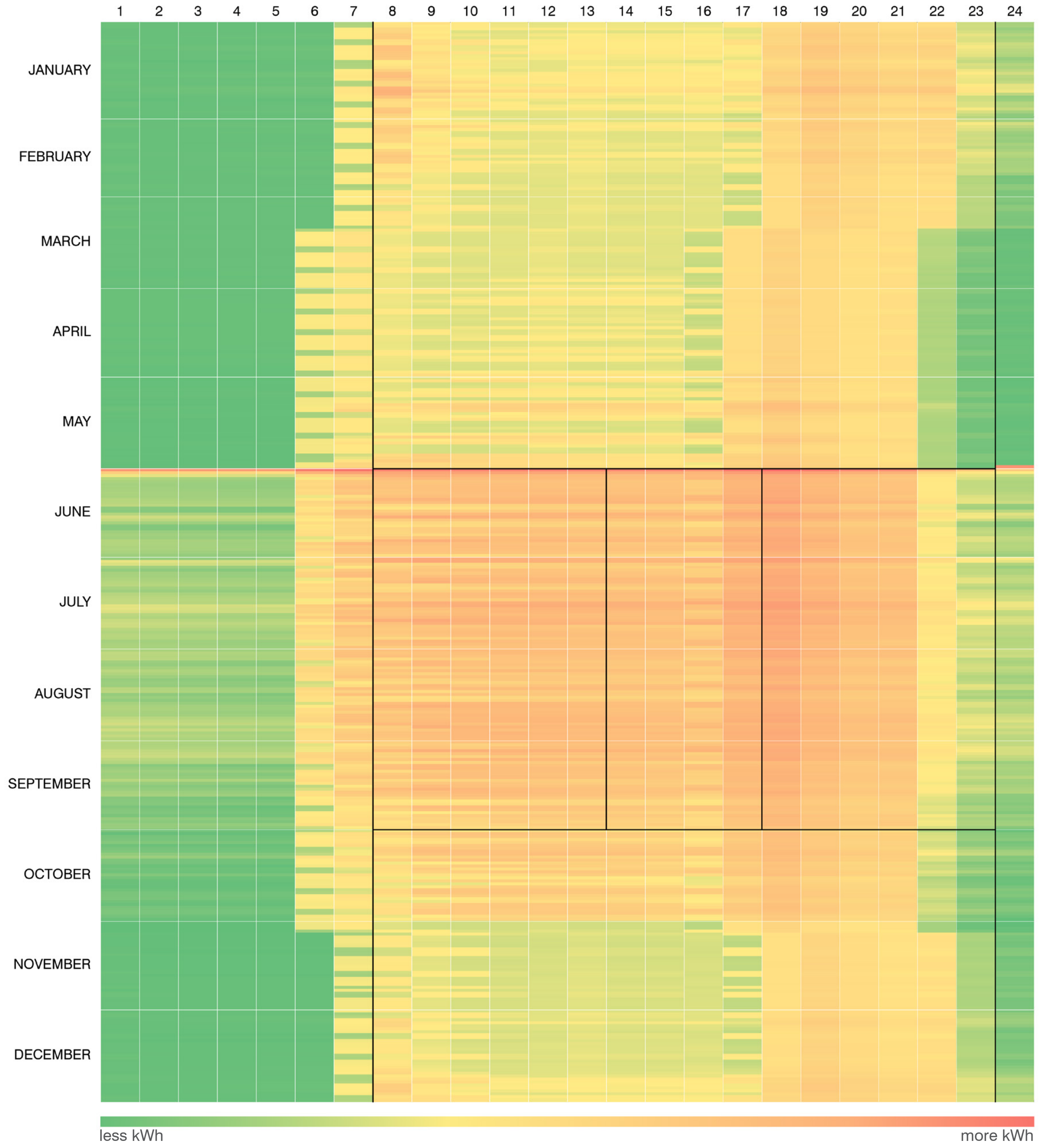


FIGURE 9 Hourly energy use heat map.

Energy use peaks in the middle of the day, with annual highs in the summer. Changes in energy use are vaguely related to time of use thresholds, but have generally gradual transitions.

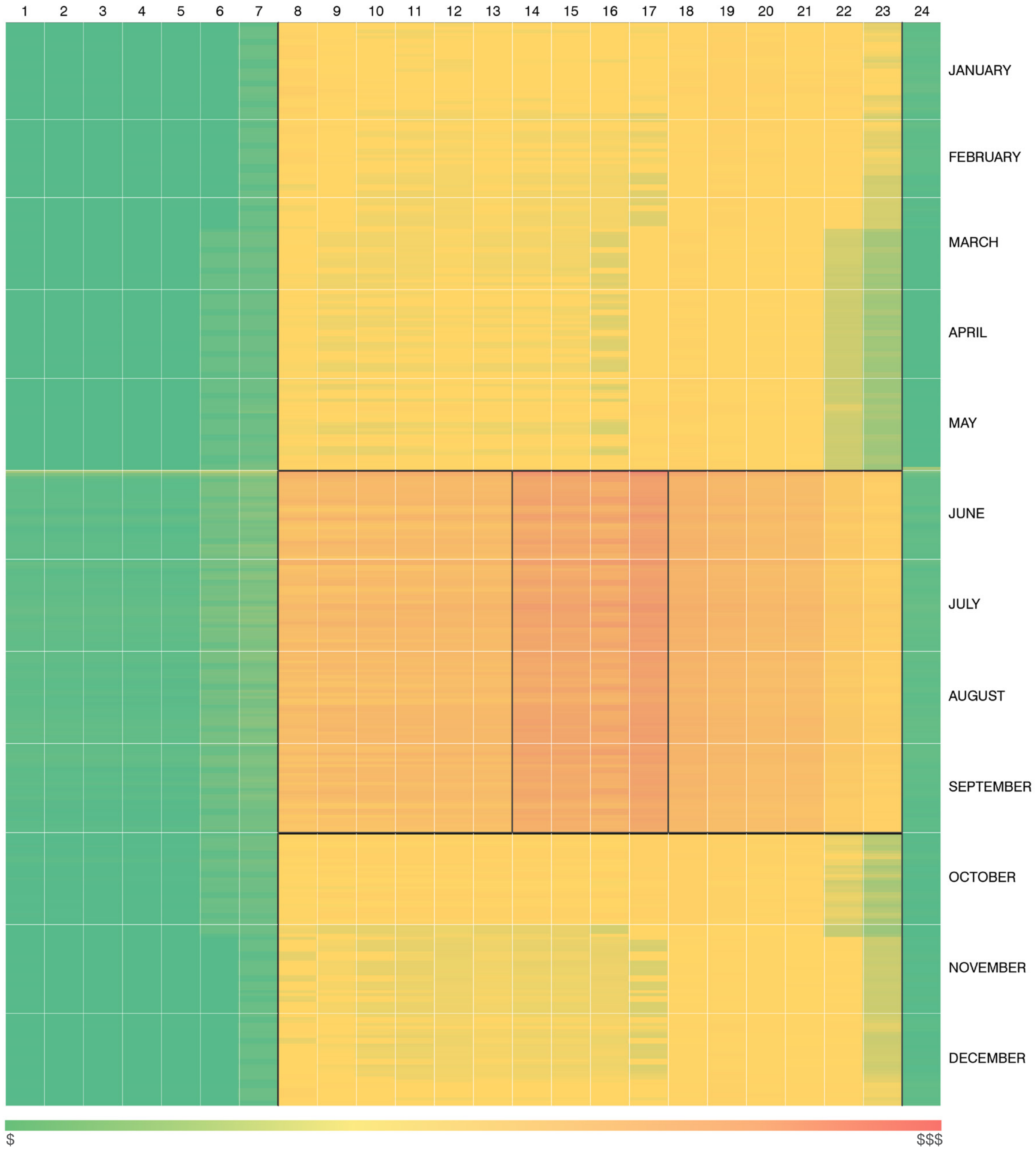
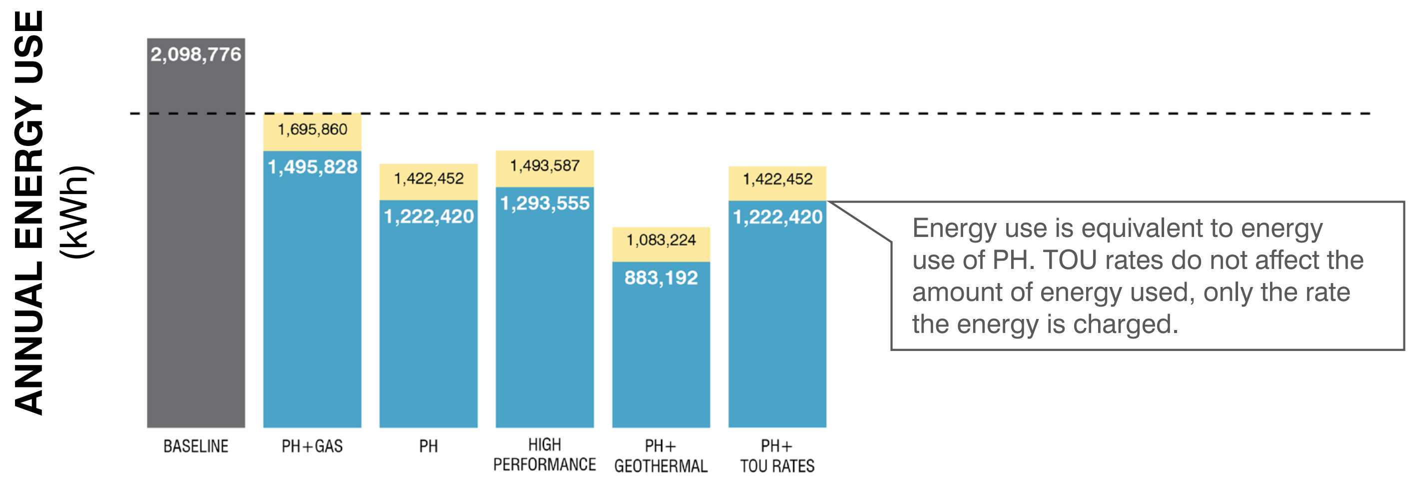


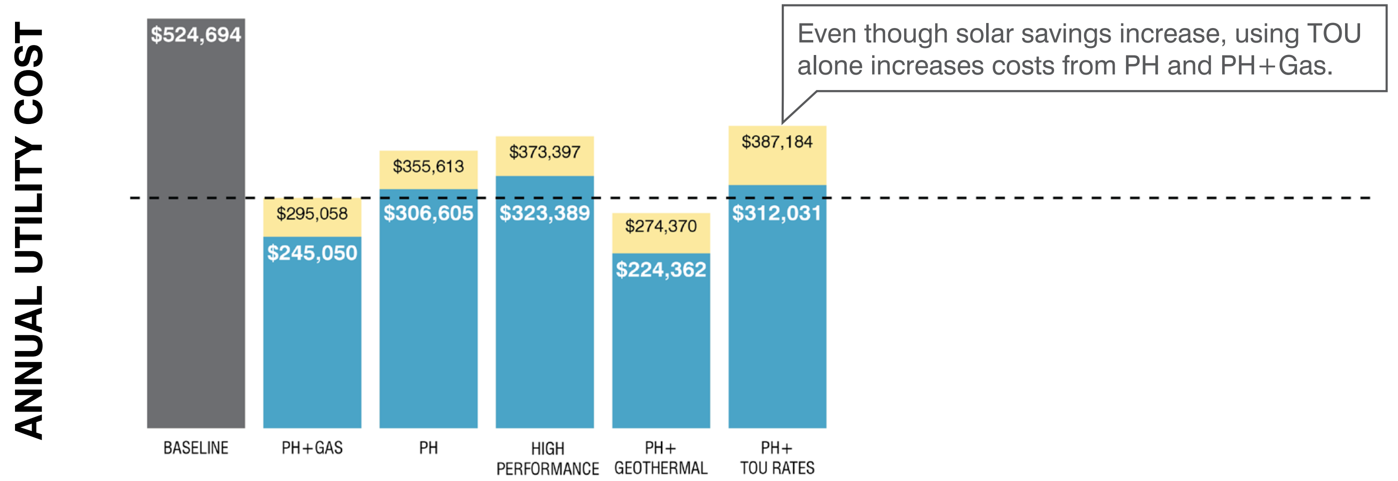
FIGURE 10 Hourly utility cost heat map using time of use rates.

Each day's energy use was multipled by its respective rate. While the transitions between energy use values are more gradual, the time of use rates make the transitions between utility cost much more discrete.



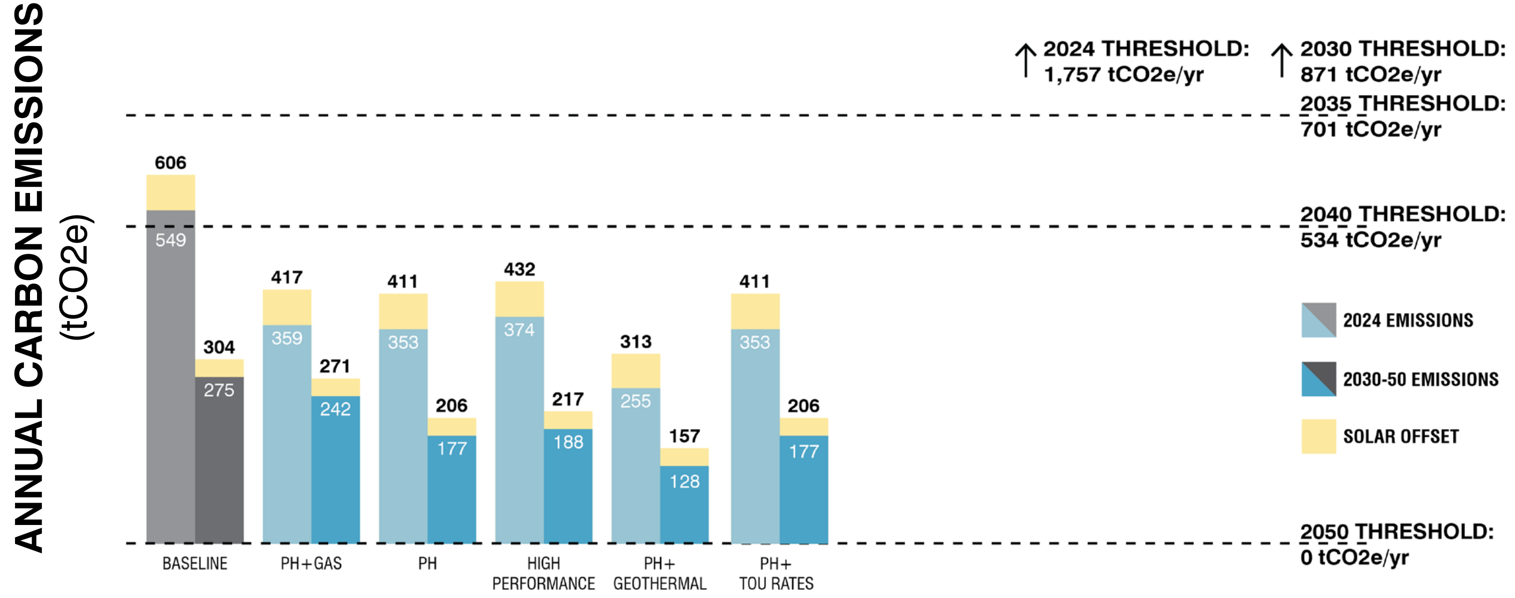
Energy use is equivalent to energy use of PH. TOU rates do not affect the amount of energy used, only the rate the energy is charged.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Even though solar savings increase, using TOU alone increases costs from PH and PH+Gas.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

Based on the available data from Con-Ed, **switching to TOU without taking measures to reduce energy consumption is not an effective standalone strategy for cost reduction.** This approach alone increases the cost of utilities by around 9% from PH+Electric scope. When solar is overlaid, the TOU strategy improves slightly, though still lags behind the PH Electric (plus solar) with standard rates by about 6%. This discrepancy in solar offset is because the solar is generated during the peak and super peak pricing times, and therefore generates around $15,000 more savings per year when using TOU rates.

