Accelerated deep energy retrofit plans for affordable public housing

Exploring how touchless audits combined with parametric modeling could support effective energy retrofit planning for residential building portfolios

Executive Summary

NRCan-registered energy advisors (EAs) in Canada often rely on "rule of thumb" recommendations for retrofit planning, but these generalized approaches can leave unrealized gains on the table due to the variability in building types, climate zones, and rapidly advancing retrofit technologies. The standard HOT2000 software lacks the ability to input itemized costs for retrofits and the growing complexity of retrofit options, combined with limited training and time constraints on EAs, further complicates their ability to offer optimized recommendations. These issues are compounded in projects that operate at the scale of many buildings, each of which will still require individualized upgrade planning.

To address these challenges, Volta Research and Clean Foundation have developed a software-based planning tool that would allow EAs to model and analyze a wide range of energy upgrade packages more efficiently, improving the accuracy and breadth of their recommendations without adding significant time burdens. This project utilizes the Volta SNAP software platform, which integrates with HOT2000 and the EnerGuide Rating System to streamline energy modelling for energy advisors. Volta SNAP enhances energy advisors' ability to manage HOT2000 project files and reduce data input requirements for enhanced energy modelling. The platform's parametric analysis feature, previously limited to single homes, was expanded to simulate energy conservation measures across entire portfolios of homes, enabling cost-optimized solutions for energy savings at the portfolio scale.

Scenario-testing for this project established three portfolio-scale objectives: achieving 50% energy savings, 40% GHG emissions reductions, and transitioning a portfolio to all-electric utilities. To find the most cost-effective solutions within these constraints, a custom genetic algorithm was designed and employed to optimize energy conservation measures across a complex solution space. A cluster analysis categorized homes based on characteristics such as year of construction and living area, helping to tailor upgrades to different groups and identifying consistent retrofit options.

Additionally, this project also investigated the application of different portfolio data-collection processes. Three “phases” of data collection were tested, each involving increasing degrees of detail, to explore the resulting impact on portfolio retrofit planning. Subsequent testing compared real-world retrofit planning outcomes with an optimized approach for 36 sample homes. The results suggest that the optimized approach could reduce total upgrade costs while achieving the same energy and emissions reductions.

Résumé

Les conseillers en efficacité énergétique (CEE) agréés par Ressources naturelles Canada s’appuient souvent sur des recommandations empiriques pour la planification des rénovations écoénergétiques. Cependant, ces approches généralisées peuvent empêcher la réalisation de gains latents en raison de la variabilité des types de bâtiments, des zones climatiques et des technologies de rénovation écoénergétique qui progressent rapidement. Le logiciel standard HOT2000 ne permet pas de saisir les coûts détaillés des rénovations écoénergétiques. De plus, la complexité croissante des options de rénovation, combinée à la formation limitée et aux contraintes de temps pour les CEE, complique davantage la capacité de ces derniers d’offrir des recommandations optimisées. Ces problèmes sont amplifiés dans le cas des ensembles résidentiels comprenant de nombreux immeubles, car chacun de ceux-ci nécessite une planification individualisée des améliorations.

Pour relever ces défis, Volta Research et Clean Foundation ont élaboré un outil de planification logiciel qui permettrait aux CEE de modéliser et d’analyser plus efficacement un large éventail de propositions de mise à niveau énergétique. L’exactitude et la portée de leurs recommandations en seraient améliorées sans ajouter de contraintes de temps importantes. Ce projet utilise la plateforme logicielle Volta SNAP, qui s’intègre à HOT2000 et au Système de cote ÉnerGuide pour simplifier le travail de modélisation énergétique des CEE. Volta SNAP accroît la capacité des CEE de gérer les dossiers des projets dans HOT2000 et réduit les exigences de saisie de données pour obtenir une modélisation énergétique améliorée. La fonction d’analyse paramétrique de la plateforme était auparavant limitée aux maisons individuelles. Elle a été élargie pour simuler des mesures de conservation de l’énergie dans tous les portefeuilles de logements. Cette amélioration a permis d’offrir des solutions optimisées sur le plan des coûts afin de générer des économies d’énergie à l’échelle du portefeuille.

La mise à l’essai de scénarios pour ce projet a permis d’établir trois objectifs à l’échelle du portefeuille : réaliser des économies d’énergie de 50 %, réduire les émissions de gaz à effet de serre de 40 % et faire passer un portefeuille aux services publics entièrement électriques. Pour trouver les solutions les plus économiques dans ces limites, un algorithme génétique personnalisé a été conçu et utilisé pour optimiser les mesures de conservation de l’énergie dans un espace de solutions complexe. Une analyse en grappe a permis de catégoriser les logements en fonction de caractéristiques comme l’année de construction et la zone habitable, d’aider à adapter les améliorations à différents groupes et de déterminer des options de rénovation uniformes.

De plus, ce projet a permis d’examiner l’application de différents processus de collecte de données sur les portefeuilles. Trois phases de la collecte de données ont été mises à l’essai afin d’explorer les répercussions sur la planification des rénovations écoénergétiques du portefeuille. Chacune des phases comportait un niveau croissant de détails. Les essais subséquents ont permis de comparer les résultats réels de la planification des rénovations avec une approche optimisée pour 36 logements de l’échantillon. Les constatations indiquent que l’approche

This study/research was led by

Clean Nova Scotia Foundation

and received funding from Canada Mortgage and Housing Corporation (CMHC) under the National Housing Strategy (NHS) Research and Planning Fund. The views, analysis, interpretations and recommendations expressed in this study are those of the author(s) and do not necessarily reflect the views of CMHC. CMHC's financial contribution to this report does not constitute an endorsement of its contents.

La présente étude/recherche a été menée par

Clean Nova Scotia Foundation

et a reçu du financement de la Société canadienne d'hypothèques et de logement (SCHL) dans le cadre du Fonds de recherche et de planification de la Stratégie nationale sur le logement (SNL). Les opinions, analyses, interprétations et recommandations présentées dans cette étude sont celles du ou des auteurs et ne reflètent pas nécessairement le point de vue de la SCHL. La contribution financière de la SCHL à la publication de ce rapport ne constitue nullement une approbation de son contenu.

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Table of Contents

List of Figures

List of Tables

Introduction

The transition towards more energy-efficient buildings is crucial for meeting Canada's climate goals and reducing overall energy consumption. However, a significant challenge persists in the practical application of energy efficiency measures. Registered Energy Advisors ("EAs") operating within Canada's EnerGuide Rating System ("ERS") are currently not equipped with specialized training and software supports in retrofit pathway optimization, nor are there training supports in place to ensure that EAs are up to date with market-available materials, equipment, and methodologies. These gaps in expertise impede their ability to provide comprehensive recommendations and represents a critical barrier to achieving the full potential of energy savings from building retrofits, resulting in unrealized gains and missed opportunities for energy savings.

To address these challenges, Volta Research ("Volta") and Clean Foundation ("Clean") have collaboratively developed an innovative software solution designed to help bridge the knowledge gap in retrofit optimization. This software aims to equip Energy Advisors with advanced tools and insights that facilitate more effective and precise retrofit recommendations. By integrating sophisticated algorithms and user-friendly interfaces, the solution not only enhances the advisors' capacity to evaluate and implement energy-efficient measures but also contributes to the broader goal of improving building performance and sustainability across Canada. This project explores the development, functionality, and potential impact of this software, highlighting its role in advancing the capabilities of EAs and addressing the current deficiencies in retrofit optimization.

Business-as-usual Retrofit Planning

EAs regularly offer advice on retrofit planning to building owners as they deliver a variety of energy efficiency programs across the country. The effectiveness of this advice in guiding building performance upgrades has historically relied on the accumulated knowledge of individual EAs, often with the application of "rule of thumb" precepts regarding the type and amount of materials and/or equipment being recommended. However, the profound variability between buildings and among climate zones all but guarantees that these rule of thumb recommendations will have inconsistent outcomes for building owners.

Additionally, the application of rule of thumb recommendations will tend to limit the consideration of new and alternative upgrade methodologies in favor of those that are most familiar to individual EAs. Energy efficiency program precepts may also intentionally or unintentionally push EAs toward making recommendations for certain upgrades over others.

Meanwhile, the commercialization of new materials and equipment continues to outpace the availability of widely deployed training regimens and updates to software supports; as the market of options for retrofit technologies continues to expand there is a risk of a growing performance gap between what is feasible and what is achieved.

For building owners, real-world operational cost savings are generally the primary motivator for the pursuit of energy efficiency upgrades. While HOT2000 does have rudimentary tools for the entry of bulk costs associated with upgrades and applied to various families of building components, it lacks the infrastructure to allow the entry of itemized retrofit costs with local pricing. While this is understandable given the intent and initial development pathway for HOT2000 software, the modern context demands deeper analyses of cost savings. This is complicated by regional differences in the costs of materials and labour, and so usage of broadly aggregated average costs could lead to misleading results. This project recognizes industry's demand for the consideration of anticipated or quoted project costs in the local context when optimizing retrofit pathways.

While it would be preferable for EAs to be trained and knowledgeable in all possible retrofit options and their associated costs in today's shifting market, there are simply too many factors to allow for their thoughtful consideration. HOT2000 software offers an opportunity for testing various upgrade materials and methods on a building model, however, this is a manual process and the time requirements of testing a multitude of upgrade variations and combinations can be prohibitive for energy advising businesses and individuals who are often pressed for time; EAs with strained capacity are more likely to make significant errors in the EnerGuide process and/or in the practicality of their recommended upgrades given the existing conditions of each individual building. We recognize that retrofit pathway optimization with the existing toolkit for EAs is a laborious and time-consuming process with no clear operational incentive for companies that offer EA services.

In an effort to address these concerns, this project aims to deliver the foundations of a planning tool for EAs that allows them to easily model, price, and analyze a large catalogue of potential energy upgrade packages for buildings, or groups of buildings. It next allows them to sort their results by terms that best fit the objectives of the building owner or energy efficiency program. This planning tool will allow EAs to consider a wider range of retrofit options without a significant increase in the time commitment required. Additionally, the introduction of this planning tool may, in time, allow for an expansion of the upgrade materials and methodologies that can be evaluated alongside the range of standardized options in HOT2000 software without creating a cumbersome workflow for EAs.

Methodology

Software Description

This work utilizes the Volta SNAP software platform, an energy advisor dashboard designed to work with HOT2000 and within the ERS workflow. The platform leverages the HOT2000 simulation engine at its core and aims to make interacting with HOT2000 more streamlined while providing EAs with an expanded analytical toolset. The platform can create and manipulate the content of HOT2000 project files ("h2k files") in both a user-driven and automated manner. Volta SNAP is supported by both government (Natural Resources Canada's Office of Energy Efficiency) and industry and is currently used by EAs across the country.

This project leveraged two key aspects of the Volta SNAP platform: the *Preliminary Home Energy Assessment* which enables the creation of h2k files from a reduced number of inputs (5-30 inputs instead of the hundreds considered in ERS), and the parametric analysis feature of Volta SNAP which facilitates the automated generation of hundreds-to-thousands of comparative upgrade plans for a single building. Volta SNAP's parametric modelling feature builds upon prior learnings from CanmetENERGY-Ottawa and their development of the Housing Technology Assessment Platform ("HTAP") and Cost Benefit Analysis Tool ("CBAT") (NRCan, 2024).

The preliminary assessment tool that Volta Research had developed prior was modified slightly for this project; this feature was designed to help educate homeowners on potential upgrade options for their homes and to act as a proof of concept which enables EAs to conduct remote energy assessments. The preliminary assessment involves a homeowner completing an online survey which creates a set of h2k files in the background and summarizes results with estimates of potential energy savings for various upgrades. Homeowners can share their results with their EA who can then import their survey link into Volta SNAP to view and modify the completed h2k file; EAs can then follow up with homeowners via phone, email, or video call to ask any questions required for completion of a reasonably accurate energy model for the home. For this project, the back-end functionality of this feature was leveraged to automatically create HOT2000 energy models from reduced sets of parameters without the need for homeowners to complete surveys. Modification was based on the types of inputs available (as described in the **Data Collection Process** section).

Volta SNAP's parametric analysis feature allows for the simulation of vast quantities of files to investigate the benefits of potential energy conservation measures ("ECMs"). Before this work, the parametric analyses were limited to simulated alterations for a single home.

Through this project, those capabilities were expanded to allow for parametric simulations which include entire portfolios or communities of homes.

By investigating the impact of various combinations of ECMs on a group of homes this analysis can identify portfolio-scale outcomes that provide increased flexibility in terms of cost-optimization. For example, given a notional portfolio of two homes and an energy savings target of 50% across the portfolio, solutions may involve 50% savings for each home, 60% savings in one home and 40% in the other, and so on. This function enables the optimization analysis to target increased savings in homes that are more cost-effective to upgrade. Additional pathways open the door to achieve a higher efficacy in realizing savings across a portfolio when compared with targets set at the individual home level.

Data Collection Process

This project investigated three different data collection processes to understand how various degrees of detail would impact the retrofit planning process. The data collection process was broken into three phases, each with a different data source:

- Phase 1: Data from the proponent and/or publicly available sources.
- Phase 2: A survey of easily identifiable opportunities and building deficiencies.
- Phase 3: Conventional ERS assessments.

The Nova Scotia Provincial Housing Agency (“NSPHA”) furnished a list of 250 public housing units to be considered in our analysis.

Phase 1

Civic addresses and assessment account numbers (“AANs”) were used to collect Phase 1 data via Property Valuation Services Corporation’s (“PVSC”) website and API (PVSC, 2024). Forty of the homes in the provided list lacked AANs; Phase 1 data was not collected for these homes, leaving a total of 210 homes considered for analysis.

