

Building Performance Professionals Association of Vermont

**Zero Energy Now Pilot Programs 2016 & 2017
Project Study Report**

Compiled by

Thomas S. Perry

New Leaf Design, LLC

&

Li Ling Young

Efficiency Vermont

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Pilot Program Overview

What is ZEN?

Comprehensive energy support including weatherization, efficient heating solutions, and solar PV, which results in drastic energy and greenhouse gas reductions for the homeowner.

Why Zero Energy Now?

Customer Benefit

Help individuals dramatically reduce energy bills, their carbon footprint, and create a more comfortable home – all at an affordable cost.

Contractor Benefit

Encouraging comprehensive energy projects makes the work more cost effective for the contractor, resulting in a vibrant and healthy energy workforce.

“

I feel proud and satisfied to be able to make a difference, and the improved comfort is significant.

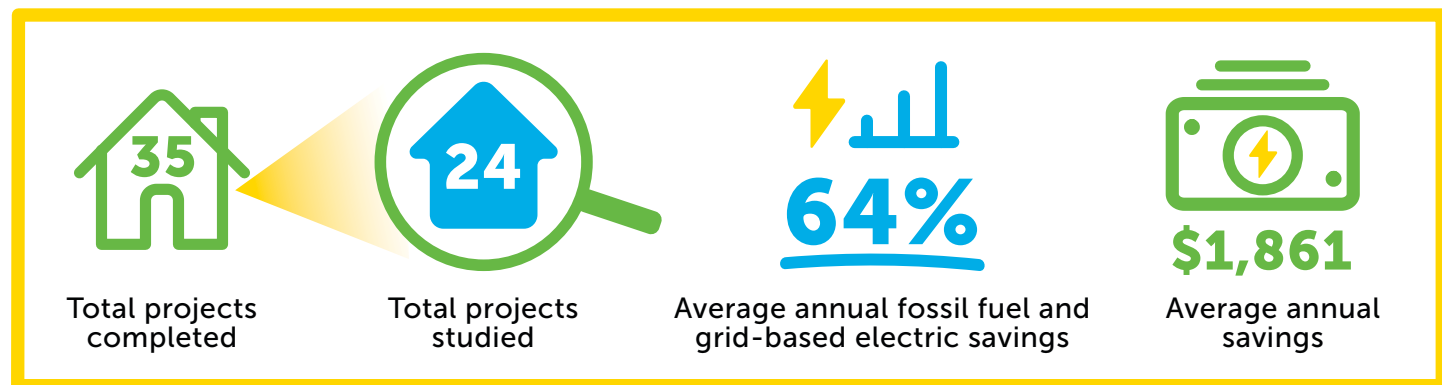
- ZEN Homeowner

“

If we could *only* do ZEN projects, that would be great. This really is our business model. We want to be involved with the clients.

- ZEN Contractor

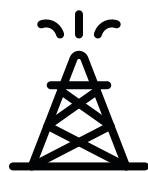
Zero Energy Now 2016-2017 Pilot Program at a Glance



Participants included homeowners across the state – from farmers to teachers to retirees. Common traits among participants were being **environmentally conscious** and **frugal**.

Each year, and **every year**, these 24 homes will:

AVOID BURNING



8,820
gallons of
fuel oil

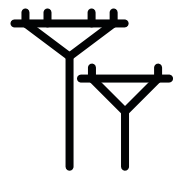


3,103
gallons of
propane



21
cords of
wood

GENERATE



201,468
kilowatt hours
of electricity

SAVE

\$44,670
in energy costs



114
metric tons
of CO2

Savings Results

DISTRIBUTION OF ENERGY SAVINGS

10%-40%	4 homes
41%-80%	14 homes
81%-100%	6 homes

HIGHEST SAVINGS

98%

in fossil fuel
and grid-based
electric savings

\$3,885

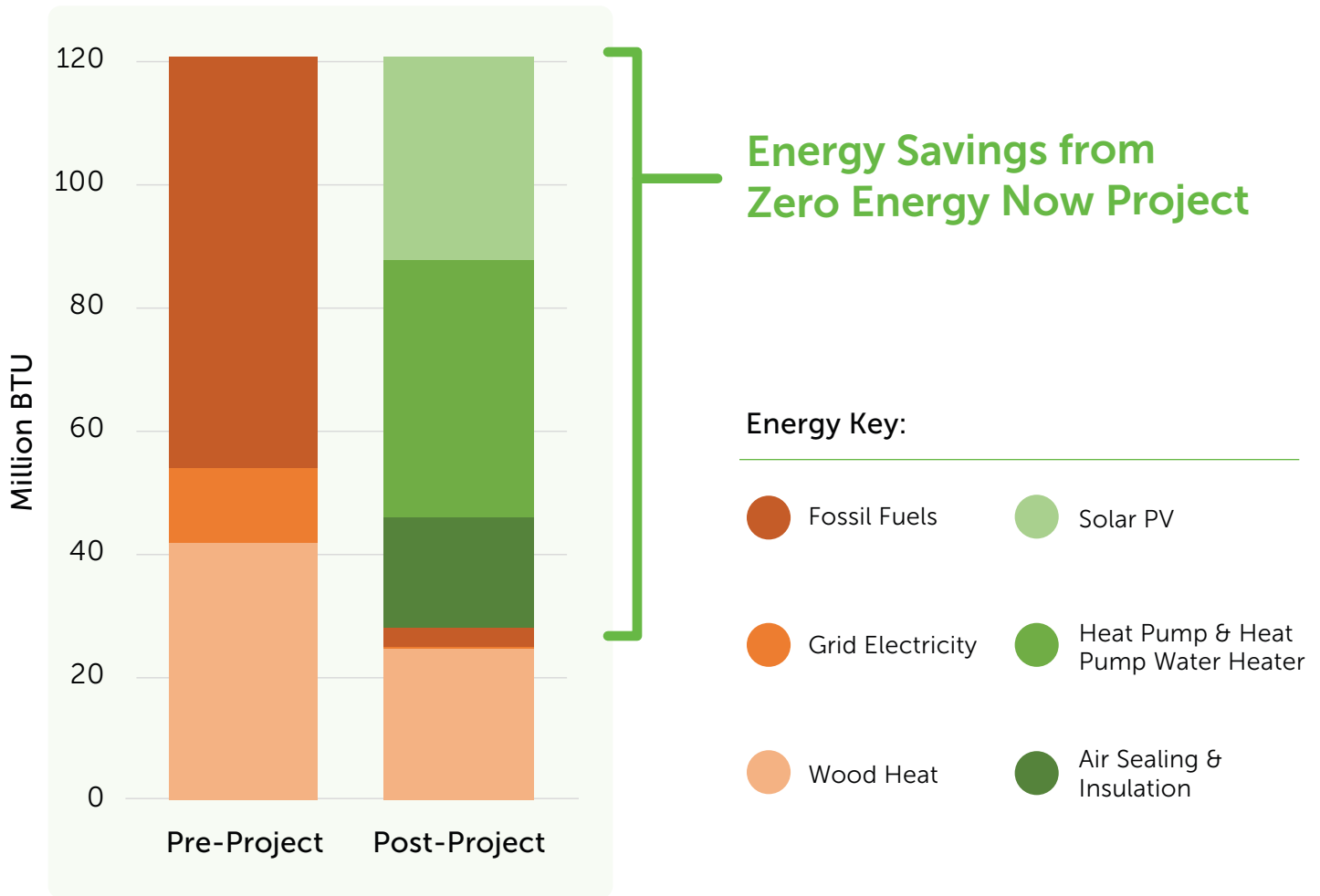
in annual
energy cost
savings

AVERAGE: \$1,861

- **AVERAGE PROJECT COST \$54,565**
- **AVERAGE INCENTIVE & REBATE \$13,022**
- **AVERAGE RETURN ON INVESTMENT 5.58%**



Annual Energy Use



Benefits

- Weatherization improves comfort and allows the heat pump to manage a significant portion of heating load.
- Super-efficient heat pump technology sharply reduces energy consumption for heating, while also providing efficient air conditioning in summer months.
- 99% of electricity is sourced renewably on site.



Pilot Program

Results: Lessons Learned

- Comprehensiveness is the key to Zero Energy Now. Each element (weatherization, heat pumps, and customer ownership of renewable generation) must work together for the project's success.
- Cost is not a defining characteristic of a successful project, but incentives are important to achieve customer commitment and promote the program.
- Project design is critical, particularly heat pump sizing. A well-designed modeling tool will be critical to effective design and sales of Zero Energy Now Projects.
- Zero Energy Now is effective in a variety of house styles.
- Wood heat works well in conjunction with heat pumps.
- Customer education is critical to ensure customer satisfaction and proper performance (particularly when it comes to new technologies like heat pumps). Contractors should plan to touch base with customers after they've had time to get to know their "new" home.



“

We're able to hit the zero energy target; and we're warmer now because we can afford to keep the house warmer.

- ZEN Homeowner

“

People would seek us out; work seemed to find us. The projects were bigger so the profit margin for time put into it was better.

- ZEN Contractor



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Overview

Introduction

In 2015, the Building Performance Professionals Association of Vermont (BPPA-VT or BPPA) applied for and received a grant through Green Mountain Power's Community Energy and Efficiency Development (CEED) Fund to create a pilot program that would allow homeowners to combine the strategies of

- weatherization,
- super-efficient mechanicals (heat pumps and heat pump water heaters) and/or efficient and clean advanced wood heat, and
- renewable electricity generation

to maximize reductions of fossil fuel use in their existing homes, and radically reduce their greenhouse gas emissions. The program came to be known as *Zero Energy Now*. Although the cost of undertaking such a comprehensive project would be quite high, by effectively minimizing actual cash outlays for energy bills, it would be possible for the homeowner to absorb the cost of the likely loan that would be required to finance the project – without substantially greater monthly financial burden.

The first pilot program in 2016 brought 22 projects to completion, and a second, less robust, pilot program was undertaken in 2017 which brought an additional 13 projects to completion. Modeling tools (EUSAVE in 2016, and CLEAR in 2017) were used to define the best strategies in each program for reducing fossil fuel usage in each home.

With one full winter season after the second pilot now behind us, and two seasons after the first pilot, it has become possible to examine fuel and electricity usage for the homes involved in these programs, to compare them to our modeling projections, and to see, generally, how they have performed with the various improvements.

Not all homeowners were available, and, in a few cases, data was impossible to obtain, but we have been able to gather significant data for 24 of the 35 completed projects.

This study you are reading now, undertaken through a grant from the Vermont Department of Public Service, attempts to review actual fuel usages for these projects – both before and after the project work scope was completed – and to discover the actual effective results of the improvements with respect to fossil fuel savings, energy cost savings, and overall cost and benefit from the point of view of the homeowner. Through interviews with the homeowner, we attempted to gain an understanding of their sense about the project – in particular, whether they are comfortable, and happy with the results.

The study also looks closely at the financeability of the projects, especially with respect to the energy savings, and at the potential of the program as a feasible and affordable broad-scale strategy to get existing homes throughout the state off of fossil fuel. For the program to be viable and scalable as such, it would also have to appeal to the contractors in the various trades associated with it as something that could be beneficial to their businesses and as something around which a successful business model could be developed. The study looks at this as well.

Overall Findings

As noted above, we obtained complete fuel data for 24 homes. Because the electric grid still has a substantial fossil fuel component, and because there are other environmentally or socially compromising elements such as nuclear power, and flooding of indigenous lands for hydropower (in the case of Hydro-Quebec), one of the program goals was to minimize grid-sourced electricity as well as fossil fuel. This was also important for savings and financing considerations as will be explained later. **The leading program metric, therefore, was defined as fossil fuel and grid-sourced electric savings.**

- **Energy Savings: average annual fossil fuel and grid electric savings were 63.93%. Four projects obtained over 90% savings.** The lowest performing project obtained only 14% savings, but this was largely because the homeowner removed her wood stove and effectively substituted one renewable fuel (solar electric) for another (cord wood). Other homes did not perform as well for a variety of reasons:
 - Substituting one renewable fuel for another -- instead of for fossil fuel, as modeled (same as above);
 - Solar array was not large enough to accommodate heat pump load;
 - Heat pump installed was not cold climate, and not designed to be used throughout winter;
 - Heat pump system was oversized and not performing efficiently;
 - Homeowner only using heat pumps supplementally, not as primary heat.

It is important to note that the *Zero Energy Now* standard for the 2016 pilot only required 50% fossil fuel and grid-drawn electric savings and a 50% post-project renewable energy portfolio; many homes in the program met this standard without exceptionally high savings numbers. (See page 24.)

- **Cost Savings: Average annual energy cost savings was 59.98%. One project obtained 96% in annual cost savings, while four others obtained savings between eighty and ninety percent, and an additional four obtained savings between seventy and eighty percent.** The project with the lowest annual savings came in at just 25%. These savings do not include the cost of the project itself, just the cost of the energy used after the project was completed. (See page 25.)
- **Financeability:** The average cost of a Zero Energy Now project, based on the 24 projects studied, was \$54,500. The average of combined incentives and the federal tax rebate was \$13,000. **The average net cost of a ZEN project to the homeowner, therefore, was \$41,500. What makes these projects feasible for most homeowners is the substantial *avoided energy costs* once the**

project is complete. The average annual energy cost reduction for these 24 projects was \$1,878 per year – over \$150 per month.

To determine the “financeability” of these projects, a uniform financing rate of 5.25% over a term of 20 years was applied. This rate and term was based on an actual financing rate that was available within the last year. It was chosen for purposes of this study because it allows the lowest monthly payment, of any “off the shelf” loan option found online from a local bank or credit union. Its use here does not imply that it was available to or used by any homeowner who participated in either of the BPPA pilot programs. **Under this financing formula, four of the 24 projects studied were effectively “cash flow positive”** in the sense that the combined post-project energy costs and financing costs were less than the pre-project energy costs alone. The best performing project in this respect had pre-project energy costs of over \$4,500 annually. After the project was completed, these costs dropped to just \$650 annually. Annual loan payments at the above rate and term would be \$2,140, which, combined with the energy costs would amount to \$2,790 – a savings of over \$1,700 per year or \$140 per month in out-of-pocket savings. **In addition to the four “cash flow positive” projects, four other projects under this financing formula would require small monthly out-of-pocket outlays ranging from \$17 to \$33. There were six other projects with a monthly outlay of less than \$100, and the rest (10 others) that ranged from \$103 to – in the case of a very large project that was not financed – \$761. (See pages 26-27.)**

- **Fossil Fuel Savings Alone:** While the argument has already been made as to why grid electric savings is important alongside of fossil fuel, program savings of straight fossil fuel was very impressive. Two participating homes were 100% fossil fuel free, and eight others achieved savings of 90% or greater. **All told, nine projects – more than a third of those studied – derived less than 10% of their total post-project energy from fossil fuels. This speaks well to the effectiveness of heat pumps as a potential alternative home heating strategy. (See pages 30-31.)**

Key correlations and other observations from findings

- **Design is critical.** The essential premise of Zero Energy Now is that the system components work together to drive down energy costs. This requires careful attention to managing the energy loads, mostly through weatherization, and to the sizing and design of the mechanical components to meet those loads. Due to very strict deadlines related to the CEED grant, and a very narrow window for completing projects, BPPA was forced to raise project numbers by finding projects that were already underway, and thus not really fully designed as Zero Energy Now projects. Qualifying components in these projects were patched together to meet the ZEN standard. Many of these projects already had one or more components – usually solar – completed or in the works. As one might expect, most of these projects did not perform as well, as the components were not designed to work together as a system. The most common combination of poorly performing elements was solar that was insufficient to cover the heating loads, along with heat pumps that were often oversized, or, in one case, not designed to perform in cold weather. One or two non-designed projects did perform well, perhaps just circumstantially, but the point of the Zero Energy Now Program is to avoid the haphazard, circumstantial approach that occurs when the market is left to its own devices.

- **Comprehensiveness of project is the key to success.** The most successful projects varied in cost, in fuels applied, in specific strategies and approaches, but they all attempted to address the energy loads in the house as comprehensively as possible. Usually this included installing a heat pump water heater, and substantial coverage of primary heating loads with heat pumps or with a combination of heat pumps and biomass heat (usually cord wood).
- **Cost is not a defining characteristic of a successful project.** The most successful project in terms of total fossil fuel and grid-sourced electricity was also the most expensive. The second most successful project, however, was the least expensive, and also one of the most affordable. Although, Zero Energy Now products are expensive by nature, no specific or general correlation between project cost and performance was found. There is an upper limit to cost if the homeowner wishes to finance, and to keep costs within range of pre-project energy bills.
- **Solar buy-in important if not critical for the affordability of the ZEN concept.** The success of the program with respect to financing in particular, but also to homeowner appeal in general, is highly dependent on steep reductions in energy costs. This is only possible if the homeowner can sharply reduce his electric bill by generating his own electricity. Maintaining the essential benefit of some form of net-metering is critical to this. If some utilities are resistant to this, a creative alternative strategy that allows – and encourages – **the homeowner’s effective “buy-in” to the home’s power generation is critical to the cost benefit and financeability of the Zero Energy Now concept.**
- **Zero Energy Now is effective in a variety of house styles.** While a simpler house with a rectangular footprint, fewer nooks and crannies and isolated spaces, will more easily accommodate a ZEN type retrofit, several of the best performing projects were notable exceptions to this. One of these was a project essentially without a budget, but another was very much on a budget, and also was by far the most successful project in terms of financeability. **Certainly, some houses will be more challenging than others to heat effectively with non-fossil sources, especially point-source heat pumps, but there are various heating options available, and used in combination, these can be made to work in most houses.**
- **Weatherization is also a key component of affordability.** All the homes that performed well in this study undertook fairly robust weatherization work. This was not necessarily expensive, but it had to be reasonably comprehensive – allowing for substantially greater effectiveness (and less use) of heat. Point source heat pumps in particular require a well-sealed envelope to provide effective comfort, to raise the temperature in a house, and to substitute effectively for a fully distributed heating system.
- **Heat pump system design and installation needs to be considered carefully in order to achieve best performance and efficiency.** Mechanical installers who have been trained on traditional equipment ranging from space heaters and wood stoves to centrally fired distribution systems, are finding that heat pumps require fundamentally different intuitions with regard to design, sizing, and appropriate seasonal use and operation. Homeowners and other users who are familiar with traditional heating systems are also likely to need instruction in best practice use of heat pumps. Heat pump technologies are also evolving more rapidly than other elements of the

Zero Energy Now system, and this will require ongoing training and evolving design expertise in the coming years.

- **Biomass heat works well in conjunction with heat pumps.** Several of the more successful projects had some form of biomass in the mix – usually a wood or pellet stove. Heat pumps work well to maintain temperature, but have less capacity than biomass to operate at high Btu output rates and bring the temperature up in a house. Biomass also is an effective backup and supplement to a heat pump system in very cold weather.

Modeling Tools

Without effective modeling, Zero Energy Now would not be marketable as a program. Because of the enormous investment – \$30,000 to \$60,000 – on the part of the homeowner, the program has to be able to prove both the environmental and economic benefit of the work undertaken. Each element of the work scope has to be carefully vetted for effectiveness and value, and the homeowner has to be convinced that the investment they are about to make is worth the money. Furthermore, if the project is financed, the financing will be contingent on reliable energy cost savings estimates.

Two different modeling tools were used for the pilots – EUSAVE, developed by Parsec Energy, and adapted for use by the Zero Energy Now program in 2016; and CLEAR developed by New Leaf Design for use in the 2017 program. The study found that both tools produced similar expectations of savings. The average fossil and grid savings projected by EUSAVE was 82.94% for the 22 projects in the 2016 pilot. The average for CLEAR was 80.29% for the 13 projects of 2017.