ANNUAL PERFORMANCE

Energy Use: **1,422,452 kWh**	**-32%** Reduction from Baseline	**-16%** Reduction from PH+Gas	**0%** Change from PH+Electric
Utility Cost: **$312,031** → **$387,184**	**-26%** Reduction from Baseline	**+31%** Increase from PH+Gas	**+9%** Increase from PH+Electric
with solar: $312,031	-41% Reduction from Baseline	+6% Increase from PH Gas	-12% Reduction from PH Electric
Carbon Emissions: **411 tCO2e/yr**	**-32%** Reduction from Baseline	**-1.4%** Reduction from PH+Gas	**0%** Change from PH+Electric

THERMAL ENVELOPE

Slab on Grade: 2” EPS ci (R10)
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: 4” mineral wool ci (R18)
Roof: 6” polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: *Time of Use*
Building Management Systems: None

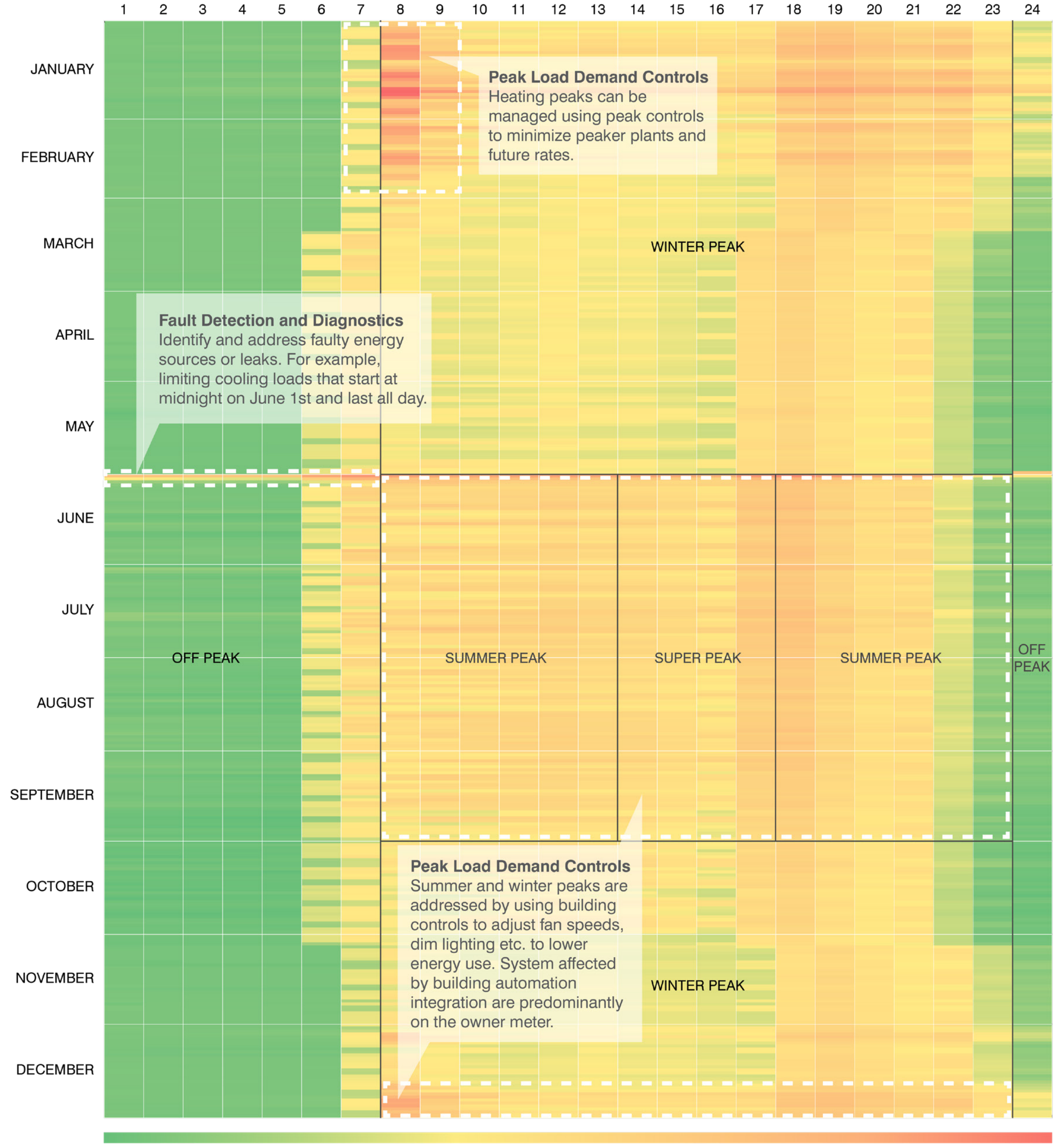
Building Controls

OVERVIEW

Opting into TOU rates alone, even when accounting for solar, still increases the utility cost. In order to take advantage of TOU rates, we need to actively control the cost per unit energy by regulating when we are using power, shifting loads whenever possible out of super peak and peak rate times. Energy management through advanced building controls is a powerful tool in optimizing TOU rates. Instead of relying on the rate to incentivize off-peak use and lower rates, building controls are the mechanism to ensure it. For this study, we are exploring the use of Energy Management Systems and Resident Engagement in order to reduce unnecessary utility energy costs, drive down plug loads, and reduce peak energy demand.

PROCESS

For this project, we are engaging Sentient Building Systems as consultants for this analysis. Sentient employs advanced building controls and automation in buildings in commercial, multifamily, hospitality, and institutional buildings. They have developed an innovative model for optimizing building energy management to maximize the ability of a building to reduce costs, respond to grid demand-response events and manage peak demand impacts. For the Beacon residential building, Sentient identifies controls across a wide range of systems, including lighting, plug loads, HVAC, and hot water. These control points can be managed through a number of strategies, including thermostat automation, seasonal lockout, comfort and efficiency management, outdoor air lockout and resident engagement strategies. Using these potential control points and strategies, Sentient Building Systems proposes four major strategies for optimizing cost, energy and occupant comfort.



Peak Load Demand Controls
Heating peaks can be managed using peak controls to minimize peaker plants and future rates.

Fault Detection and Diagnostics
Identify and address faulty energy sources or leaks. For example, limiting cooling loads that start at midnight on June 1st and last all day.

Peak Load Demand Controls
Summer and winter peaks are addressed by using building controls to adjust fan speeds, dim lighting etc. to lower energy use. System affected by building automation integration are predominantly on the owner meter.

FIGURE 11 **Heat map diagram of Peak Load Demand Control interventions on the hourly energy use from the owner's meter.**

Included in the owner meter:
Heating
25% total plug loads
25% total lighting
Auxiliary pumps
Vent fans
Supplemental heat pumps
Domestic hot water
Exterior to the building end uses

Peak Load Demand Control Strategy

This control strategy optimizes peak load demand through a series of control 'levers', and offers significant cost savings potential, as well as reduces reliance on local, dirty 'peaker' generators (often located in the lowest income neighborhoods) that turn on during times of peak demand.

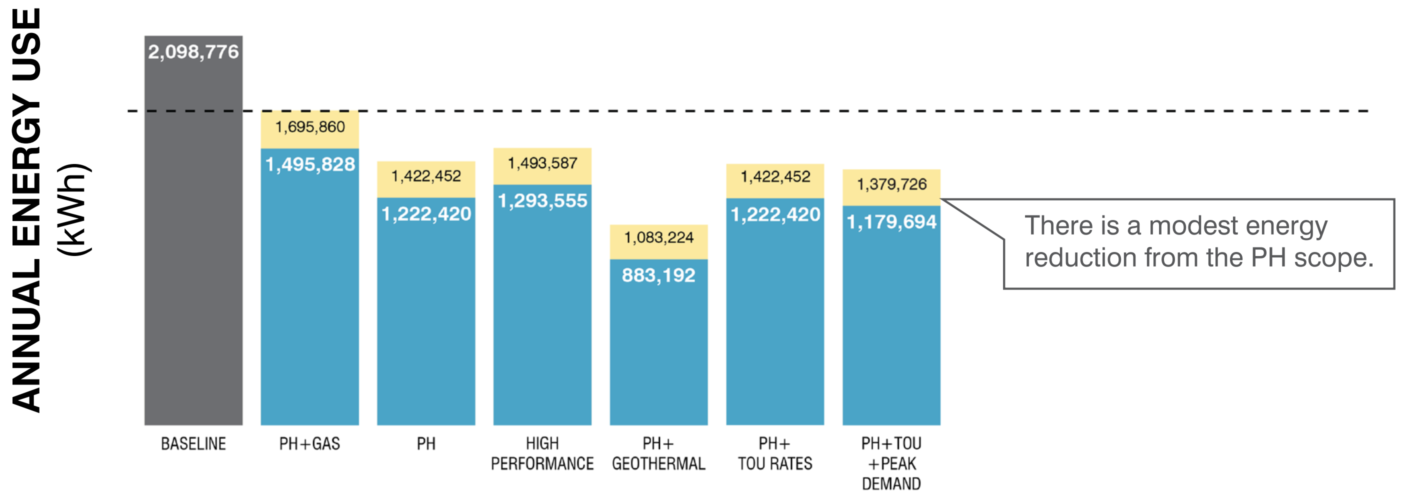
Sentient's models provide real time monitoring and control of the building systems to reduce the annual average peak demand load. These controls are operated automatically and by building managers, lowering energy end-uses that tenants may not control. The average annual peak demand load is used by the utility company to set rates in 6-month intervals. Reducing this annual average load is a powerful tool in cost optimization. The target peak load reduction is 18%, which is significant and requires savings across heating and cooling, lighting, and pump and fan systems, combined with local energy generation (solar PV) and resident engagement.

Typical control levers for Peak Load Demand Control include:

1. Thermostat management – adjusting status or setpoint to manage use
2. Lighting – controlling status and dimming level (if available)
3. Pumps and fans – controlling drive speeds to meet operational and saving targets
4. Local energy generation – if available, may be used to offset grid resources
5. Resident Engagement - the target for average peak load reduction is 18%, which is significant and requires engagement and cooperation from building residents. There are a number of strategies the owner can utilize to engage with residents:
   - Resident Education and Orientation at lease signing;
   - Energy Feedback Loops - Real time information feedback at high traffic common spaces;
   - Resident Cost Savings - Incentivize residents to use less energy and avoid peak loads through payment programs, especially through 3rd party applications like Meltek. For more information on this strategy, see **SIDEBAR: RESIDENT INCENTIVE APPS**

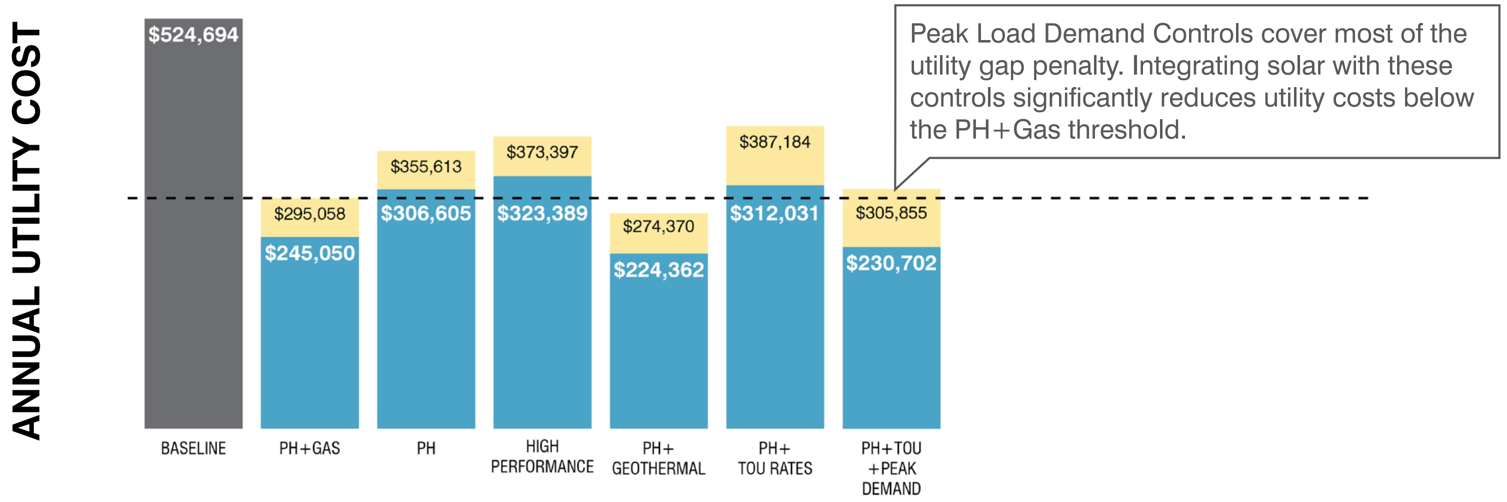
Low Hanging Fruit: Fault Detection and Diagnostics

These measures require simple analytics to identify basic equipment operational issues. While these measures don't offer improvement over our modeled energy use, they do prevent us from underperforming compared to the energy models due to easily correctable issues like identifying overrides.



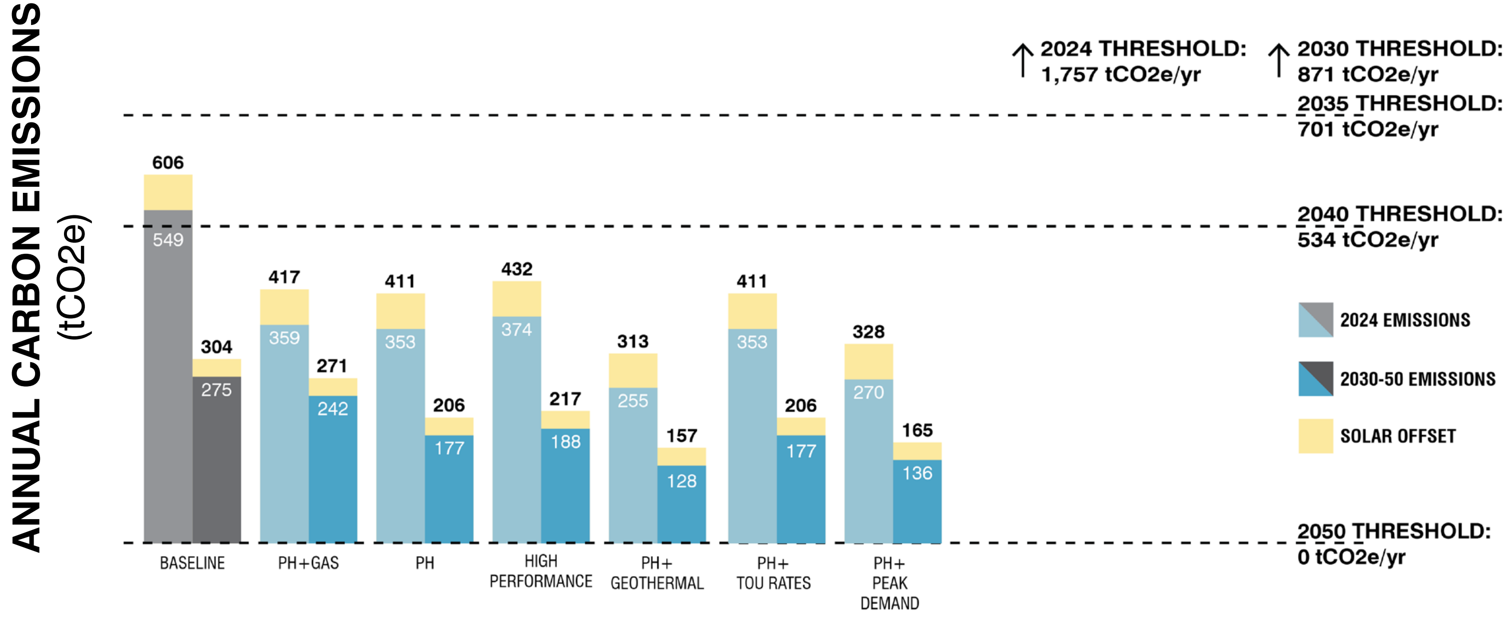
There is a modest energy reduction from the PH scope.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Peak Load Demand Controls cover most of the utility gap penalty. Integrating solar with these controls significantly reduces utility costs below the PH+Gas threshold.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