Beyond the physical location of each building, this initial Phase 1 data collection process yielded the following details about each home:

- Number of living units (eg: single-family, duplex, etc.)
- Year of construction
- Size of living space (heated area; m^2)
- Construction type (e.g. one-storey, two-storey, split level, semi-detached, etc.)
- Number of bedrooms and bathrooms
- Grade (e.g. state of repair)

- Finished basement (yes/no)
- Attached garage (yes/no)

While this data set includes most of the core requirements of the preliminary assessment process (size of home, location, and year built), details were lacking on two key characteristics of the homes: their foundation type and their primary heating fuel source. Discussions with the housing provider and an analysis of archetypical homes in the region indicated that most homes investigated had full basement foundations, which was the default assumption for the preliminary assessment process already, and this input parameter was not explored further during Phase 1. A clustering exercise was conducted on the phase one homes to identify archetypical categories of homes within the dataset. However, the primary heating fuel type has a drastic impact on the estimated energy and emission savings potential for the homes. As such, the Phase 1 analysis was expanded beyond its initial intention via a mapping exercise using Google services to collect the following additional information:

- Number of building corners
- Roof type
- Visible oil tanks or fill lines
- Visible chimneys
- Number of outdoor heat pump units
- Number of exterior vent hoods

The combination of all parameters listed above comprised the Phase 1 dataset from which 210 energy models were created, collectively representing the Phase 1 portfolio. This portfolio, supported by the clustering analysis, acted as the foundation for both the Phase 2 and Phase 3 portfolio analyses.

Phase 2

Data collection for Phase 2 involved site visits to a subset of homes by individuals who do not have explicit training in energy auditing; this was an intentional decision to investigate whether reasonable data collection outcomes could be achieved without engaging EAs. These site visits involved the completion of an Opportunities and Omissions Survey ("O&O Survey") created for this project, a copy of which is included in Appendix A: Opportunities and Omissions Survey.

The O&O Survey collected data on the following features of the home:

- Attic insulation
- Main wall insulation

- Foundation wall insulation
- Heating and cooling system type and fuel
- Ventilation systems
- Hot water system type and fuel
- Damaged areas of home

This version of the O&O survey is intended to act as a prototype for this type of data collection procedure, as the strengths and weaknesses of Phase 2's data collection plans could not be assessed until its completion. Future iterations may be refined by analysis of results in this project, however, the refinement of this is outside of project scope.

A subset of 55 homes were visited by a non-EA field technician for the Phase 2 analysis; this staff member was normally tasked with product installations (eg: CO alarms, dehumidifiers, etc) and administrative tasks such as acquiring participant signatures and participant consent for energy upgrades, and did not have any formal training on energy efficiency upgrade planning. The selection process was not entirely random, which would have been ideal to generate a statistically even spread of data. Instead, it was dictated by ease of access and scheduling availability of building managers and tenants. The archetype cluster analysis conducted on the Phase 1 homes was then used to apply and/or extrapolate common features from the Phase 2 data collection process onto the Phase 1 homes that did not receive site visits, creating a new dataset representing the Phase 2 portfolio.

Phase 3

Phase 3 data collection involved conventional ERS home energy assessments. In total, 51 of the 210 homes from phase one had full ERS audits conducted. These homes were selected with explicit direction from NSPHA and their regional housing management teams based on their interest in collecting data on homes that had not been recently evaluated for maintenance needs; 20 of these overlapped with homes from the Phase 2 analysis with an O&O survey completed. The data collected via the onsite ERS assessments was analyzed and the same archetypical cluster extrapolation process conducted in Phase 2 was applied for the Phase 3 data. Note that this was an independent cluster extrapolation, and the portfolio of Phase 3 homes does not include information gleaned from Phase 2.

Upgrades & Costs

Clean collects detailed costing information for all retrofits undertaken and collects and analyzes contractor quotes on an ongoing basis. As such, their past work in collecting and analyzing retrofit costing data could be leveraged in this work.

The project team discussed appropriate retrofit options based on common retrofits implemented by Clean under previous programs and projects. Table 1 contains a summary of the retrofit ECMs considered in this analysis. Costing is sourced from recent projects and agreements executed by Clean in the context of Part 9 building retrofit initiatives in the province of Nova Scotia. The majority of costs use a simple average among real-world observed or agreed-upon prices for these projects. However, there are some costs here which have great variability in real-world projects; in these instances we have used pricing algorithms developed by Clean which are based on historic observations of invoiced costs. As such, these prices are only valid within the temporal and geographic boundaries within which they were collected.

Table 1. Summary of retrofit ECMs considered.

Category	**Retrofit Description**	**Cost**
Ceilings with Attic Space	Increase total attic insulation to R60 with blown-in insulation	$1.81 / ft^2
Sloped / Flat / Cathedral Ceilings	Baffles, R22 mineral wool batt, and 6 mil vapor barrier in sloped ceiling	$6.42 / ft^2
Above Grade Walls	Blown cellulose to main walls - 2x4" wall cavity	$3.41 / ft^2
Above Grade Walls	Blown cellulose to main walls - 2x6" wall cavity	$3.70 / ft^2
Above Grade Walls	R9 (1.5") polyisocyanurate insulation + vinyl siding	$14.53 / ft^2
Exposed Floors	R22 mineral wool batt + 2" EPS to floor; mechanically fasten & sealed with foam	$7.77 / ft^2
Exposed Floors	2” Expanded polystyrene (EPS) foam insulation	$6.05 / ft^2
Floor Headers	Insulate headers with 4" closed-cell spray foam and thermal barrier	$9.75 / ft^2
Foundation (Basement) Walls	R20 closed cell spray foam insulation	$7.40 / ft^2

Windows	Window insert or replacement; insulated vinyl, Energy Star rated for Canadian climate	Equation 1
Door	Door, insulated steel, Energy Star rated for Canadian climate	$1,728 per typical door
Air Sealing	Approximately 10% reduction in ACH	Equations 2 and 3
Ventilation	HVI-certified HRV, Energy Star, new ducting	Equation 4
Ventilation	HVI-certified HRV, Energy Star, existing ducting	$2130 for a typical unit
Heating and Cooling	ASHP (15 kBTU/h) with existing heating system back-up	$4,392 for a typical unit
Heating and Cooling	ASHP with electric heating back-up	Equation 5
Hot Water	Install a new 40-gallon electric hot water tank; Energy Star; minimum UEF = 0.92	$807.50
Hot Water	Install a new hybrid heat pump hot water tank; Energy Star; minimum UEF = 3.3	$5,693
Generation	Solar PV covering 40% of roof area, up to a 10kW maximum	Equation 6

Costs determined via equations are presented below.

$$C_{per\ window}[\$] = \$1{,}050 + 31.68 \cdot A_{window}[ft^2] \tag{1}$$

$$Air\ sealing\ efficacy\left[\frac{\Delta ACH}{h}\right] = \begin{cases} 0.02ACH_i + 0.05, & ACH_i < 12.5 \\ 0.06ACH_i - 0.45, & ACH_i \geq 12.5 \end{cases} \tag{2}$$

$$C_{air\ sealing}[\$] = \$60 \cdot \frac{ACH_f - ACH_i}{Air\ sealing\ efficacy} \cdot \tag{3}$$

$$C_{hrv,new\ ducts}[\$] = 4180 + 0.635 \cdot A_{floor,served}[ft^2] \tag{4}$$

A multiplier of 1.25 was applied to the HRV cost in Equation 4 if the attic had limited access and again if the basement had limited access.

$$C_{ASHP}[\$] = \$10{,}758 + 0.2847 \cdot HL_{design}[W] \cdot 3.41 \cdot 1.07 \quad (5)$$

If new ductwork was needed, an additional \$2/ft2 of heated area was added to the air-source heat pump (“ASHP”) system cost in Equation 5.

It is worth noting that the *existing* ASHP system had a strict system size of 15 kBTU/h, while that of the ASHP system with a new back-up was sized to the design heating load of the home. In reality, a heat pump selection process would need to occur in order to accurately quantify the cost of the heat pump and ensure that it was sized appropriately for the home.

$$C_{PV}[\$/W] = -0.4504208 \cdot \ln(System\ size[W]) + 6.6575 \quad (6)$$

All costs have been determined based on real-world retrofit costs observed by Clean in past recent programs and were last updated in July of 2023. Cost equations are based on aggregate cost data from which correlations could be drawn.

Within each category was also the option to not alter that aspect of the home. As a result, the simulation “mesh” created by all possible combinations of upgrades would result in 41472 individual simulations per home. This would produce about 8.7 million individual simulations across 210 homes. This would have created a significant computational load and resulted in very long simulation times. Instead, the simulation size was reduced by taking a random sampling of the simulation space for each home. For this analysis, the total simulation size for each phase was about 100,000 unique simulations, comprised of 500 ECM combinations per home. Each home had a different random set of ECM combinations applied, and the random sampling was uniform across the solution space. The impact of taking a 500-model sample size for each house’s solution space is investigated in the Real World Case Study and Validation Section.

The selected ECM combinations were also constructed such that the final state of every home would result in all-electric consumption. This depended on the base case of the home, for example, a home with electric space and hot water heating could potentially not require updates to those systems, but all oil-fired mechanical systems would be replaced.

Portfolio Optimization

For this analysis, three portfolio-scale requirements were defined:

- The entire portfolio must achieve 50% energy savings;
- The entire portfolio must achieve 40% GHG emission savings; and
- The final state of the portfolio must be all-electric.

These requirements defined the constraints to the optimization problem, where the ultimate goal of the portfolio optimization was to find the lowest total cost option within the set of defined constraints. The output of the optimization is a set of ECMs for each individual home that achieve the portfolio-scale goals as defined within the constraints.

The optimization was conducted through a custom genetic algorithm (GA) procedure developed specifically for this purpose. A GA is a flexible method for solving optimization and search problems inspired by biological processes (i.e. mutation, crossover, and selection). The process allows for the efficient searching of overly complex solution spaces, such as the solution space that results from the ECM mesh analysis in this work.

This methodology was applied to this project due to the project team's past success applying GA to similar problem sets. In this custom algorithm, a "gene" is analogous to an upgrade instruction for a single home, while a "chromosome" is analogous to the upgrade instructions for the portfolio of homes. The GA effectively "crosses-over" chromosomes of a population with the highest "fitness" (performance) to attempt to produce subsequent populations of chromosomes with greater performance. Additional steps, such as mutation, were introduced to prevent pre-mature convergence.

Analysis and Results

Cluster Analysis

A cluster analysis was performed on the ~210 homes in the Phase 1 dataset. In this analysis, each cluster can be thought of as a group of homes that share similar archetypical characteristics. The following variables, which were available at the Phase 1 stage, were used to perform the cluster analysis:

- Year built
- Living area (ft^2)
- Split level (Y/N)
- Above grade storeys
- Attached/detached

A density-based spatial clustering of applications with noise ("DBSCAN") clustering algorithm was applied to the dataset (eps = 0.7, minimum sample size = 3). This analysis produced 11 distinct clusters of homes and one "noise" cluster (i.e. group of homes that did not fit into any other cluster). Figure 1 displays the clusters, differentiated by color and plotted by living area & year built, with cluster size and descriptions presented in Table 2.

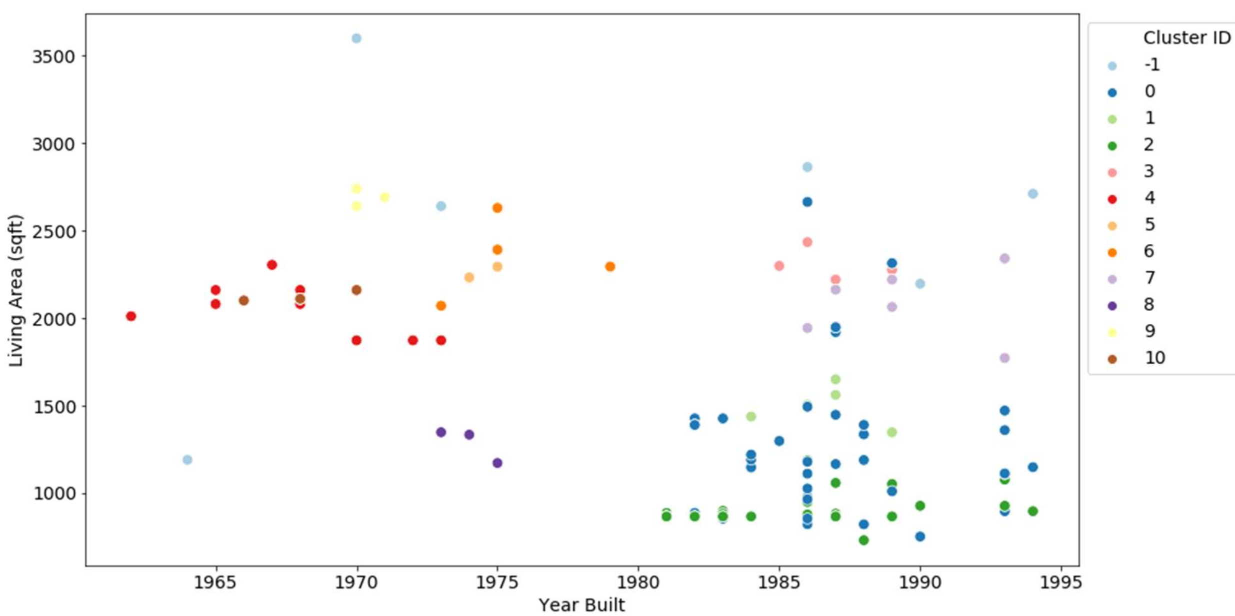


Figure 1. Visualization of cluster grouping by size of living area and year build.

Table 2. Cluster ID, size, and description for Phase 1 dataset.