For the 24 projects studied:

- The average variance between projections (in either tool as used) and actual savings was 22.39%.
- For 5 of the projects, modeling projections came within 5% of actual savings;
- 11 projects came in at worse than the average variance.

As part of this study, a controlled modeling study was completed using the CLEAR tool with pre- and post-project fuel usage carefully entered by one person in a format adjusted for heating degree days.

- The average variance between projections and actual savings was 16.17%.
- 7 projects were modeled to within 5% of their actual fossil fuel and grid-drawn electric usage.
- 9 projects came in at worse than the average variance.

It is important to note that these variances were not all due to faulty modeling; many were related to other failings in the projects themselves or in the way heating equipment was used by the homeowner. In the controlled modeling projections above, seven of the nine homes that came in at worse than the average had issues related to use of the home or heating equipment that would have been impossible to predict through modeling. Anomalies related to the last two (of the nine that came in worse than the average variance) may be similar issues that are simply undetermined at this point.

The questions around effective modeling are multi-faceted. In particular, it is difficult to separate the effectiveness of the tool from the quality of the data that is entered into it. Given all of the variables involved (and what is known of some of the haphazardness of the data inputs), it is surprising that the projections of the modeling were as good as they were.

Only one metric – grid and fossil energy usage – was examined as part of this study, however. More study is needed, both of the other metrics employed in the modeling process, and of the effectiveness and feasibility of modeling in general to adequately predict results. This will be critical to designing and establishing effective modeling methodologies, to designing and administering program parameters, and to making a future program attractive to the financing community. **(For further information see pages 48-52.)**

Homeowner Satisfaction

In general, homeowner satisfaction – with the results of their individual project and with the program as a whole – was very high. In spite of (or perhaps because of) the large investment, homeowners felt that they received good value. A pilot program is likely to attract early adopters, and early adopters by nature look beyond standard measures of value such as cost and financial benefit. Many of these homeowners, therefore, may be more embracing of the goals and values behind the program, and more forgiving of the stresses of getting the work done in a tight time frame, and of bugs in the system that need to be worked out. In reflecting back on the projects themselves, most had few complaints of any kind, and most of the complaints were minor, and typical to the intrusion of any major in-home construction project. There were two homeowners who were genuinely disappointed in the results – one because his heat pump system was costing him too much money to operate, and the other because she felt she had to keep her house cold to avoid paying high energy bills. Closer professional follow-up post-project would likely have resolved at least some of their issues or concerns.

Demographically, participating homeowners came from all different backgrounds, and a wide variety of income levels. Many highlighted their frugality in their spending habits, and looked very closely at the cost and benefits of the program concept. Most of the projects required some amount of financing, though in none of these was the financing contingent on estimated project savings. Most were informed by a very strong environmental consciousness, and were strongly motivated by the desire to get their homes off of fossil fuels.

A key finding from the homeowner interviews was the recognition that a much greater post-project follow-up by contractors and by program administrators would have been beneficial to most homeowners, and will be an important part of a future Zero Energy Now program.

Contractor Assessment

Contractor assessment of the program was generally favorable and positive. All those interviewed felt that the program aligned well with their business goals and mission. Many were very judicious and somewhat critical in their assessment of program elements – the modeling tools, in particular – and some felt that the learning curve was too great, especially for such a short window of program

time. All, however, saw the potential for the program and the longer term value for their businesses. Some (mostly larger) businesses are more suited to scaling up within a ZEN program model than others, but the concept itself with its rigorous standards and strong building science foundation provides an important structure that contracting businesses of a variety of sizes and structures can connect with and build business around.

With respect to incentives, all contractors agreed that they gave significant impetus to homeowners to learn more about the program, to connect with a contractor who could deliver the incentive, and to go ahead and proceed with their projects so as to obtain the incentive. The incentive also gave the program important credibility in the marketplace – both for the homeowner, and for the contractors weighing its potential benefit to their businesses. All contractors suggested that a modest incentive directed to the contractor, was also important – at least to help overcome the initial program learning curve.

Program Administration

Administration of the pilot programs was very competently developed and managed by Energy Futures Group (EFG) of Hinesburg, with support from the BPPA Board. EFG's approach was to develop and promote the program concept, and establish its components and standards in a supportive administrative structure under which contractors could promote the program in their normal project sales process. Contractors were given full responsibility for developing and implementing the specifics of the project design and work scope – using the modeling tool, their own background and skills, and contacts within the local trades community. This arrangement was a familiar one for contractors to work within, and it gave them full flexibility to develop their business relationship with the homeowner in a way that suited them.

The modeling tools and the general mechanics of the program required substantial training and support. EUSAVE – the tool used in the 2016 pilot – required a steep learning curve. Many contractors did not gain enough experience using the tool to fully overcome the learning curve before the program was over.

The “General Contractor Model” was very effective at sales, and in the specific delivery and installation of the program components in the home. Its weakness was in follow-up with homeowners after the job was completed. The need for this has only recently become apparent (largely in the process of completing this study). The systems involved in the program components – especially the heat pumps – require significant homeowner education, as well as technical adjustment and evaluation – for a period of up to several years after the project completion.

The other weakness in the administration of the pilots was in marketing the program. Much more robust marketing on multiple levels will be needed to promote a concept as complex and expensive as Zero Energy Now, especially in that it requires a substantive change in our elemental thinking about managing costs and debt.

The primary complaint about the Zero Energy Now program was the draconian time frame (approximately 8 months) – mandated by the structure of the CEED grant funding the program – in which all projects had to be marketed, developed, sold, implemented, and reported. Relatively few homeowners could accommodate such a complex, large scale, and costly project in such a short time – even with strong monetary incentives. Program administrators did not have sufficient time to

make adjustments or accommodate needs, concerns, or suggestions as they arose – before the program was essentially over.

Economic Benefits of Program

The pilot programs demonstrated the program’s capacity to provide enormous economic benefit to the state and regional economy. The 35 projects that participated directly engaged over 30 businesses and between 300 and 550 workers. In addition to those employed on site, the program drew upon suppliers across the state for materials and system components.

Small-scale biomass, which can be utilized at least in a limited way in a carbon neutral energy system, can support Vermont’s local farm and forest economy (much as it has been doing).

Financing through local credit unions and banks helps to build capital capacity at the local level to finance and empower other local enterprises.

Zero Energy Now also provides the homeowner with an opportunity to invest in their homes and domestic infrastructure – increasing the value of their home, and their economic stability and personal independence.

Directly mitigating the effects of climate change empowers homeowners to participate in a positive and optimistic way in improving the lives of their children and grandchildren, and the stability of the community and world they live in.

Considerations for a Future Zero Energy Now Program

The greatest success of the pilot programs was in delivering very strong fossil fuel and grid-sourced electricity savings: the average just under 64%, multiple instances of savings greater than 90%.

Savings in energy costs were equally dramatic, though not quite as high. These cost savings made financing of these projects effectively feasible and affordable, making the Zero Energy Now concept accessible and affordable for a broad cross-section of Vermont homeowners.

The general administrative structure of the program – the General Contractor Model – was successful, especially at sales and delivery of the essential Zero Energy Now product.

The modeling tools, as used in the pilots, had mixed success predicting results. This was not always the fault of the tool, however. Successful modeling is as much about communicating project goals as it is about applying tools correctly. Modeling tools for a future program will have to be chosen or developed with an eye to

- Developing effective work scope design, including effective sizing of mechanical systems;
- Strict methodology for inputting fuel usage and correlating to climate data;
- Modeling accuracy to within 5%;
- Straightforward, intuitive use by contractors;
- Adaptability to changes in program structure, parameters, and technological developments;
- Verifiability with post-project inputs for follow-up purposes.

The weakness in the General Contractor Model – and in the pilot program as it was conceived – was that it provided no effective follow-up with homeowners to verify system performance. This is something new, that most contractors would not consider, but which is really important to the success of Zero Energy Now in that performance is critical both to the savings guarantee and ultimately to effective financeability.

In general, homeowner interface – at time of sales and at time of test-out and conclusion of the work scope needs to be more robust with respect to how the program works, and how the savings can be best achieved. In order for the modeling to be accurate, the heat pumps, and any biomass component have to be used in the same way that they are modeled to achieve the modeled savings. Any divergence from the modeled strategy will produce substantially different results. This must be carefully communicated, and clearly understood.

Marketing was another weak point of the pilots, and a key consideration for the success of any future Zero Energy Now program. Marketing will have to be particularly robust to address natural resistance to the overwhelming expense and complexity of Zero Energy Now projects, and to taking on debt.

The Zero Energy Now concept has huge potential. Much has been learned in the process of carrying out the two pilots. Much is still to be learned through further follow-up with homeowners and contractors, and in the process of designing a future program.

Program Background and Study Methodology

Summary of the *Zero Energy Now* Program

The concept of the *Zero Energy Now* Program was first put forth at a retreat of the Building Performance Professionals Association of Vermont (BPPA-VT) in June of 2015.

A contractor who was a strong advocate of getting homeowners to reduce their fossil fuel usage had worked with a number of his clients to combine weatherization improvements on their homes with the installation of cold climate heat pumps and solar PV systems that were large enough to cover their entire electric load, including full time use of the heat pumps. By doing so, these homeowners became effectively free of their fossil fuel heating bills, and most of their electric bills. Money that had been previously spent on those ongoing energy costs was now available to help cover the costs of the home improvements. Following the installations, some of the clients were paying less on their loan payments than they had been paying for energy. Others were paying just slightly more.

This concept was taken up by BPPA-VT, and a funding opportunity to develop a program based on the concept became available through Green Mountain Power's Community Energy and Economic Development (CEED) Fund in August of 2015. Green Mountain Power awarded a grant of \$698,000 to BPPA-VT to develop and administer a one-year pilot program with the goal of completing 50 projects in the calendar year 2016.

Key elements of this program were the following:

- A minimum energy and fossil fuel reduction standard based on the following requirements:
 - 10% energy savings through weatherization and specific building envelope improvement measures;
 - 50% reduction (as measured in MMBtus¹) in combined fossil fuel and electricity drawn from the grid;
 - 50% of the home's energy portfolio (post-project) to be drawn from renewable sources.²
- A designated strategy for achieving these standards was defined and verified through a software modeling tool, EUSAVE³ - developed and adapted for this purpose. The strategy could include specific weatherization measures, biomass heating,⁴ heat pumps, improvements to domestic hot water and appliance upgrades, and renewable electricity –

¹ 1 MMBtu = one million Btus (British thermal units)

² Renewable energy sources were defined either as renewable electric – which could include solar, wind, or micro-hydro power, or as biomass energy – which could include, woodchips, pellets, or cordwood.

³ EUSAVE – Energy Use, Savings, Analysis and Evaluation software, a product of Parsec Energy Consulting.

⁴ Existing wood stoves could be included in a home's renewable portfolio, but the program did not allow for increased dependence on an existing wood stove. In other words, a homeowner could not claim fossil fuel savings by committing to use more cord wood in their existing system and thereby become eligible for an incentive. If, however, the homeowner purchased new wood heating equipment that met the most up-to-date EPA standards (including a stove), they could commit to as much wood use as they wished to minimize their fossil fuel consumption.

installed on site, or purchased through a community solar⁵ or group net-metered array on some other property.

- Project coordination provided by BPI certified *Zero Energy Now* contractors, who completed an energy audit on the home, completed the modeling necessary to qualify the project, and then provided the job coordination necessary to complete the work;
- A program-specific incentive designed to maximize reductions in fossil fuel usage and electric power drawn from the grid. This was set at \$50/MMBTU of modeled fossil fuel and grid electricity saved – and was capped at \$5000 (100 MMBTUs).
- Access to additional customer incentives, including the following:
 - The standard building efficiency incentives obtained through Efficiency Vermont’s Home Performance with Energy Star Program – up to \$2000;
 - Incentives through Vermont’s Renewable Energy Resource Center (RERC) available for pellet boiler and furnace installations – up to \$6000;
 - Incentives available through RERC for solar hot water installations – up to \$3000;
 - the 30% federal tax rebate available to homeowners for qualifying energy improvements – most notably solar PV installations.
- A “savings guarantee” that was underwritten by the grant funding.
- Project completion by the end of calendar year 2016. This was a specific requirement of the funding constraints of the CEED fund.

The program was administered through a contract between Green Mountain Power and the BPPA-VT Board, and development of the specific elements of the program and its ongoing administration was delegated to a contract with Energy Futures Group, Inc. (EFG) of Hinesburg, an energy consulting firm. EFG developed many of the program details – its administrative structure, day-to-day operation, marketing requirements, training requirements, program verification, documentation, and reporting responsibilities. EFG also organized and hosted specific trainings for the *Zero Energy Now* participating contractors and “in-network partners” (the solar, wood heating, heat pump, or other weatherization contractors), introducing them to all the program details, the modeling tools, contractor requirements, customer requirements, standards, and reporting requirements. For further details regarding specific program design and implementation, the reader is referred to the *Zero Energy Now Program Plan*, a 57-page pdf document developed by EFG.⁶

While the grant was announced by Green Mountain Power in late summer 2015, the use of the funds had to be approved by the Public Service Board (now Public Utility Commission) in early 2016. The funds therefore did not become available until March of 2016. While some preliminary work could be done before the funds were available, all of this was “at risk” work by motivated BPPA personnel who could be paid afterwards for their services. All other work such as contractor engagement, training, marketing, and sales work with homeowners could only begin after the funds became available. Because normal marketing materials such as a website and other promotional elements were not in place until after the funds became available, the program was not publicly rolled out until

⁵ In order for the community solar to qualify, the Renewable Energy Certificates (RECs) associated with the project (or the portion of it purchased by the *Zero Energy Now* consumer) had to be purchased as well, so that the energy produced by this project was not resold to another consumer or another utility’s renewable energy portfolio. .

⁶ Available by contacting Energy Futures Group, Inc. P.O. Box 58, Hinesburg, Vermont 05461
info@energyfuturesgroup.com

early June. This delayed release of funds, combined with the December 31 deadline for project completion, became a significant handicap in the success of the program, especially limiting the number of clients who could be convinced in a very short timeframe to undertake the large scale of project the program required. This was a significant factor in the number of projects that were able to be completed in the pilot program.

As a result of this, several projects were effectively “made to qualify” by motivated ZEN contractors by piecing together the work of other contractors. If, for example, a solar array had recently been installed, or a conversion to heat pumps, contractors would apply additional components as needed to allow the home to qualify for the incentives. Contrasting these projects were those that underwent the fully integrated step-by-step process of completing an audit, modeling the home’s energy potential, and identifying the best options for savings and comfort. The projects that more closely aligned with the designed approach may provide some indication of the benefits of the Zero Energy Now program.

A total of 22 projects were qualified and completed in the narrow time frame before the end of calendar year deadline in 2016.

Zero Energy Now in 2017

Because it was felt that a great deal was learned from the 2016 program, and the marketing capacity and promotion was cut short, BPPA-VT was eager to offer the program again in 2017. Due to their limited success in meeting their goals of 2016, however, and the fact that the CEED Fund was winding down, only \$118,000 was made available for a program in 2017.

Because of this, customer incentives were necessarily smaller – capped at \$1,000, and a less ambitious standard for qualifying them was established. Instead of the 10-50-50 thresholds of 2016, the following requirements were created:

- Either of the following:
 - Achieving a ten percent reduction in air infiltration as tested with a blower door before and after the project;
 - Meeting a pre-project (or post-project) standard of maximum 3.00 ACH at 50cfm depressurization⁷, also as tested with a blower door.
- A fifty percent reduction in on-site fossil fuel usage as measured in MMBtus. (The grid electric component was no longer required as a contributing factor to the savings.)

The incentive was based entirely on the amount of solar PV installed and was set at \$188 per kilowatt of generation capacity installed. The \$188 reflected an assumed annual savings of just over 3.75 MMBTUs (1100 kWh) per kilowatt installed, thus approximating as closely as possible the \$50 per MMBTU savings incentive of the year before.

Because the qualifying standards were significantly less stringent, and the incentives were also reduced, the program was given a different name – *Solar Bonus*. The modeling tool, used to qualify projects for the new program, CLEAR,⁸ maintained a parallel track detailing the project’s ability to

⁷ Three air changes per hour with the entire house depressurized by 50 pascals with respect to the outside. This is a measurable standard of air leakage that can easily be determined with a blower door.

⁸ Clean Energy Assessment and Reinvestment Analysis Tool

meet the original *Zero Energy Now* standard, and many of the projects under the *Solar Bonus* label were successful in meeting the *Zero Energy Now* standard as well.

A total of 13 projects were completed in 2017 under the *Solar Bonus* program name. Nine of these thirteen projects would have qualified under the original terms of the *Zero Energy Now* program.

Definitions of Energy and Energy Savings

Total Energy – as used anywhere in this study – is defined as the entire energy consumption of the house and its occupants, combining all fuels used – electricity, combustible liquid fuels (kerosene, #2 fuel oil, liquefied petroleum gas), combustible natural gas, and combustible solid fuels (cord wood, wood pellets, or coal). Sourcing of fuels, especially whether the electricity is renewably sourced through solar, wind, or hydroelectric systems is not considered in the definition of total energy. Entire energy consumption of the house and its occupants includes all the energy used for heating, domestic hot water, appliances, lighting, and domestic equipment, which may include a pool or a hot tub or small portable tools that need to be charged electrically. The single notable load excluded is that associated with charging an electric vehicle such as a car. On-site commercial loads such as those required for a home-based manufacturing business or farm operation are excluded where they can be isolated, but simply noted as a questionable and potentially complicating factor where isolation is not possible.

Fossil and Grid Electric Energy is defined as a distinct component of total energy which includes all combustible fossil fuel products – refined liquid fuels, natural gas, and coal – and electricity that is sourced exclusively from the grid. For purposes of this study, all electricity renewably produced on site, or produced by an exclusively purchased participation contract with a community solar or wind installation are recognized as renewable. These can be credited against any use of grid-based electricity over the course of a single year.

Non-fossil components of liquid fuels such as biodiesel, corn, or sugar-based additives were not, for purposes of the program (or this study), credited against the essential fossil nature of these fuels.

Renewable sources of electric power in the grid itself – industrial scale wind, hydroelectric, or woodchip installations – are not considered, for purposes of this study, to reduce a home's consumption of “non-renewable” energy. Use of the term “non-renewable energy” is generally avoided for this reason.

We are aware that there is currently a great deal of discussion about what does, and does not, constitute renewable energy. For purposes of the two pilot programs studied here, the above rules and definitions apply.

Goals of the Study

Zero Energy Now made significant claims of total energy savings, and in particular, fossil fuel savings. Modeling by EUSAVE indicated average fossil fuel savings of 82.94% for the 22 homes that participated in the 2016 program, and modeling through the CLEAR tool in 2017 indicated average savings of 80.29% for the 13 homes that participated in that program. While the modeled savings claims were impressive, they were just that – claims. The primary goal of this study is to examine

actual fossil fuel and MMBtu reductions as determined by comparing pre- and post-project fuel purchases.

Secondary goals are to glean an understanding of homeowner sensibilities about the projects, their satisfaction with the work completed, their sense about the improvements, general levels of comfort in the home with some kind of comparison of pre- and post-project warmth and air quality. Satisfaction with the cost of the work, and some sense of whether they feel it was justified vis-à-vis the savings in energy costs are also looked at

A third objective of the study is to get a sense of the viability of *Zero Energy Now* as a program for businesses – as a conduit for generating customers, and as a structure around which to develop and expand their contracting work. If the concept is cumbersome and complicated for them to manage or take on, or if it is difficult for them to make money doing it, it would have limited appeal as a potential industry approach to addressing climate change in existing buildings. If, however, it had potential as a growth industry in Vermont – good income potential both for businesses and for workers, and a strong market for entrepreneurs to build businesses around, it would be a win-win both for addressing climate change and for building the local Vermont economy.