As discussed above, the **Fault Detection and Diagnostics strategy won't decrease our modeled load, but is a real-time and ongoing commissioning tool to ensure that the building operates as intended.** The Peak Load Demand Control strategy results in a marginal decrease in overall energy use (42,726 kWh / approx 3%). However, when strategically implemented to decrease the average annual peak load demand, the associated decrease in utility rate results in **estimated savings of $49,758 per year, or nearly 14% per year.**

ANNUAL PERFORMANCE

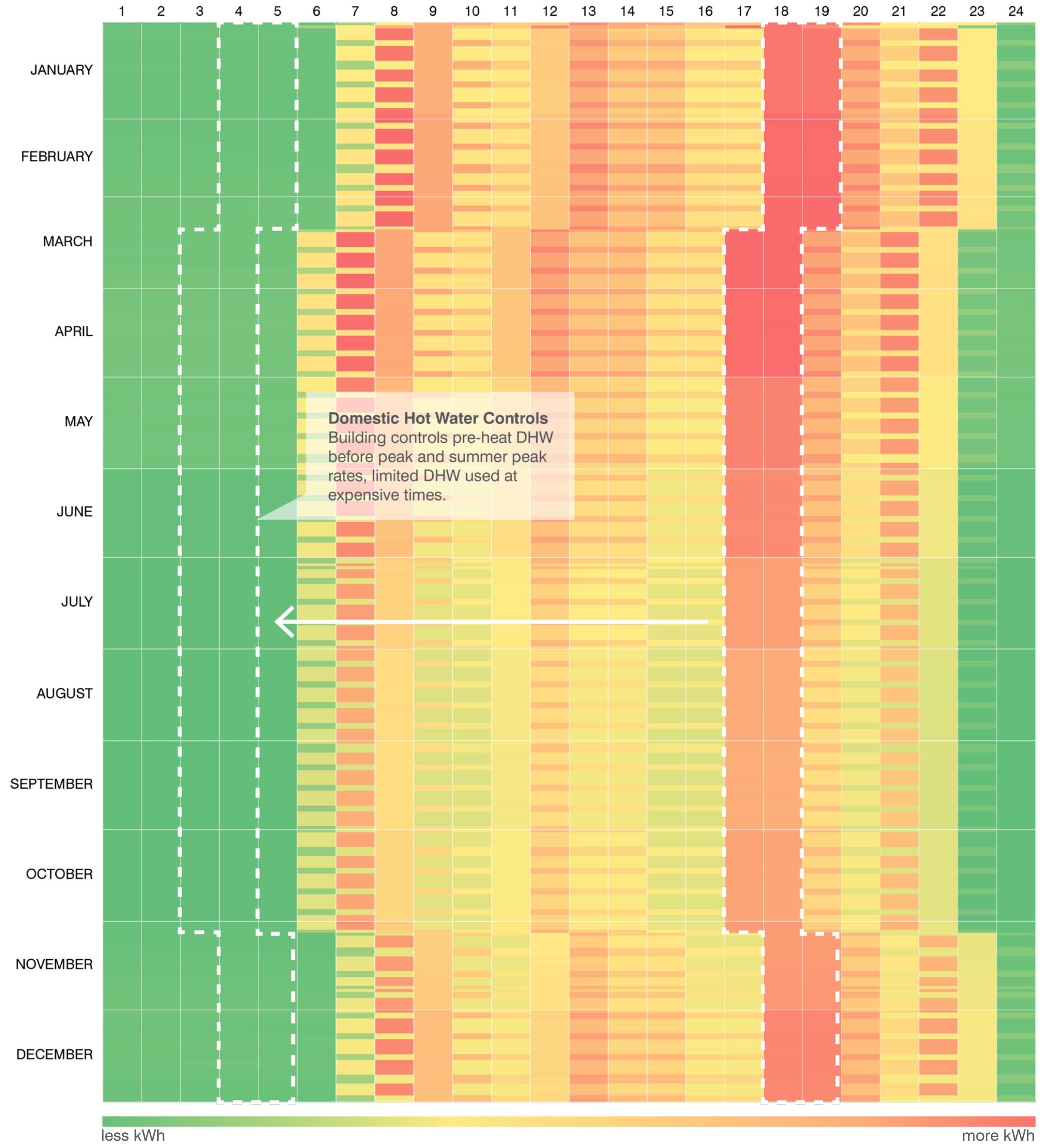
Energy Use: **1,379,726 kWh**	**-34%** Reduction from Baseline	**-19%** Reduction from PH+Gas	**-3%** Reduction from PH+Electric
Utility Cost: **$305,855**	**-42%** Reduction from Baseline	**+4%** Increase from PH+Gas	**-14%** Reduction from PH+Electric
with solar: $230,702	-56% Reduction from Baseline	-22% Reduction from PH Gas	-35% Reduction from PH Electric
Carbon Emissions: **328 tCO2e/yr**	**-46%** Reduction from Baseline	**-21%** Reduction from PH+Gas	**-20%** Reduction from PH+Electric

THERMAL ENVELOPE

Slab on Grade: 2" EPS ci (R10)
Foundation Walls: 3" EPS ci (R13)
Overhanging Floors: 4" polyiso ci (R26)
Above Grade Walls: 4" mineral wool ci (R18)
Roof: 6" polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: *Time of Use*
Building Management Systems: *Peak Load Demand Control*



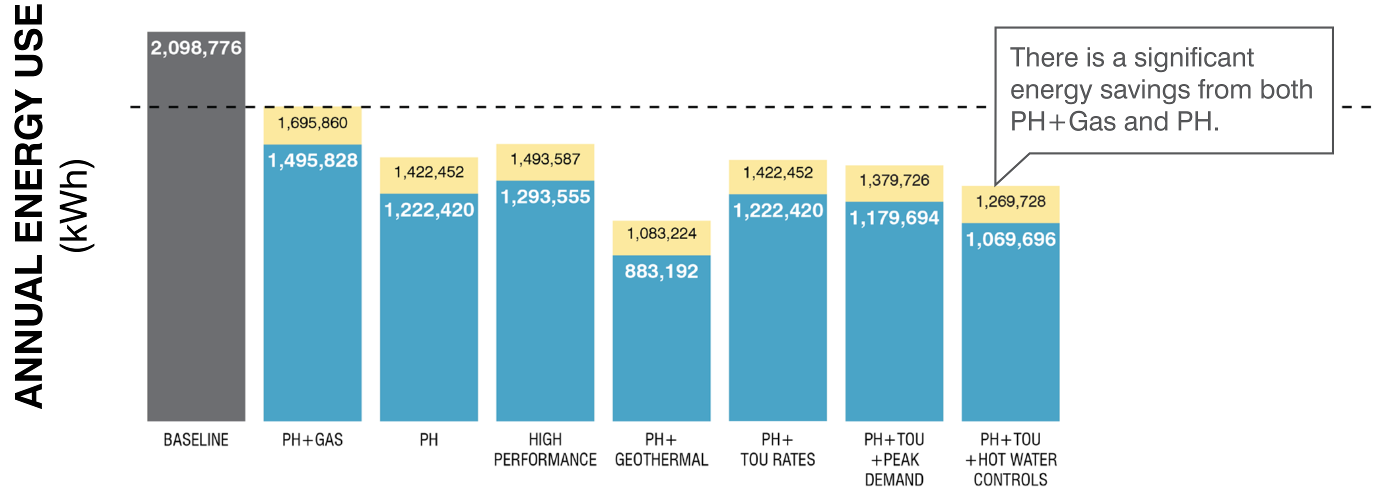
Domestic Hot Water Controls
Building controls pre-heat DHW before peak and summer peak rates, limited DHW used at expensive times.

FIGURE 12 **Domestic hot water energy use heat map with control description overlay.**

Hot water use peaks in the evening, when rates are high. Domestic hot water controls opt to pre-heat water in the off peak time period as much as possible.

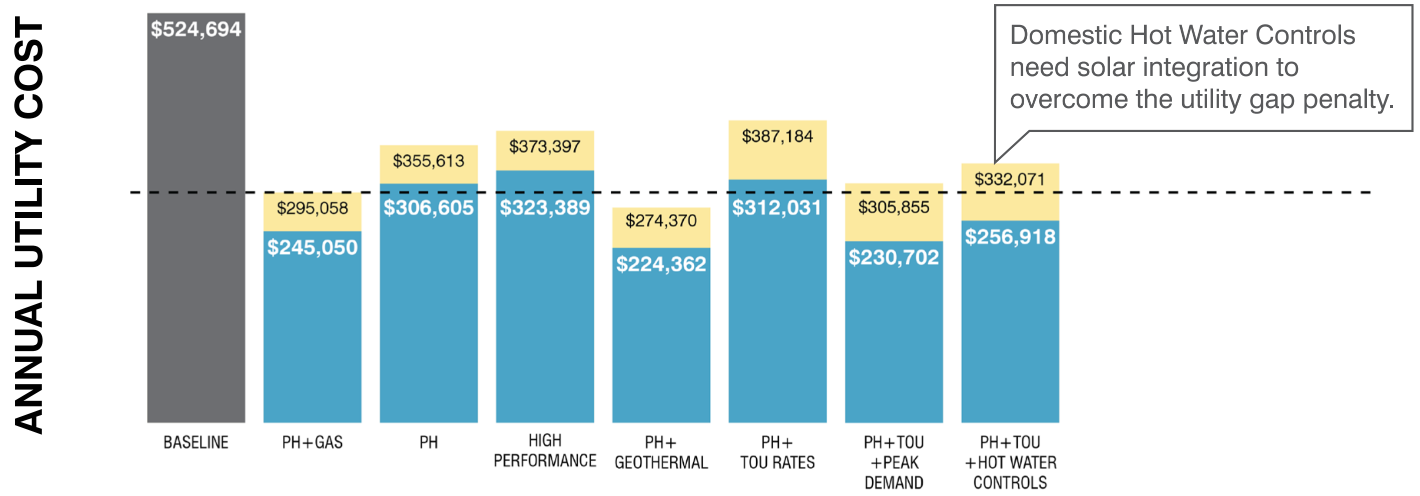
Domestic Hot Water Time of Use Strategy

This strategy overlays optimization *when* energy is used to heat hot water to tackle the critical issue of electrified hot water cost. In this scenario, the owner would opt into the optional TOU rates from Con-Ed. Building controls can call for domestic hot water to be pre-heated before peak and super peak energy rates, with an option to create short term lockouts if desired.



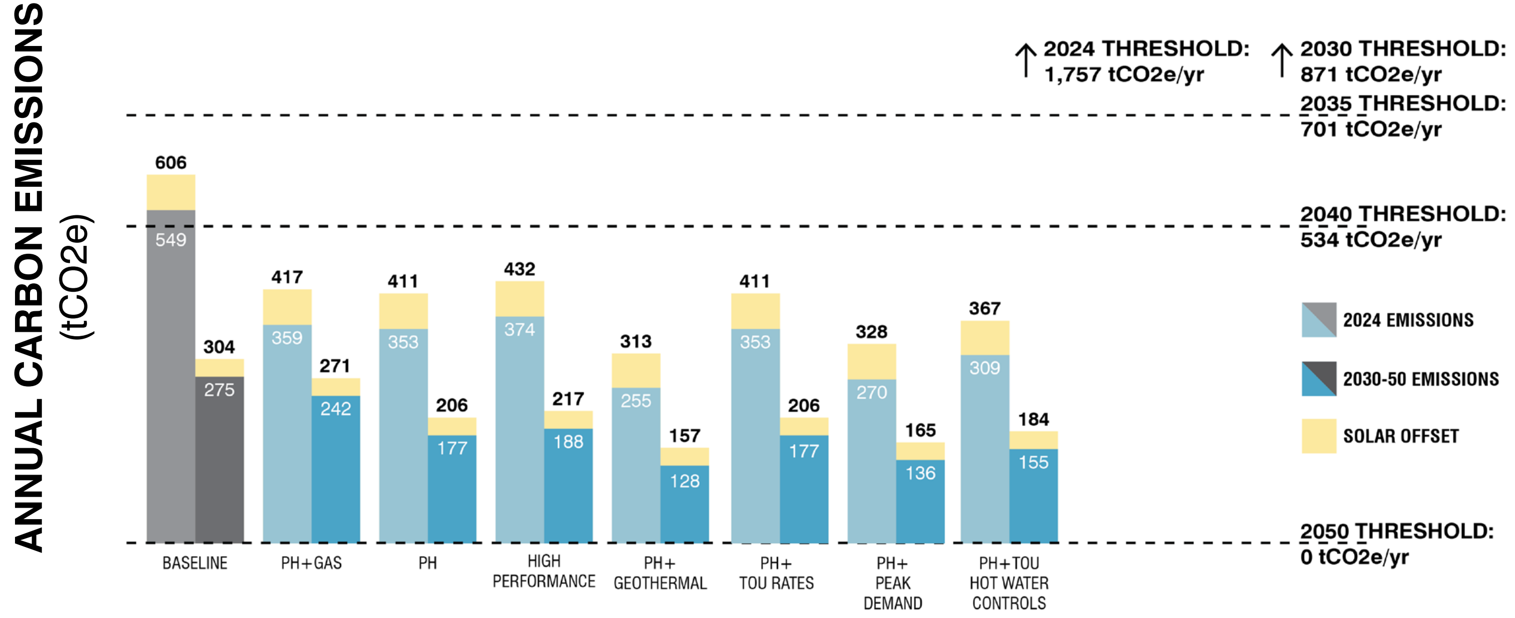
There is a significant energy savings from both PH+Gas and PH.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Domestic Hot Water Controls need solar integration to overcome the utility gap penalty.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

The Domestic Hot Water strategy is calculated to save 42,746 kWh annually, with yearly cost savings of $49,757. This decreases the utility gap penalty by more than 80%. Careful consideration needs to be given to how this strategy interplays with other strategies such as solar PV and Time of Use Rates, as well as occupant comfort factors.