ID	Size	Description
-1	9	Noise cluster
0	52	Various sized, split level, detached homes built in the 80s/early 90s
1	5	Average sized, 2-storey, attached homes built in the 80s
2	40	Smaller, 1-storey, detached homes built in the 80s
3	8	Larger, 2-storey, attached homes built in the 80s
4	37	Above average sized, 2-storey, attached homes built in the 60s/early 70s
5	8	Larger, 1-storey, attached homes built in the mid-70s
6	12	Larger, split level, detached homes built in the mid-70s
7	10	Larger, 1-storey, attached homes built in the late 80s/early 90s
8	3	Below average sized, split level, detached homes built in the 70s
9	6	Larger, 1-storey, attached homes built in the early 70s
10	10	Above average sized, 2-storey, detached homes built in the late 60s/early 70s

Of the homes analyzed, the average size was 1600 ft^2. Large homes are defined as greater than 2000 ft^2, while small homes are defined as less than 1000 ft^2.

Using these clusters of homes allowed later stages of the analysis to programmatically extrapolate building characteristics into similar clusters. For example, if the Phase 2 analysis determined that many homes in cluster 4 had a given amount of attic insulation, other homes in cluster 4, for which the O&O survey was not completed, would be more likely to have that same type of insulation applied to their Phase 2 energy model files.

Optimization Performance

The mesh ECM data from each phase was passed through the genetic algorithm optimization process to determine the optimal portfolio upgrade plan. The optimization algorithm would only select plans that met the constraints of the system (50% energy and 40% emission savings while electrifying where non-electric), attempting to find the most cost-effective option. With each iteration the process aims to find a more cost-effective plan than the previous attempt, eventually plateauing at an optimal solution. Each optimization was run for 50,000 iterations (also referred to as “generations”) which takes 450 seconds; this was a sufficient number of iterations to identify the plateau point of peak operational efficiency of the algorithm itself. Figure 2 displays the portfolio’s energy and emission savings along with the cost of implementation per home for the optimal solution of each generation. These results show that a plateau is achieved after about 10,000 generations, which takes the system about 90 seconds.

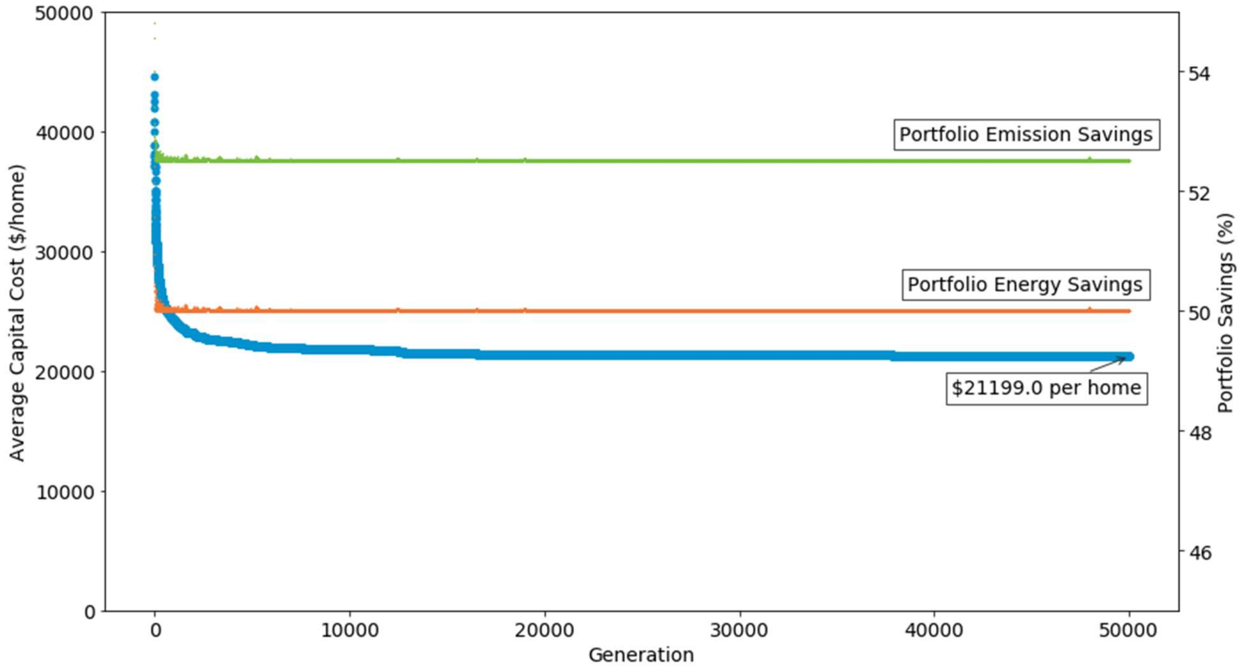


Figure 2. Visualization of optimization performance over each generation (iteration).

Phased Retrofit Plans

After constructing the energy model files for all homes in each phase, running the ECM mesh analysis, and the genetic algorithm optimization process, the system outputs a retrofit plan for the community. Each plan is comprised of the relevant metrics associated with the community on both a per-home and aggregate basis (e.g. total energy and GHG savings, total cost), along with a list of which upgrades to apply to each home. Table 3 provides the high-level metrics associated with the overall retrofit plan for each phase, utilizing costing data provided by Clean as referenced in Table 1.

Table 3. High-level performance metrics resulting from the optimized retrofit plans for each phase.

	Phase 1	**Phase 2**	**Phase 3**
Energy Savings	50%	50%	50%
Emission Savings	52%	52%	53%
Total Cost	$ 4,435,766	$ 4,583,007	$ 4,451,754
Avg. Cost per Home	$ 21,023	$ 22,034	$ 21,199

These results show that by achieving the target level of 50% energy reduction for the entire community we always surpass the emissions saving target of 40%. Additionally, the results show very consistent total costs for the optimal solutions, which averaged at approx. $21,000 - $22,000 in upgrade costs per home. The maximum observed single-home upgrade cost in a retrofit plan was found to be $64,250. The Phase 1 and 2 plans left 20 and 18 homes without upgrades, respectively, while the Phase 3 plan left 12 homes untouched. This demonstrates that the algorithm is able to direct upgrades to buildings where they will have the greatest possible impact per dollar invested.

Figure 3 shows an excerpt of a heat map visualization of the optimization process over time, which demonstrates how the optimization process targets certain homes for more energy savings than others; darker colors indicate greater energy savings.

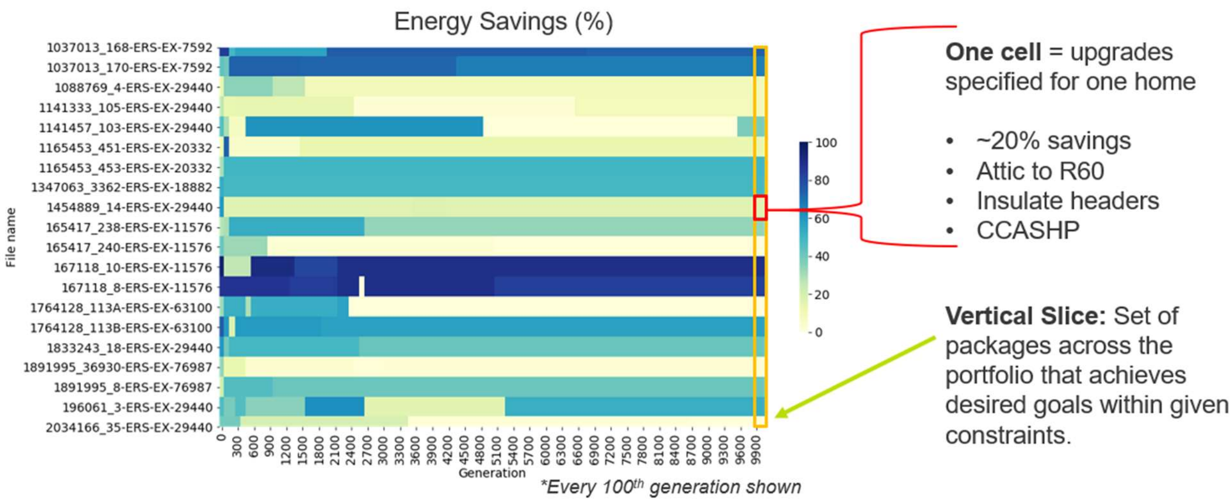


Figure 3. Heat map visualization of portfolio optimization over time.

Figure 4 and Table 4 display the frequency of upgrades selected by phase in graphical and tabular formats, respectively, for the optimized retrofit plan in each of the three phases. These results show a strong degree of consistency across the plans produced by each phase of the analysis.

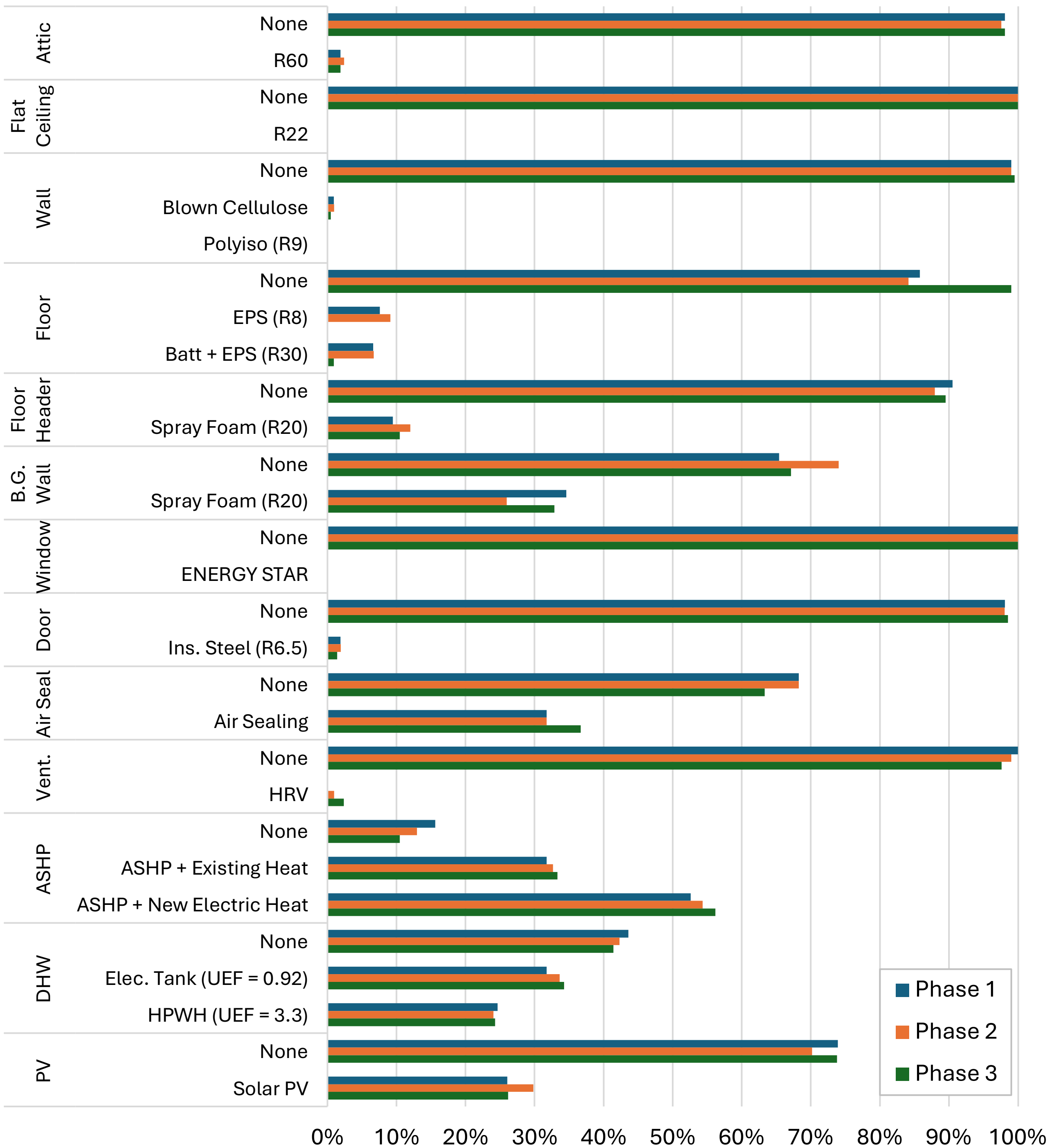


Figure 4. Percentage of homes per phase determined to receive each type of upgrade.

Table 4. Percentage of homes per phase determined to receive a given upgrade.

		Phase 1	Phase 2	Phase 3
Attic	None	98%	98%	98%
	R60	2%	2%	2%
Flat Ceiling	None	100%	100%	100%
	R22	0%	0%	0%
Wall	None	99%	99%	100%
	Blown Cellulose	1%	1%	0%
	Polyiso (R9)	0%	0%	0%
Exposed Floor	None	86%	84%	99%
	EPS (R8)	8%	9%	0%
	Batt + EPS (R30)	7%	7%	1%
Floor Header	None	91%	88%	90%
	Spray Foam (R20)	9%	12%	10%
Basement Wall	None	65%	74%	67%
	Spray Foam (R20)	35%	26%	33%
Window	None	100%	100%	100%
	ENERGY STAR	0%	0%	0%
Door	None	98%	98%	99%
	Ins. Steel (R6.5)	2%	2%	1%
Air Seal	None	68%	68%	63%
	Air Sealing	32%	32%	37%
Ventilation	None	100%	99%	98%
	HRV	0%	1%	2%
ASHP	None	16%	13%	10%
	ASHP + Existing Heat	32%	33%	33%
	ASHP + New Electric Heat	53%	54%	56%
DHW	None	44%	42%	41%
	Elec. Tank (UEF = 0.92)	32%	34%	34%
	HPWH (UEF = 3.3)	25%	24%	24%
PV	None	74%	70%	74%
	Solar PV	26%	30%	26%

In general, the most common categories to receive upgrades (those showing more than 25% of homes that receive an upgrade) are:

- Foundation insulation (33%)
- Air sealing (37%)
- ASHP (90%)
- DHW (59%)
- Solar PV (26%)

Some of the reason for the high frequency of recommending heat pump retrofits is associated with the electrification constraint. However, as the following section highlights, this is also because heat pumps save a significant amount of energy relative to their cost.