Further goals of the study are to examine the modeling tools themselves – their overall reliability as predictors of savings and value. The modeling tools may have had their own specific limitations, but another question in need of follow-up is how they were used by contractors or project managers. Was the data entered into them reliable? How was it obtained? Was it properly entered into the tools so that they could interpret it in the manner they were designed to? What are the liabilities of any modeling software? What degree of precision or accuracy can be anticipated in their use? Do homeowner habits interfere with the tools' capacities to make reasonable projections?

Finally, we also wish to complete a more detailed examination of the specific projects – why some were very successful while others were less so, and what factors tended to lead to greater or lesser success. Were these factors within the control of the homeowner or installation technicians? Do they have to do with structural issues, such as the shape and layout of the house? Were there site-based issues such as reduced solar production due to placement of panels? Or was weather, such as lingering snow on a low pitched roof in March, a substantial impediment?

Methodology of Study

The primary source of data in this study is actual fuel usage from before and after the project. An effort was made to obtain very specific usage for as many years as possible prior to commencement of the project, and continuing through the project to as recent as possible. (Where possible, data was collected from July of 2012 to the spring of 2019.) Most of this data gathering was done in March and April of 2019 to attempt to get at least one full winter's usage data after completion of the project. (2017 projects were often not completed until close to the end of December – i.e. well into the winter heating season.)

For fuel oil and propane usage, the assumption was made that the fuel tank was filled with each delivery, and therefore, the fuel delivered on a given date represented total fuel used since the last delivery date. This is a workable strategy for determining fuel usage in a high-usage home, but it becomes problematic when usage drops to the point where several heating seasons pass without a fill-up. Some of the post-project data may be skewed somewhat by this circumstance, and

alternative data assumptions, potentially less reliable, such as homeowner estimates, have to be employed. Cord wood and pellet usage is also difficult to determine precisely. Pellets often come in bags which provide a measure by weight, and it is not too difficult for a homeowner to keep track of the number of bags purchased and used over the course of a season. Bulk pellets delivered by truck can also be measured if their delivery is systematized and properly recorded. The most problematic fuel is cord wood, which is frequently gathered and stored in less than measurable quantities or arrangements. Verifying homeowner assumptions of how much wood was purchased or used in a given season was almost impossible. Furthermore, the quality and BTU content of cordwood is highly variable. An assumed “middle of the pack” 22 million BTUs per cord was employed as a measure for purposes of modeling, verifying, and validating the home’s energy performance.

Data was sometimes not easy to obtain. Homeowners often switched fuel dealers over the course of several years; fuel dealers sometimes did not have records going back to the earliest parts of the requested time frame, or even just to 2016. Ensuring that the data received was sound and complete was challenging.

Limitations on Methodologies within the Study

Since the study only includes aggregate fuel usages, and no specific monitoring devices were installed in any of the houses before or after the project, none of the fuel usage is disaggregated between any specific devices or functions. Kilowatt hours used over the course of a year could not be disaggregated between what was used for appliances and lights, what was used for hot water, or what was used for heat. Unless fuel use was specific to a specific function – e.g. fuel oil only used in a furnace or propane only used for domestic hot water – it was impossible to assign definitive quantities of fuel to a specific function. Where fuels served multiple functions, and no effective disaggregation could be determined, estimates were based on a combination of thermostat settings, occupancy numbers, Efficiency Vermont estimating methods or algorithms, and homeowner testimony regarding specific lifestyle habits or tendencies (e.g. “My husband cooks a four course meal every night” or “our daughter *lives* in the shower”).

As a rule, and as a matter of representing data in a uniform manner across all the projects analyzed, where fuel usage could not be disaggregated, usage before the project and usage after the project – that was not altered by the nature of the project itself – was assumed to be the same and recorded as such in usage estimates.

An example would be electricity usage for appliances and lights. If 5500 kWh of electricity was used before the project exclusively for appliances and lights, 5500 kWh was recorded as used for those same appliances and lights after the project. All additional kWh was categorized as being used for heat pumps and, if a heat pump water heater were installed, domestic hot water. If a heat pump water heater was installed, the same MMBtu usage load was assumed for the domestic hot water as before the project, but translated into kWh at an assumed efficiency based on the water heater’s energy factor. In reality, actual usage in all these areas varies from year to year due to a wide range of circumstances, but all of these variables are indeterminant, and therefore consistency requires employing a standardized assumption regarding all indeterminant values.

The following chart indicates the quality of data – both overall, and as broken out, and became a general guide for the methodology and assumptions of the study.

Discussion of Factors Affecting Variability & Quality of Data				
Fuel Type or Factor	How Values Obtained	Precision of Values	Assumptions	Comments
Fuel Specific Factors				
Electric	Efficiency Vermont	High if single point generation and consumption usage available. Highly questionable in group net metered situations.	Used data where available.	This problem was never really resolved. Green Mountain Power only recorded electricity purchased by each homeowner in group net metered project, and the overall power generated by array. Disaggregation rarely possible.
Kerosene	Fuel Dealer(s)	High if complete billing records available. Multiple fuel dealers over time	Assume tank filled to legal limit at each delivery. Therefore, usage for period was total of gallons delivered at next fill-up.	If fill-up assumption is reasonable, and all fuel dealer data included and recorded, this data value is very high.
Fuel Oil	Fuel Dealer(s)	High if complete billing records available	Assume tank filled to legal limit at each delivery. Therefore, usage for period was total of gallons delivered at next fill-up.	If fill-up assumption is reasonable, and all fuel dealer data included and recorded, this data value is very high.
LP	Fuel Dealer(s)	High if complete billing records available	Assume tank filled to legal limit at each delivery. Therefore, usage for period was total of gallons delivered at next fill-up.	If fill-up assumption is reasonable, and all fuel dealer data included and recorded, this data value is very high.
Natural Gas	Homeowner billing	High if complete billing records available	Usage data completely valid, as long as homeowner's data complete.	Most precise data available.
Coal	n/a	n/a	n/a	No projects studied were burning coal.

Wood Pellets	Homeowner	Variable	Qualified homeowner estimates as best we could	If clients had good records of purchases, it was relatively straightforward to generate good data.
Cord Wood	Homeowner	Variable	Qualified homeowner estimates as best we could	Cord wood MMBTU data generally is highly problematic. Variability in specific BTU content of wood, quality of wood (e.g. green, dry, punky), difficulty of properly estimating usage, and high behavioral variability around usage make any analysis complicated. Recommend further research to develop useful default values for modeling.
Other Factors				
Disaggregation of Fuel Usage	Estimated.	High only if fuel unique to a particular use (e.g. LP used only for DHW)	Uses unaffected by project work scope kept the same unless otherwise determinant	
Performance Efficiency of Equipment	Used AFUE data if available; otherwise estimated.	Not really determinant. Based largely on anecdotal evidence and likely value of other improvements.	Started with default values of single head ductless mini-split heat pumps given at 220%. Multi-head systems at 120%.	The effective efficiency variability of heat pumps is very problematic. This is due to a variety of factors -- having to do with the equipment, the house, and the homeowner. For purposes of the study, we started with the defaults and adjusted from there to obtain a value picture for the project that made the most sense.
Circumstantial Performance of Equipment	Not measurable, and no specific metric given.	Not specifically represented. May affect performance efficiency of equipment, or envelope improvement assumptions.	Adjustments made to estimated heat pump efficiency based on anecdotal evidence from homeowner	Key metric here is homeowner comfort, although circumstantial performance also is a key factor in fossil fuel savings.
Envelope Efficiency Metrics	No way to verify except through assumed heating fuel usage & estimated equipment efficiency.	Envelope improvement values depend on equipment efficiency. Both are fudged somewhat.	Improvements estimated based on fuel usage and assumed equipment efficiencies.	Not as bad as it sounds. If the goal is to minimize fossil fuel use, that is still the one clear measure we have in the study. The question here is what default metrics make sense for modeling purposes
Homeowner Education	Interview	General feedback indicated homeowner education limited to none.	Very significant in heat pump performance.	Needs to be addressed extensively in any future program.

Homeowner Equipment Usage Variability	Interview	Anecdotal	Based on homeowner statements and comments.	High variability around use of certain types of equipment -- especially wood stove or pellet stove, but also heat pumps. Education around heat pump use a key factor.

It is important to note that, while the above chart seems to suggest that much of the data is unreliable, the really valuable and critical data is fossil fuel and grid electric usage – both before and after the project was undertaken. The reliability of this data is, in most cases, quite high. Since minimization of fossil fuel usage and reliance on grid-based electricity is the primary goal of the program, having clear data on these two essential fuels is of the highest value.

Adjusting for Heating Degree Days

Fuel usage data comparing one heating season's usage to another is significantly affected not just by changes in the home, but also by changes in the seasonal weather from year to year. General temperature variability and overall severity of a winter heating season is frequently measured in "heating degree days" which are usually recognized as the difference between the average temperature on a given day and 65 degrees Fahrenheit, the temperature below which a thermostat might typically call for heat. A day in January might have an average temperature of 12 degrees, so the heating degree days for that day would be 53. Average temperatures in July on the other hand rarely drop below 65 degrees, so HDDs on a given day in July are more likely to be at or near zero. It is important to note that heating degree days really only measure average temperature variability. Other climate characteristics which may vary from year to year and which may affect heating season fuel usages include moisture and humidity, and especially wind. Some studies also suggest that a shorter, intensely cold winter may affect heating loads in a house differently than a longer, warmer winter with the same number of degree days. The purpose of heating degree days is essentially to be used as a modeling tool that helps to measure a specific winter's intensity. Like all such tools, it isn't perfect, but adjusting for heating degree days in a study such as this is important – as the following chart suggests.

In the chart below, two heating seasons are compared – the season from July 1, 2014 to June 30, 2015, and the season from July 1, 2017 to June 30, 2018. The first is wholly and completely before the Zero Energy Now project, and the second is wholly and completely after it.

Effect of Heating Degree Days on Raw Fuel Usage Data					
Raw Data	HDDs Recorded for Heating Season at Burlington, VT	HDD Variability with respect to compared data	Usage Before Project (Sample Project)	Usage After Project (Sample Project)	Apparent Measured Savings
2014-2015 Unadjusted Fuel Usage	7629	10.37%	92.04	?	
2017-2018 Unadjusted Fuel Usage	6912	-9.40%	?	56.86	38.22%
Adjusted Data	Adjusted HDDs	HDD Variability with respect to compared data	Usage Before Project (Sample Project)	Usage After Project (Sample Project)	Actual Measured Savings
Post-Project Fuel Usage Adjusted to Match Pre-Project HDDs	7629	0.00%	92.04	62.76	31.81%
Fuel Usage Before and After Both Adjusted to Match 12 Year Average HDDs	7060	0.00%	85.18	58.08	31.81%

Without adjustments based on heating degree days, the fuel usages from the first winter to the second (shown in the upper part of the chart) have no relationship to one another, and modeling of improvements can't be verified in any meaningful sense.

However, adjusting fuel usage to reflect HDD differences (shown in two different ways in the lower part of the chart), makes a much closer approximation of savings possible. The first row in the lower part of the chart shows the 2nd heating season's fuel usage adjusted to match the heating degree days of the first season. In the bottom row, both heating seasons' HDDs are adjusted to match a twelve-year average of heating degree days. Since fuel usages from both seasons recorded are adjusted to this 12-year average, they provide a better sense of what the homeowner can expect to use in a typical heating season.

Because climate in Vermont has become so irregular in the last few decades, and temperature averages and heating degree days can vary so much from one winter to another – as much as 24% between 2012 and 2014, for example – genuinely “average” energy use is hard to gauge by comparing the savings from one season before a project is done to one season after, even when the season after is adjusted to match the season before. For modeling purposes, in particular – but also for verification purposes – it is important, to base anticipated savings on a broader average of heating degree days. Therefore our verification software also provides a twelve-year average of Heating Degree Days. When applied, the usage data available from both before and after the project is adjusted to align with this twelve year average, which is a rolling average based first on the date of

the audit (for modeling purposes), and then on whatever date is chosen for the verification date – one or more heating seasons *after* completion of the project. Twelve years was chosen because it is broad enough to be representative as a seasonal average, but narrow enough to reflect recent shorter-term trends in our climate. An HDD average going back to the 1980s or earlier may not be reflective generally of temperatures we are experiencing now, and in the years to come. (Twelve years also brings adjustments for leap years to a consistent whole number, which ten years, for example, does not).

The twelve-year average adjustment for heating degree days is therefore the standard utilized for quantifying all heat energy savings in this study.

It should be noted that, even with heating degree days factored in, the twelve-year averages employed in the study are not a perfect measure, as they are limited by the amount of data available to enter into the average. Data recorded for one season, when tied to a twelve-year average, is not the same and not as valid as data recorded over several seasons and then tied to the same twelve year HDD average.⁹

What does all this mean? More data – in an ongoing fashion – is needed. More analysis of data that we already have may be useful – and in general the more data we have, the more meaningful our averages and modeling assumptions will be. For the time being, however, we should recognize that though our modeling will be imperfect at best (and only as perfect as our data), being as careful and precise as we can in applying the data we have will provide significant returns. On a case by case basis, it will give us the clearly defined outlines of what we can anticipate for savings and what are the best strategies for obtaining those savings at the best cost value. We will examine data precision as entered into the modeling tools at a later point in this report.

⁹ For further discussion and explanation of methods employed to allocate heating degree days to specific periodic fuel usage records – e.g. propane tank fill-ups that can best be annualized from March to March, alongside of fuel oil usage annualized from, say, November to November, see appendix.

Findings and Results from 24 Projects

Sample Details

A total of 35 projects were completed in the two pilot programs – 22 in the original *Zero Energy Now* program of 2016, and 13 in the *Solar Bonus* program of 2017. Ideally there would be 35 projects to report data from, but due to various circumstances data was incomplete for a substantial number of them. In all, there were eleven projects for which data was incomplete or otherwise compromised.¹⁰

Of the 24 projects that have been included in this study, one – Project 21 – is a house that wasn't occupied by the owners until after the project was complete. Former owners had not occupied the house in any way for several years. Available baseline fuel consumption numbers provided no effective basis of comparison.¹¹ Modeled energy usage numbers provided by the auditing software used by the HPwES auditor were used to determine pre-project fuel usages. In spite of the validity concerns about using “modeled” pre-project fuel data, this project was included in the study for two reasons. First, because the project was very comprehensive and will help to reinforce our program analysis of what works and doesn't work; and second, because the circumstance of a project being

¹⁰ For four projects [7, 12, 29, 31], the homeowner did not respond to any efforts to reach them. On two [15, 34], the participating homeowners had moved away shortly after the projects were completed, and purchasing homeowners were uncooperative. Some contact was made with two others [27,30], but one of these was dropped because there were multiple units (and even buildings) involved in their energy usage, because the homeowner was difficult to reach to resolve the multiple questions, and would not take the time to even disclose fuel dealers; the other was dropped because the fuel dealer given had no record of the homeowner as a client, and the homeowner was unresponsive to all efforts to correct the situation. The last three [12, 22, 26] were dropped because of complications or incompleteness in the data – unresolvable group net metering disaggregation problems, combined with other circumstantial issues such as, in one case, residence had been unoccupied and completely unheated before the project, or, in another case, the heat pump installed in an isolated structure different than the one the rest of the data was referenced to. Altogether, eleven projects have not been included in the study. We will continue to try to approach some of these homeowners with the hope of obtaining useable data to further inform this study.

¹¹ Using the existing fuel consumption numbers from before the project – even with significant envelope improvements and newly installed heating equipment – the performance numbers for the house were very low. The envelope number in particular was negative by over 80% (i.e. showed that it was over 80% *less* efficient), an extremely unlikely situation. The Home Performance with Energy Star auditor managing the project used an “Asset Rating” modeling program within the CAKE auditing software he was using to come up with pre-project fuel consumption numbers. These numbers were applied in this study as a baseline for this project. While this method may be questionable as a valid way of qualifying the effectiveness of this project, the post-project performance of the home is fully verified, and the improvement numbers are not in any way out of line with what might be anticipated and what has occurred in projects of similar scope. The project came in at just three places above the median in our data distribution for fossil and grid savings, and three places below the median for total energy savings. The savings – both in energy and costs – claimed for this project affect the overall averages in the study by less than one percent. For energy savings, the project increases the average for the 24 projects by exactly 0.5% (from 61.72% to 62.22%), and cost savings are increased by exactly 0.75% from (57.22% to 57.92%).

done prior to the homeowner actually living there is not uncommon, and the capacity to model such projects effectively – without available prior fuel usage data – is important.

Overall Energy Savings

The two programs together **delivered total annual energy savings averaging 38.76%, and annual fossil fuel and grid electric (F&G) savings¹² averaging 63.93%.**

The medians for the two savings measures corresponded with the averages quite closely. **The median total energy savings was 36.83%, and the median F&G savings was 64.97%.** Interestingly, however, there was no correlation between the two medians with respect to individual projects. The two projects closest to the median for total energy savings at 36.47% and 37.19% respectively had corresponding F&G savings of 65.63% and 72.48%. The two closest to the median for F&G savings – 64.3% and 65.63% -- had corresponding total energy savings of 22.91% and 36.47% respectively. The lack of correlation is even more dramatic at the low and high ends of the savings spectrum. The project which saved the most in total energy – 65.33% – saved only 47.30% in fossil and grid energy, while the project which saved the least in total energy, at 9.75%, did quite a bit better – 54.86% – in fossil fuel and grid electricity savings. **The highest and lowest in fossil and grid savings were 98.02% and 14.46%, and were 58.44% and 32.06% in total energy savings, respectively. (All savings figures are annual.)**

Table 1 Median Annual Total Energy & Fossil Fuel & Grid Electric Energy Savings

Total Energy				Fossil & Grid Energy			
	Proj	Total Energy Saved	Corresponding F&G Energy Saved		Proj	F&G Energy Saved	Corresponding Total Energy saved
Lowest Savings	4	9.75%	54.88%	Lowest Savings	9	14.46%	32.06%
Just Bel Median	9	32.06%	14.46%	Just Bel Median	8	65.83%	36.47%
Just Abv Median	8	36.47%	65.63%	Just Abv Median	23	67.87%	26.17%
Highest Savings	25	65.33%	47.30%	Highest Savings	17	98.02%	58.44%

¹² See definitions of “Total Energy” and “Fossil Fuel and Grid Electric Energy” on page 15.

Energy Cost Savings

Annual Energy cost savings were similarly robust, though not quite as dramatic:

Average cost savings: 59.98%

Median cost savings: 51.31%

Highest cost savings: 95.75%

Lowest cost savings: 24.97%

Cost savings generally correlated with high fossil fuel and grid savings, though not perfectly (as one would expect). There were several reasons for the occasional anomalies in this correspondence.

For projects where biomass heat was a significant component of the renewable portfolio, the cost of the biomass fuel reduces the important cost savings benefit of the renewable energy component. This was a notably limiting factor for Project 18, and Projects 32 and 33, for example.

Project 4, in which the fossil component is natural gas, and a substantial solar array was installed, saved significantly on their energy bills by virtually cutting out their electric bill and replacing their gas water heater with a heat pump water heater. However, their gas heat usage did not change because the installed heat pump was placed in an attached addition that was hardly used before the project.

Anomalies of this type were not uncommon in these projects as the standards of the program did not distinguish or try to address homeowner goals that were inconsistent with program goals, and the standards were not comprehensive enough to weed them out. Several projects were not really consistent with the goals of Zero Energy Now, and most of these did not perform well in either MMBtu savings or cost savings. As mentioned elsewhere, the pressure to get projects into the program and completed under the deadline became a liability both to the design and the proper screening of truly viable Zero Energy Now projects.