ANNUAL PERFORMANCE

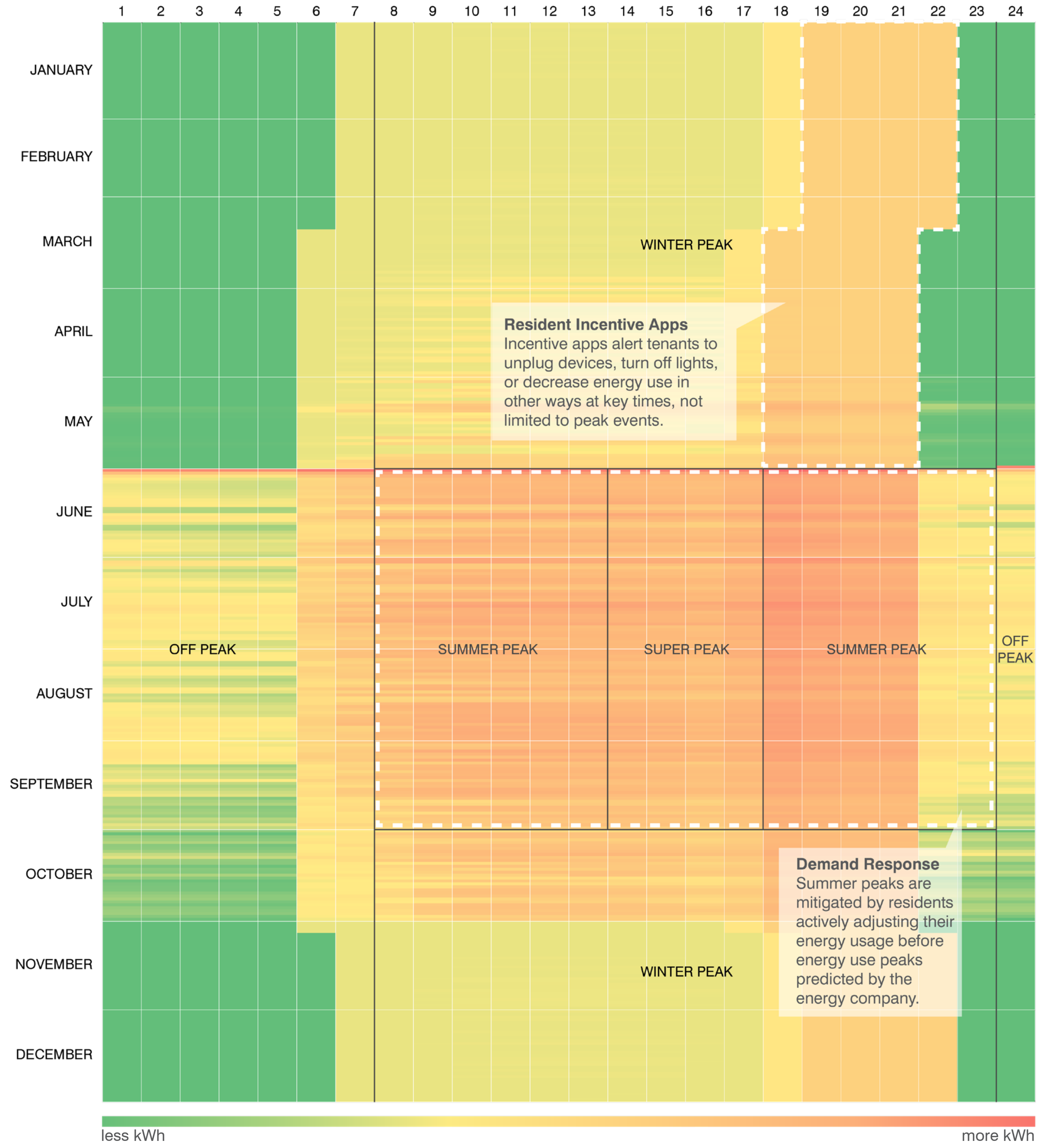
Energy Use: **1,269,728 kWh**	**-40%** Reduction from Baseline	**-25%** Reduction from PH+Gas	**-11%** Reduction from PH+Electric
Utility Cost: **$332,071**	**-37%** Reduction from Baseline	**+13%** Increase from PH+Gas	**-7%** Reduction from PH+Electric
with solar: $256,918	-51% Reduction from Baseline	-13% Reduction from PH Gas	-28% Reduction from PH Electric
Carbon Emissions: **367 tCO2e/yr**	**-39%** Reduction from Baseline	**-12%** Reduction from PH+Gas	**-11%** Reduction from PH+Electric

THERMAL ENVELOPE

Slab on Grade: 2” EPS ci (R10)
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: 4” mineral wool ci (R18)
Roof: 6” polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: *Time of Use*
Building Management Systems: *Domestic Hot Water Controls*



Resident Incentive Apps
Incentive apps alert tenants to unplug devices, turn off lights, or decrease energy use in other ways at key times, not limited to peak events.

Demand Response
Summer peaks are mitigated by residents actively adjusting their energy usage before energy use peaks predicted by the energy company.

FIGURE 13 **Heat map diagram of Demand Response controls and Resident Incentive App interventions on the hourly energy use from the tenant's meter.**

Included in the tenant meter:
Cooling
75% total plug loads
75% total lighting

Demand Response Strategy

This strategy uses similar energy control levers as Peak Load Demand Control, but is used to avoid energy costs by opting into a voluntary program for reducing demand at time intervals identified by the utility company. This strategy varies from Peak Load Demand Control as it is controlled by tenant action, instead of an process that is automated or controlled by a building manager. This is a TOU strategy with a controls overlay.

SIDEBAR

RESIDENT INCENTIVE APPS

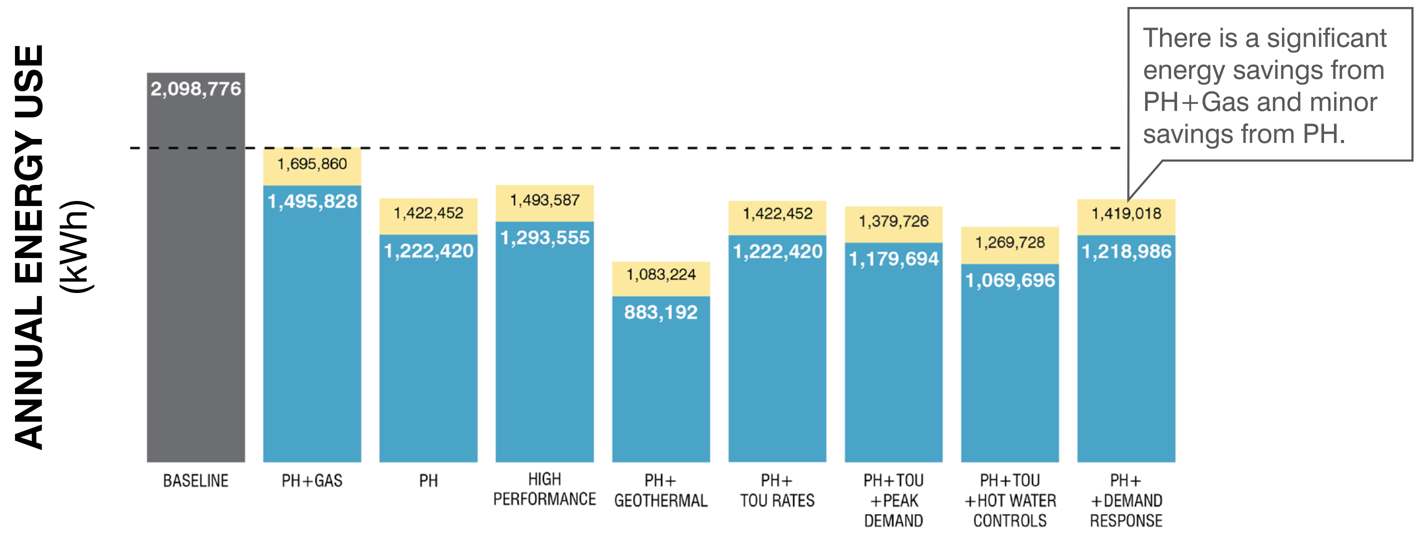
Once the project is constructed and occupied, the designers work is complete and the owner must continue work with the occupants. Designers seek to equip building owners with tools to help influence occupant behavior. Engaging and empowering building residents to reduce energy used within their apartments is a high priority for designers working on high performance buildings. After drastically driving down energy use through Passive House design, finding strategies to influence occupants to reduce their own energy consumption has been as elusive as it has been enticing.

Companies such as Meltek, Ecogy and Logical Buildings have entered the market with products to address this need. Meltek, for example, pays residential building tenants who rent their apartments, to reduce their energy use during intervals of peak demand. Building residents can opt in to the program optionally, which operated through a smartphone app. We would recommend that the building owner encourage the use of the program through their own resident engagement and orientation. Users are alerted to times when they can earn money for reducing their energy consumption. In addition to direct savings to the resident (Con-Ed Users save between 10% and 20% of their monthly utility bill), these programs engage the residents in the goal of reducing energy. This program has also proven to reduce carbon emissions in buildings, and provide the significant environmental justice benefit of reducing reliance on the dirty, peak demand generators.

For a full list of companies participating in resident energy savings incentive program with Con-Ed, please see the *Smart Usage Rewards (Demand Response) Aggregator List.* **5**

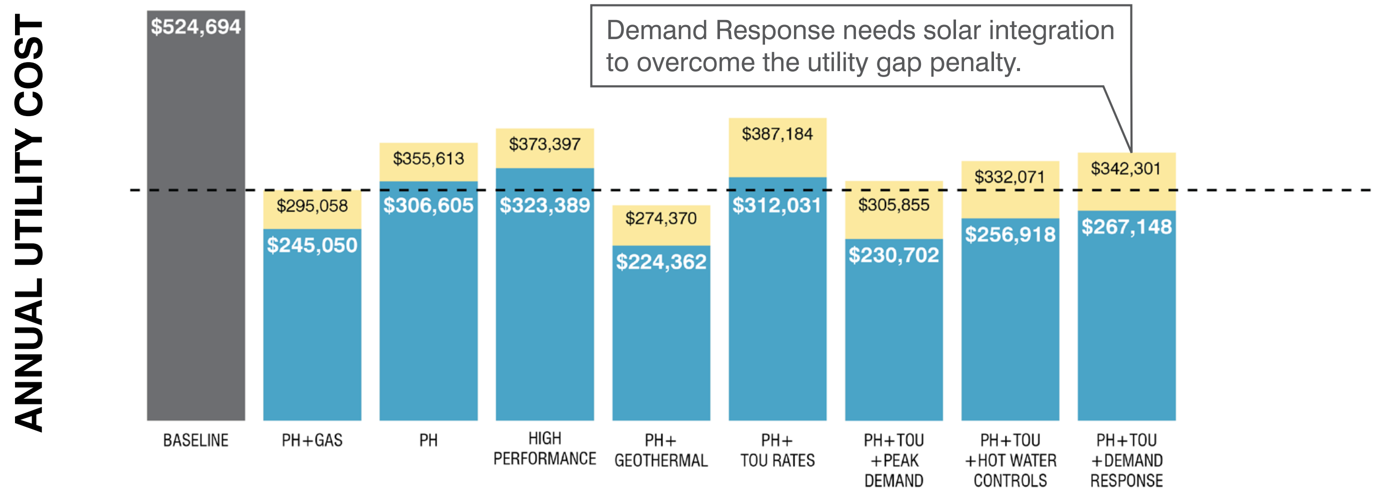
---

5 *Smart Usage Rewards (Demand Response) Aggregator List.* Con Edison, 2023, https://www.coned.com/-/media/files/coned/documents/save-energy-money/rebates-incentives-tax-credits/smart-usage-rewards/aggregator-list.pdf?la=en



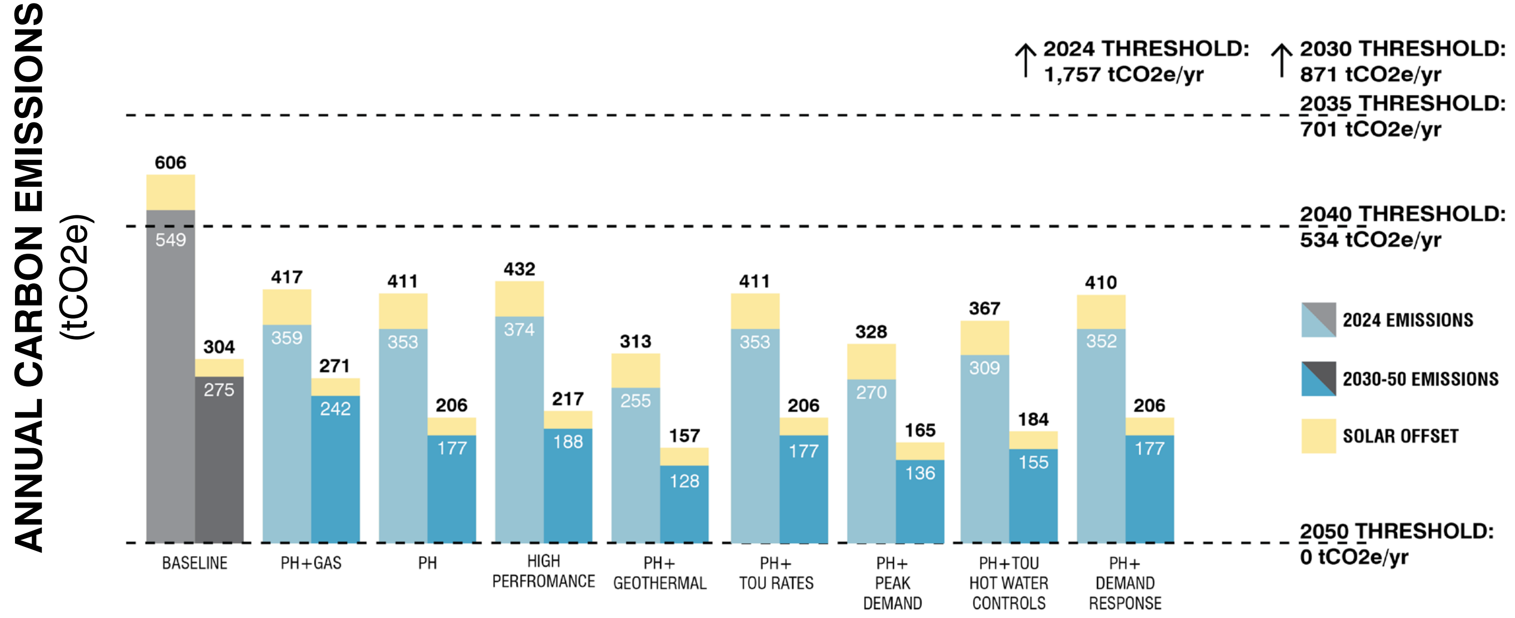
There is a significant energy savings from PH+Gas and minor savings from PH.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Demand Response needs solar integration to overcome the utility gap penalty.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

The Demand Response strategy boasts a modest annual savings of 3,434 kWh, but leverages Time of Use Rates to save an estimated $13,312 per year. As with the other Building Management System strategies, this approach must be carefully calibrated to each building's unique systems and energy use profile. Here again, the relationship to this approach and other strategies has a complex interplay, so further study is required on the individual building level to optimize energy and cost savings with initial costs and occupant comfort considerations.