The exposed floor category appears to show the greatest degree of variation between the phases. This is likely because the Phase 1 and 2 datasets overestimated the number of homes with exposed floors, while the Phase 3 analysis revealed that there were very few homes with exposed floors. Additionally, the Phase 2 analysis seems to disagree slightly with the Phase 1 and 3 analyses regarding the number of homes that would require basement wall insulation upgrades, although this amounts to less than a 10% difference. The exposed floor discrepancy can be addressed through an added question in the O&O survey. The foundation wall discrepancy may require a deeper analysis into the source archetypes that form the basis of the Phase 1 and 2 analyses, or it may be a result of a disproportionately high number of insulated basements identified in Phase 2.

It is also worth noting that the flat or cathedral ceiling ECM is never selected because very few homes were identified with those types of ceilings in all phases of the analysis. Additionally, while HRV upgrades are often recommended when improving HVAC systems and/or performing significant air sealing, they were seldom included in the outputs of this project because they *increase* the energy consumed by the home. Because the air sealing modelled was minor (often no more than 10% improvement) HRVs were not coupled with air sealing activities. Such upgrades could be included more frequently through modification of the portfolio-level constraints.

The full retrofit plan for each phase is provided in **Appendix B: Phased Retrofit Plans**.

Investment Energy Saving Efficacy

The driving factor influencing the frequency of upgrade selection was the cost per unit of energy saved. The nature of the optimization analysis will always strive to meet the defined constraints and targets while keeping costs as low as possible. The analysis will therefore tend to select upgrades that will save the most energy per dollar invested.

Figure 5 and Figure 6 plot the distributions of observed cost per unit energy saved for all ECMs and the "best energy value" ECMs, respectively. These values were calculated against the 51 houses that received onsite assessments as part of the Phase 3 work. These results show that the ECMs with the lowest cost per unit energy saved tended to be those selected the most often in the retrofit plans. Table 5 displays the full set of descriptive statistics behind the boxplots presented.

The boxplots (sometimes called a box and whisker plot) demonstrate the spread of observed data, where the top and bottom of the boxes represent the 75th and 25th percentiles, respectively, the horizontal line through the middle of the box represents the median value, and the "whiskers" (thin vertical lines extending from green boxes) above and below the boxes represent the maximum and minimum observed values.

Generally, because the optimization aimed to minimize a single variable (cost), it would tend to select retrofit plans that involved the lowest $/GJ ECMs. However, it is worth noting that in certain cases, ASHP and DHW retrofits will have "skipped the line", due to the requirement for electrification of all fossil fuel energy systems as defined within the constraints in the portfolio retrofit plan requirements.

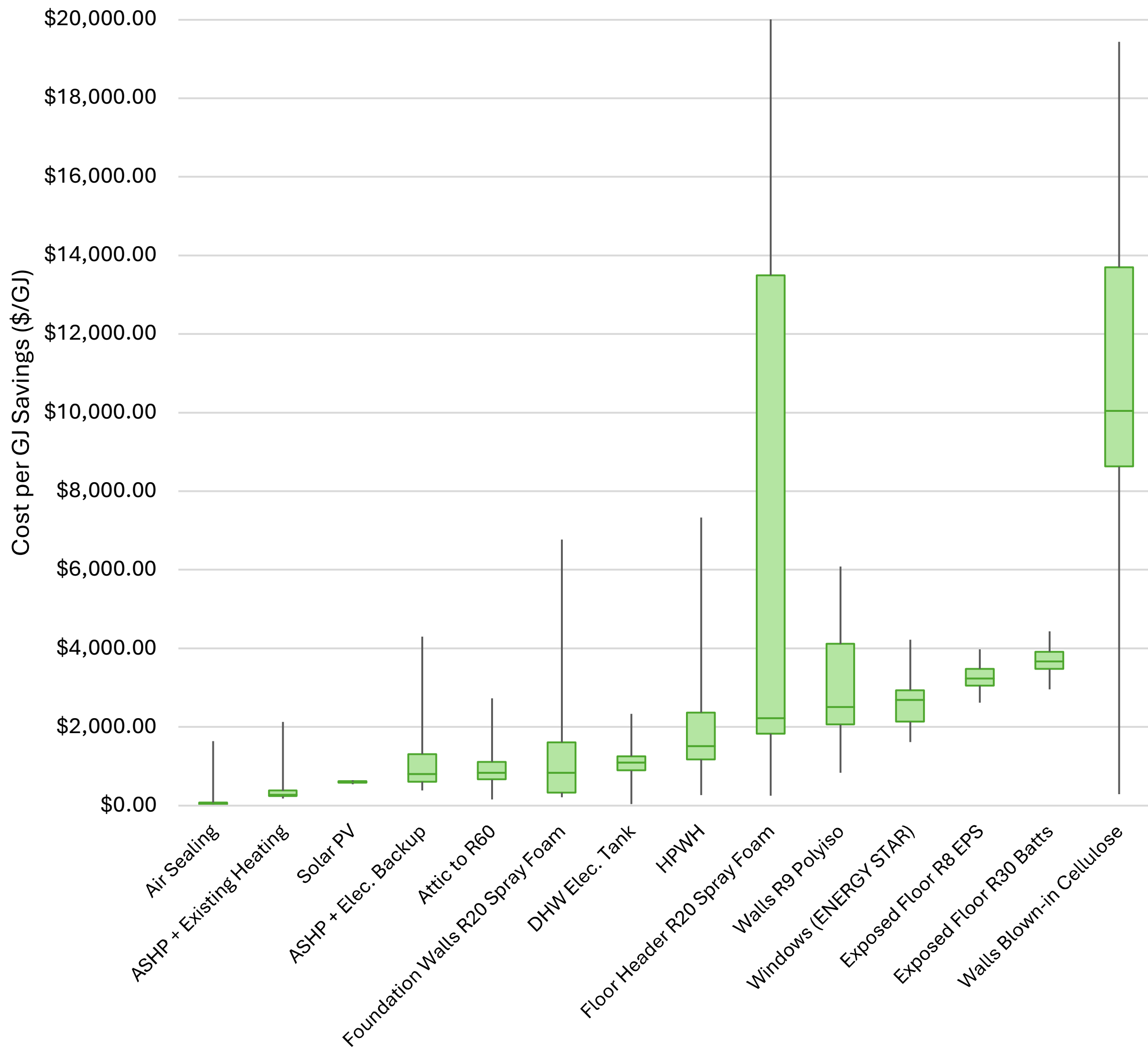


Figure 5. Boxplots demonstrating cost per GJ savings for ECMs investigated based on savings associated with Phase 3 onsite assessment files (n = 51).

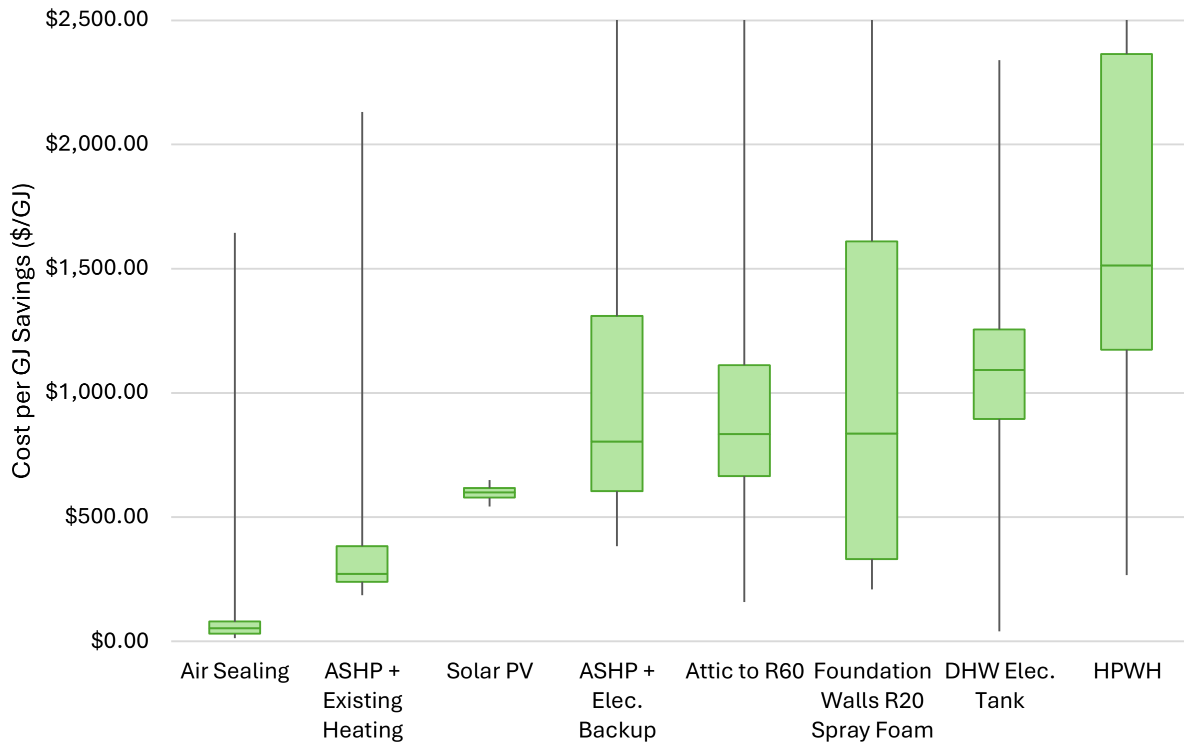


Figure 6. Boxplots demonstrating cost per GJ savings for ECMs investigated based on savings associated with phase 3 onsite assessment files (n = 51) for ECMs with the lowest observed cost per GJ saved.

These results also help to explain the prevalence of solar PV in the optimal solutions. Because solar PV has such a small observed range of cost per GJ savings, and the optimization sought to optimize a single variable (cost), it becomes very difficult to "push past" solar PV to find more cost-effective options. For example, the minimum $/GJ observed value for solar PV was $543, while the 25th percentile value for attic insulation was $664. This means that insulating the attic would yield a better $/GJ output compared to solar PV for fewer than 25% of homes. Note that PV system size was capped at the lesser of 40% of roof area or 10kW DC. This analysis could be further enhanced by considering roof repair costs prior to PV installations.

This also explains why the optimization produced more options with foundation insulation compared to attic insulation, because the spread of foundation ECM energy savings values drops well below that of solar PV and attic insulation; somewhere between 25 – 50% of homes would achieve a better $/GJ result from foundation insulation compared to solar PV. Therefore, foundation insulation options could, in some cases, produce energy savings at a greater value than that of solar PV and "push past" solar PV in the optimization search. Should solar PV be excluded from the analysis, a greater mix of foundation and attic insulation would be observed in the final retrofit plans. However, such a retrofit plan will also have an overall higher cost, because one of the best $/GJ value ECMs would be excluded.

Table 5. Descriptive statistics of cost per GJ saved for ECMs included in the study based on savings associated with Phase 3 onsite assessment files (n = 51)

Upgrade	Minimum	25%	50%	75%	Maximum
Air Sealing	$12.98	$29.78	$51.77	$79.00	$1,645.65
ASHP + Existing Heating	$185.27	$239.33	$271.68	$382.47	$2,130.80
Solar PV	$543.38	$578.03	$598.56	$616.44	$649.91
ASHP + Elec. Backup	$383.56	$604.30	$803.60	$1,308.84	$4,301.62
Attic to R60	$158.08	$664.89	$834.13	$1,110.88	$2,734.24
Foundation Walls R20 Spray Foam	$209.51	$331.38	$836.62	$1,610.27	$6,772.34
DHW Elec. Tank	$40.45	$896.05	$1,090.92	$1,255.45	$2,340.23
HPWH	$266.31	$1,174.15	$1,513.80	$2,364.69	$7,332.65
Floor Header R20 Spray Foam	$249.67	$1,829.40	$2,219.62	$13,496.13	$86,858.90
Walls R9 Polyiso	$839.75	$2,061.88	$2,506.00	$4,116.11	$6,084.67
Windows (ENERGY STAR)	$1,619.46	$2,135.02	$2,690.97	$2,933.57	$4,224.10
Exposed Floor R8 EPS	$2,621.51	$3,052.47	$3,233.99	$3,477.43	$3,982.25
Exposed Floor R30 Batts	$2,957.38	$3,474.58	$3,670.41	$3,913.52	$4,436.05
Walls Blown-in Cellulose	$288.41	$8,629.11	$10,042.99	$13,700.92	$19,440.52

These results show a potential shortcoming in the analysis used in this work, which is that the optimization relied solely on the capital cost of measures as the metric to minimize. This ignores a variety of factors that a program designer or portfolio manager might want to consider such as the operational cost savings, durability and maintenance consideration of measures, embodied carbon, etc. Future iterations of this analysis could consider a compound metric, such as total cost of ownership (normalized over a time horizon), to attempt to more accurately reflect the real-world cost implications associated with each upgrade considered. This would result in an optimization process that produces solutions with a more holistic view of the homes and their occupants.

Real World Case Study and Validation

The Phase 1 through to Phase 3 analyses investigate the process of optimized portfolio planning on a set of homes that have not yet received retrofits. To assess the proposed novel process against business-as-usual retrofit planning, the portfolio optimization was re-run on a set of 36 homes that had recently undergone retrofits within similar program scopes to those considered in this exercise (e.g. similar energy and emissions targets). The high-level results of that comparison are summarized in Table 6. In order to normalize differences between the two scenarios the optimization case had forced HRV upgrades, and the optimization case was instructed to achieve 47% savings to match the real-world case.

Table 6. Comparison of real-world retrofit plans to optimized retrofit plans.