Distributions of Savings

Distribution of project fossil & grid energy savings:

90% - 100: 4

80% - 90%: 2

70% - 80%: 4

60% - 70%: 4

50% - 60%: 2

40% - 50%: 4

30% - 40%: 2

20% - 30%: 1

10% - 20%: 1

Distribution of cost savings:

90% - 100: 1

80% - 90%: 4

70% - 80%: 4

60% - 70%: 1

50% - 60%: 3

40% - 50%: 7

30% - 40%: 3

20% - 30%: 1

10% - 20%: 0

Financeability

Cost value and financeability are very closely tied to one another, and for most people, co-dependent. Without the one you don't get the other. While some people can afford to do Zero Energy Now without financing, the program was not intended as a boutique, "feel-good" option for environmentally minded high-end homeowners, but rather to be a robust and compelling engine of broad scale change in our energy and economic infrastructure. Without the deep, deep energy savings component and ultimate financeability of Zero Energy Now, the program would have little value.

To measure the financeability of each of the ZEN projects, a search was made of loan options with local credit institutions for the one that would provide the lowest possible monthly payment. A long-term home equity loan underwritten by Vermont State Employees Credit Union was found to meet this standard. At the time this search was done, the rate for such a loan was 5.25% and the term was 20 years.

Since that time, the rates have gone up, and the current rate for this same loan is now 5.8%. Since most of the data base for this study was entered by hand, and it would be extremely time consuming to reenter it at the higher rate, and since rates continue to be somewhat volatile, it does not make sense to reconstruct this part of the data sheet to reflect what may well be a temporary condition. Furthermore, other options, such as mortgage refinance (which would almost certainly be at a lower rate) may be available to some homeowners. In general, loans requiring a shorter term had a higher monthly payment, even when the rate was substantially lower, but these might make more sense for some homeowners. Again, our interest in applying a specific financing rate for analysis purposes is not to prescribe or reflect the details of any particular homeowner's financing options (which will be highly variable), but to provide a measure of the financeability of these projects in a consistent way with a single, program-wide metric.

Using this specific financeability measure (rate and term) described above, there were a number of consistent successes within the pilots. The *monthly energy cost* – pre-project – (in dollars) was specifically compared to the *monthly energy cost plus loan payment* – post-project – (also in dollars).

Using this measure, four projects actually were cash flow positive when compared to their prior, pre-project energy use. Monthly savings in three of four cases were substantial -- \$145, \$92, \$32 per month respectively, and the fourth -- \$7 per month -- was circumstantially lower and could easily be improved¹³.

Four other projects were not cash flow positive but would require relatively small additional monthly outlays -- \$17, \$23, \$30, & \$33 each. Depending on the volatility of fuel prices over time, and general rates of inflation, costs of these marginal amounts may diminish substantially or even turn into savings.

An important thing to consider with respect to financeability, again, is the depth of the energy savings. This usually depended on how well the solar array covered the electric load, and, in general, how well the loads in the home were matched to properly sized and placed heating equipment. An

¹³ Homeowner reduced reliance on a heat pump because of an idiosyncratic problem with back draft odors in house.

attempt to examine cost effectiveness and financeability related to some of these variables will be looked at more closely later.

Other Correlations

Other interesting correspondences revealed just by sorting different columns of the spreadsheet include a strong though not perfect correlation between F&G savings and the renewable energy component (as just mentioned).

Table 2 Projects Sorted by Combined Fossil Fuel and Grid Electric Energy Savings

Project Number	Pctge F&G Energy Savings	Pctge Total Energy Savings	Pctge Renewable Post-Eff	Percentage Cost Savings	Project Cost	Incentives & Solar Rebate	Net Project Cost w Incentives
17	98.02%	58.44%	93.94%	95.75%	\$169,334.00	\$21,734.00	\$147,600.00
3	95.23%	49.82%	94.25%	84.04%	\$26,635.00	\$10,492.90	\$16,142.10
19	94.92%	58.01%	90.04%	89.90%	\$56,612.00	\$13,402.65	\$43,209.35
18	90.79%	38.97%	94.35%	63.45%	\$37,474.00	\$13,549.82	\$23,924.18
2	87.53%	58.63%	70.62%	85.60%	\$34,549.00	\$8,050.66	\$26,498.34
10	86.60%	60.55%	69.73%	75.69%	\$36,511.00	\$10,987.10	\$25,523.90
21	73.63%	42.27%	58.05%	75.29%	\$127,046.00	\$26,171.06	\$100,874.94
35	72.48%	37.19%	56.46%	74.66%	\$46,700.00	\$13,020.59	\$33,679.41
16	71.11%	48.52%	52.22%	48.59%	\$53,995.00	\$13,898.50	\$40,096.50
6	70.86%	30.98%	83.84%	71.21%	\$34,251.00	\$12,542.64	\$21,708.36
33	69.18%	27.24%	64.39%	60.82%	\$32,142.76	\$9,233.67	\$22,909.09
23	67.87%	26.17%	57.04%	46.49%	\$99,386.00	\$12,548.38	\$86,837.62
8	65.63%	36.47%	47.73%	43.63%	\$65,015.21	\$16,835.20	\$48,180.01
32	64.30%	22.91%	72.33%	51.53%	\$30,011.00	\$9,245.30	\$20,765.70
1	60.25%	48.32%	33.86%	38.90%	\$21,808.00	\$2,639.20	\$19,168.80
20	59.26%	54.68%	32.52%	51.09%	\$33,075.00	\$7,332.02	\$25,742.98
4	54.86%	9.75%	56.72%	85.99%	\$52,357.13	\$18,103.58	\$34,253.55
14	50.08%	23.77%	37.04%	54.45%	\$47,597.00	\$14,024.79	\$33,572.21
11	49.33%	30.27%	32.06%	55.16%	\$48,845.00	\$11,540.00	\$37,305.00
25	47.30%	65.33%	33.03%	40.57%	\$88,712.00	\$17,476.48	\$71,235.52
28	32.93%	25.96%	32.38%	48.20%	\$51,934.00	\$12,762.56	\$39,171.44
24	30.81%	27.31%	53.66%	40.53%	\$32,389.00	\$6,507.20	\$25,881.80
5	27.03%	14.30%	40.27%	24.97%	\$38,892.00	\$13,878.58	\$25,013.42
9	14.46%	32.06%	39.12%	32.77%	\$44,300.00	\$16,543.20	\$27,756.80

There was no discernable correlation between fossil fuel and grid electric savings and the overall project cost or the net project cost after incentives and rebates.¹⁴ While the most expensive project hauled in the greatest percentage of F&G savings, the least expensive project achieved the *second* greatest percentage of F&G savings! There will be more discussion of this as we look at strategies for achieving savings later in this report.

Table 3 Energy Intensity & Envelope Savings Compared to Overall F&G Savings (in Btus)

Project Number	CFA Square Footage	Pctge F&G Energy Savings	Fossil & grid BTUs/Sq Ft Post	Total BTUs/Sq Ft Post	Estimated Heat Pump Efficiency	Apparent Envelope Savings	Pctge Renewable Post-Eff
17	3,800	98.02%	655.26	13,728.95	220.00%	8.57%	93.94%
3	1,688	95.23%	2,221.56	35,841.23	180.00%	20.45%	94.25%
19	1,336	94.92%	2,949.10	24,378.74	207.00%	38.12%	90.04%
18	1,832	90.79%	2,467.25	53,673.58	220.00%	26.32%	94.35%
2	1,908	87.53%	5,744.23	19,994.76	250.00%	43.64%	70.62%
10	1,056	86.60%	8,125.00	23,910.98	250.00%	19.91%	69.73%
21	2,226	73.63%	21,495.96	47,066.49	140.00%	29.65%	58.05%
35	2,263	72.48%	7,901.02	18,033.58	149.40%	0.07%	56.46%
16	4,089	71.11%	9,180.73	20,630.96	120.00%	38.17%	52.22%
6	2,568	70.86%	6,140.97	40,358.26	250.00%	27.58%	83.84%
33	1,527	69.18%	22,527.83	65,491.81	120.00%	38.05%	64.39%
23	2,787	67.87%	7,434.52	17,082.88	120.00%	3.61%	57.04%
8	1,752	65.63%	23,361.87	43,179.22	120.00%	20.85%	47.73%
32	2,278	64.30%	10,223.88	38,248.46	180.00%	6.23%	72.33%
1	1,836	60.25%	28,872.55	42,608.93	200.00%	13.87%	33.86%
20	1,315	59.26%	25,764.26	37,353.61	200.00%	16.55%	32.52%
4	1,400	54.86%	29,778.57	59,535.71	100.01%	-6.23%	56.72%
14	1,982	50.08%	28,471.24	43,476.29	120.00%	24.81%	37.04%
11	2,399	49.33%	30,587.74	42,088.37	200.00%	24.54%	32.06%
25	4,160	47.30%	25,622.60	36,295.67	140.00%	48.31%	33.03%
28	4,000	32.93%	31,890.00	45,732.50	120.00%	27.76%	32.38%
24	2,304	30.81%	15,095.49	35,203.99	160.00%	5.95%	53.66%
5	2,050	27.03%	44,546.34	77,756.10	100.01%	16.81%	40.27%

¹⁴ As a reminder, it should be mentioned that two of the incentives were directly tied to energy savings – Efficiency Vermont incentives (up to \$2000) based on specific air sealing and insulation improvements, and the Zero Energy Now incentive of \$50 per MMBTU of combined fossil fuel and grid electric energy saved (up to \$5000). Three others, the equipment rebate for heat pumps, and the RERC incentives for advanced biomass installations and solar hot water were fixed amounts based on equipment purchased, and were not tied to specific savings. The federal tax rebates for solar and other energy improvements varied, but were based on a percentage of cost – e.g. the installed cost of the solar array, or the material cost of the cellulose and the foam purchased to insulate the house.

Energy Intensity (measured in BTUs per square foot – both for fossil & grid energy intensity and total energy intensity) and **the Estimated Envelope Improvement** for each project are shown in Table 3 above.

As we would expect, there is generally a reverse correlation between fossil and grid energy savings and fossil and grid energy intensity. Some outliers include Project 21 in which energy intensity is higher than expected, and Project 24 in which the energy intensity is quite a bit lower than expected. A closer look at each of these projects may reveal why they are such outliers, but they are both very near the median in conditioned floor area, so it is not because they are unusual in that regard.

Envelope Efficiency & Efficiency of Heating Equipment

The Estimated Envelope Improvement has almost no discernable correlation to either F&G Energy Savings or Total Energy Savings. This points to the fact that specific strategies for addressing a home's energy load vary significantly from house to house. It also is indicative of another factor, common to the pilots, and the narrow time frame for selling and completing the pilot projects – the fact that several of them were not fully designed in advance of their execution. Instead, as has been mentioned elsewhere in the study, they were patched together as Zero Energy Now projects after one or another of the components was completed or in progress. There will be more discussion of this as we look further into the specific projects.

It also should be noted that this Estimated Envelope Improvement is one of the *least definable numbers in the study*, having no standard methodology associated with obtaining it. Since – for purposes of this study at least – the estimated envelope improvement is tied very closely to the assumed efficiency of the heat pumps, it is worth discussing this question in some detail.

EUSAVE attempted some heat loss evaluation, but often only of the modeled area of the house¹⁵, and often other energy usage in the house wasn't included at all (e.g. for appliances or lights). In CLEAR, the essential method for defining the home's pre-project energy load is actual fuel usage prior to the project. To translate fuel usage into measurable energy loads, however, the efficiency of the heating equipment must be included as a factor. This is measurable within a reasonable range for fossil fuel heating equipment, and the pre-project heating load can be estimated fairly accurately where much of these fuels are used. Biomass heating equipment, especially older wood stoves or cord wood furnaces and boilers, is much more variable, and, because they are almost impossible to measure, usually have to be estimated.

On the improved side, where these fossil fuels have been replaced by heat pumps, the assumed energy load of the envelope depends substantially on the assumed efficiency of the heat pump. This used to be considered a pretty definable number within a reasonably narrow range – 230 to 270%. More recent study (almost all of which has occurred in the time since the 2017 pilot) indicates that this is a far from reliable range, however. In particular, multi-head systems, many of which were installed in the pilot projects, have been showing a wide range of efficiencies – anywhere from well over 200% to as low as just 100% (and perhaps lower).

¹⁵ The parts of the envelope where improvements were anticipated.

This extreme variability is compounded by the fact that heat pumps are powered by electricity, which is typically used for many other functions in the house. To obtain precise efficiencies for the heat pumps (and therefore precise data for the envelope improvement), we would need to attach monitoring equipment to the heat pump itself or at least to the heat pump circuit, neither of which was within the scope of this study. There is no other way to disaggregate this data effectively. Further factors complicating the question of heat pump efficiency include how heat pumps are used by the homeowner, and how well the heat pump raises the general temperature inside the house. If the house is broken up into many small spaces with less air movement from room to room, point-source heat like that of an air source heat pump will not easily raise the general temperature in the house.

For purposes of this study, the heat pump efficiency was given a default value – 250% for single head mini-splits, and 120% for multi-head systems, and then *adjusted up or down in an almost intuitive estimating process, keeping a close eye on the envelope improvement number*. In most cases an efficiency number that made sense for the heat pump could be found alongside of an improvement number that made sense for the envelope efficiency, and also the various other numbers that could not be disaggregated from the heat pump load – i.e. appliances, lights, and often the domestic hot water. In some cases, the numbers did not make sense, and these have been left as anomalies to be looked at more closely elsewhere in the study or at another time.

Where heat pump water heaters were a part of the project, the straight default efficiency number of 200% was used in most cases, unless there was a good reason to assume it should be higher. As mentioned in the introduction, appliance and lighting numbers were not changed unless some part of these was changed in the course of the project.

All of this discussion seems to suggest a high potential for “fudged” assumptions, wide margins of error, and a contradiction of the principles of strictly maintained “before” and “after” consistency referenced earlier. This principle of consistency was, in fact, one of the margins helping to limit and contain this estimating process, however. *More importantly, these estimated numbers are strictly contained within very well-defined fuel usage numbers – especially the two numbers we are most concerned with minimizing – fossil fuel and grid-tied electricity*. While we may be uncertain how much of the overall improvement is due to the efficiency of a heat pump or the improved efficiency of the envelope, we know how much fossil fuel and kilowatt hours of grid-tied electricity were used in the years before the project, and how much were used in the years after the project. These are the critical metrics we are addressing in this program.

Another Metric – Straight Fossil Fuel

There was some discussion in developing the *Zero Energy Now* Program about whether grid-tied electricity was really something to be avoided, since much of it – in Vermont, at least – comes from renewable, or, at least, non-fossil sources. ISO New England still has many links to fossil sources, however, and Green Mountain Power reports fossil dependencies of around ten percent, and given all the questions about the environmental and cultural liabilities of Hydro Quebec and other large scale out-of-state power systems, it was decided that the requirement and incentive tied to minimizing grid-sourced electricity was important. In particular, it was recognized as important to encourage and develop on-site and local renewable power, and to encourage Vermont homeowners to “buy in” to such systems. The financeability for Zero Energy Now also required that the

homeowners' energy bills be driven down as close to zero as possible, and this could only occur if they purchased their own generating capacity.

While most program participants purchased some solar (as was encouraged in the 2016 pilot and was specifically incentivized in the 2017 pilot), many came up a little short on their overall F&G reduction goals, and the solar component in particular, because the solar didn't perform as well as expected, or because they didn't install as much as was actually needed to cover their heating loads and meet the ZEN standard.

However, the program-wide showing on fossil fuel reduction alone was very significant as the following chart attests.

Table 4 Straight Fossil Fuel Savings – Annual (in MMBtus)

Project Number	Fossil Fuel Usage Prior	Fossil Fuel Usage Post	Percentage Fossil Fuel Reduction	Fossil Portion Prior Total Energy	Fossil Portion of Post Total Energy	Pctge F&G Energy Savings	Pctge Renewable Post-Eff
10	50.72	0.00	100.00%	0.00%	0.00%	86.60%	69.73%
23	45.82	0.00	100.00%	0.00%	0.00%	67.87%	57.04%
17	107.91	0.93	99.14%	0.74%	1.78%	98.02%	93.94%
2	66.02	1.24	98.12%	1.34%	3.25%	87.53%	70.62%
35	48.41	1.00	97.93%	1.54%	2.45%	72.48%	56.46%
16	97.46	4.58	95.30%	2.79%	5.43%	71.11%	52.22%
3	66.37	3.32	95.00%	2.75%	5.49%	95.23%	94.25%
18	39.56	2.58	93.48%	1.60%	2.62%	90.79%	94.35%
8	97.06	6.67	93.13%	5.60%	8.82%	65.63%	47.73%
19	54.02	3.91	92.76%	5.04%	12.00%	94.92%	90.04%
1	135.89	21.85	83.92%	14.43%	27.93%	60.25%	33.86%
20	48.52	11.30	76.71%	10.43%	23.00%	59.26%	32.52%
32	56.09	17.98	67.94%	15.91%	20.64%	64.30%	72.33%
21	83.01	28.78	65.33%	15.86%	27.47%	73.63%	58.05%
33	93.95	37.91	59.65%	27.57%	37.89%	69.18%	64.39%
25	146.21	61.59	57.88%	14.14%	40.79%	47.30%	33.03%
14	92.28	52.95	42.62%	46.84%	61.45%	50.08%	37.04%
11	106.83	63.45	40.61%	43.82%	62.84%	49.33%	32.06%
5	105.20	73.27	30.35%	39.39%	45.97%	27.03%	40.27%
24	42.67	29.87	30.00%	26.77%	36.83%	30.81%	53.66%
4	66.85	47.60	28.80%	51.54%	57.11%	54.86%	56.72%
28	170.00	137.46	19.14%	55.64%	75.14%	32.93%	32.38%
9	56.81	64.54	-13.61%	40.32%	59.36%	14.46%	39.12%
6	18.69	21.91	-17.23%	14.59%	21.14%	70.86%	83.84%

This chart is sorted by greatest to least reduction in straight fossil fuel. Ten out of 24 projects reduced their fossil fuel usage by well over 90%. These ten projects reduced their actual fossil fuel usage to less than a tenth of what they had been consuming before undertaking their Zero Energy Now project. For nine of them, fossil fuel made up *less than a tenth of their current – post-project – energy portfolio*.

Again, the straight fossil reduction doesn't correlate perfectly with fossil and grid energy reduction. This is mostly because renewable energy systems (in the right-hand column) were sometimes not large enough to substantially cover the electric load.

It should be noted here as well, however, that two homeowners in fact *increased* their fossil fuel consumption, while others showed less than robust reductions. This sometimes signified a problem, and sometimes did not. In Project 6, the homeowner – who increased her usage by the greatest percentage – actually used very little fossil fuel to begin with. Her increased usage was essentially the same as that of Project 1 who *decreased* hers by almost 84%. Project 9, however, essentially switched fuel usage from wood to heat pumps, and thus substituted one renewable option for another – rather than using the project improvements to reduce fossil fuel.

Projects 28 and 24 similarly substituted at least some heat pump usage for former wood heat usage with a less substantial reduction in fossil fuel usage, while Project 4 installed a heat pump in a newly added section of the house that did not impact substantially on the existing fossil fuel system in the original part of the house.

Program wide, these less successful projects were more than offset by the very robust successes of the twelve best projects, all of which were better than 75%. But they also highlight a liability inherent in the design of the program. While it is not possible or appropriate to tell homeowners how to use the fuel options available to them once a project is complete, the program goals – and even the homeowners' intentions – may be subverted circumstantially by the continued availability of and reliance on fossil fuels. This is especially problematic in a program where incentives are involved, and where qualifying for financing may be contingent on significantly reduced energy bills.