ANNUAL PERFORMANCE

Energy Use: **1,419,018 kWh**	**-32%** Reduction from Baseline	**-16%** Reduction from PH+Gas	**-0.2%** Reduction from PH+Electric
Utility Cost: **$342,301**	**-35%** Reduction from Baseline	**+16%** Increase from PH+Gas	**-4%** Reduction from PH+Electric
with solar: $267,148	-49% Reduction from Baseline	-9% Reduction from PH Gas	-25% Reduction from PH Electric
Carbon Emissions: **410 tCO2e/yr**	**-32%** Reduction from Baseline	**-2%** Reduction from PH+Gas	**-0.2%** Reduction from PH+Electric

THERMAL ENVELOPE

Slab on Grade: 2” EPS ci (R10)
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: 4” mineral wool ci (R18)
Roof: 6” polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: *Time of Use*
Building Management Systems: *Demand Response*

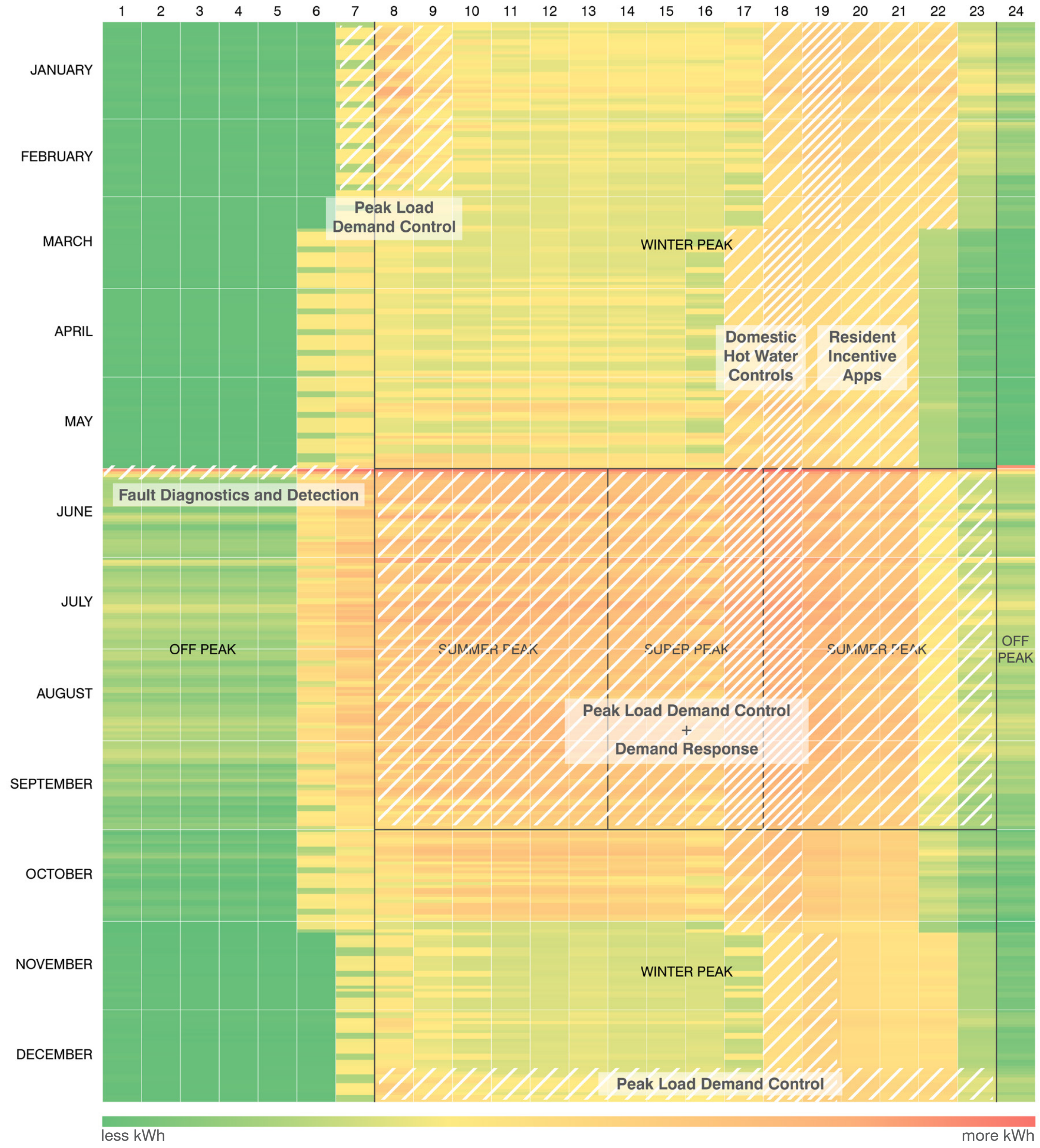
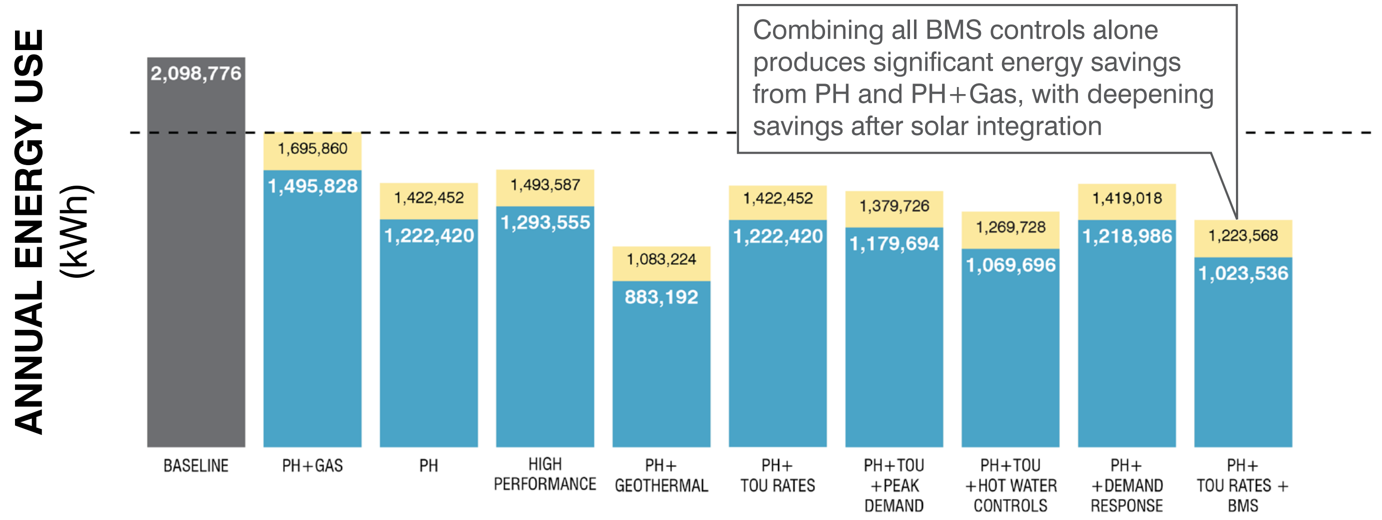


FIGURE 14 Heat map diagram of total hourly energy with all BMS interventions overlaid.

Areas with the warmest colors are addressed using an array of targeted BMS controls.

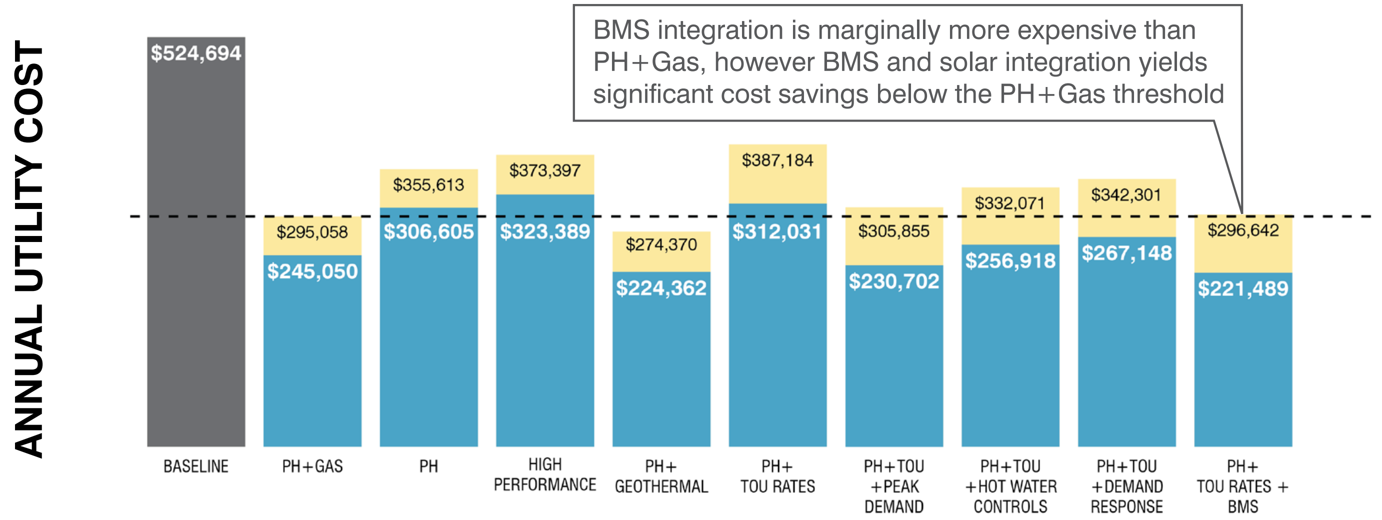
Combined BMS Controls

The energy and cost savings for the Energy Management Control strategies is attributed to the Peak Load Demand Control and Time of Use + Building Control strategies. The interaction of these strategies is not exactly cumulative, meaning the savings from each can't simply be added. In reality, using these strategies in conjunction will shift the savings slightly and should be studied after implementation. **The target annual average peak load reduction for this strategy is 18%.** This is significant, and is expected to require cooperation from residents. Strategies that affect residents could include rolling thermostat setbacks and light dimming (on 15-minute intervals) and HVAC cycling (on 15-minute intervals). To drive further savings, **we recommend resident engagement and energy orientation**. Strategies can include real time energy feedback, delivered in prominent locations such as the lobby and/or through smartphone software, and, potentially, resident incentives. A particularly promising strategy is the use of 3rd Party incentive programs that pay residents to reduce energy use during peak demand events (see the **SIDEBAR** above).



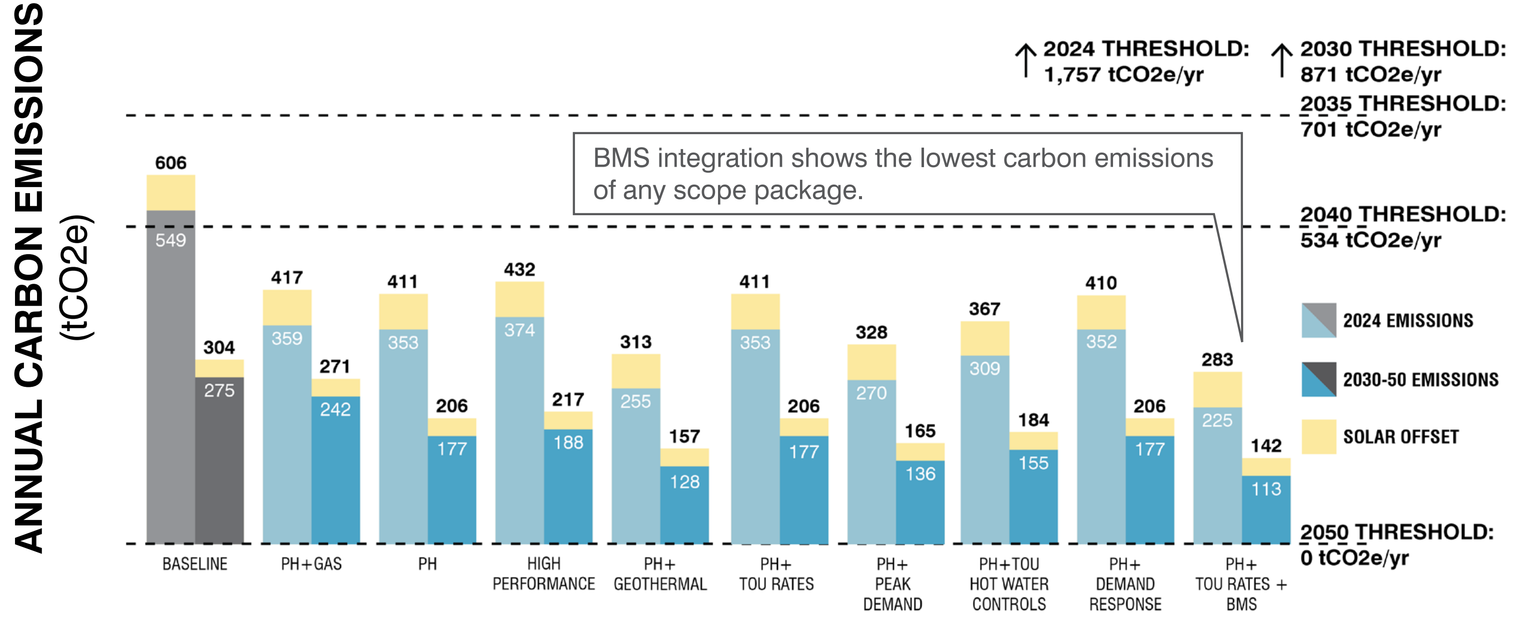
Combining all BMS controls alone produces significant energy savings from PH and PH+Gas, with deepening savings after solar integration

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



BMS integration is marginally more expensive than PH+Gas, however BMS and solar integration yields significant cost savings below the PH+Gas threshold

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



BMS integration shows the lowest carbon emissions of any scope package.

Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

While interaction of BMS and other buildings system cannot be determined without further case study research, these preliminary results show **a combination of BMS controls can bring down the utility cost to a PH+Gas standard, overcoming the utility gap penalty. When solar generation is integrated, this scope package reduces the utility cost by 25% from the PH+Gas standard.** From an energy standpoint, adding a combination BMS package to the PH envelope can produce a 14% energy savings from a PH scope.

ANNUAL PERFORMANCE

Energy Use: **1,223,568 kWh**	**-42%** Reduction from Baseline	**-28%** Reduction from PH+Gas	**-14%** Reduction from PH+Electric
Utility Cost: **$296,642**	**-43%** Reduction from Baseline	**+0.5%** Increase from PH+Gas	**-17%** Reduction from PH+Electric
with solar: $221,489	-58% Reduction from Baseline	-25% Reduction from PH Gas	-38% Reduction from PH Electric
Carbon Emissions: **283 tCO2e/yr**	**-53%** Reduction from Baseline	**-32%** Reduction from PH+Gas	**-31%** Reduction from PH+Electric

THERMAL ENVELOPE

Slab on Grade: 2” EPS ci (R10)
Foundation Walls: 3” EPS ci (R13)
Overhanging Floors: 4” polyiso ci (R26)
Above Grade Walls: 4” mineral wool ci (R18)
Roof: 6” polyiso ci (R38)
Windows: UPVC casement, U-0.17 Frame, U-0.09 Glass, SHGC 0.38 (triple pane)
Storefront: Thermally broken alum. U-0.39 Frame, U-0.09 Glass, SHGC 0.38
Air Sealing: 0.6 ACH50

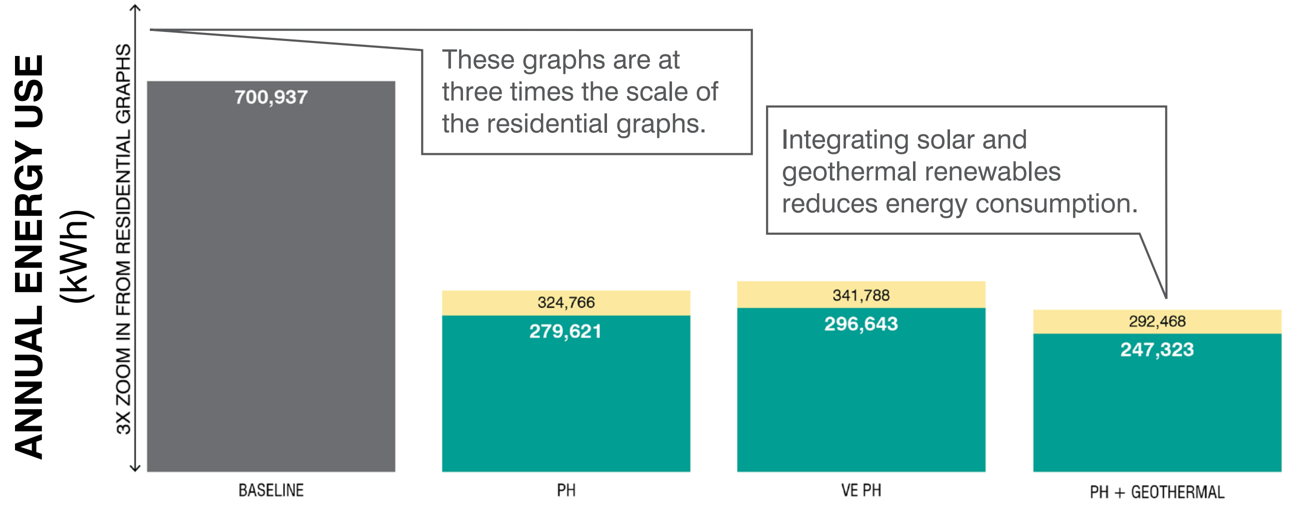
BUILDING SYSTEMS

Heating and Cooling: VRF heat pump (COP 3.8 @ 47F/ COP 2.4 @ 17F)
Domestic Hot Water: Air to Water Heat Pump (0.38 COP)
Ventilation: Rooftop ERV (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None
Rate Structure: *Time of Use*
Building Management Systems: *Fault Detection and Diagnostics, Peak Load Demand Control, Domestic Hot Water Time of Use Strategy*