	Real World	**Optimization**
Building Portfolio Size	36	
Total Base Consumption (GJ)	3398	
Total Retrofit Consumption (GJ)	1802	1801
Total Portfolio Energy Savings (%)	47%	47%
Total Base Emissions (tCO2/y)	233	
Total Retrofit Emissions (tCO2/y)	117	117
Total Emissions Savings (%)	50%	50%
Total Portfolio Retrofit Cost ($)	$969,048	$888,093
Average Cost per Home ($)	$26,918	$24,669

These results show that, for the same set of targets, the optimized case is estimated to save $80,955 across the portfolio, an average of $2,249 per home. It is encouraging to see that the optimization produced a result with costs coming within 10% of real-world planning activities, suggesting that this method may be able to produce reasonably equivalent results.

Table 7 displays the proportion of each upgrade category that received an upgrade within the portfolio for the real-world case study comparison. This shows a general shifting of upgrade direction away from envelope improvements towards DHW and solar PV. In practice, the “optimal” plan produced would be continuously re-evaluated against sets of other real-world requirements (e.g. maintenance or comfort) to modify priority of different ECMs on different homes until retrofit planners are satisfied with the proposed plan.

Table 7. Percentage breakdown of ECM selection in each category for the real-world and optimization cases.

	Real World	Optimization
Attic	56%	3%
Flat Ceiling	0%	0%
Wall	0%	0%
Exposed Floor	0%	0%
Floor Header	47%	25%
Basement Wall	50%	25%
Window	0%	0%
Door	0%	0%
Air Seal	72%	78%
Ventilation	100%	100%
ASHP	100%	100%
DHW	67%	97%
PV	0%	6%

In addition to validating the optimization case against a real-world retrofit plan, the decision to use a reduced sample size (500 / 41,000) retrofit options for the mesh analysis was also evaluated. It was determined that a sample size of 500 is sufficient in finding an optimal solution, as increasing the sample size to 2000 yielded results with total costs within 0.3% of the initial analysis. This demonstrates that a high efficacy can be realized without exhaustive exploration of the solution space, resulting in greater operational efficiency.

Portfolio Planning Analysis

The housing provider project partner was open to the idea of exploring solar PV in the analysis, however, it is possible that some retrofit planning activities may want to exclude PV from the analysis and focus solely on the building envelope and mechanical systems. As such, the Phase 3 analysis was repeated with solar PV excluded from the set of allowable upgrades. Table 8 compares the high-level Phase 3 results with and without solar PV. These results show that the inclusion of PV allows the 50% savings target to be met with savings of about $124,000 (3%) across the portfolio.

Table 8. High-level performance metrics for Phase 3 retrofit plans with and without solar PV.

	Phase 3 - With PV	**Phase 3 – No PV**
Energy Savings	50%	50%
Emission Savings	53%	53%
Total Cost	$ 4,451,754	$ 4,575,573
Avg. Cost per Home	$ 21,199	$ 21,788

Rather than define targets prior to attempting to build retrofit plans, the analysis toolkit can allow planners to determine exactly what targets they may want to define for a given program or portfolio. For example, it may be that there is a “knee” in the cost effectiveness curve of portfolio improvements, a point at which the ratio of cost of implementation to energy savings becomes too high to be feasible. On the other hand, it may also be possible that the additional cost required to achieve 60% savings instead of 50% savings is marginal, which may allow planners to define more ambitious targets with minimal additional financial burden.

To investigate these factors, the Phase 3 analysis was repeated, with and without PV, across a range of energy savings targets. Figure 7 demonstrates the impact of the energy savings target on the resulting optimal solution cost for the Phase 3 analysis with and without PV.

These results are very interesting in that they show, perhaps coincidentally, that energy savings through solar PV start to become more cost-effective than retrofit plans that exclude PV when energy savings targets are greater than 46 – 48%. Beyond 50% energy savings, it is more financially effective to seek further savings through solar PV than the upgrades considered in this work.

Additionally, the cost of retrofit plans that exclude PV begins to climb dramatically above 50% energy savings. When attempting to achieve 53% savings without PV, the resulting solutions utilize nearly all upgrades available, resulting in unrealistically high incremental costs for minimal energy savings gains. This is due to the specific upgrades chosen for the analysis, and should more ambitious targets be sought, more intensive upgrades would have been considered. However, this analysis shows that, given the set of upgrades defined that the housing provider is comfortable in applying, a target of 50% is a very reasonable target that can achieve savings before undertaking upgrades with diminishing returns.

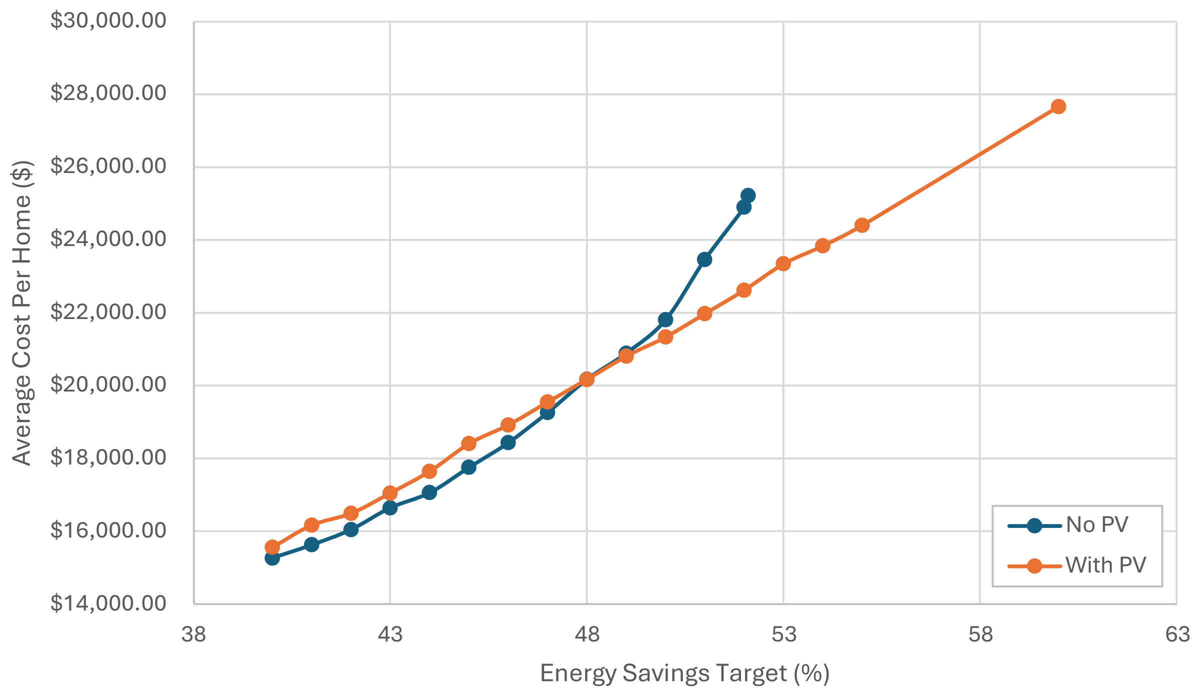


Figure 7. Impact of energy savings target on optimal solution cost.

Figure 8 and Figure 9 display the frequency of observed upgrades in optimal portfolio solutions with varying degrees of energy savings. These results demonstrate how upgrades with lower cost per GJ efficacies “come online” as energy performance requirements are increased. Additionally, the linear nature of the additional benefits PV can provide are clear.

This analysis shows how this planning toolkit could be leveraged at a higher level: helping to define the portfolio targets themselves before diving into the act of detailed retrofit planning. For example, should a portfolio manager be given a target (arbitrarily) of 70% savings, they could use this analysis to determine that they could achieve 50% savings in a cost-effective manner through building envelope and mechanical system improvements, while achieving the remainder of the required savings through solar PV installations.

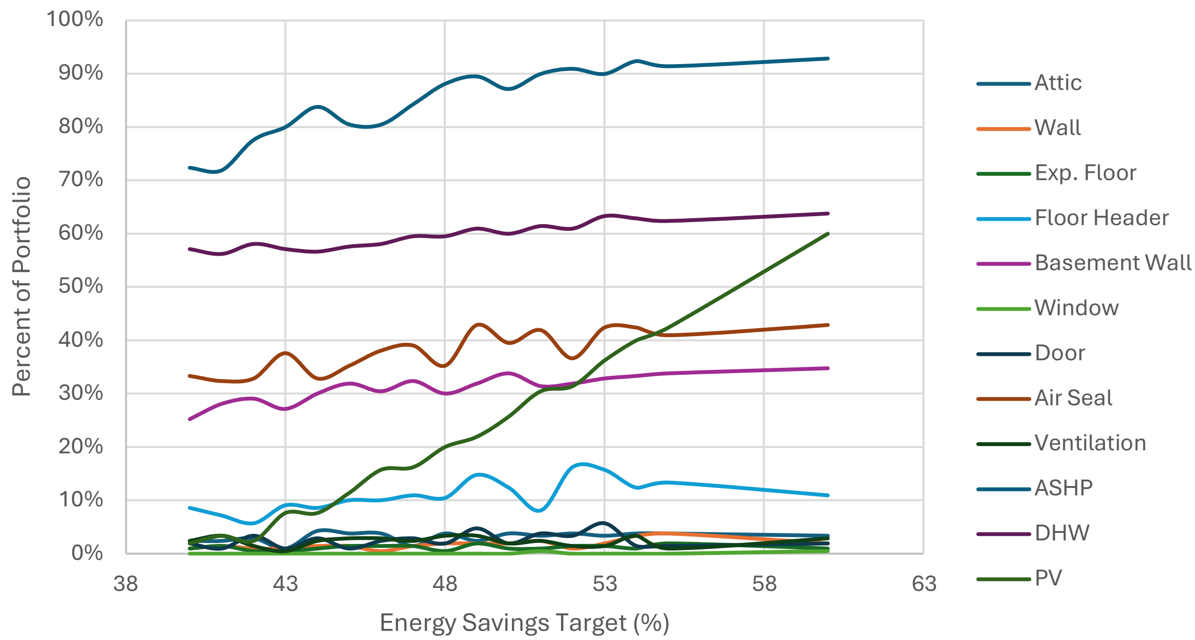


Figure 8. Changes in observed upgrade frequency with varying energy savings targets (including solar PV)

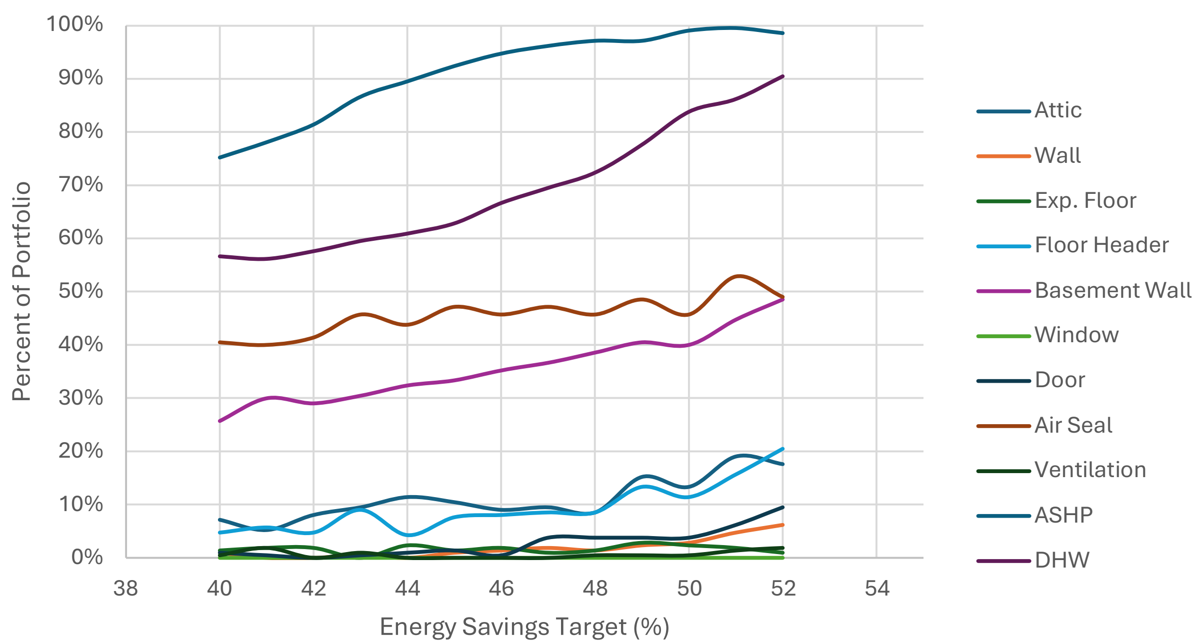


Figure 9. Changes in observed upgrade frequency with varying energy savings targets (excluding solar PV)

Conclusions and Recommendations

The combination of itemized line-item pricing with parametric modelling and optimization offers a promising new planning tool for Canadian energy advisors. While further work is needed to refine and expand upon this tool, these trials show that it can already provide preliminary estimates with reasonable accuracy for portfolio-scale retrofit projects with minimal on-site evaluation required. This tool can also function as a planning aid for energy advisors working on just a single home, offering a rapid first-pass analysis of building upgrade opportunities that can be further refined by an experienced estimator.

Our real-world case study validation suggests that parametric optimization may offer a reasonable facsimile of EA planning activities, capable of achieving equivalent levels of planned bulk energy and GHG savings with greater speed and the potential for lower overall retrofit costs. This result suggests that our parametric modelling and planning toolkit could be a useful aid in the practical planning of energy upgrades at scale. We do note, however, that the real-world retrofit plans leaned toward insulation upgrades over mechanical upgrades due to their superior durability. We recognize that future iterations of this analysis platform could be improved by including estimates of durability for the purposes of calculating full life-cycle energy and GHG savings.