The Design of Zero Energy Now

The ZEN Path – A Comprehensive Systems Approach

Zero Energy Now, in its most constructive form, is not simply a matter of throwing together some weatherization, improved heating technologies, and solar energy in a willy-nilly fashion to get a house off of fossil fuel. It is a carefully designed approach that works judiciously to reduce and manage the energy loads in a home to achieve the most effective outcome – a comfortable home, powered by clean, renewable energy, at an affordable price. The most successful *Zero Energy Now* projects did this, and it is time now to look closely at how this was brought about in these projects.

The first step is to look at the house as a system:

- How well does the envelope contain the heat produced by the heating system?
- How effective is the ventilation system at managing the relative humidity and indoor air quality in the home?
- Is cold air and mold kept out of the conditioned space?

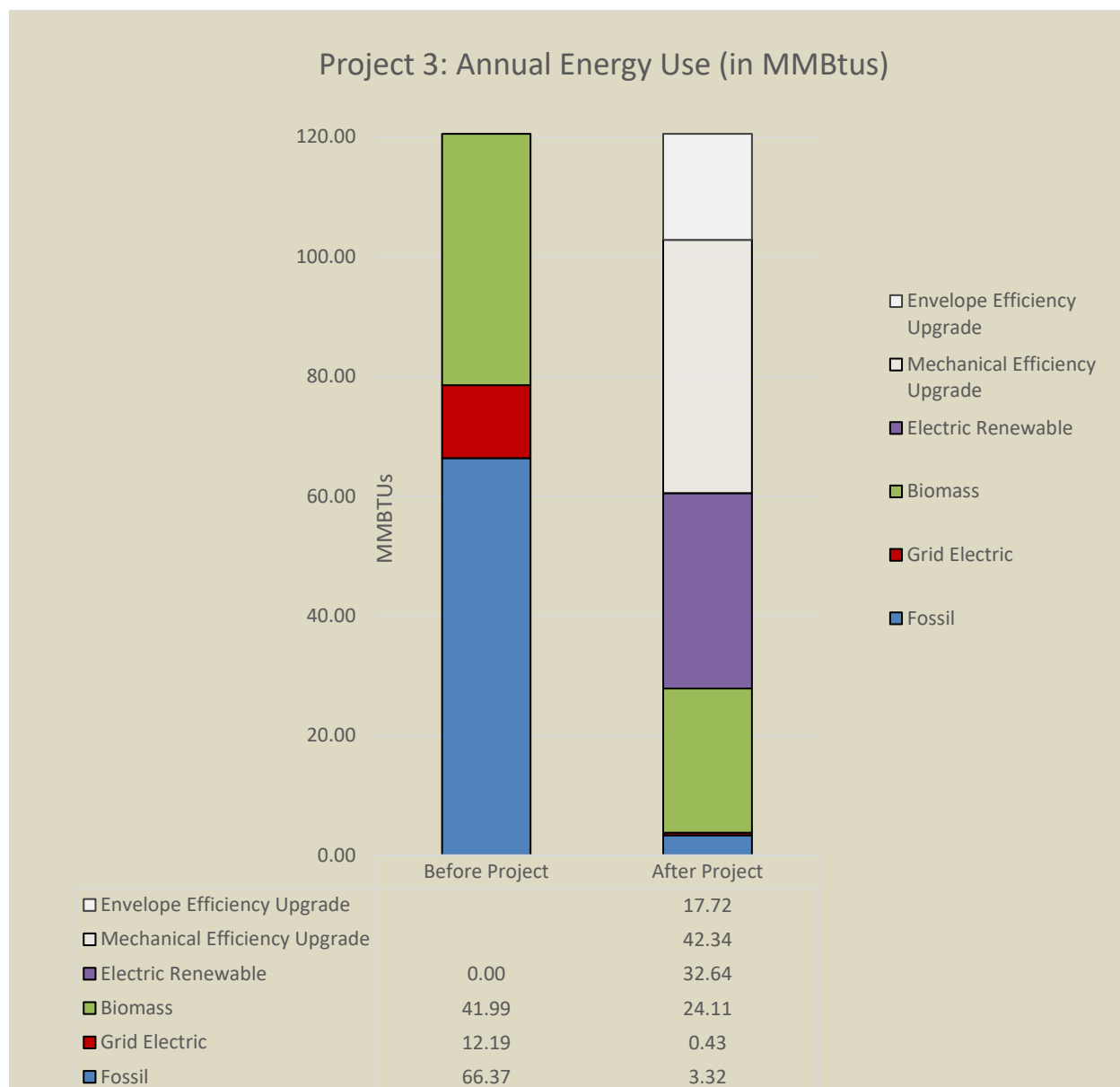
- Is warm air kept effectively inside the envelope, so that it doesn't migrate into the walls where humidity can condense and create serious moisture problems?

These are the essential concerns of an energy audit.

In addition to addressing these concerns, the ZEN Coordinator or Contractor will specifically propose the following steps to maximize reductions in the home's reliance on fossil fuels:

1. **Reduce the heating load by making the envelope more efficient** – this tightens up the house to make it more comfortable and reduces the heating load to where it can be managed by heat pumps. **Reduction: 10 - 30 MMBtus average.**
2. **Install superefficient mechanicals (heat pumps and/or a heat pump water heater)** – this reduces the energy load further and converts much of it to electricity, which can then be powered by solar or other renewable generation. **Reduction: 20 - 40 MMBtus average.**
3. Alternatively (or if further heating options needed), install advanced wood heat as a less efficient but sometimes more powerful, and in some ways more effective, heating option (a pellet boiler can fire hydronic distribution for example); for heating only: conversion to directly renewable biomass fuel.
4. **Install a solar array or other renewable electric generation** that will power all electric loads in the house. **Makes virtually all remaining energy loads – 25 - 40 MMBtus – renewable.**
5. Remaining fossil: might be a gas or propane cookstove, or an oil or propane furnace or boiler left in place for backup heat.

The following graph shows how this concept actually worked in Project 3:



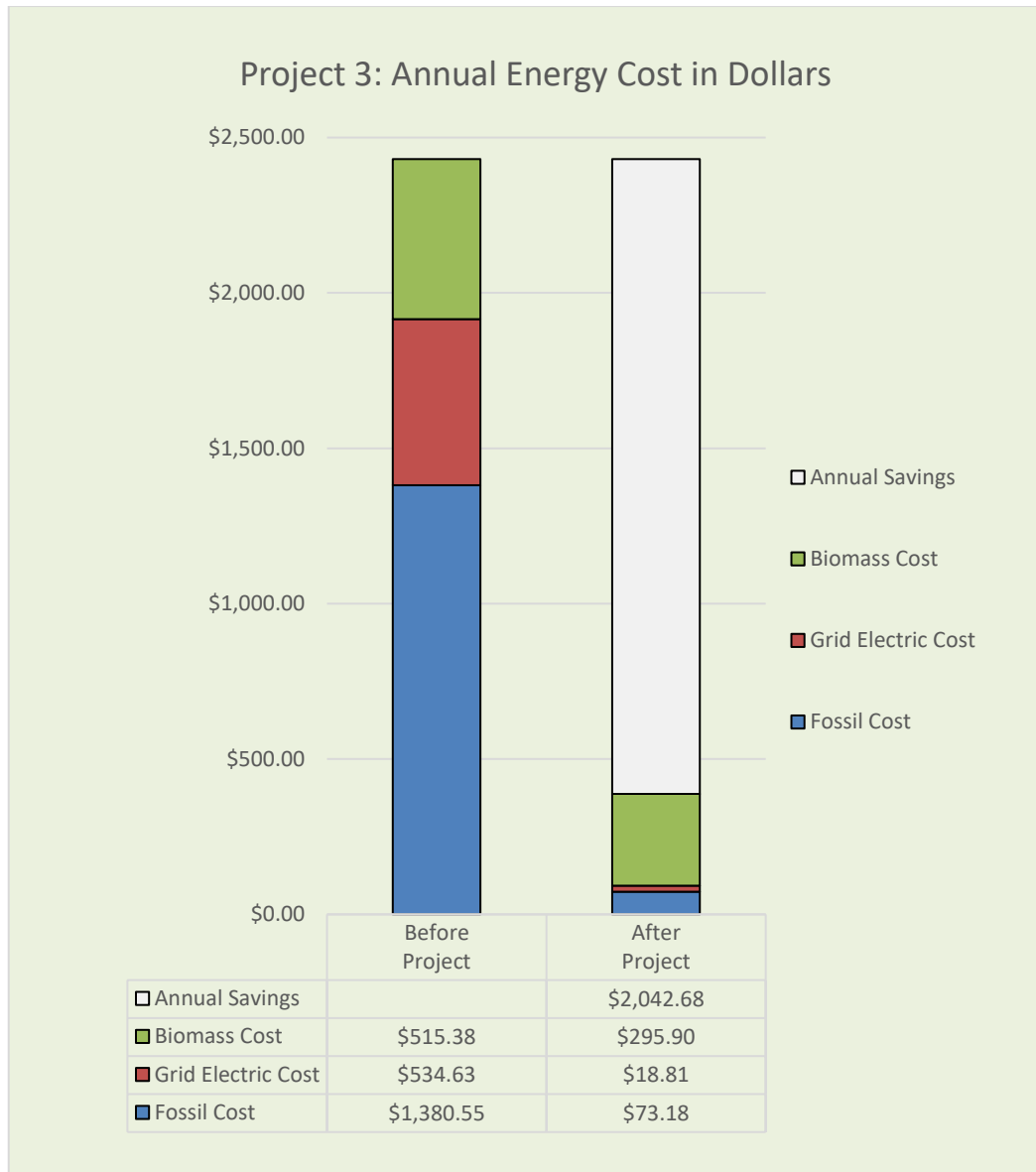
Specific measures to improve the efficiency of the envelope reduced air infiltration by 42% (not shown on graph) and reduce the overall heating load by almost 18 million Btus (over 20%).

With the reduced load and tighter house, it became possible to introduce mini-split air-source heat pumps, which through their high efficiency – well above 100% – effectively reduced the heating load by another 27 million Btus. The existing stand-alone propane-fired water heater was then replaced with a heat pump water heating unit to reduce the overall energy load by an additional 15 million Btus.

A 7.8 kilowatt solar array installed on the roof was able to power most of the additional electric loads, as well as existing appliances and lights, effectively driving down the home's use of grid-tied electricity to less than half a million Btus.

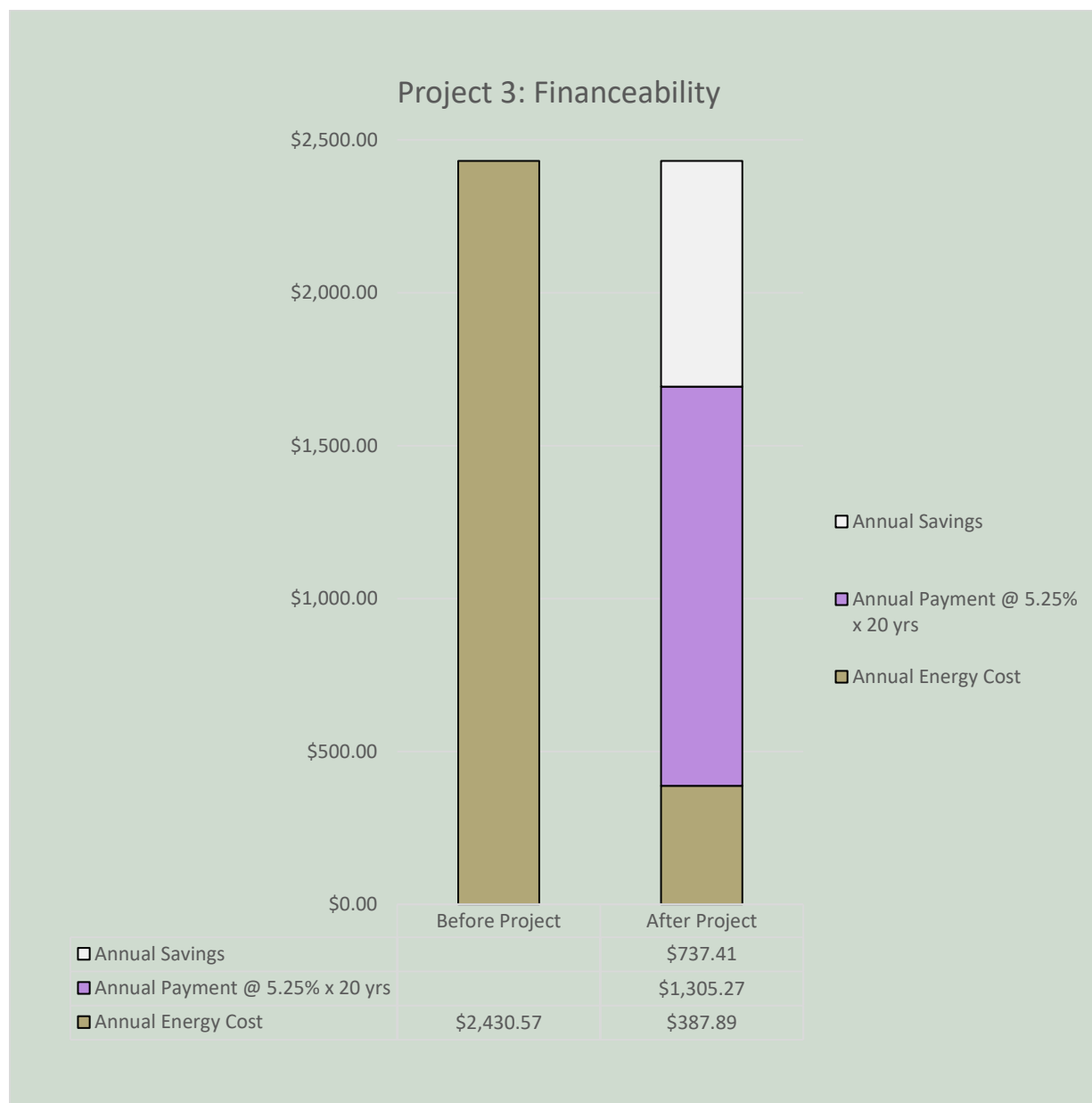
The existing oil boiler was left in place for backup, and the only other fossil fuel in the house is propane used for cooking – totaling a little over three million Btus. The combination of the tighter

house and the heat pumps also allowed the homeowner to reduce his reliance on wood heat from two cords to one cord.



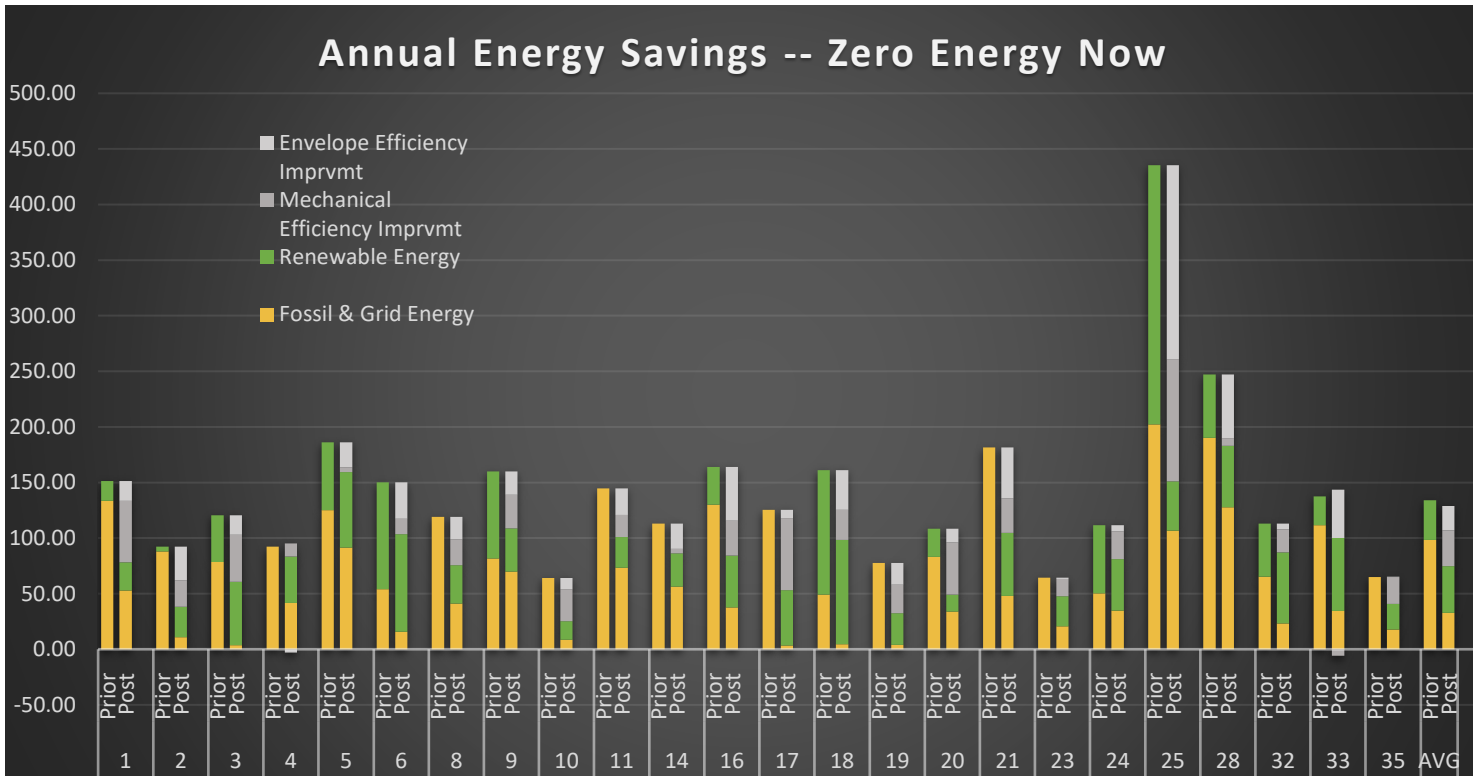
As the chart above indicates, energy costs were driven down in a similar manner, from \$2,430.56 annually to \$387.89 annually. This leaves over \$2,000 in savings which can be applied towards paying off a loan financing the project.