Community Facility Analysis and Results

Community Facility

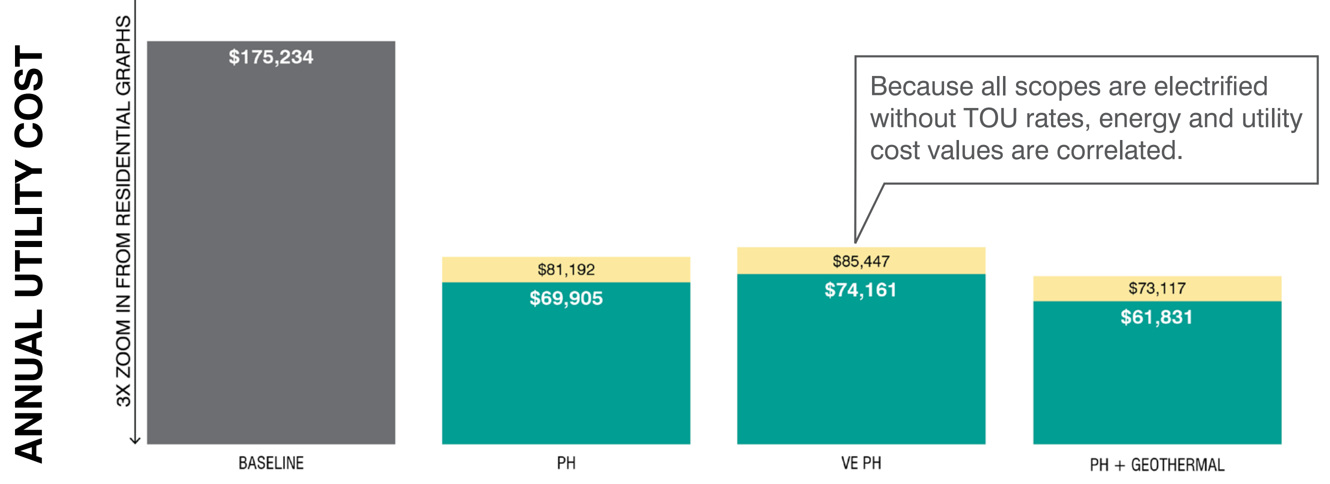
The focus of this report is on electrification of multifamily buildings, specifically, affordable housing multifamily, but the community facility building is a useful point of reference. For the community facility building, we study an energy code compliant Baseline Building, a Passive House Electric, a High Perfromance Passive House Electric, and Passive House plus Geothermal strategy, and solar photovoltaic scope. For the community facility building, the rooftop addition is designed to maximize the available roof space for solar, while allowing for the required FDNY access and mechanical equipment. All scopes are fully electrified.



These graphs are at three times the scale of the residential graphs.

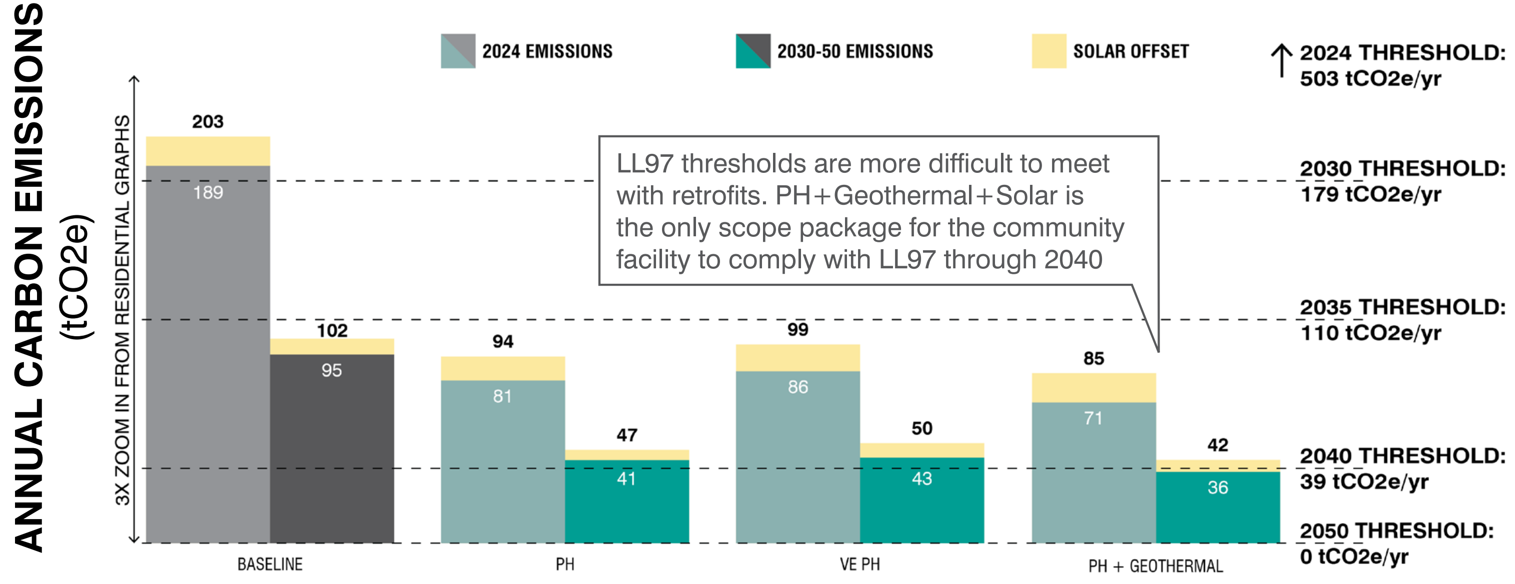
Integrating solar and geothermal renewables reduces energy consumption.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown. This graph is based on a conservative estimate. Further study and case study application is necessary.



Because all scopes are electrified without TOU rates, energy and utility cost values are correlated.

Note: Exact interaction of Peak Demand, Demand Response, and DHW TOU with solar is unknown as the savings are part of mutually exclusive programs. This graph is based on a conservative estimate. Further study and case study application is necessary.



LL97 thresholds are more difficult to meet with retrofits. PH+Geothermal+Solar is the only scope package for the community facility to comply with LL97 through 2040

Note: Values based on *Building Energy Exchange LL97 Calculator*.

RESULTS

For the Community Facility building, implementing Passive House or High Performance strategies lead to significant energy, cost and carbon savings. **Unlike the residential typology, the hot water load is low for the Community Facility, so full electrification doesn't carry the same cost penalty.**

Solar is expected to generate 45,145 kWh per year, and to produce **$11,286 worth of annual savings.** This generation accounts for about **13% of the building's total energy load** and cost for the PH+Electric scenario.

Using the PH+Electric strategy decreases the utility cost by 54% from the energy code baseline. Overlaying this approach with **solar and geothermal realizes dramatic savings of 70%.** With these savings, exploring TOU and Energy Management Control strategies is not as critical for the community facility as the residential typology.

ANNUAL PERFORMANCE	BASELINE	PH	HIGH PERFORMANCE	PH + GEOTHERMAL
Energy Use: (kWh)	700,937kWh	324,766kWh -54% Reduction from Baseline	341,788kWh -51% Reduction from Baseline	292,468 kWh -58% Reduction from Baseline
Utility Cost: ($)	$175,234	$81,182 -54% Reduction from Baseline	$85,447 -51% Reduction from Baseline	$73,117 -58% Reduction from Baseline
with solar:		$69,905 -60% Reduction from Baseline	$74,161 -58% Reduction from PH Gas	$61,831 -65% Reduction from PH Electric
Carbon Emissions: (tCO2e)	203 tCO2e	94 tCO2e -54% Reduction from Baseline	99 tCO2e -51% Reduction from Baseline	85 tCO2e -58% Reduction from Baseline

COMMUNITY FACILITY MODELING PARAMETERS

BASELINE: CODE COMPLIANT

THERMAL ENVELOPE

Slab on Grade: No Insulation
Foundation Walls: No Insulation
Above Grade Walls: R-13.3 ci
Roof: R-30 ci
Windows: Metal casement, U-0.4 Operable, U-0.3 Fixed, SHGC 0.38
Storefront: Metal storefront, U-0.77 Doors, U-0.36 Fixed, SHGC 0.38
Air sealing: 3 ACH50

BUILDING SYSTEMS

Heating and Cooling: PTAC (3.7-(0.052xCap/100)/COPH Heating / 14.0-(0.30xCap/100)cEER
Domestic Hot Water: Resistance Electric Hot Water (0.3+ 27/Vm), %/h
Ventilation: Trickle Vents in Apartments / ERVs in Corridor Only (85% sensible eff. / 65% laten eff. / 0.76 watts/cfm fan)
Generation: None

PASSIVE HOUSE (ELECTRIC)

THERMAL ENVELOPE

Slab on Grade: R-8 ci
Foundation Walls: R-13 ci
Above Grade Walls: R-22 in studs
Roof: R-38 ci
Windows: U-0.16
Storefront: U-0.16
Air sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: VRF
Domestic Hot Water: Electric Heat Pump
Ventilation: ERV
Generation: None

HIGH PERFORMANCE (ELECTRIC)

THERMAL ENVELOPE

Slab on Grade: None
Foundation Walls: R-13 ci
Above Grade Walls: R-22 in studs
Roof: R-38 ci
Windows: U-0.25
Storefront: U-0.16
Air sealing: 0.8 ACH50

BUILDING SYSTEMS

Heating and Cooling: High Performance HPAC
Domestic Hot Water: Electric Heat Pump
Ventilation: ERV
Generation: None

PASSIVE HOUSE + GEOTHERMAL + SOLAR

THERMAL ENVELOPE

Slab on Grade: R-8 ci
Foundation Walls: R-13 ci
Above Grade Walls: R-22 in studs
Roof: R-38 ci
Windows: U-0.16
Storefront: U-0.16
Air sealing: 0.6 ACH50

BUILDING SYSTEMS

Heating and Cooling: Geothermal
Domestic Hot Water: Geothermal
Ventilation: ERV
Generation: Ground heat exchanger with interior water HVAC (43 ton capacity)

SOLAR SYSTEM

Solar Array: 39.6 kWdc (45,145 kWh annual production)
Annual Savings: $11,286/year (13% of building utility costs)

Conclusions

Summary of Results

We are pleased to submit the results of this analysis to building owners and developers, public policy officials, builders, and our fellow designers. *Fully electrified buildings can increase utility costs of buildings without thoughtful systems intervention, discouraging wide-spread electrification*. This report has identified multiple strategies, including MEP systems and electric rate strategies, that lower annual utility costs beneath the threshold of an industry-standard hybrid gas/electric building, nullifying the utility gap penalty. These findings pave a pathway for building electrification to no longer be a cost burden to building owners.

Using the Beacon as a case study, this report analyzed multiple scope strategies for lowering energy loads and utility costs. These strategies focus on the affordable multifamily building because this typology uses more space heating and domestic hot water than commercial typologies, and because these costs contribute more to overall costs for affordable housing than other typologies. These strategies specifically target controlling domestic hot water costs, as electrifying domestic hot water is the most expensive hurdle to wide-spread adoption of fully electric buildings.

PASSIVE HOUSE + GAS

The first scope analysis is the Passive House + Gas, a fully Passive House compliant scope with a high efficiency gas boiler. As the current industry standard approach for Passive House affordable housing in New York City, it is the most salient point of comparison for utility costs. High efficiency gas hot water heaters are available on the market and benefit from what we call the utility gap penalty: the fact that gas is five times cheaper than electricity. This scope provides significant thermal and ventilation upgrades from a code compliant case because of the electrified HVAC systems and the robust Passive House envelope. However, this scope locks in fossil fuel use, is not carbon-neutral ready, and will not meet LL97 2050 compliance. From an owner's decision-making perspective, this is currently the most cost-effective way to have a high-performance building. The following scope strategies aim to challenge this status quo.
UTILITY COST: 44% Reduction from Baseline
ENERGY PERFORMANCE: 19% Reduction from Baseline
BARRIERS TO IMPLEMENTATION: This is not a fully electrified strategy, and is not suitable to the future utility and regulatory environment and therefore is not a viable solution moving forward. We do not see this as a solution to be considered moving forward for most buildings.

PASSIVE HOUSE + ELECTRIC

Passive House + Electric scope is a nearly identical scope to Passive House + Gas, but with an electric heat pump hot water heater swapped in for the gas hot water heater. This scope retains all the benefits of increased thermal comfort, improved ventilation, and resilience as the previous scope, but also further reduces the energy loads and is fully electric, carbon-neutral ready, and will comply with LL97 2050 criteria. However, the utility gap penalty disincentivizes this option as nearly 2/3 of the savings from the Passive House scope are lost to the increased cost of electric domestic hot water. *While better overall in terms of energy performance, the Passive House + Electric scope is predicted to yield 20% more utility costs than Passive House + Gas. This hurdle drives us, practitioners committed to a carbon neutral future, to find complementary strategies to make fully electric buildings as cheap, or cheaper, than Passive House + Gas options.*
UTILITY COST: 32% Reduction from Baseline /// 20% *Increase* from Passive House+Gas
ENERGY PERFORMANCE: 32% Reduction from Baseline /// 16% Reduction from Passive House+Gas
BARRIERS TO IMPLEMENTATION: This is a fully electrified, highly efficient design approach that utilizes strategies and materials that are commonly implemented in the market. However, the increased cost of utilities compared to Passive House + Gas is a significant issure requiring designer and owner attention.

HIGH PERFORMANCE + ELECTRIC

High Performance + Electric represents a reduced and more affordable Passive House + Electric scope, which is a realistic outcome in affordable multifamily projects on a tight budget. While full Passive House certification is always the goal, affordable housing budgets oftentimes will not support a fully certifiable scope. This design scope still follows a Passive House methodology, but with slightly reduced performance at the most cost-intensive interventions. This approach strives to provide the highest possible performance even within a budget. This scope is thoughtfully crafted to maximize cost reduction and minimize performance degradation. These design changes include switching from triple to double pane windows and swapping VRF heating/cooling to through wall terminal package units. This approach saves roughly $2 million in upfront costs while only increasing utility costs by 5% compared to the Passive House + Electric Scope. Compared to Passive House + Gas, energy use is still reduced by 12%, but suffers a 27% increase in utility cost.
UTILITY COST: 29% Reduction from Baseline /// 27% *Increase* from Passive House+Gas
ENERGY PERFORMANCE: 29% Reduction from Baseline /// 12% Reduction from Passive House+Gas
BARRIERS TO IMPLEMENTATION: Similar to the full Passive House + Electric Scope, the High Perfromance scope is highly efficient and proven in the marketplace. This approach has the advantage of potential to reduce installation cost, but has a significant utility cost increase compared to Passive House + Gas.

SOLAR PV ARRAY

A photovoltaic array is one of the best ways to offset utility costs and reliance on fossil fuels by generating energy on site. In our practice, we find solar arrays often have a payback period under 10 years. In the residential tower, a solar array can produce around 200,000 kWh annually, or around $50,000 in savings. This can cover about 85% of DHW costs. We strongly advise implementing solar arrays whenever possible for utility cost reduction, as well as increased resiliency in power outage events. The following performance results represent the Passive House Electric scope with the rooftop solar photovoltaic array.

UTILITY COST: 42% Reduction from Baseline /// 3.5% *Increase* from Passive House+Gas

ENERGY PERFORMANCE: 42% Reduction from Baseline /// 28% Reduction from Passive House+Gas

BARRIERS TO IMPLEMENTATION: This approach is highly effective and has a proven track record of implementation. The strategies and materials utilized are commonly implemented in the marketplace, and the total utility cost penalty is significantly decreased (from 16% to 3.5%).