Further refinement of upgrade plans would require additional information about building upgrade line items. Our dataset of line items is non-exhaustive; a sample of commonly implemented line items was used to minimize compute time. To some extent, this reinforces the same "rule-of-thumb" upgrade methodology that we aim to avoid. The inclusion of additional line items would offer a more comprehensive comparative analysis of potential upgrade pathways. Furthermore, the prices utilized in this analysis were averages from across the province of Nova Scotia as recorded in late 2023. Future iterations of this tool would offer more pertinent results to users if they could enter local pricing for available retrofit options as well as disable any options that may be unavailable.

We recognize that the desired outcomes of these evaluations are bounded by the current limitations of the HOT2000 and Volta SNAP software platforms as they exist today. The energy and GHG savings are derived from HOT2000 outputs which indicate the change in ERS-rated energy and GHG usage; these can deviate significantly from real-world measures. Prior research by Clean (Clean, 2019) has indicated that the ERS rating of single-family homes in Nova Scotia was, on average, 52% higher than their actual energy consumption in gigajoules. With a disparity of this magnitude, building upgrade plans that are developed using HOT2000 software as the basis for calculation are unlikely to result in the specific real-world performance that is targeted by building owners or program administrators. Future iterations of this tool must incorporate data regarding real-world fuel usage patterns in order to produce accurate performance estimates. Additionally, future analyses should rely on more representative performance metrics, such as total cost of ownership or a similar compound metric that captures many facets of each measure, rather than solely considering capital cost which ignores aspects such as measure lifetime, operating costs, embodied carbon, and more.

We recommend further development of this tool, as it could be a powerful item in the energy advisor toolkit. One can envision an EA conducting a “Level 2” site visit, which would be supported by archetypal building inputs as they collect data. Parametric modelling could be run while the advisor is still on site. The EA would need to vet the resulting plan for potential conflicts, as site-specific conditions such as construction details or moisture conditions may render certain upgrade line items to be non-viable. The EA may also need to include ‘enabling’ upgrades, e.g.: the inclusion of an insulation dam around an attic hatch prior to insulating with cellulose, or the upgrade of an electrical service prior to installing a central electric furnace & heat pump. However, with only modest effort, a detailed retrofit plan including reasonably accurate cost and savings estimates could be developed by the EA while they are still on-site and able to discuss options with the building owner.

Works Cited

Clean Foundation. (2019). *Clean Net Zero Pilot Project: Municipal and Private Financing Options and Capacity-Building for Net Zero Home Energy Upgrades*.

NRCan. (2024). *Housing Technology Assessment Platform (HTAP).* Retrieved from https://github.com/NRCan-IETS-CE-O-HBC/HTAP

PVSC. (2024). Retrieved from Property Valuation Services Corporation: https://www.pvsc.ca/

Appendix A: Opportunities and Omissions Survey

See document on the following page:

Appendix A – Opportunities & Omissions Survey (v1.1 January 2024)

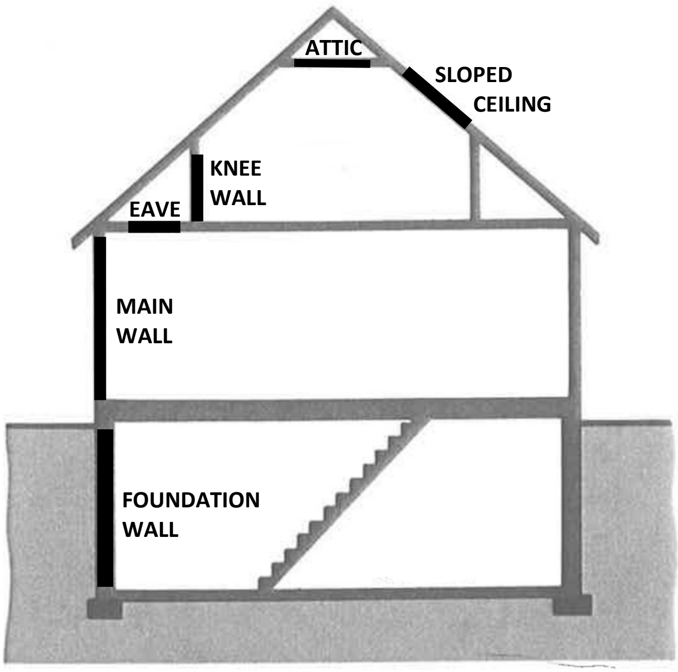
Opportunities and Omissions Survey

circle answers, or check all that apply

please include notes about any missing or damaged insulation & equipment

ADDRESS: ______________________________

CITY: ______________________________



Insulation

Attic Insulation					*no attics*
no insulation	4"	6"	12"	____"	*unknown*
Sloped Ceiling Insulation					*no slopes*
no insulation	2"	4"	6"	____"	*unknown*
NOTE:					
Kneewall Insulation					*no kneewalls*
no insulation	2"	4"	6"	____"	*unknown*
Eave Insulation					*no eaves*
no insulation	4"	6"	12"	____"	*unknown*
NOTE:					
Main Wall Insulation					*exterior is insulated*
no insulation	2"	4"	6"	____"	*unknown*
NOTE:					
Foundation Wall Insulation					*exterior is insulated*
no insulation	2"	4"	6"	____"	*unknown*
NOTE:					

Heating & Cooling

- ☐ *wood/pellet stoves* 1 2 3 4
- ☐ *mini-split heat pumps* 1 2 3 4
- ☐ *oil-fired forced air furnace*
- ☐ *propane fireplace*
- ☐ *electric baseboards*
- ☐ *central heat pump*
- ☐ *oil-fired hot water boiler*
- ☐ *other* ____________

NOTES

Ventilation

- ☐ *bathroom fans*
- ☐ *range hood*
- ☐ *central ventilation (HRV)*
- ☐ *other* ____________

NOTES

Hot Water

- ☐ *electric storage tank*
- ☐ *oil-fired storage tank*
- ☐ *heat pump water heater*
- ☐ *other* ____________

NOTES

Air Leakage & Drafts

- ☐ *damaged windows*
- ☐ *damaged doors*
- ☐ *damaged attic hatch*
- ☐ *holes in the drywall*

NOTES

Appendix B: Phased Retrofit Plans

See document on the following pages:

Appendix B – Phased Retrofit Plans

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	1037013_168-ERS-EX-7592	82.37992	5.331808	4392.36	100.5294495	6.506485	18.05394	18.05394	0	None
50000	1037013_170-ERS-EX-7592	79.68274	5.157241	5003.85	100.5294495	6.506485	20.73692	20.73691	0	None
50000	1088769_4-ERS-EX-29440	49.89132	3.229075	16679.5	75.57688904	5.226794	33.98602	38.22072	3.533905	None
50000	1141333_105-ERS-EX-29440	39.06283	2.528232	25514.06	74.82000732	5.172763	47.79093	51.12414	3.480751	None
50000	1141457_103-ERS-EX-29440	49.63497	3.212484	16879.97	74.82000732	5.172763	33.66083	37.89616	3.480751	None
50000	1165453_451-ERS-EX-20332	83.19366	5.384475	4392.36	96.55058289	6.248964	13.83412	13.83411	0	None
50000	1165453_453-ERS-EX-20332	83.19366	5.384475	4392.36	96.55058289	6.248964	13.83412	13.83411	0	None
50000	1347063_3362-ERS-EX-18882	87.3064	5.650661	6141.76	136.4229126	8.829588	36.00312	36.00312	0	None
50000	1454889_14-ERS-EX-29440	55.10741	3.566672	4392.36	65.62470245	4.247375	16.02643	16.02644	0	None
50000	165417_238-ERS-EX-11576	68.29755	4.420367	4392.36	81.62043762	5.282654	16.32298	16.32299	0	None
50000	165417_240-ERS-EX-11576	68.29755	4.420367	4392.36	81.62043762	5.282654	16.32298	16.32299	0	None
50000	167118_10-ERS-EX-11576	64.45123	4.171424	4392.36	80.37570953	5.202092	19.81255	19.81256	0	None
50000	167118_8-ERS-EX-11576	64.45123	4.171424	4392.36	80.37570953	5.202092	19.81255	19.81256	0	None
50000	1764128_113A-ERS-EX-63100	75.10485	4.86095	4392.36	91.27896881	5.907775	17.71944	17.71944	0	None
50000	1764128_113B-ERS-EX-63100	75.10485	4.86095	4392.36	91.27896881	5.907775	17.71944	17.71944	0	None
50000	1833243_18-ERS-EX-29440	43.25554	2.799593	22579.13	84.21392822	5.843489	48.63612	52.09038	4.141908	None
50000	1891995_36930-ERS-EX-76987	56.96395	3.686831	29463.54	119.8663101	7.758009	52.4771	52.4771	0	None
50000	1891995_8-ERS-EX-76987	56.96395	3.686831	29463.54	119.8663101	7.758009	52.4771	52.4771	0	None
50000	196061_3-ERS-EX-29440	41.24008	2.669149	21530.03	75.31669617	5.208217	45.24444	48.75121	3.515606	None
50000	2034166_35-ERS-EX-29440	55.38995	3.584959	4392.36	66.41337585	4.29842	16.5982	16.59821	0	None
50000	2057883_33-ERS-EX-29440	49.59942	3.210183	16585.96	74.88671112	5.177518	33.76739	37.99764	3.485365	None
50000	2333848_83-ERS-EX-77315	59.26497	3.835758	4392.36	68.47338104	4.431747	13.44817	13.44817	0	None
50000	2352389_2-ERS-EX-7592	74.98964	4.853493	25339.03	149.904129	10.53367	49.97493	53.92402	8.764343	None
50000	2352389_4-ERS-EX-7592	63.58217	4.115177	30570.24	149.904129	10.53367	57.58478	60.93312	8.764343	None
50000	2352397_17-ERS-EX-7592	68.10427	4.407857	30251.73	149.904129	10.53367	54.56812	58.1546	8.764343	None
50000	2352397_19-ERS-EX-7592	63.89653	4.135523	31958.86	149.904129	10.53367	57.37507	60.73997	8.764343	None
50000	2410567_241-ERS-EX-30247	60.59558	3.921879	0	60.59558487	3.921879	0	0	0	None
50000	3059308_170-ERS-EX-13327	43.40265	2.809115	22176.27	80.05443573	5.546528	45.78358	49.35363	3.849447	None
50000	3399044_1072-ERS-EX-7592	92.03521	5.95672	7167.15	116.8591232	7.563378	21.2426	21.2426	0	None
50000	3399044_1074-ERS-EX-7592	78.1335	5.05697	11559.51	116.8591232	7.563378	33.13873	33.13873	0	None
50000	3399095_1068-ERS-EX-7592	32.12958	2.079497	38789.53	116.8591232	7.563378	72.50571	72.50571	0	None
50000	3399095_1070-ERS-EX-7592	67.72762	4.383479	21237.71	116.8591232	7.563378	42.04337	42.04337	0	None

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	3399125_121-ERS-EX-7592	55.41238	3.586411	33224.78	152.0619202	10.68774	63.55933	66.44368	8.916196	None
50000	3399125_123-ERS-EX-7592	63.7471	4.125852	28608.57	152.0619202	10.68774	58.0782	61.39639	8.916196	None
50000	3399141_137-ERS-EX-7592	19.73128	1.277053	52519.06	152.0619202	10.68774	87.02418	88.05122	8.916196	None
50000	3399141_139-ERS-EX-7592	63.7471	4.125852	28608.57	152.0619202	10.68774	58.0782	61.39639	8.916196	None
50000	3399168_127-ERS-EX-7592	53.8971	3.488339	34682.93	152.0619202	10.68774	64.55582	67.36129	8.916196	R60
50000	3399168_129-ERS-EX-7592	63.76949	4.127301	28552.07	152.0619202	10.68774	58.06347	61.38283	8.916196	None
50000	3399176_133-ERS-EX-7592	63.81055	4.129958	28339.21	152.0619202	10.68774	58.03647	61.35797	8.916196	None
50000	3399176_135-ERS-EX-7592	55.41238	3.586411	33224.78	152.0619202	10.68774	63.55933	66.44368	8.916196	None
50000	3399567_332-ERS-EX-7592	29.03902	1.879469	47063.67	140.748291	9.879973	79.36812	80.97698	8.120229	None
50000	3399567_334-ERS-EX-7592	21.74291	1.40725	51949.24	140.748291	9.879973	84.55192	85.75654	8.120229	None
50000	3425045_754-ERS-EX-8131	55.75665	3.608692	4392.36	67.51158905	4.369498	17.41174	17.41173	0	None
50000	3425045_756-ERS-EX-8131	34.51603	2.233953	18219.91	67.51158905	4.369498	48.87392	48.87392	0	None
50000	3445151_9259-ERS-EX-62821	57.25699	3.705797	4432.74	67.07957459	4.341537	14.64318	14.64319	0	None
50000	3462277_28-ERS-EX-8131	93.88148	6.076215	14601.24	130.5836487	8.451659	28.10625	28.10625	0	None
50000	3462331_3A-ERS-EX-8131	8.329824	0.539125	47566.06	103.2300568	6.681275	91.93081	91.9308	0	None
50000	3462331_3B-ERS-EX-8131	79.7434	5.161168	8737.94	103.2300568	6.681275	22.75176	22.75175	0	None
50000	3462404_305A-ERS-EX-8131	72.30545	4.679767	10289.72	110.956604	7.181354	34.83448	34.83447	0	None
50000	3462404_305B-ERS-EX-8131	91.8248	5.943101	4722.36	110.956604	7.181354	17.2426	17.24261	0	None
50000	3556212_20-ERS-EX-13327	56.24646	3.640394	4392.36	65.72981262	4.254178	14.42778	14.42777	0	None
50000	3556255_8-ERS-EX-13327	56.24646	3.640394	4392.36	65.72981262	4.254178	14.42778	14.42777	0	None
50000	3556263_40-ERS-EX-62749	41.82071	2.706728	21649.65	76.49841309	5.292632	45.33128	48.85856	3.599203	None
50000	3556379_48-ERS-EX-13327	56.24646	3.640394	4392.36	65.72981262	4.254178	14.42778	14.42777	0	None
50000	3559785_1470-ERS-EX-30247	7.5742	0.49022	42859.84	75.48342896	5.220152	89.96575	90.60908	3.527653	R60
50000	3559793_357-ERS-EX-30247	8.209504	0.531339	41473.7	75.48342896	5.220152	89.1241	89.82139	3.527653	None
50000	3559807_353-ERS-EX-30247	41.75821	2.702684	22735.75	75.48342896	5.220152	44.67897	48.22596	3.527653	None
50000	3560201_514-ERS-EX-62749	41.82071	2.706728	21649.65	76.49841309	5.292632	45.33128	48.85856	3.599203	None
50000	3560708_1-102-ERS-EX-7592	13.0494	0.844587	61300.78	183.5531158	12.9362	92.89067	93.47113	11.13259	None
50000	3560708_2-102-ERS-EX-7592	18.55399	1.200855	55659.42	183.5531158	12.9362	89.89176	90.7171	11.13259	None
50000	3561267_6-ERS-EX-77315	61.58001	3.985593	38825.67	157.4839325	11.07495	60.89759	64.01255	9.298702	None
50000	3561267_8-ERS-EX-77315	14.09306	0.912134	64247.23	157.4839325	11.07495	91.05112	91.76399	9.298702	None
50000	3561313_10-ERS-EX-8131	51.11253	3.308115	31909.87	138.8920898	9.747458	63.19982	66.06177	7.989768	None
50000	3561429_86-ERS-EX-8131	55.21714	3.573774	33557.1	154.5239563	10.86357	64.26629	67.10312	9.089888	None