Even with a significant annual loan payment of \$1,305.27, the homeowner can enjoy over \$700 in savings each year, compared to what he was paying each year prior to the project. After the loan is paid off, the homeowner's out of pocket cost is reduced from around \$1700 annually to around \$400 annually, a reduction of over \$2,000 from his pre-project out-of-pocket energy costs. While the added



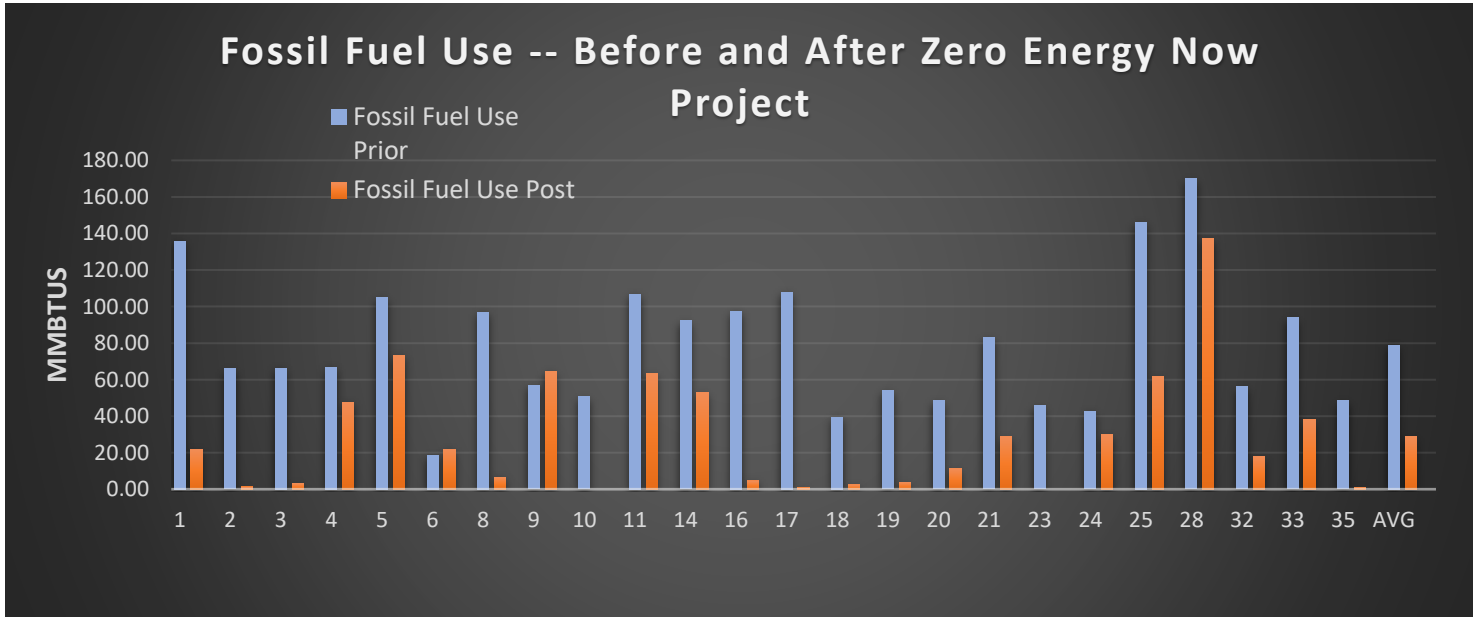
debt of a loan may feel burdensome to some people, the \$2,000 in energy costs was a considerably greater burden that has been eliminated altogether. A debt disappears once it has been paid off; energy costs, by contrast, will never disappear on their own. Debt put into a home improvement of this nature, furthermore, can be considered an investment – repaid in the form of energy savings, energy independence, comfort, home value, environmental quality, and cost savings.

Of course, not all the projects in the pilot performed as well as the project above. With the exception of a few projects, however, as the chart below shows, fossil and grid savings were significant. In several cases (2, 6, 10, 17, 18 & 19), savings were exceptional.



Fossil Fuel Only Savings

Looking once again at fossil fuel only use – before and after the project – the savings, in most cases, are even more spectacular. If you look closely at the chart below, you will note that projects 10 and 23 show no fossil fuel use at all after the Zero Energy Now project.

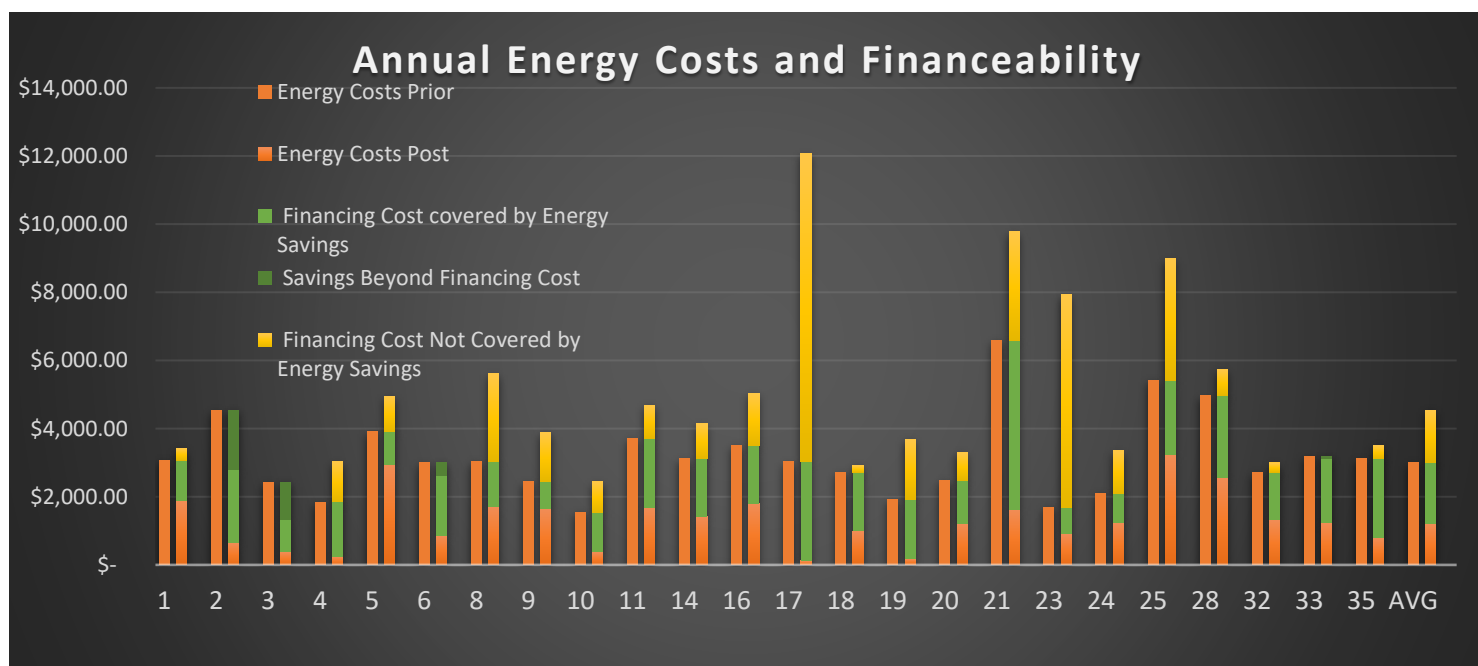


Cost Savings & Financeability

The chart below shows both the energy savings and the financeability of each of the projects. The financing metric, again, is based on a long-term home equity loan with an APR of 5.25% and a term of 20 years.

While only four out of the twenty-four projects were cash-flow positive after financing at the above rate, four other projects required additional out-of-pocket outlays of less than \$35 per month – a potentially reasonable balance of cost for benefit, and one that could well disappear against inflated energy costs over a twenty year period. Six other projects would require less than a \$100 per month additional out-of-pocket outlay. Even those might be considered by some to be marketable expenses in favor of the benefits of the project.

It should be noted at this point that the thresholds required for obtaining the 2016 Zero Energy Now program incentives were substantially less than net zero or even 90% renewable. The program required only a 10% envelope efficiency improvement, a 50% reduction in fossil fuel and grid based electricity, and 50% of post-project energy derived from renewable sources. The 2017 Solar Bonus Program required even less.



Note: Chart shows financeability under 20 year home equity loan at 5 ¼ percent – not actual financing of projects by homeowners.

Individual Projects – Some Analysis

The Most Successful Projects

The most successful projects in terms of fossil fuel and grid electric savings were (in order of deepest savings) project numbers 17, 3, 19, 18, 2. The most successful in terms of cost savings were 17, 19, 4, 2, and 3. The most successful in terms of financeability were 2, 3, 6, 18, 32. Projects 2 and 3 were the only two who made it into all three groups. 17, 18, and 19 made it into two groups.

NOTE! In the charts below, all numbers that are not in otherwise identified, are in MMBtus. Note in particular that the “Envelope/Mech. Load” numbers in the “pre-project” column, indicate the entire heating load, pre-project; in the “Post-Project” column, indicate first the heating load with just the envelope improvements, and then the heating load with the mechanical improvements. In the example shown to the right, the pre-project heating load is 67.25 MMBtus; the envelope improvements reduced that load to 61.49 MMBtus, and the mechanical improvements to the heating system reduced the heating load still further, to 28.34 MMBtus. “Net Project Cost” is total project cost, less incentives and solar tax rebate.

Size of house: 2500 sq ft
Style of house: Colonial
Number of Occupants: 4
Net Project Cost: \$30,000

	Pre-Project	Post-Project
Fuels Used:	Oil, kW	kW
Envelope/Mech. Load:	80.00	60.00/24.00
Domestic Hot Water:	15.00	6.00
Total Energy Consmd:	110.00	45.00
Solar Array:		14.56 kW
Solar generation:		49.68 (14560)*
Other Renewable:		
Fossil & Grid Total	125.00	3.42
Annual Energy Costs:	\$3,000	\$150
Monthly OP	\$250.00	\$200.00

*Solar generation shown in both MMBtu and (kWh)

Project Sample *Net Monthly Savings: \$50.00!*

Project 17 (below) was the most successful project in terms of overall fossil and grid electric savings – over 98%. It was a rambling colonial farmhouse, the original section brick. Because attic areas were limited and difficult to get at, the primary focus of the weatherization work scope was in the basement – the field stone foundation and the perimeter of the floor framing – and an isolated floor area with radiant heat over a crawl space beneath an addition unconnected to the basement.

Because the homeowner had ample funding resources and the project was not being financed, a ground source heat pump was installed which made it possible to work with the existing hydronic heat distribution system to heat this rambling house very effectively. Domestic hot water tied into the original boiler was replaced with a heat pump water heater. A large solar array was installed to power the heating system and all the other electric loads. A planned expansion of the solar array will make it possible to power the home 100% (except for backup), and also power an electric vehicle. The existing oil boiler was retained to provide supplemental heat in extremely cold weather by pre-heating the water in the under-floor radiant tubing, and also for backup during power outages when it can run off of a generator.

Due to the installation of the ground source heat pump and a large solar array, this project was the most expensive project that went through the ZEN program, and for that reason was quite atypical. Due to the difficulty of weatherizing this house, and its rambling, broken up nature, it would have been difficult, to achieve net zero without a substantial investment, even without the ground source heat pump.



Project 17 **Net Monthly Cost: \$751.23 (not financed)**

Size of house: 3800 sq ft
 Style of house: W Colonial Farmhouse (part brick)
 Number of Occupants: 4
 Net Project Cost: \$169,334

	Pre-Project	Post-Project
Fuels Used:	Oil, kW	kW
Envelope/Mech. Load:	67.25	61.49/28.34
Domestic Hot Water:	20.00	7.04
Total Energy Consmd:	125.54	53.10
Solar Array:		14.56 kW
Solar generation:		49.68 (14560)
Other Renewable:		
Fossil & Grid Total	125.54	3.42
Annual Energy Costs:	\$3,030	\$129
Monthly OP	\$252.47	\$1,003.70



Project 3 **Net Monthly Savings: \$82.57!**

Size of house: 1688 sq ft
 Style of house: Raised Ranch
 Number of Occupants: 4
 Net Project Cost: \$16,142

	Pre-Project	Post-Project
Fuels Used:	Oil, LP, kW, CdW	LP, kW, CdW
Envelope/Mech. Load:	59.02	46.95/33.57
Domestic Hot Water:	20.43	5.11
Total Energy Consmd:	120.56	60.50
Solar Array:		7.8 kW
Solar generation:		32.64 (9567)
Other Renewable:	41.99	24.11
Fossil & Grid Total	78.57	3.75
Annual Energy Costs:	\$2,655	\$359
Monthly OP	\$221.29	\$138.72

Project 3 (above), a raised ranch in Orange County, was the second most successful project in terms of overall fossil and grid electric savings. It also happened to be the least expensive project in the program. The combination of these features made it the most successful project all around -- in terms of energy savings and financeability, and one of four projects that were cash flow positive under the standard financing formula applied. An extensive weatherization work scope (attics, basement, and exposed framed walls in the basement) reduced the original heating load of 59 million BTUs by 20%, a multi-head heat pump system with two heads was able to cover 30 million BTUs of the heating load with just 17 million BTUs of electricity, reducing the original heating load by another

23%. A heat pump water heater replaced 20 million BTUs (223 gallons) of propane with just 5 million BTUs of electricity, and a 7.8 kW solar array was able to generate all but a fraction of the electricity needed to power all this equipment. The only remaining fossil fuel in the house was propane used for cooking. Wood heat, which had been a staple component of the home's energy portfolio at two cords, was also reduced to one cord. At the twenty year 5 ¼ percent financing rate the homeowner's monthly out of pocket would be \$82 less than his energy costs before the project.

Project 19 (below), a ranch house in Chittenden County, achieved savings quite similar to project 3. A very frugal couple, the homeowners kept their thermostats low and their energy costs to less than \$2,000 per year, prior to the ZEN project. Because of this, and because their weatherization work scope was extensive and involved replacement of some doors and basement windows, the project did not perform as well in our financeability formula. This was not a problem for this couple, however, as they had saved some money to cover some of the costs and paid for the rest of the project by effectively extending their mortgage for an additional five years. (They actually retired their mortgage just prior to taking on the project and took out a separate home equity loan for five years with a similar payment.)



Size of house: 1336 sq ft
 Style of house: Ranch
 Number of Occupants: 2
 Net Project Cost: \$43,209

	Pre-Project	Post-Project
Fuels Used:	Oil, LP, kW	LP, kW
Envelope/Mech. Load:	43.34	26.82/13.11
Domestic Hot Water:	7.55	2.95
Total Energy Consmd:	77.57	32.57
Solar Array:		7.98 kW
Solar generation:		28.64 (8393)
Other Renewable:		
Fossil & Grid Total	77.57	3.94
Annual Energy Costs:	\$1,926	\$194
Monthly OP	\$160.52	\$307.37

Project 19 Net Monthly Cost: \$146.85

Project 18 (below), a two story colonial in Franklin County, had a heavy reliance on wood heat – five cords per winter, along with 175 gallons of fuel oil. A combination of a 20% envelope upgrade, with installation of a single mini-split heat pump allowed the homeowners to reduce their wood usage to less than 3 ½ cords, and a heat pump water heater also installed allowed them to cut out use of their boiler altogether as it was no longer needed for heat or hot water. A 6.4 kW solar array covered over 90% of their newly increased electric load. The project was not financed, but, using our finance formula, would have had an added out-of-pocket cost of less than \$20 per month over pre-project energy costs.



Size of house: 1832 sq ft
 Style of house: Colonial
 Number of Occupants: 3
 Net Project Cost: \$23,924

	Pre-Project	Post-Project
Fuels Used:	Oil, Cd Wd, kW	Oil, Cd Wd, kW
Envelope/Mech. Load:	84.73	62.43/53.65
Domestic Hot Water:	15.85	5.23
Total Energy Consmd:	161.13	98.33
Solar Array:		6.4 kW
Solar generation:		19.76 (5792)
Other Renewable:	67.24	44.43
Fossil & Grid Total	78.57	3.75
Annual Energy Costs:	\$2,718	\$993
Monthly OP	\$226.50	\$243.99

Project 18 **Net Monthly Cost: \$17.49**



Size of house: 1908 sq ft
 Style of house: Farmhouse with ell
 No of Occupants: 1
 Net Project Cost: \$26,498

	Pre-Project	Post-Project
Fuels Used:	LP, CdW, kW	LP, kW, CdW, Pe
Envelope/Mech. Load:	54.37	30.64/16.79
Domestic Hot Water:	7.00	7.00
Total Energy Consmd:	92.22	38.15
Solar Array:		4.62 kW
Solar generation:		16.19 (4746)
Other Renewable:	4.34	10.99
Fossil & Grid Total	87.89	10.96
Annual Energy Costs:	\$4,538	\$653
Monthly OP	\$378.20	\$233.01

Project 2 **Net Monthly Savings: \$145.19!**

Project 2 (above), a nineteenth century farmhouse in rural Chittenden County, had exceptionally high pre-project energy costs (over \$4,000) due to heavy reliance on propane heat and a resistance electric water heater. A pellet stove was installed to provide relief from the propane, which the very frugal homeowner stopped using altogether, and this was also assisted by a wood stove, which had been in place all along, but not used much. The real improvement came with the ZEN contractor, who provided substantial weatherization improvements (over 40%), along with the installation of a single mini-split heat pump, a heat pump water heater, and a 4.62 kW solar array. The 4750 kWh generated by the rooftop array didn't provide enough power to cover more than 70% of the home's electric load, but, in spite of this, reduced the home's energy costs by 86%. Because of the high pre-project energy costs, this home as financed through our financing formula came out with monthly out-of-pocket *savings* of just under \$150!

Least Successful Projects

Fossil & Grid Savings – Projects 9, 5, 24, 28, 25

Cost Savings – Projects 5, 9, 1, 24, 25

Financeability – Projects 17, 23, 25, 21, 8

Project 17, the least successful project with respect to financeability, was the most successful overall project with respect to savings. But it was also the most expensive, because the homeowner installed a ground source heat pump, and a very large solar array. Nothing was done with an eye to making it financeable or cash flow positive. Of the four other projects listed as least successful with regard to financeability, Project 8 was financed as part of an active farm operation which had expanded electrical use related to the farm, and Projects 23 and 21 were partially financed – but neither included energy savings in their income qualification for the loan. Project 25 was also financed intensively (without including savings in income qualification). This project had specific peculiarities, and was one of two in which the homeowner expressed genuine disappointment.

Project 9 (below) started with an existing fuel mix essentially consisting of 350 gallons of oil, one ton of pellets, and three cords of wood – a heating load of almost 88 million BTUs. A modest weatherization work scope focusing on insulating the basement above grade, and air-sealing and upgrading of insulation in the attic was completed. A multi-head heat pump system with two interior heads and 33,000 BTUs/hr of heating capacity was installed. The weatherization work was actually quite successful, performing better than anticipated. For the project to succeed in meeting its goals, however, it was critical that the heat pump system be used to replace the fossil fuel boiler. Instead, the homeowner removed the wood stove and actually burned an extra 50 gallons of oil, effectively replacing one renewable heat source with another, rather than displacing the fossil fuel.



Project 9

Net Monthly Cost: \$120.20

Size of house:	2043 sq ft
Style of house:	Cape
Number of Occupants:	2
Net Project Cost:	\$27,757

	Pre-Project	Post-Project
Fuels Used:	Oil, LP, WdPe CdWd, kW	Oil, LP, WdPe, kW
Envelope/Mech. Load:	87.97	73.30/61.79
Domestic Hot Water:	7.01	7.01
Total Energy Consmd:	126.94	108.73
Solar Array:		11.89 kW
Solar generation:		30.90 (9057)
Other Renewable:	49.21	5.36
Fossil & Grid Total	81.56	69.77
Annual Energy Costs:	\$2,477	\$1,645
Monthly OP	\$203.95	\$324.15

Project 5 (below) started with a similarly heavy heating load – over 97 million BTUs, approximately 1/4 of which was cord wood. A fairly aggressive weatherization work scope was completed in the basement and two attics, and excellent air-sealing results – over 50% – were achieved. The two single-head mini-split heat pumps, although used only part of the time, effectively displaced less than a third of the fuel oil, along with a modest reduction in wood usage, from 2 cords to 1 ½ cords. The group net-metered solar array was divided between this house and a barn with shop and office space using a separate meter on the same property. The allocation to the house was not sufficient to accommodate the added load of the heat pump, so the total fossil & grid usage was reduced by only 27%.

Another interesting concern about this project is that the heat pumps didn't appear to be operating at as high efficiency as expected.¹⁶ The homeowner indicated that she and her husband had both grown up in the first years of the Arab oil embargo in the 1970s. "I think we are not out of the lifelong habit of keeping the thermostat for *everything* down low. I believe we are still in the mindset that the heat pumps are primarily for 3 seasons and oil for the winter," she said. It is possible that the radiant heat in the kitchen/living area was operating at higher temperature than was necessary, causing the heat pump to be used much less than it could have been in the winter, and to operate less efficiently when it was in use. "This winter I am trying to see if we can use even less oil by turning the temp up on the heat pump in the kitchen/living area (old garage space) and rely less on the radiant heating," the homeowner said. The homeowner was very happy with the project overall, however, and called contractors back two years later to install a third heat pump in the house, an additional heat pump in the office, and to nearly double the size of their solar array.