SOLAR BATTERY STORAGE

While these scopes pursue full electrification for day to day operation, electrifying emergency backup power remains difficult. This report explores the use of solar batteries in lieu of gas-powered emergency generators. This would completely electrify both day to day operations and emergency power, but is not currently feasible for the Beacon. The solar battery market is nascent, meaning both capital and installation costs are high. Regulatory hurdles pose another challenge, requiring extensive fire safety and construction approvals which impose prohibitive spatial hurdles to dense urban sites. Roof positioning poses a fire hazard and grade-level placement eats into limited outdoor areas. Even if these hurdles were overcome, peak solar production that could charge the batteries coincides with peak electric use, meaning “setting aside” power for the batteries is unlikely on a regular basis. We look forward to including solar batteries in our fully-electrified designs once the approval process is streamlined, the market becomes more competitive, and research has identified ways to safely place batteries indoors or adjacent to occupied areas.

BARRIERS TO IMPLEMENTATION: The regulatory and cost challenges to implementing this newer technology are significant. We recommend that design teams explore and implement ‘solar battery ready’ designs to be ready to implement the technology when the barriers are reduced.

PASSIVE HOUSE + GEOTHERMAL

Passive House + Geothermal scope introduces a ground-loop heat exchanger that works with water source heat pumps above ground to provide heating, cooling, and DHW. Combining the deeply sustainable and fully electrified geothermal system with a Passive House scope yields one of the top performing options in terms of energy, utility cost, and carbon emissions. This combination is one of the most promising scope packages for better utility cost performance than Passive House + Gas, boasting a 7% utility cost reduction.

UTILITY COST: 48% Reduction from Baseline /// 7% Reduction from Passive House+Gas

ENERGY PERFORMANCE: 48% Reduction from Baseline /// 36% Reduction from Passive House+Gas

BARRIERS TO IMPLEMENTATION: Passive House +Geothermal is a conceptually straightforward and effective electrification strategy, resulting in deep energy and cost savings, with a 7% cost improvement compared to Passive House + Gas. Currently available incentives for geothermal make it a highly appealing option. Lack of local experience and performance data, however, are a barrier for building developers. Additionally, the technology does require enough space for the geothermal wells, which can be an issue in dense urban sites. For the Beacon, our client’s past experience with geothermal systems was negative, citing unreliable performance and additional cost of adding a redundant thermal system in case of geothermal failure. Technologic advances may minimize or bypass these hurdles, but past issues may prevent building owners from moving forward.

TIME OF USE RATES

Time of Use rates combined with Passive House envelope show potential to be another option for reducing utility cost below the Passive House + Gas threshold. While Passive House scope aims to reduce energy loads and solar or geothermal systems aim to produce their own energy to offset loads, Time of Use rates aim to adjust the actual rate charged to each unit of energy. The standard Con Edison rate structure attributes a set rate, 12.73 cents delivery charge, per kWh. Time of Use rates offer variable delivery rates, ranging from 1.8 to likely 40 cents per kWh, depending on the time of year and time of day. These rates incentivize using energy in the early morning when rates are low (Off Peak) and disincentives using energy in the middle of the day (Summer Peak), and especially in the middle of the day in the middle of the summer (Super Peak).

While the rates incentivize usage patterns, they do not control them. Using Time of Use rates alone without taking measures to control usage patterns will increase utility cost 9% above the Passive House + Electric Scope, or 31% more than Passive House + Gas. When solar is included, this difference marginally drops to 27%. Time of Use rates should only be considered after energy loads have been sufficiently reduced using a robust thermal envelope and advanced MEP solutions. These steps are important to minimize the size of the active systems required. Implementation of Time of Use rates has not been widely documented, and Con Edison does not release information on what the Super Peak rate is. While we have repeatedly attempted to contact them about this rate, we were forced to make an educated guess for the Super Peak rate. We strongly advise gaining clarity on the actual rate before opting into a Time of Use rate structure. We believe that once a building has a Con-Ed account, this information will be more readily available.
UTILITY COST: 26% Reduction from Baseline /// 31% *Increase* from Passive House+Gas
ENERGY PERFORMANCE: 32% Reduction from Baseline /// 16% Reduction from Passive House+Gas
BARRIERS TO IMPLEMENTATION: Implementing Time of Use Rates *alone* does not appear to be a financially viable option, but more clarity about the Con Edison Time Of Use rates is required to make a final determination on a building by building basis.

TIME OF USE RATES + BUILDING CONTROLS AND ENERGY MANAGEMENT

Combining Time of Use rates with Building Controls and Energy Management systems allows for building managers to control both the total amount and time of energy consumption, harnessing the full potential of Time of Use rate incentives. Building Management Systems (BMS) acts as the mechanism to activate the cost savings of the Time of Use rates, by shifting DHW loads to Off-Peak rate wherever possible and blocking excessive energy use at Super Peak times. From a building management standpoint, it also limits costly and preventable errors, like machine overrides, by alerting building managers to problems in real time. While the exact interaction of all BMS cannot be exactly known without further study, our estimates predict the Passive House + TOU + BMS utility costs are less than 1% above the Passive House + Gas scope. When solar is included in both scopes, the Passive House + TOU + BMS + Solar scope decreases utility costs by 10%. This is because TOU rates stretch the savings of solar output because peak solar generation coincides with peak rates.

This scope requires the use of proprietary software and additional capital costs for control monitors and ensuring active systems that can work with those monitors. While BMS systems are not new, they are not widely implemented in affordable multifamily buildings, especially for controlling DHW. These results show the higher end of savings by activating all levers discussed earlier in the report, but building owners, managers, mechanical consultants, and architects must discuss together what levers are realistic and desired. For example, DHW load management is the critical lever for managing DHW cost, but requires close coordination with MEP teams while designing the system. Thermostat controls require ownership to decide which minimum and maximum temperature setpoints, if any, to program into resident thermostats. Seasonal lockouts prevent excessive plug loads and temperature controls at peak times, which may not be desired for certain occupant groups.

While these decisions are being made, we urge owners and designers to consider thermal comfort, resident self-determination, and energy savings on a balanced scale. Some of these strategies may increase energy savings, but decrease resident comfort and control over their space – leading to resident dissatisfaction, feelings of powerlessness, and complaints. Further implementation and research is needed to understand what the balance of load control and resident choice is best. We actively advocate for demonstration case studies of TOU rates and BMS controls, especially in affordable multifamily buildings, as a promising solution to surpassing the utility cost penalty and making full electrification more affordable and widespread.

UTILITY COST: 43% Reduction from Baseline /// Less than 1% *Increase* from Passive House+Gas
ENERGY PERFORMANCE: 42% Reduction from Baseline /// 28% Reduction from Passive House+Gas
BARRIERS TO IMPLEMENTATION: Barriers to entry include the need for greater transparency of the Time of Use program, additional installation costs associated with the Building Management System, and the need for more demonstration projects that track real world performance of the approach.

COMMUNITY FACILITY

For the adaptive reuse community facility building, we demonstrate the viability of some of these strategies for controlling electrification costs across typologies. Community facility buildings are not as penalized by the utility gap penalty because domestic hot water loads are significantly lower. We highly encourage building to a High Performance Scope where budgets are tight to realize a 51% energy reduction from a baseline building. A fully electric, Passive House scope can drive down the total utility cost by 54%. By incorporating renewables like solar and geothermal, this approach can yield utility cost savings of 70%. High performance, fully electrified buildings with low utility costs are possible even in adaptive reuse buildings.

UTILITY COST: Combining solar and geothermal energy generation with a Passive House envelope can reduce utility cost by 70%.

ENERGY PERFORMANCE:

Combining solar and geothermal energy generation with a Passive House envelope can reduce energy use by 70%.

BARRIERS TO IMPLEMENTATION: Retrofitting an existing building provides different challenges than a new construction one, including different methods for ensuring airtightness, minimal thermal bridges, condensation concerns, and historic preservation. However, there is a significant library of case studies for deep energy retrofits and energy reduction strategies of commercial and office typologies.

SIDEBAR

CHALLENGES FOR THE NEW GRID

Renewable energy has been shown to increase overall grid reliability in terms of consistent energy and price, but it also is expected to increase voltage frequency volatility. [7] This means that the frequency of electricity will experience more extreme fluctuations than we currently see. Machines that require electricity require steady voltages that are in sync with the voltages of interconnected machinery. Variations in voltage can lead to poor interaction and increased failures. To ensure the consistency and longevity of active systems and valuable digital devices, applying Active Power Management is one potential solution to standardizing voltage frequency. Proprietary systems like Legend Power Systems SmartGATE can adjust and standardize incoming voltage up to 8%. While our evolving grid and associated technology may adapt in the future to standardize voltage comprehensively, Active Power Management systems are worthy of owner's consideration, especially as they incorporate more advanced electric equipment.

SIDEBAR

RESIDENT INCENTIVE APPS

When considering occupancy use and controls, resident incentive apps show real potential to engage residents directly in reducing energy loads. Companies like Meltek, Ecogy, and Logical Buildings offer products that empower residents to make energy-conscious decisions, and then pay them for it. These programs are optional and residents opt-in directly with the company. We recommend building owners educate residents at orientation about these apps, energy savings strategies, and sustainable features in the building to facilitate wide-spread adoption.

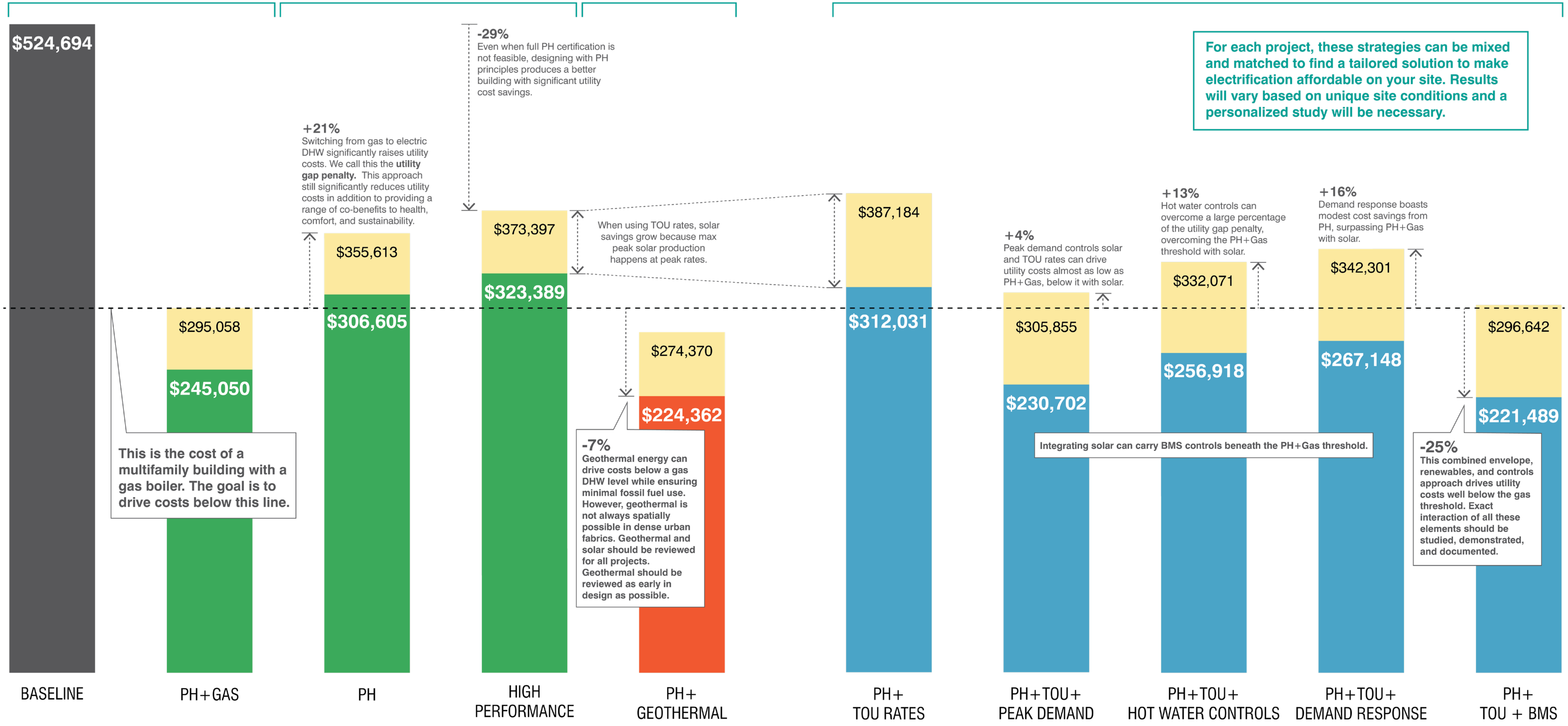
Residential Strategies Cost Impact Summary

STATUS QUO DEVELOPMENT: Not viable in the future with LL97 and LL154.

STEP 1: PASSIVE HOUSE ENVELOPE Recommended for all buildings for driving down energy loads. Necessary first step before MEP interventions.

STEP 2: RENEWABLES Review feasibility for solar and geothermal to bring costs at or below the gas DHW threshold.

STEP 3: CONSIDER TIME OF USE RATES AND BUILDING MANAGEMENT SYSTEMS These controls work well with solar to drive costs below the gas DHW threshold. Implementation of these aspects are nascent, holding significant potential for future opportunities in demonstration, data collection, and market research



For each project, these strategies can be mixed and matched to find a tailored solution to make electrification affordable on your site. Results will vary based on unique site conditions and a personalized study will be necessary.

This is the cost of a multifamily building with a gas boiler. The goal is to drive costs below this line.

+21%
Switching from gas to electric DHW significantly raises utility costs. We call this the **utility gap penalty.** This approach still significantly reduces utility costs in addition to providing a range of co-benefits to health, comfort, and sustainability.

-29%
Even when full PH certification is not feasible, designing with PH principles produces a better building with significant utility cost savings.

When using TOU rates, solar savings grow because max peak solar production happens at peak rates.

-7%
Geothermal energy can drive costs below a gas DHW level while ensuring minimal fossil fuel use. However, geothermal is not always spatially possible in dense urban fabrics. Geothermal and solar should be reviewed for all projects. Geothermal should be reviewed as early in design as possible.

+4%
Peak demand controls solar and TOU rates can drive utility costs almost as low as PH+Gas, below it with solar.

+13%
Hot water controls can overcome a large percentage of the utility gap penalty, overcoming the PH+Gas threshold with solar.

+16%
Demand response boasts modest cost savings from PH, surpassing PH+Gas with solar.

Integrating solar can carry BMS controls beneath the PH+Gas threshold.

-25%
This combined envelope, renewables, and controls approach drives utility costs well below the gas threshold. Exact interaction of all these elements should be studied, demonstrated, and documented.

FIGURE 15 Utility cost performance of all cost reduction strategies for the residential building. The sequence at the top indicates the order these strategies should be implemented. PH+Geothermal, PH+Peak Load Demand Controls, and PH+TOU+BMS show potential to overcome the utility gap penalty.

Conclusion and Recommendations

The cost of building electrification is high, especially in affordable housing, where the utility represents roughly 25% of the operating budgets for the building, as opposed to 10% for market rate multifamily. Domestic hot water is a critical factor to multifamily residential building electrification as usage is high and largely unaddressed in energy efficiency practices. Designers and building owners should be aware that electrifying the hot water systems will have a significant impact on operating budgets. When moving from a high efficiency gas boiler to high efficiency heat pump for hot water heating in a Passive House building, the cost for heating hot water more than doubles, and the overall utility costs increases by 20%. This is because domestic hot water loads are not affected by building envelope and HVAC upgrades. Because of this large domestic hot water load, combined with the utility gap penalty which makes electricity five times as expensive as gas in New York City, we seek to find solutions to drive down the cost of fully electrified domestic hot water below a gas boiler system level.