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	3561429_88-ERS-EX-8131	38.21609	2.47343	43657.47	154.5239563	10.86357	75.2685	77.23188	9.089888	None
50000	3561445_90-ERS-EX-8131	37.99315	2.459001	44516.39	154.5239563	10.86357	75.41278	77.3647	9.089888	None
50000	3561445_92-ERS-EX-8131	75.03072	4.856152	25234.59	154.5239563	10.86357	51.44396	55.29873	9.089888	None
50000	3561461_94-ERS-EX-8131	30.29698	1.960888	49475.12	157.788269	11.09664	80.79897	82.32899	9.319635	None
50000	3561461_96-ERS-EX-8131	66.00851	4.272215	29572.61	157.788269	11.09664	58.1664	61.49991	9.319635	None
50000	3561526_102-ERS-EX-8131	54.14922	3.504656	34328.94	154.5239563	10.86357	64.9574	67.73936	9.089888	R60
50000	3561526_104-ERS-EX-8131	38.21609	2.47343	43657.47	154.5239563	10.86357	75.2685	77.23188	9.089888	None
50000	3561631_27-ERS-EX-19491	19.87642	1.286445	46191.91	128.4644775	9.002943	84.5277	85.71084	7.256017	None
50000	3561712_568-ERS-EX-8131	65.30254	4.226524	12265.45	98.71836853	6.389269	33.84966	33.84966	0	None
50000	3561712_570-ERS-EX-8131	79.13235	5.121619	4722.36	98.71836853	6.389269	19.84029	19.84029	0	None
50000	3561828_449-ERS-EX-8131	63.32898	4.09879	28747.49	154.5239563	10.86357	59.01672	62.2703	9.089888	None
50000	3561828_453-ERS-EX-8131	36.74413	2.378161	45364.18	154.5239563	10.86357	76.22108	78.10883	9.089888	R60
50000	3561879_448-ERS-EX-8131	40.54975	2.624469	44049.27	154.5239563	10.86357	73.75828	75.84155	9.089888	None
50000	3561879_452-ERS-EX-8131	55.19239	3.572173	33653.41	154.5239563	10.86357	64.28231	67.11786	9.089888	None
50000	3561909_489-ERS-EX-8131	58.60345	3.792944	34379.2	157.788269	11.09664	62.85944	65.81898	9.319635	None
50000	3561909_493-ERS-EX-8131	63.79876	4.129196	30026.95	157.788269	11.09664	59.56686	62.78876	9.319635	None
50000	3561992_55-ERS-EX-19038	11.57328	0.749049	60884.19	194.5070496	13.7183	94.04994	94.53978	11.90338	None
50000	3561992_57-ERS-EX-19038	13.48228	0.872603	60511.91	194.5070496	13.7183	93.06849	93.63913	11.90338	None
50000	3562093_1613-ERS-EX-13327	62.68011	4.056794	28581.17	149.7566528	10.5232	58.14536	61.44903	8.75452	None
50000	3562093_1615-ERS-EX-13327	62.68011	4.056794	28581.17	149.7566528	10.5232	58.14536	61.44903	8.75452	None
50000	3562123_1621-ERS-EX-13327	8.10148	0.524346	58537.92	149.7566528	10.5232	94.59024	95.01723	8.75452	None
50000	3562123_1623-ERS-EX-13327	64.44011	4.170705	28792.86	149.7566528	10.5232	56.97012	60.36655	8.75452	None
50000	3562204_1833-ERS-EX-13327	18.88857	1.22251	56751.65	170.9509735	12.03642	88.95088	89.84324	10.24569	None
50000	3562204_1835-ERS-EX-13327	57.86575	3.745198	37577.33	170.9509735	12.03642	66.15068	68.88444	10.24569	None
50000	3562212_2242-ERS-EX-13327	56.85529	3.679798	25386.76	122.2324753	8.557998	53.48594	57.00165	6.817595	None
50000	3562301_91A-ERS-EX-8131	50.44347	3.264811	32800.24	131.9492645	8.540045	61.77056	61.77057	0	None
50000	3562301_91B-ERS-EX-8131	77.14896	4.993249	14315.1	131.9492645	8.540045	41.53134	41.53135	0	None
50000	3562344_131A-ERS-EX-8131	82.40401	5.333368	8577.64	105.1736145	6.807066	21.64954	21.64954	0	None
50000	3562344_131B-ERS-EX-8131	31.63374	2.047407	36204.92	105.1736145	6.807066	69.92236	69.92233	0	None
50000	3766039_196-ERS-EX-30247	39.34198	2.5463	21303.8	70.19107819	4.842277	43.95016	47.41524	3.155146	None
50000	3854205_163-ERS-EX-31351	61.6917	3.992822	32258.03	175.6212158	12.36992	64.8723	67.72153	10.57491	None
50000	3854205_165-ERS-EX-31351	28.41118	1.838835	50263.34	175.6212158	12.36992	83.82246	85.13463	10.57491	None

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	3854248_151-ERS-EX-31351	37.06652	2.399026	43876.51	175.6212158	12.36992	78.89406	80.60597	10.57491	None
50000	3854248_153-ERS-EX-31351	37.06652	2.399026	43876.51	175.6212158	12.36992	78.89406	80.60597	10.57491	None
50000	3883728_73-ERS-EX-13327	51.6204	3.340985	17082.38	78.87186432	5.462084	34.55157	38.83313	3.766119	None
50000	4078721_12563-ERS-EX-7462	61.54193	3.983129	0	61.54193497	3.983129	0	0	0	None
50000	4103025_45A-ERS-EX-11576	57.96593	3.751682	4392.36	70.37200928	4.554631	17.62928	17.62928	0	None
50000	4103025_45B-ERS-EX-11576	30.4819	1.972856	21569.46	70.37200928	4.554631	56.68462	56.68462	0	None
50000	4641159_9-ERS-EX-76989	40.27477	2.606671	17829.02	72.575737	4.69726	44.50657	44.50655	0	None
50000	4653025_19-ERS-EX-13327	43.40265	2.809115	22176.27	80.05443573	5.546528	45.78358	49.35363	3.849447	None
50000	4653378_105-ERS-EX-13327	51.89447	3.358724	17290.7	80.05443573	5.546528	35.17602	39.44456	3.849447	None
50000	4699424_36-ERS-EX-11576	69.46994	4.496247	24532.83	143.2661896	10.05974	51.50988	55.30454	8.297312	None
50000	4699424_36A-ERS-EX-11576	35.62598	2.305791	43447.52	143.2661896	10.05974	75.13302	77.07901	8.297312	None
50000	4699637_561-ERS-EX-7830	53.16283	3.440815	24101.68	133.3601379	9.352475	60.13589	63.20958	7.600405	None
50000	486744_633-ERS-EX-7462	59.01194	3.819382	0	59.01193619	3.819382	0	0	0	None
50000	4913515_100-ERS-EX-7662	82.0101	5.307873	4599.77	100.8672867	6.528352	18.69505	18.69505	0	None
50000	4913515_102-ERS-EX-7662	84.68684	5.481118	4392.36	100.8672867	6.528352	16.04133	16.04132	0	None
50000	4935292_138-ERS-EX-7830	61.31471	3.968423	0	61.31471252	3.968423	0	0	0	None
50000	5021987_718-ERS-EX-14995	61.92505	4.007925	4392.36	75.43872833	4.88256	17.91345	17.91346	0	None
50000	508128_25-ERS-EX-76987	17.98624	1.16411	47371.68	117.7765427	8.239939	84.7285	85.87235	6.504975	None
50000	508128_36947-ERS-EX-76987	11.85642	0.767374	50842.35	117.7765427	8.239939	89.93312	90.68714	6.504975	None
50000	5133491_16-ERS-EX-30247	39.64855	2.566142	22036.44	69.96665192	4.826258	43.33221	46.82958	3.139415	None
50000	5250196_8-ERS-EX-29440	49.66894	3.214683	16632.53	75.23123169	5.202115	33.9783	38.20432	3.509594	None
50000	5282136_2241-ERS-EX-13327	43.40265	2.809115	22176.27	80.05443573	5.546528	45.78358	49.35363	3.849447	None
50000	5282152_2363-ERS-EX-13327	51.89447	3.358724	17290.7	80.05443573	5.546528	35.17602	39.44456	3.849447	None
50000	5282179_1687-ERS-EX-13327	51.89447	3.358724	17290.7	80.05443573	5.546528	35.17602	39.44456	3.849447	None
50000	5283337_152-ERS-EX-30247	48.71644	3.153035	16418.23	70.19107819	4.842277	30.59454	34.88529	3.155146	None
50000	5283345_140-ERS-EX-30247	39.34198	2.5463	21303.8	70.19107819	4.842277	43.95016	47.41524	3.155146	None
50000	5313414_150-ERS-EX-62749	25.01377	1.618947	32593.13	76.49841309	5.292632	67.30159	69.41131	3.599203	None
50000	5336724_44-ERS-EX-13327	40.24531	2.604765	21649.07	76.68723297	5.306127	47.5202	50.91024	3.612635	None
50000	5363608_158-ERS-EX-62749	50.51537	3.269465	16764.08	76.49841309	5.292632	33.96547	38.22611	3.599203	None
50000	5391644_1043-ERS-EX-19491	70.29435	4.549604	0	70.29434967	4.549604	0	0	0	None
50000	5401135_1041-ERS-EX-19491	24.93989	1.614164	23559.36	70.29434967	4.549604	64.52078	64.52078	0	None
50000	5434475_89-ERS-EX-32181	45.14602	2.92195	22233.63	81.48829651	5.648952	44.59815	48.27448	3.950853	None

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	5521157_56-ERS-EX-77315	20.91901	1.353925	24539.12	68.47338104	4.431747	69.44943	69.4494	0	None
50000	5521173_120-ERS-EX-77315	45.56306	2.948942	23001.66	81.59298706	5.656409	44.15811	47.86548	3.958024	None
50000	5575419_1040-ERS-EX-19491	57.36527	3.712806	5199.86	70.29434967	4.549604	18.39277	18.39278	0	None
50000	5575427_1035-ERS-EX-19491	35.57224	2.302313	19167	70.29434967	4.549604	49.39531	49.3953	0	None
50000	5627966_28-ERS-EX-62749	51.17756	3.312323	16990.25	77.71875	5.379759	34.15031	38.42989	3.68503	None
50000	5628008_43-ERS-EX-8131	73.72813	4.771846	0	73.72812653	4.771846	0	0	0	None
50000	5628008_45-ERS-EX-8131	31.06998	2.010917	22970.36	73.72812653	4.771846	57.85872	57.85873	0	None
50000	563129_6-ERS-EX-29440	49.66894	3.214683	16632.53	75.23123169	5.202115	33.9783	38.20432	3.509594	None
50000	5703824_8-ERS-EX-13327	61.23831	3.963478	4392.36	72.75408936	4.708804	15.82836	15.82835	0	None
50000	5703832_4-ERS-EX-13327	61.23831	3.963478	4392.36	72.75408936	4.708804	15.82836	15.82835	0	None
50000	5745497_18-ERS-EX-29440	55.42615	3.587301	4392.36	66.510849	4.304728	16.66601	16.66601	0	None
50000	5759331_6B-ERS-EX-11576	54.44819	3.524006	6406.35	66.62473297	4.312098	18.27631	18.27629	0	None
50000	580481_13-ERS-EX-14995	57.32704	3.710332	28571.94	155.7960205	10.95436	63.20379	66.12918	9.179141	None
50000	580481_15-ERS-EX-14995	23.04449	1.491492	48760.23	155.7960205	10.95436	85.20855	86.38449	9.179141	None
50000	580538_12-ERS-EX-14995	24.9209	1.612937	50789.93	174.1044006	12.26157	85.68623	86.84559	10.46761	None
50000	580538_14-ERS-EX-14995	63.39532	4.103084	29179.17	174.1044006	12.26157	63.58775	66.53704	10.46761	None
50000	580597_41-ERS-EX-14995	66.71576	4.31799	31084.71	158.0410919	11.1147	57.78581	61.15065	9.337599	None
50000	580597_43-ERS-EX-14995	62.87045	4.069113	30131.13	158.0410919	11.1147	60.21892	63.38982	9.337599	None
50000	580783_10-ERS-EX-8131	61.30177	3.967585	21531.94	121.5919495	8.512262	49.58403	53.38977	6.772493	None
50000	580783_12-ERS-EX-8131	29.67427	1.920585	38932.81	121.5919495	8.512262	75.5952	77.43744	6.772493	None
50000	580791_14-ERS-EX-8131	52.04395	3.368399	25093.45	121.5919495	8.512262	57.19786	60.42887	6.772493	None
50000	580791_16-ERS-EX-8131	61.05915	3.951882	21482.52	121.5919495	8.512262	49.78356	53.57424	6.772493	None
50000	580813_6-ERS-EX-14995	21.18233	1.370968	53797.67	158.0410919	11.1147	86.59695	87.66528	9.337599	None
50000	580813_8-ERS-EX-14995	28.39177	1.837578	50708.08	158.0410919	11.1147	82.0352	83.46714	9.337599	None
50000	580953_2-ERS-EX-14995	64.95558	4.204067	31234.19	166.4365692	11.71414	60.97277	64.11116	9.928452	None
50000	580953_4-ERS-EX-14995	32.16907	2.082053	52362.77	166.4365692	11.71414	80.67187	82.22615	9.928452	None
50000	581127_33-ERS-EX-14995	34.32736	2.221744	35523.69	120.7578278	8.452728	71.57339	73.71566	6.714026	None
50000	5816106_5-ERS-EX-11576	69.3215	4.486639	4392.36	82.91817474	5.366645	16.3977	16.39769	0	None
50000	5816106_7-ERS-EX-11576	69.3215	4.486639	4392.36	82.91817474	5.366645	16.3977	16.39769	0	None
50000	5820006_298-ERS-EX-30247	32.84737	2.125954	15528.05	59.80330277	3.870601	45.07433	45.07433	0	None
50000	5854156_373-ERS-EX-20338	25.75293	1.666787	29303.64	87.13926697	5.639844	70.44624	70.44621	0	None
50000	5854156_373A-ERS-EX-20338	87.13927	5.639844	0	87.13926697	5.639844	0	0	0	None