Size of house: 2050 sq ft
 Style of house: Raised Ranch
 Number of Occupants: 3
 Net Project Cost: \$25,013

	Pre-Project	Post-Project
Fuels Used:	Oil, LP, CdW, kW	Oil, LP, kW,
CdW,		
Envelope/Mech. Load:	97.38	81.02/81.02
Domestic Hot Water:	20.34	20.34
Total Energy Consmd:	185.99	159.40
Solar Array:		6.60 kW
Solar generation:		20.27 (5940)
Other Renewable:	38.77	30.94
Fossil & Grid Total	125.14	91.32
Annual Energy Costs:	\$3,911	\$2,935
Monthly OP	\$325.94	\$413.10

Project 5 **Net Monthly Cost: \$121.42**

¹⁶ To show modest envelope efficiency gains (16.81%, compared to HERO's 19.18%) in the verifying software, the heat pump efficiency had to be estimated at just over 100%. While we can't measure either the heat pump efficiency or the envelope efficiency precisely, together they indicate that some part of the system was underperforming.

Project 24 (below), a simple 1 ½ story house with a somewhat open floor plan and a walkout basement, did not perform as well as expected for two reasons. First, the weatherization work scope was quite modest, consisting mostly of basement insulation. (HERO anticipated less than 6% improvement. It actually performed better.) Secondly, with the heat pump operational, the homeowner cut his cord wood usage in half – from three cords down to 1 ½ cords, replacing 17.35 million BTUs of wood heat with 14.8 million from the heat pump. This may have been a significant benefit to the homeowner, but allowed him to save only 10 gallons of fossil fuel over the course of the year. In other ways, the project was very successful. A heat pump water heater was installed, saving 125 gallons of propane annually, and a solar array was installed, which, even with the low solar yield of the past two years, covered 74% of his electric load. Thus, even with the reduction in cord wood usage, this homeowner still met the 50% renewable standard of the program.



Project 24 **Net Monthly Cost: \$103.12**

Size of house: 1073 sq ft
 Style of house: Contemporary cape
 Number of Occupants: 1
 Net Project Cost: \$25,882

	Pre-Project	Post-Project
Fuels Used:	Oil, LP, CdW, kW	Oil, LP, kW, CdW,
Envelope/Mech. Load:	61.12	57.48/51.93
Domestic Hot Water:	11.45	2.86
Total Energy Consmd:	111.58	81.22
Solar Array:		4.64 kW
Solar generation:		14.00 (4104)
Other Renewable:	36.78	19.43
Fossil & Grid Total	50.27	34.84
Annual Energy Costs:	\$2110	\$1255
Monthly OP	\$175.86	\$278.98



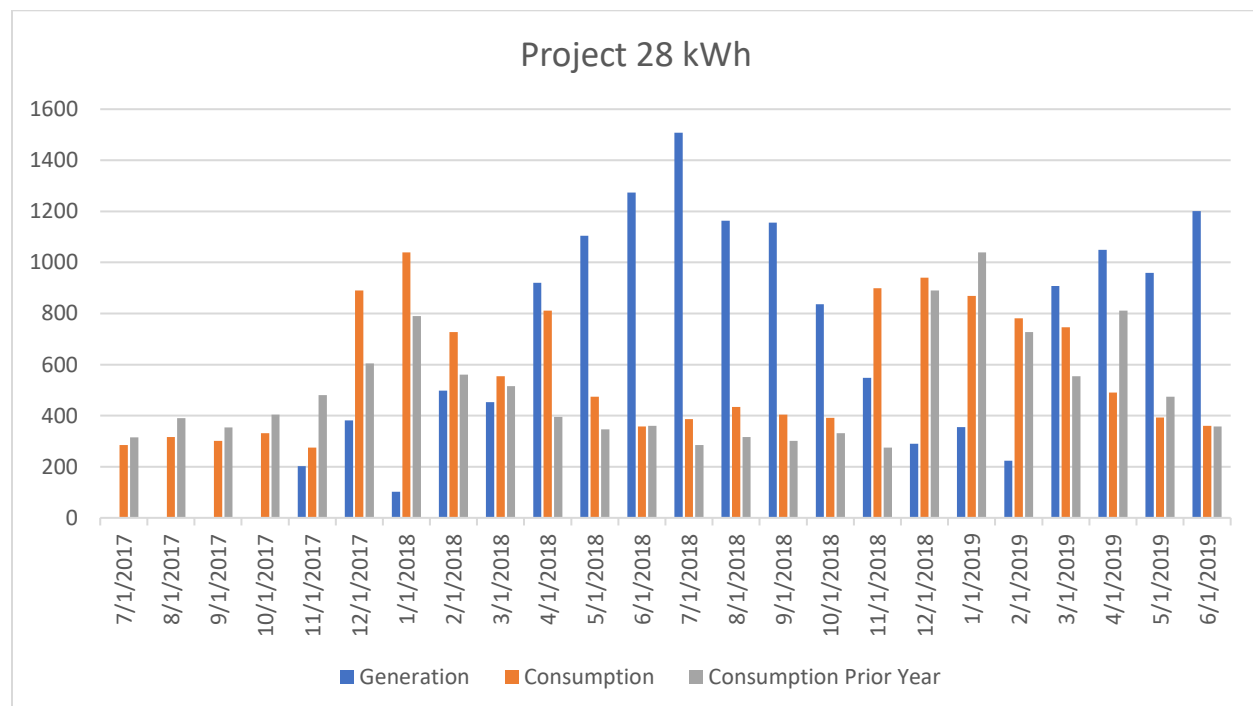
Project 28 **Net Monthly Cost: \$64.58**

Size of house: 4000 sq ft
 Style of house: Farmhouse with ell
 Number of Occupants: 3
 Net Project Cost: \$39,171

	Pre-Project	Post-Project
Fuels Used:	Oil, CdW, kW	Oil, kW, CdW
Envelope/Mech. Load:	153.32	110.76/109.85
Domestic Hot Water:	21.01	21.01
Total Energy Consmd:	247.07	182.93
Solar Array:		9.67 kW
Solar generation:		35.10 (10286)
Other Renewable:	34.13	12.17
Fossil & Grid Total	190.19	127.56
Annual Energy Costs:	\$4,964	\$2,571
Monthly OP	\$413.65	\$478.23

Project 28 (above) was a large farmhouse in Addison County with an exceptionally high – 153 million BTU – heating load. The weatherization work scope attacked three attic areas and part of the basement, and appears to have performed quite effectively, reducing the envelope load by as much as 27%. (An air infiltration reduction of over 40% was achieved.) A three-head Daikin MXL series heat pump system was installed in two bedrooms and in a large area downstairs, and a large solar array – 9.67 kW – was installed which produced at just below par¹⁷ – 10,286 kWh, substantially more than the 7,383 kWh used in the home in the same period. The homeowners had been using 2 ½ cords of wood prior to the project, and reduced that usage to just one cord. Partially because of that, they were only able to save a little over 200 gallons of oil. What is curious about this project, is that even with the outsized solar array, the heat pumps appear to have been used only very moderately. The relatively comprehensive three-head system, which should have covered a substantial part of their heating load, only accounted for 5 ½ million BTUs – less than 5% of their post-project heating load. (Again these numbers are somewhat indeterminate. This calculation assumes that their appliance and plug load before and after the project was essentially similar.)

Looking at the power and consumption graph below, which compares recent usage to the season before the heat pumps were installed, there are moderate indicators of heat pump use in November 2017 and in December and January that same winter, and strong spikes in consumption in March 2018 and then again in October 2018. (Since the readings are dated the 1st of the month, power indicated is for the month prior.)



¹⁷ Par generation of kWh annually for a fixed system in Vermont is 1.1 times the system size in kW. Actual production varies from system to system and from year to year due to factors related to siting and weather.

An important thing to note about this project is that the homeowner was unwilling to have the ZEN contractor coordinate the work, and hired him only to complete the weatherization portion. The homeowner opted to hire heat pump and solar contractors on their own. It is uncertain why the heat pumps were used so little when there was a substantial surplus of power generated and available at no cost to the homeowners. They may have been away part of each winter or they may simply have preferred the heat provided by the existing fossil fuel system, and found it difficult to effectively displace it with heat pumps. Or, as is not uncommon, they may have been instructed by their heat pump installer (who is also their fuel supplier) to use the heat pumps only during shoulder seasons. The spikes in usage at these times of year seem to suggest this. A follow-up with the homeowner may resolve some of these problems now. In any case, this project makes clear the benefit of having a ZEN contractor design the project scope, and then ensure that all of its components are working smoothly together to achieve the homeowner's goals. It is clear also that good communication and follow-up *after* completion of the project to fine-tune the components, resolve problems, and ensure proper function is also critical to the project's overall performance.



Size of house: 4160 sq ft
 Style of house: Quasi-Industrial
 Number of Occupants: 4
 Net Project Cost: \$73,236

	Pre-Project	Post-Project
Fuels Used:	Oil, Cd Wd,	Oil, kW
Envelope/Mech. Load:	163.72	79.09/73.31
Domestic Hot Water:	12.07	6.04
Total Energy Consmd:	435.45	150.99
Solar Array:		15.96 kW
Solar generation:		44.40 (13014)
Other Renewable:	233.20	
Fossil & Grid Total	202.25	106.59
Annual Energy Costs:	\$3,126	\$1,724
Monthly OP	\$451.58	\$748.39

Project 25: Net Monthly Cost : \$296.81

Project 25 (above) is a good example of a project that suffered from a lack of coordination among contractors. The work took place over a period of more than a year, from the fall of 2016 to mid-December 2017. An extensive weatherization – effectively a deep energy retrofit – was completed that involved replacing the roof, extensive insulation and air-sealing in the attic and roof framing, along with re-siding and reinsulating many of the walls. Windows were also replaced. Work on the roof began in the fall of 2016 – stripping and opening up roof cavities, and insulating with 7” of closed cell foam. The roof was finished, and the solar installed that winter. Siding and wall insulation replacement, and windows, followed in the spring – 5.5” rock wool batts with 1” polyisocyanurate sheathing. Lastly, the heat pump system was installed – three 15,000 BTU per hour ceiling cassette evaporators, plus a 9000 BTU per hour wall unit, powered by two exterior condensers – a 30,000 Btu unit and a 24,000 Btu unit.¹⁸ Two heat pump water heaters were installed, one for domestic hot water, the other to heat radiant tubing in the garage slab. While the thermostat for the heated

¹⁸ The living space served by the heat pumps is probably less than 1600 square feet. The heat pump system is likely substantially oversized, thus short-cycling, and operating very inefficiently.

garage space is kept low 58-60 degrees, and the arrangement appears to be working (the homeowner is pleased with it), it is an unusual application since heat pump water heaters draw heat from conditioned air to heat the water. It is not clear whether drawing heat from a conditioned utility room within the house, transferring that heat from air to water, and then using the water to heat a slab in a garage space within the same structure is an efficient use of either the technology or the energy. (The homeowner may be commended for conducting what may be a worthwhile experiment, but it will be challenging to tease out the parameters and come to a clear conclusion on the results.)

The Zero Energy Now Coordinator arrived on site in October 2017, to find most of this work done, and the project was able to be certified to comply under the 2017 Solar Bonus program rules. This allowed the homeowner to receive an incentive, but there was no systematic or comprehensive design to the work that had been done, and no opportunity to develop one when the ZEN coordinator came on. By this time, the homeowner, had spent over \$84,000 with another \$6,000 due when the heat pumps were installed and turned on in December. The energy audit by an HPwES contractor (different from the Zero Energy Now coordinator) had occurred in December 2016, after the work (and perhaps the insulation?) on the roof had begun. Solar panels were installed on the roof as soon as the roof project was completed in that same month; the solar system appeared to match the existing load prior to any added heating loads (whether or not by design is unknown). The deep energy retrofit continued in the spring of 2017 with walls and windows, and the heat pump system which was specifically designed to match existing loads (although it is unclear when those loads were determined – vis-à-vis the envelope improvements), was installed late in the fall, becoming operational in mid-December. After using it for a little over a month, the homeowner discovered that it was costing him “\$900 a month”¹⁹ to operate – on top of the solar. He shut it off, and went back to oil.

How much of this disappointment and unguided process could have been avoided is hard to say. Certainly, every contractor involved was doing the best that he could, and all were motivated, presumably, by good intentions and deep capacities within their professional purview. But the idea of the ZEN program is to enhance the purview of everyone involved, and get them working together so that their expertise provides the best outcome within the context of the whole. Unless this is done, the results are going to be variable or haphazard at best.

While there is much to learn from this project, it is important to note that it was far from a complete failure. In spite of the dissatisfactions of the homeowner, this project:

- Reduced his fossil fuel and grid electric energy usage by 47%;
- Reduced fossil fuel use by 58%;
- Achieved a 47% apparent envelope improvement -- the highest out of the 24 projects examined in this study;
- Reduced total energy use by 65% -- also the highest of the 24;
- Reduced the homeowner’s actual energy costs in dollars by 41%.

The real problem with respect to the homeowner’s costs, is that the rooftop solar array is not sufficient to power the heat pump system. This home, which includes a metal fabricating shop, had enormous electric loads (16,400 kWh) before the project. Powering these, and then adding a heat

¹⁹ Put in quotes because the highest actual monthly bill that included the heat pumps was approximately \$650 higher than for the same period in previous years.

pump system that, along with weatherization, will displace ten cords of wood and 900 gallons of fuel oil, is going to require more than a 16 kW array. The project is actually a good project. It is just not complete. Its biggest failure – and this is significant – may be the loss of faith of the homeowner.

The projects discussed above – both the five “best” and five “worst” – provide a glimpse of how the elements of the Zero Energy Now concept interact with a home’s design and construction, and how the assets and liabilities of a home’s envelope and energy system can be managed and improved with both new and traditional technologies to substantially reduce its carbon footprint.

Each of these projects had a story to tell, as does each and every Zero Energy Now project. It is clear, however, that ZEN works best when the Zero Energy Now contractor or coordinator can evaluate the various characteristics of the house and then work with the homeowner to develop a strategy using current technology and best building science practices to meet the homeowner’s goals and the goals of the program – in the most affordable manner possible.

Modeling Tools

In order for the Zero Energy Now concept to be marketable as a program, it has to be able to assess the value and essentially prove both the environmental and economic benefit of its proposed improvements in advance. Because the proposed investment on the part of the homeowner -- \$30,000 to \$60,000 – is so large, the work scope elements have to be carefully vetted for effectiveness and value, and the homeowner has to be convinced that the investment is worth it.

The key performance requirements of the modeling tools were

- to evaluate the existing envelope and energy systems of a house and their level of performance;
- to measure the benefit of proposed energy improvements in terms of MMBtus saved and dollars saved;
- to evaluate the economic feasibility of the project for the homeowner, its short and long term benefit, and financeability;
- to convince the homeowner that the enormous investment required by the Zero Energy Now work scope is worth the cost and the trouble.

There were two modeling tools that were used for the two pilots – EUSAVE, developed by Paul Scheckel of Parsec Energy Consulting, and CLEAR, developed by the author of this study.

EUSAVE – “Energy Use, Savings, Analysis, and Valuation Estimator” – is a fully developed and vetted on-line tool for contractors to evaluate new or existing buildings and design the best energy parameters for their performance.

CLEAR – the “Clean Energy Assessment and Reinvestment” analysis tool was initially developed as a simple Excel spreadsheet tool to sort out some of the key parameters of the ZEN program.²⁰ The

²⁰ Specifically, whether it was reasonably feasible to achieve both fossil fuel and grid electric savings of 50% or more with the designated program elements – weatherization, heat pumps, and solar PV. Also, whether

spreadsheet format was more immediately transparent and made it easier to apply different metrics and immediately observe the consequences of using one measure or another.

The early spreadsheet tool, which became the Zero Energy Now Pre-Qualification Tool, was rolled out as a “quick” version of EUSAVE that would allow projects to be vetted quickly and also to find various strategies for meeting the ZEN standards. It was developed into CLEAR for the Solar Bonus program in 2017. CLEAR has since been upgraded further to provide more specific controls for entering fuel usage and weather data, and also for verifying project performance using the same controlled strategies for entering data post-project.

Both programs use some of the same strategies and metrics with regard to determining energy loads and potential savings.

EUSAVE had a heat loss modeling program built into it, along with a “true-up” factor to adjust the modeled usage to match actual fuel usages in the house. Like many audit and performance modeling tools designed primarily to serve weatherization programs, EUSAVE was designed to model energy usage of the whole house, and then apply specific savings from the portions of the house where weatherization work was to be done and any new heat installed, and then translate those savings into modeled savings for the whole house. EUSAVE was set up specifically to compare potential improvement “scenarios”. This was partly to tie it into one of the marketing strategies of the ZEN program developed by a business consultant. EUSAVE also was designed to provide a sales presentation to the homeowner – including, if desired, a fully developed report.

CLEAR did not contain a heat loss program, and instead used HERO (Efficiency Vermont’s modeling software) to determine projected envelope savings for purposes of the Solar Bonus program. To avoid confusion between “load” values (which include equipment efficiencies), and “consumption” (straight MMBtus per unit of fuel) values, both were fully represented in the tool in various contexts for a home’s “existing” and “projected” usage. As originally set up, it was possible to enter all the values in CLEAR very quickly, and to reproduce any number of scenarios, so no special function was created for that. There were opportunities to apply either default, estimated, or otherwise defined equipment efficiencies, methods for weighting different types of equipment, depending on their intended usage or effect on the envelope load as a whole, and otherwise teasing out the effect of applying various components of the Zero Energy Now work scope in different ways. A distinct benefit of CLEAR is its spreadsheet format, which allows a lot of useful information to be examined, manipulated, and analyzed quickly to determine value and effectiveness – and then adjusted to find better alternate strategies.