FIGURE 16 The Beacon residential building south entrance. Adaptive re-use multiservice center to the right.

SCOPE RECOMMENDATIONS

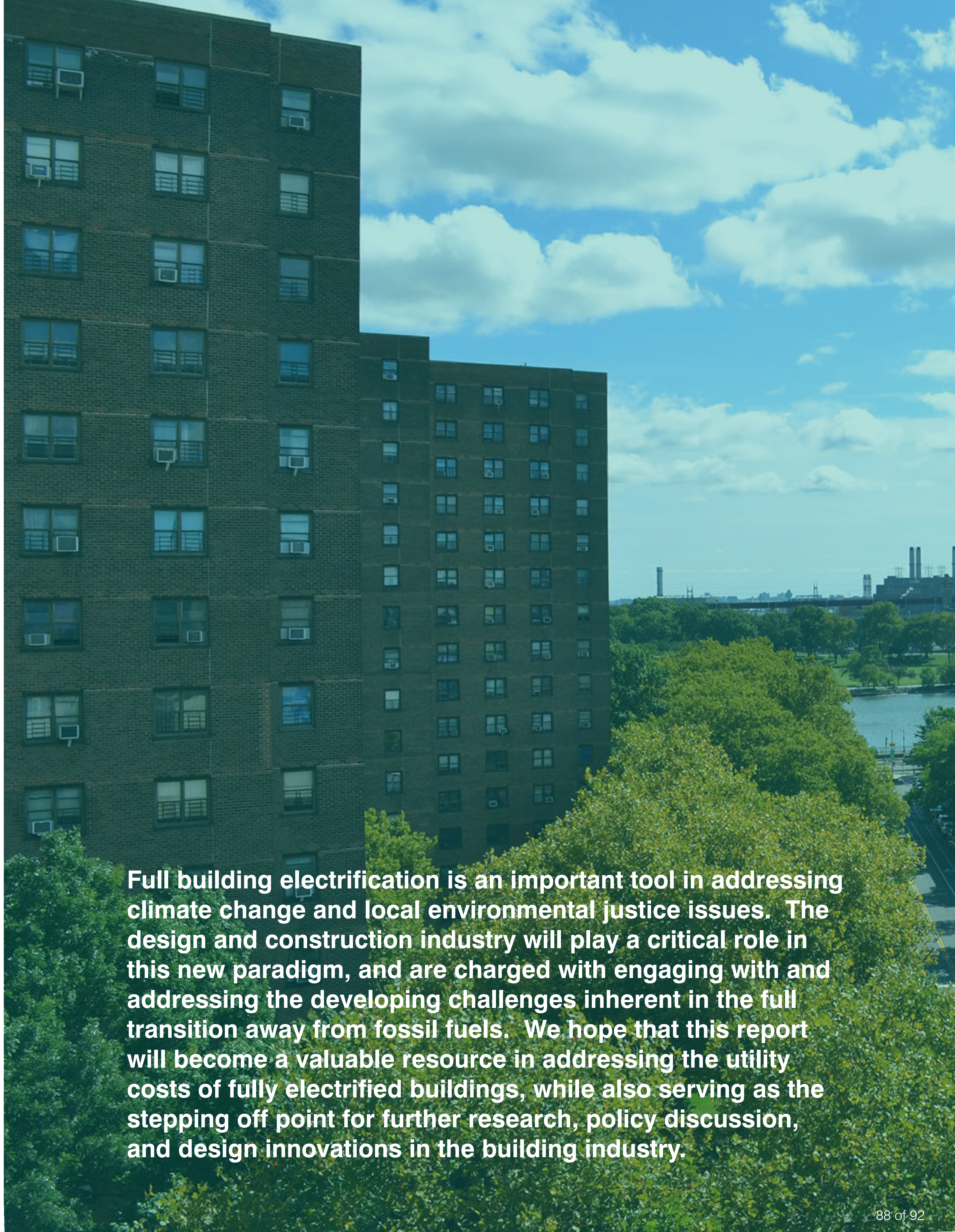
We identify multiple strategies to implement in electrified buildings so that they meet and exceed the cost performance of the current implemented industry standard for high performance buildings (the PH+Gas strategy), but note that there is not a one size fits all strategy for every project. Each building project will have its own unique set of variables. Designers, builders, and building owners should collaborate to fine-tune their electrification strategy to those conditions. Keeping this caveat in mind, the data obtained in this research recommends the following strategies:

- Building owners are strongly recommended to implement **Passive House, High Performance** or other energy-efficient building design approaches in electrified buildings. For the Beacon, a fully electric building built to the current energy code has an 32% utility cost increase in comparison to the Passive House Electric Design. While not cheaper than **PH+Gas**, this approach can reduce loads 32% below a code compliant building where budgets are tight. Applying Passive House principles is a good first step to lowering energy demand and reducing the necessary size of active systems.
- Rooftop **Solar PV** is a cost-effective strategy for reducing electrification costs. For the Beacon, the maximized rooftop solar produces enough output to cover 85% of the increased hot water cost in changing from gas to electric.
- Geothermal is a highly cost-effective strategy for reducing electrification costs. The **PH+Geothermal strategy** decreases utility costs of the Beacon by almost 10% when compared to the implemented industry standard (PH+Gas). When overlaid with rooftop solar, this strategy decreases utility costs by 48% when compared to the baseline, code compliant building. **During initial design phases, we would encourage teams to assess feasibility of geothermal for the project.**
- Using Con-Ed's optional **TOU Rates** as a standalone strategy did not decrease costs for the Beacon. Even when accounting for the fact that rooftop solar PV is more valuable if TOU rates are used, there is a cost increase of 2%.
- **Time of Use combined with Energy Management Controls** is a promising strategy that we recommend project teams to consider for high performance, fully electric affordable housing and other multifamily projects. In the analysis of the Beacon, we noted a 17% reduction in utility costs from the PH + Electric case, and less than 1% increase from the PH+ Gas case.
- The most effective strategy studied for reducing utility costs is the layering of envelope, renewable, rate structure, and BMS interventions: **PH+Electric Strategy with Rooftop Solar, and Building Controls with TOU rates**. This strategy resulted in a 58% reduction in utility costs compared to the baseline, energy code compliant case; a 38% reduction in utility costs compared to the PH+Electric case, and 25% reduction in utility costs compared to the PH+Gas industry standard case. There is 1% reduction in utility costs compared to the PH+Geothermal+Solar case.

FUTURE RESEARCH AND POLICY CONSIDERATIONS

In addition to the design strategy recommendations detailed above, we believe that we should continue to strive for further improvements in fully electric buildings. To this end, we recommend the following policy efforts and industry wide coordination:

- Solar battery implementation is currently difficult in NYC. Policy makers should coordinate with industry experts to identify and address risk factors, streamline permitting processes, and concurrently incentivize the use of solar batteries over gas generators.
- Implementing new strategies carries risk for building owners, which is a barrier to entry. As project teams enact these and other energy efficiency and cost optimization strategies, industry wide information sharing is needed to identify and refine the best performing solutions.
- For all design and construction projects, installation costs and maintenance costs are critical information points to include in decision making. For this study, finding installation and maintenance costs for each strategy is difficult. Without an ‘apples to apples’ comparison of these costs available for each strategy, we exclude analysis of those costs from the report. With that said, these costs are an important part of the decision-making process in comparing these strategies.
- Con-Ed does not provide clear and specific information about their Time of Use rates. Information about the super peak rate, total cost comparison, and program eligibility and requirements is not readily available. Further, despite repeated efforts through contacts at both NYSERDA and Con-Ed, no Con-Ed representatives were able to discuss the program with clarity. It is thought that more program specifics are available to projects once they have a Con-Ed account, but access to this information is critical before making decisions on opting in. Because it makes sense to utilize Time of Use rates in combination with other strategies, more program transparency is needed for widespread implementation.
- In the course of this research, we identify new problems, but also new potential solutions worthy of further consideration and research. These include:
  - Resident incentive programs for energy demand reduction;
  - Active Power Management;
  - In our analysis, we consider a series of Building Controls + Time of Use rate strategies independently. In order to avoid ‘double dipping’ of savings, we take conservative assumptions when combining strategies. Further research and analysis are needed to show how multiple demand reduction, time or use and solar strategies perform when implemented simultaneously.



Full building electrification is an important tool in addressing climate change and local environmental justice issues. The design and construction industry will play a critical role in this new paradigm, and are charged with engaging with and addressing the developing challenges inherent in the full transition away from fossil fuels. We hope that this report will become a valuable resource in addressing the utility costs of fully electrified buildings, while also serving as the stepping off point for further research, policy discussion, and design innovations in the building industry.

Tear Sheet

ELECTRIFIED	ICON	STRATEGY	DESCRIPTION	ANNUAL PERFORMANCE	COST & SAVINGS		NOTES	
⚡		**BASELINE**	Fully electric building meeting the 2020 NYC Energy Code	Electric 2,098,776 kWh Gas Carbon 606 tCO2e	**ANNUAL UTILITY COST**	**$524,694**	Fully electric buildings that meet code minimum lock the building owner into decades of higher utility costs and subpar energy and carbon performance.	**CODE**
		PASSIVE HOUSE + GAS DHW	Passive house envelope with high efficiency gas DHW heater	Electric 1,017,400 kWh Gas 2,315,000 kBTU (678,459 kWh) Carbon 417 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline:	**$295,058** $229,636 (44%)	This is the industry standard for affordable Passive House housing and serves as the utility cost threshold to exceed for a fully electric building to be cheaper than a mostly electric building.	**PASSIVE HOUSE**
⚡		**PASSIVE HOUSE + ELECTRIC DHW**	Passive house envelope with electric heat pump domestic hot water heater	Electric 1,422,452 kWh Gas Carbon 411 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Increase** from PH+Gas:	**$355,613** $169,531 (32%) $60,555 (21%)	The standard fully electrified building switches from gas DHW to an electric heat pump hot water heater, reducing savings from the baseline and increasing cost from the gas DHW scope.	
⚡		**HIGH PERFORMANCE + ELECTRIC DHW**	Value-engineered passive house envelope with high performance HPAC window units for heating and cooling	Electric 1,493,587 kWh Gas Carbon 432 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Increase** from PH+Gas:	**$373,397** $151,297 (29%) $78,339 (27%)	"Pretty Good House" scope locks in 95% of the energy savings of the PH+Electric strategy with considerable installation cost savings. Special consideration is needed for air tightness at the HPAC in this strategy.	
⚡		**PASSIVE HOUSE + SOLAR**	PH + Electric scope with maximized (168 kW) rooftop solar photovoltaic system	Electric 1,222,420 kWh Gas Carbon 353 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Increase** from PH+Gas:	**$306,605** $218,089 (42%) $11,547 (4%)	Implementing a solar roof photovoltaic system recovers 85% of the cost savings difference lost in the switch from PH+Gas to PH+Electric. Solar savings would be applied to owner meter.	**RENEWABLE ENERGY**
⚡		**SOLAR BATTERIES**	Energy batteries to store solar generation. Replaces emergency generator.	Electric Gas - Carbon	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Increase** from PH+Gas:	**-** - -	Significant policy and incentive initiatives are required in order for solar battery installation to be commonplace in NYC.	
⚡		**PASSIVE HOUSE + GEOTHERMAL**	PH + Electric scope with closed-loop geothermal system for DHW, heating, & cooling	Electric 1,083,224 kWh Gas Carbon 313 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Savings** from PH+Gas:	**$274,370** $300,332 (57%) $70,696 (24%)	Geothermal outperforms the PH+Gas industry standard. This is the first fully electrified scope to lower utility cost from PH+Gas. Initial site feasibility for geothermal is strongly recommended.	
⚡		**PASSIVE HOUSE + TIME OF USE RATES**	PH + Electric scope with Con Edison's optional time of use electric rates	Electric 1,422,452 kWh Gas Carbon 411 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Increase** from PH+Gas:	**$387,184** $137,510 (26%) $92,126 (31%)	Time of Use (TOU) Rates without any strategies to reduce peak demand result in utility cost increase. Solar PV works well with TOU rates, but does not overcome the cost increase.	**ENERGY CONTROLS**
⚡		**PASSIVE HOUSE + TIME OF USE + ENERGY CONTROLS**	PH + Electric scope with energy management controls for peak energy, DHW, and demand control	Electric 1,419,018 kWh Gas Carbon 410 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Increase** from PH+Gas:	**$296,642** $228,052 (43%) $1,584 (<1%)	Energy management controls in conjunction with time of use rates are a key lever to bringing electrified building utility beneath the PH+Gas threshold. No energy generation is included, so PH+Geothermal still outperforms this scope.	
⚡		**PASSIVE HOUSE + SOLAR + TIME OF USE + ENERGY CONTROLS**	PH Electric scope with solar, time of use rates, and energy management controls	Electric 1,023,536 kWh Gas Carbon 296 tCO2e	**ANNUAL UTILITY COST** Cost **Savings** from Baseline: Cost **Savings** from PH+Gas:	**$221,489** $303,205 (58%) $73,569 (25%)	PH+Electric scope with TOU rates, energy controls, and solar is the highest performing scope, well below the PH+Gas threshold. Before implementing, Con Edison must clarify TOU rates and a custom control strategy should be designed. Exact interaction of building controls and solar may vary.	

Citations + Footnotes

1 Analyzing Embodied Carbon for Retrofit and New Construction, Paul A. Castrucci Architects, 2024.

2 Data and insight courtesy of Ryan Cassidy of Riseboro Community Partnerships.

3 Hudson Robbins, Shelley, "The Peaker Problem: An Overview of Peaker Power Plant Facts and Impacts in Boston, Philadelphia, and Detroit," *Clean Energy Group*, July 2022, https://www.cleanegroup.org/wp-content/uploads/The-Peaker-Problem.pdf (accessed January 18th, 2024)

4 New York City, Sustainable Buildings. (n.d.). Local law 97.
Local Law 97 - Sustainable Buildings. https://www.nyc.gov/site/sustainablebuildings/ll97/local-law-97.page
NYC Buildings. (n.d.). Building electrification. building-electrification. https://www.nyc.gov/site/buildings/codes/building-electrification.page

5 Clean Heat Program: https://www.nyserda.ny.gov/All-Programs/Heat-Pump-Program
NYC Accelerator: https://accelerator.nyc/
Buildings of Excellence Competition: https://www.nyserda.ny.gov/All-Programs/Multifamily-Buildings-of-Excellence
Empire Building Challenge: https://www.nyserda.ny.gov/All-Programs/Empire-Building-Challenge
HPD Retrofit Electrification Pilot: https://www.nyc.gov/site/hpd/services-and-information/hpd-nyserda-retrofit-electrification-pilot.page

6 Standardized modeling parameters for Passive House certification and energy code are helpful tools to provide a one-to-one comparison across projects. In our decades of experience across new construction and retrofits, New York usage patterns for energy and hot water are usually significantly elevated above Passive House standard criteria. In our office, we provide additional calculations for client-decision making based on more realistic temperature set-points and hot water usage. We are still refining these set points, and further research is needed for a best practice of realistic usage parameters. This report is intended as an applicable tool for addressing hot water costs in electrified buildings, requiring our team to elevate water usage parameters above Passive House standards based on our experience in New York City.

7 Muelaner, Jody. "Grid Frequency Stability and Renewable Power." Engineering.Com, WTWH Media, LLC, 5 Feb. 2021, www.engineering.com/story/grid-frequency-stability-and-renewable-power.

8 *Smart Usage Rewards (Demand Response) Aggregator List.* Con Edison, 2023, https://www.coned.com/-/media/files/coned/documents/save-energy-money/rebates-incentives-tax-credits/smart-usage-rewards/aggregator-list.pdf?la=en