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	5957613_371-ERS-EX-13327	65.62415	4.247338	0	65.62414551	4.247338	0	0	0	None
50000	5970482_1402-ERS-EX-13327	51.63867	3.342168	17544.42	81.79393768	5.670738	36.86737	41.06291	3.971962	None
50000	5986559_95-ERS-EX-7592	85.99447	5.565749	4392.36	104.1069641	6.738031	17.39797	17.39798	0	None
50000	5986559_97-ERS-EX-7592	85.99447	5.565749	4392.36	104.1069641	6.738031	17.39797	17.39798	0	None
50000	5990394_920-ERS-EX-30247	59.02159	3.820007	0	59.02159119	3.820007	0	0	0	None
50000	6033229_2727-ERS-EX-20105	42.65264	2.760573	21914.77	76.82579041	5.315996	44.48136	48.07045	3.622116	None
50000	6034608_270-ERS-EX-13327	59.8362	3.87273	4392.36	70.20806885	4.544019	14.77304	14.77302	0	None
50000	6052797_81-ERS-EX-19491	65.81545	4.25972	0	65.81545258	4.25972	0	0	0	None
50000	6055478_1357-ERS-EX-63100	63.72734	4.124573	0	63.72734451	4.124573	0	0	0	None
50000	6113672_1037-ERS-EX-7830	62.34962	4.035404	0	62.349617	4.035404	0	0	0	None
50000	6119611_1171-ERS-EX-20338	65.71602	4.253284	4392.36	77.71365356	5.029797	15.43826	15.43826	0	None
50000	6120822_54-ERS-EX-13327	63.74603	4.125783	4392.36	75.84539795	4.90888	15.95267	15.95266	0	None
50000	6137679_201-ERS-EX-14995	37.72464	2.441622	24797.04	75.68908691	5.234813	50.15841	53.35799	3.541889	None
50000	6160336_19-ERS-EX-11576	48.09974	3.113121	10085.43	67.76784515	4.386083	29.02278	29.02276	0	None
50000	6199496_11A-ERS-EX-8131	20.42362	1.321863	26376.21	71.3425293	4.617445	71.37244	71.37241	0	None
50000	6199496_11B-ERS-EX-8131	20.42362	1.321863	26376.21	71.3425293	4.617445	71.37244	71.37241	0	None
50000	6218911_118-ERS-EX-7462	52.20325	3.378709	4392.36	62.30278397	4.032373	16.2104	16.21041	0	None
50000	6250505_145-ERS-EX-7194	52.8336	3.419507	4392.36	61.86510468	4.004045	14.5987	14.59869	0	None
50000	6254683_33-ERS-EX-13327	70.42026	4.557753	0	70.42025757	4.557753	0	0	0	None
50000	6254705_37-ERS-EX-13327	56.06659	3.628753	4392.36	64.78400421	4.192962	13.45612	13.45611	0	None
50000	6256279_53-ERS-EX-11576	70.75765	4.57959	89.87	70.7821579	4.581177	0.034621	0.034626	0	None
50000	6269788_28-ERS-EX-7830	60.32758	3.904534	0	60.32758331	3.904534	0	0	0	None
50000	6302017_42-ERS-EX-7592	68.08574	4.406658	4392.36	80.26912689	5.195193	15.17817	15.17816	0	None
50000	6381316_655-ERS-EX-30247	58.67273	3.797428	0	58.67272949	3.797428	0	0	0	None
50000	6388116_44937-ERS-EX-77315	86.42484	5.593605	0	86.42484283	5.593605	0	0	0	None
50000	6388116_44968-ERS-EX-77315	74.49225	4.821301	4392.36	86.42484283	5.593605	13.8069	13.80692	0	None
50000	64211_33-ERS-EX-32181	53.59754	3.46895	17348.06	81.48829651	5.648952	34.2267	38.59126	3.950853	None
50000	6440975_28-ERS-EX-29440	57.11359	3.696517	4392.36	69.34848785	4.488386	17.64264	17.64264	0	None
50000	6440983_30-ERS-EX-29440	57.11359	3.696517	4392.36	69.34848785	4.488386	17.64264	17.64264	0	None
50000	6465978_28-ERS-EX-13327	63.17799	4.089018	4392.36	74.66004944	4.832162	15.37912	15.37911	0	None
50000	653055_24-ERS-EX-13327	43.40265	2.809115	22176.27	80.05443573	5.546528	45.78358	49.35363	3.849447	None
50000	653071_13-ERS-EX-8131	49.849	3.226337	31065.28	131.8286743	9.24315	62.18652	65.09483	7.492832	None

iteration	houseFileName	totalEnergy	totalEmissi	totalCost	baseEnergy	baseEmiss	energySavi	emissionSa	nonElectric	Attic
50000	653071_15-ERS-EX-8131	26.01662	1.683853	44609.72	131.8286743	9.24315	80.26482	81.78269	7.492832	None
50000	7015585_110-ERS-EX-7194	66.58946	4.309816	0	66.58946228	4.309816	0	0	0	None
50000	7624905_209-ERS-EX-11576	56.81922	3.677464	4392.36	68.9769516	4.464339	17.62579	17.62578	0	None
50000	7624905_211-ERS-EX-11576	56.81922	3.677464	4392.36	68.9769516	4.464339	17.62579	17.62578	0	None
50000	7645287_28-ERS-EX-11576	56.23642	3.639744	4392.36	65.08943176	4.21273	13.6013	13.6013	0	None
50000	8046735_6568-ERS-EX-30247	59.03261	3.820719	0	59.03260803	3.820719	0	0	0	None
50000	8074402_945-ERS-EX-30247	59.5587	3.854769	201.32	59.84415817	3.873245	0.477008	0.477014	0	None
50000	8157510_8-ERS-EX-31599	54.64131	3.536506	4392.36	68.75689697	4.450096	20.5297	20.52969	0	None
50000	8175616_23-ERS-EX-30247	60.59558	3.921879	0	60.59558487	3.921879	0	0	0	None
50000	8175624_29-ERS-EX-30247	60.59558	3.921879	0	60.59558487	3.921879	0	0	0	None
50000	8191158_282-ERS-EX-30247	40.80223	2.64081	22155.12	71.88292694	4.963075	43.23794	46.79085	3.27423	None
50000	824445_25-ERS-EX-8131	27.93994	1.808335	39252.73	123.8712692	8.675061	77.44437	79.15479	6.933503	None
50000	824445_29-ERS-EX-8131	60.47902	3.914335	21238.18	123.8712692	8.675061	51.17591	54.8783	6.933503	None
50000	824461_21-ERS-EX-8131	28.35727	1.835345	38511.73	123.8712692	8.675061	77.10747	78.84343	6.933503	None
50000	824461_23-ERS-EX-8131	51.20322	3.313985	25636.49	123.8712692	8.675061	58.66416	61.79871	6.933503	None
50000	8359482_865-ERS-EX-30464	40.59484	2.627387	20769.93	89.42159271	5.787561	54.60287	54.60286	0	None
50000	8400342_87-ERS-EX-5985	48.14515	3.11606	16198.4	73.89768982	5.106936	34.84891	38.98376	3.416096	None
50000	8400350_89-ERS-EX-5985	48.14515	3.11606	16198.4	73.89768982	5.106936	34.84891	38.98376	3.416096	None
50000	8470081_79-ERS-EX-14995	55.82206	3.612926	4392.36	67.98808289	4.400338	17.89435	17.89435	0	None

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement \	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	Batt + EPS (	None	None	None	None	Air Sealing	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	EPS (R8)	None	Spray Foam	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15k	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	Batt + EPS (	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	Spray Foam	None	None	None	None	None	None	None
None	None	None	None	Spray Foam	None	None	None	None	ASHP (15k	None	None
None	None	Batt + EPS (	None	Spray Foam	None	Ins. Steel (	Air Sealing	None	ASHP (15k	Elec. Tank (	Solar PV
None	None	Batt + EPS (	None	Spray Foam	None	Ins. Steel (	Air Sealing	None	ASHP (15k	HPWH (UE	None

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement V	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	None
None	None	Batt + EPS (	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	Batt + EPS (	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	None
None	None	EPS (R8)	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	None	None	Solar PV
None	None	EPS (R8)	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	Spray Foam	Spray Foam	None	None	None	None	ASHP (15kE	Elec. Tank (	None
None	None	None	None	Spray Foam	None	Ins. Steel (F	Air Sealing	None	ASHP (15kE	HPWH (UEI	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	None	None	None
None	None	None	None	Spray Foam	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	None
None	None	EPS (R8)	None	Spray Foam	None	None	None	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	None
None	None	EPS (R8)	None	Spray Foam	None	None	None	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	Batt + EPS (	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	None

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement W	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	Batt + EPS (	None	None	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	EPS (R8)	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	Solar PV
None	None	EPS (R8)	None	Spray Foam	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	Blown Cell	None	None	Spray Foam	None	None	None	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP (15k	None	None
None	None	EPS (R8)	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	EPS (R8)	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	Batt + EPS (	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	EPS (R8)	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Ne	HPWH (UE	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	None
None	None	None	Spray Foam	Spray Foam	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	Blown Cell	None	Spray Foam	None	None	None	Air Sealing	None	ASHP (15k	None	Solar PV
None	None	EPS (R8)	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP (15k	None	None
None	None	None	None	Spray Foam	None	None	None	None	None	None	None
None	None	None	Spray Foam	None	None	None	Air Sealing	None	ASHP (15k	HPWH (UE	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	Spray Foam	None	Ins. Steel (	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	Solar PV

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement W	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	None	None	Solar PV
None	None	None	None	None	None	None	None	None	None	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	EPS (R8)	None	None	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	None
None	None	Batt + EPS (	None	Spray Foam	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	EPS (R8)	Spray Foam	None	None	None	Air Sealing	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	Spray Foam	None	None	None	None	None	ASHP + Ne	HPWH (UE	Solar PV
None	None	None	None	None	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP + Ne	HPWH (UE	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement \	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	None	None	None	Air Sealing	None	None	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	None	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	EPS (R8)	Spray Foam	None	None	None	Air Sealing	None	ASHP (15kE	Elec. Tank (	None
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	Elec. Tank (	None
None	None	Batt + EPS (	None	Spray Foam	None	None	None	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	Spray Foam	None	None	None	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	None	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	Solar PV
None	None	None	None	None	None	None	None	None	None	None	None

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15k	HPWH (UE	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15k	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	EPS (R8)	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP (15k	None	None
None	None	None	None	None	None	None	None	None	ASHP + Ne	HPWH (UE	None
None	None	EPS (R8)	None	Spray Foam	None	None	None	None	ASHP + Ne	HPWH (UE	None

Flat Ceiling	Wall	Exp. Floor	Floor Head	Basement \	Window	Door	Air Seal	Ventilation	ASHP	DHW	Solar PV
None	None	None	None	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	HPWH (UEI	Solar PV
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	Air Sealing	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	None	None	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	HPWH (UEI	None
None	None	None	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	Batt + EPS (	None	None	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	Batt + EPS (	None	Spray Foam	None	None	None	None	ASHP + Nev	Elec. Tank (	Solar PV
None	None	Batt + EPS (	Spray Foam	Spray Foam	None	None	Air Sealing	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	Solar PV
None	None	None	None	None	None	None	None	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP + Nev	Elec. Tank (	None
None	None	None	None	None	None	None	None	None	ASHP (15kE	None	None

Appendix C: Volta SNAP Software

A screenshot of the results page of the Community Parametric Analysis tool in Volta SNAP is included below. At the time of report writing, this feature is going through quality assurance and will be released to the public alongside the next iteration of the single-home parametric analysis feature (Q4 2024).