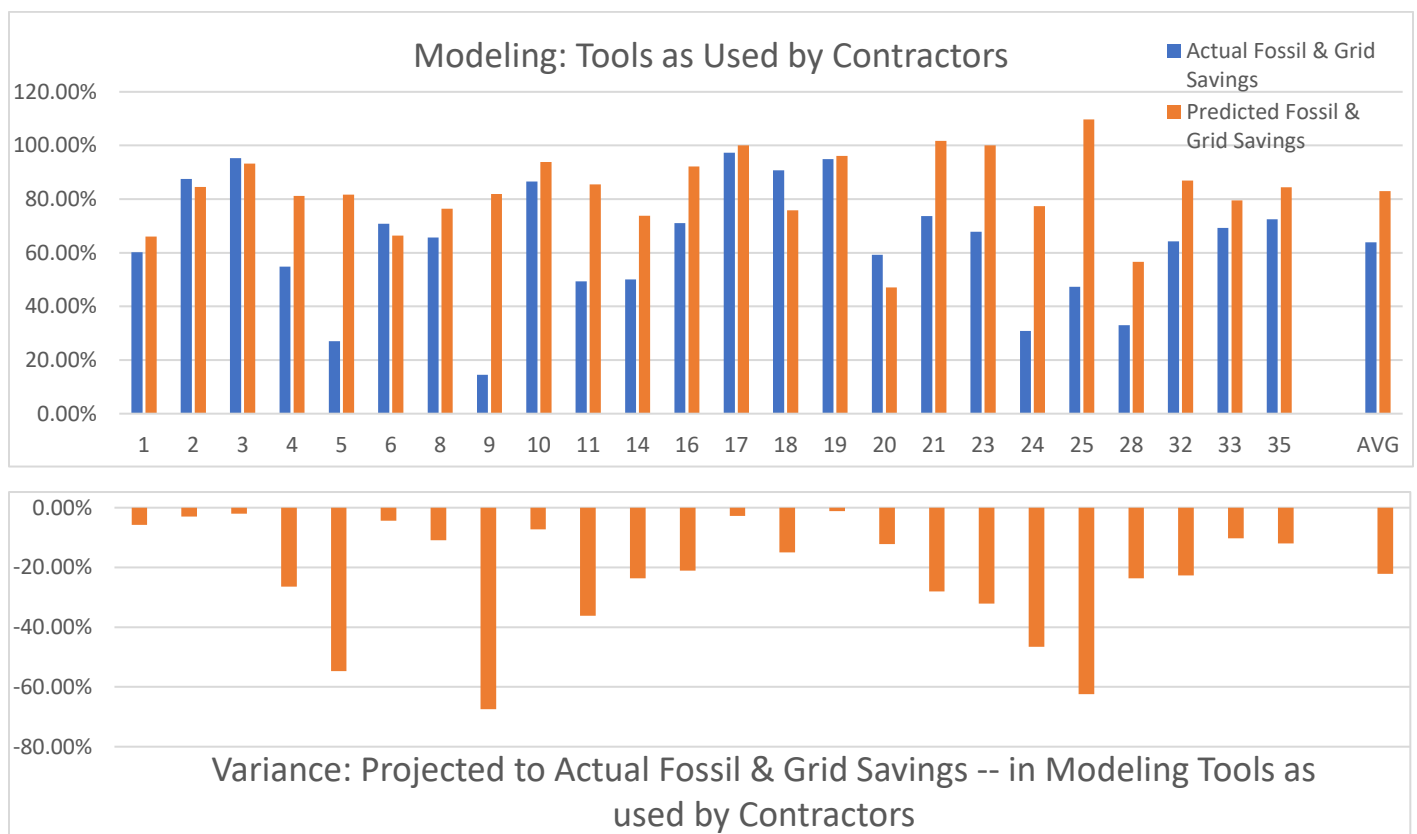
It is difficult to evaluate the modeling effectiveness of the tools themselves, however, outside of the context of their use.

The biggest factor affecting the quality, value, or effectiveness of these tools or any modeling software is the quality of the data entered into it. Neither EUSAVE nor CLEAR (at the time it was used in the Solar Bonus program) provided specific controls within the tools or specific methodologies or instructions for obtaining good data, delineating it in a way that can be managed within the metrics of the program, or even guidelines for generating defined “annual” or otherwise meaningful periodic fuel usage. The quality of the data entered by contractors who participated in the two programs was

certain program standards and parameters should be measured in “consumption” BTUs or “load” (i.e. post-efficiency) BTUs.

highly variable as a result, and the quality and effectiveness of the modeling was somewhat arbitrary depending on how the data was obtained and measured.

In spite of this, the charts below seem to suggest that, in many cases, the modeling was actually pretty good. The upper chart indicates *modeled* fossil and grid electric savings (in orange) as compared to *actual* savings (in blue). In many cases the modeled savings are reasonably close, although usually slightly higher than the actual savings.

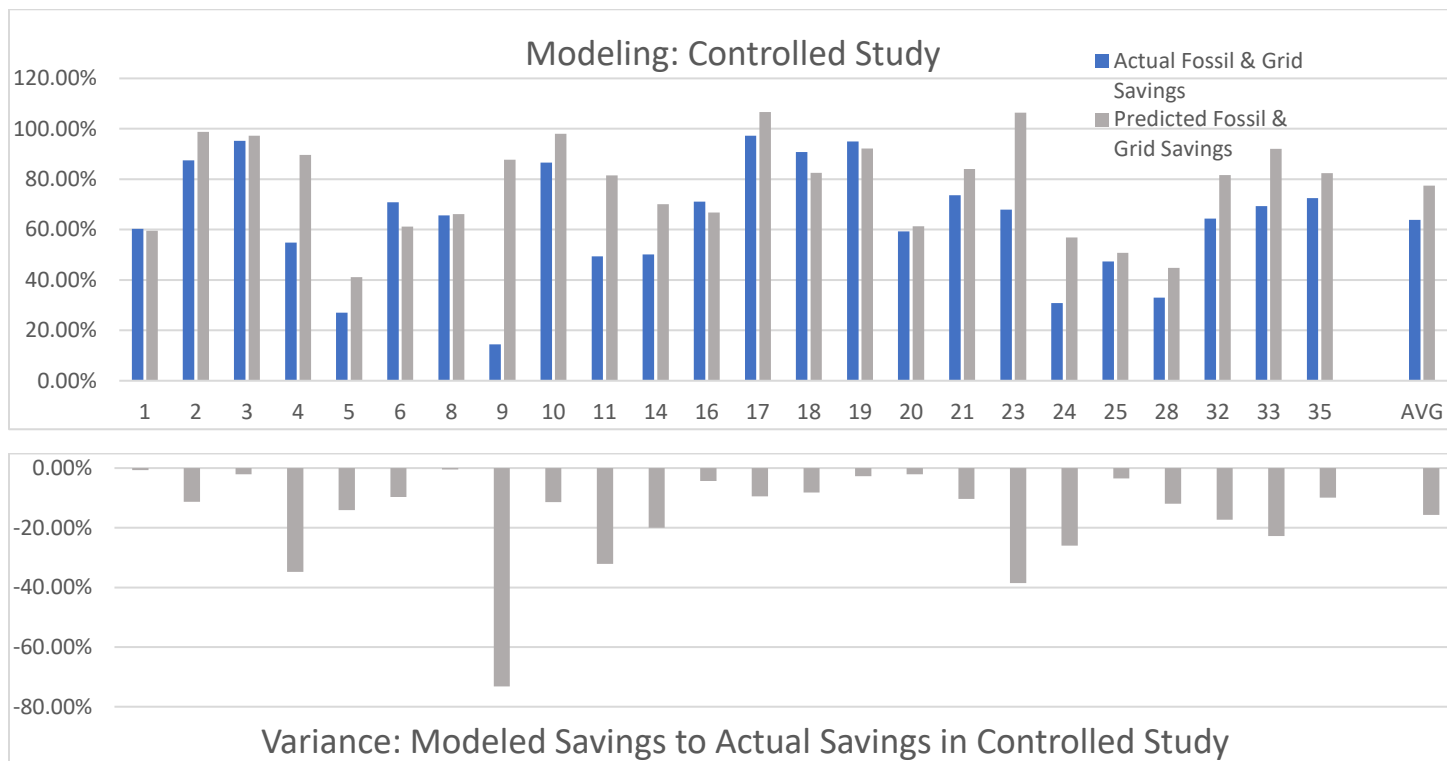


The “reflection chart” below shows the variance between predicted and actual savings. These are measured in the same units out of 100% (savings) as the graph above. The less variance the better, as it indicates a better prediction of savings. The average variance here (on the far right) is just over 22%, but for most projects the pattern of actual savings “followed” the modeled savings, and five projects were modeled within a 5% variance. Note that some of the greater variances shown here are for the same projects that performed least well in our discussion above – especially project numbers 5, 9, and 24, where the homeowners opted to substitute heat pumps for biomass in contrast to the design goals of the project.

“Controlled” Modeling Study

For purposes of this study, an expanded version of the CLEAR tool was used to compare post-project fuel usage to pre-project fuel usage. To do so, very specific “before” and “after” fuel and electric data were collected, and then configured and corrected for heating degree days within the tool. Since the modeling component of the tool populated automatically as this was done, a “controlled modeling” of each of the above projects was also effectively done in the process. The results of this are shown in the graphs below.

The key difference in this controlled modeling is that a very precise and consistent methodology was used for obtaining the fuel usage, entering it, annualizing it, and correlating it with heating degree days, both before and after the project. All of it was entered by one person. Another key difference is that estimated heat pump efficiencies were adjusted (mostly downward) to reflect general empirical data gathered through specific monitoring of performance of this type of equipment from the years since these projects were completed. This does not affect the actual fossil and grid savings shown below, but it does significantly affect the *projected* savings. The purpose of this exercise is partly to get a sense of whether it is possible – even under controlled circumstances – to effectively model or forecast energy savings.



While the results are certainly better – an average variance of under 16%, as opposed to 22% -- and seven projects were successfully modeled to within 5% of actual fuel use, there were still some substantial anomalies, again many (though not all) the same projects.

It is important to note that neither set of graphs indicates whether the variance is due to a flaw in the modeling or a flaw in the project. In the case of Project 9, it was certainly a flaw in the project – the homeowner changed her fuel mix from what had been modeled in the tool. Project 4, Project 11, Project 24, Project 28, and Project 33 all would have done quite a bit better if they had simply used

the heat pump more to displace fossil fuel (as was in fact modeled). In Project 4 and Project 11, this may have been due to circumstances related to placement of the heat pump that were not properly considered in the original modeling by the contractors (and also in the controlled study). In Project 33, there was a problem with the chimney back drafting, which prevented the homeowner from using the heat pump as much he intended to. In Project 24, the heat pump was used to displace cord wood instead of fossil fuel, and in Project 28, the heat pumps were mostly used as a three-season supplement and displaced limited fossil fuel. None of these things are modeling problems, although they may reflect communication issues with the client, or other considerations which have to be observed in order for the modeling to be effective. Project 23 is a true anomaly²¹ – and one that continues to be in spite of significant and detailed inspection, testing, on-going monitoring of the heat pumps, and examination of the data. It is unlikely that modeling, however, is a part of the problem in that project.

One of the important benefits of effective modeling is providing a clear estimate of cost savings. This is important not only to homeowners, but also to program guarantors and to financial institutions. The pilot programs offered a savings guarantee allowing homeowners to recoup costs for one year if the savings indicated were not realized. While none of the program participants made any claim on the guarantee, the above charts suggest that some of them may have been eligible to do so. Project 9 and project 23 stand out in particular. By removing her wood stove, the Project 9 homeowner did not maintain the system components understood in the work scope, and she would not have qualified for the savings guarantee. In Project 23, however, all the directives in the work scope were followed, and the shortfall in savings remains somewhat of a mystery. Trying to resolve mysteries such as this is important. Unless we can do so, a savings guarantee will become problematic and expensive. Furthermore, if a Zero Energy Now program is going to be brought to scale, financing will be required for most projects. Accurate savings projections will be a critical part of determining a project's financeability.

There is room – and a need – for further study here. There were three metrics guiding the program, and only one of them is reviewed here. Reviewing the other two metrics would help to verify the effectiveness both of specific modeling strategies, and the overall effectiveness (i.e. the feasibility and, potentially, the limitations) of modeling in general. It would perhaps guide a process for determining the key modeling parameters a future program would require. The controlled modeling above seems to suggest that very accurate modeling *is* possible, but is subject to human variables that may be difficult to correct or contain to a point where the modeled values can be used as effective margins for financing or a savings guarantee. One thing that is *unclear* from this review of a single metric is whether the somewhat haphazard data entry of contractors was somehow corrected

²¹ It has not been looked at closely as part of this study, but Project 23 was unusual in that it was a deep energy retrofit of what was already a low load house (30 MMBtus). A \$62,000 investment resulted in a 60% air infiltration reduction, along with an R-80 attic and R-40 walls, and replacement of all windows & doors with U-0.19 triple glazed units. Yet the combination of the heat pumps and extraordinary weatherization upgrades produced only a slightly better than average 67.87% reduction in fossil fuel & grid electric usage. The home's energy became 100% electrified but the heat pump used over 6 times the anticipated energy required to heat the house, and the solar array designed for the lower load could not cover it. A well designed project that should have been a true "zero energy home" fell short by approximately 43%. Monitoring evidence suggests that the heat pumps, even though the original multi-head system was replaced with single mini-split units, are still not performing efficiently. They may have been seriously oversized, and logically this may be the source of the problem, but no complete determination has been made as the contractor is out of the country, the homeowner is very happy, and it is not our place to get involved.

or validated within the modeling tools, or whether it was more a matter of chance that the modeling fell within the fairly proximate range that it did. Studying all of these factors will be an important part of any future modeling tool development.

Qualitative Assessment of Homeowner Satisfaction

Out of 35 projects completed, we were able to conduct interviews with twenty homeowners. Our interview included thirteen questions.²² Some of these were designed to obtain a sense of the homeowner's interest in the program, environmental sensibilities, motivations for taking on a ZEN project; others sought to get a sense of their experience of the project and the work of the contractors involved; and finally a sense of their project's overall performance in terms of comfort, energy savings, cost savings and general satisfaction. The impact/importance of rebates and incentives as motivational factors were also discussed.

The homeowners interviewed had discovered Zero Energy Now in various ways. Eight heard about it from a contractor with whom they were already working; three learned about it through special events held, usually by local energy committees, to spread the word about the program; one learned about it during an energy audit; one learned about it from Green Mountain Power at the Home Show; two mentioned reading about the program in a newspaper;²³ one was an employee of a contracting company; the rest (five) learned about it through another contact (friend, employer, family member).

Top Reasons Mentioned for Doing a ZEN Project (20 responses):

- | | |
|--------------------------------|-----------|
| 1) Get off fossil fuel: | 10 |
| 2) Improve house: | 7 |
| 3) Save money: | 3 |

While our questions did not specifically address income or wealth demographics, we did ask if the projects were financed, and many participants discussed their financial capacities in response to this and other questions.

While there were a significant subset of homeowners – perhaps 5 or 6 – who were in upper income brackets, and two or three that did not live in their home full time, the majority of participants were working people of relatively moderate income. One couple were farmers and saw their investment in energy infrastructure as an investment in the ongoing viability of their farm. Many homeowners were distinctly frugal in their inclinations, making mention of their attention to financial details – one mentioned using the program to obtain points on her credit cards, another had adjusted their thermostats down for a number of years to reduce fuel costs to help save money for college – or otherwise expressing strong sensibilities about cost and value when it came to their homes and saving energy. All had a clear faith in the benefit of investing in the infrastructure of their home to avoid being subject to ongoing energy costs.

Most participants interviewed had pretty strong environmental sensibilities, and these were certainly part of their motivations. Most had a mix of motivations for choosing to participate. These were balanced somewhere between frugal spending habits, environmental (particularly climate change)

²² See Appendix

²³ *Green Energy Times* No. 37, April 15, 2016

concerns, and a specific desire to improve their homes for comfort and energy savings. Perhaps only one of those interviewed was doing it specifically and principally for the financial benefit.

General Observations

Of the twenty people interviewed, most expressed solidly positive reflections on the project as a whole, with only minor reservations or complaints – many simply to offer constructive criticism. There were two homeowners who expressed substantial disappointments. (Curiously, these were not the poorest performing projects.)

Weatherization

With a few exceptions, there were a lot of favorable comments specifically about the weatherization improvements. Comfort in general got very positive reviews, and eleven homeowners remarked specifically that the weatherization improvements were a major factor. There was a complaint from one homeowner about overheating in the summer (did he try heat pump AC?), and regrets by two others that they weren't able to go further with their weatherization (in both cases due to accessibility problems) and that their heat pumps couldn't keep up with the load in very cold weather. The only other complaint about comfort came from a homeowner who said on the one hand that she didn't mind keeping the thermostat set at 55 degrees and wearing a sweatshirt, and, on the other hand, that she wished the house didn't have to be so cold. She also kept two doors open to an enclosed but uninsulated porch, so that her cats could go in and out to use the cat box. I think this homeowner's main complaint was that her rooftop solar did not cover the load, as she had expected, and that keeping the house warmer would cost her money that she didn't want to spend. As the homeowner with the single most financeable project of the 24 studied, she might have some options to solve this problem.

Heat Pumps

Heat pumps also got many very positive reviews. Comments such as "heat is reliable and works" and "Cozy and warm – heat pumps kept us comfortable at minus 22 degrees F." were reflected in the responses of many others. One liked the "sophisticated controls", another said "can turn the heat on/off in individual rooms; can control what's going on in the house", and a third said he liked "that the new heating system has web connectivity." Several were especially happy to have AC in the summer – "Cooling is #1", said one – along with the knowledge that, on those hot days, the AC was powered by the sun.

Out of 20 respondents:

Reasons to be Happy:

Project as a Whole:	7
Weatherization:	11
Heat Pumps:	8
Solar:	6
Cooling:	2
Bills/Savings/Financing	6
Doing part for climate	8

Reasons to be unhappy:

None:	6
Problem with equipment:	8
Problem with comfort:	4
Problem with cost/savings:	4
Problem with administration:	4
Problem with expectations:	2

Heat pumps, however, were, in a few cases, a focus of concern or serious problems. A few of these were projects where the Zero Energy Now contractor had come on site after the heat pumps were installed, or where the heat pump installer's experience and intentions were not well aligned with the program goals, or where the program goals were not well aligned with the homeowner's use of the equipment. In one case, Project 14 mentioned above, the Lennox heat pump, which was installed prior to the engagement of a ZEN contractor, was not a cold climate heat pump, and was not designed for use under winter conditions (specifically at temperatures below 27 degrees Fahrenheit). It was built into a forced hot air ducting system that automatically shuts the heat pump off and switches over to a fossil fuel furnace below that temperature.

Heat pumps are fundamentally different in the way they perform and heat the house than traditional fossil fuel heating systems, and the adjustment and learning curve can be difficult for installers as well as homeowners. A traditional heating system overwhelms a space and blasts it until it is warm – whether it is insulated or not. Heat pumps do not put out heat like a wood stove or a fuel-fired space heater, so it takes time for them to warm up the house, and it is important for the house to be able to hold heat in order for them to be effective. These are nuances that heating installers traditionally haven't had to think about. The advancements in heat pump technology are also difficult for an installer (or anyone) to keep up with, and any new technology has an element of risk that most contractors want to avoid. Heating contractors, if anything, have a temperamental conservatism in their approach to their work for two reasons. First, the consequences of failure don't show up until the coldest days of the year, often months away, and when it is most difficult to fix. Secondly, they are purveyors of comfort after all, and an uncomfortable homeowner is an expensive (and often unpleasant) fix – much more expensive and difficult than simply oversizing a heating system slightly to make sure that comfort is not a problem. This approach works reasonably well for fossil fuel systems, although even here it is easy to overdo it. Heat pumps, on the other hand, do not perform any better and at the same time lose their efficiency – dramatically – if they are oversized.

Program wide, only a few homeowners received any instruction from their contractors – either Zero Energy Now or the heat pump installer – on how to operate the heat pump for maximum comfort and efficiency. The Project 16 homeowner said, "Learning to live with heat pumps was complicated, but in the past now." He indicated his contractors did not help initially, but that he followed up with Efficiency Vermont "to address problems and got guidance in the course of that process."

Heat pump efficiencies are also subject to where they are placed and how they are used in the house. If they are located in an isolated room where they cannot effectively contribute to the home's heating load, they will not displace other sources of heat and their impact on pre-project fuel mix will be minimal. Often, in recent years, heat pumps have been placed in isolated spaces where the central heating distribution system doesn't reach, and this occurred in several ZEN projects – contrary to the goals of the program, which were to displace fossil fuel based central heating.

There was still quite a bit of confusion about the proper use of heat pumps, and in particular overcoming the sensibility that they should primarily be used in shoulder seasons. "I think we are still in the mindset that the heat pumps are primarily for three seasons and oil for the winter," said the Project 5 homeowner. Project 28's kWh graph above also showed distinctly increased usage of heat pumps in November, March, and April, and very little use in the winter. The Project 5 homeowner added that she grew up with a strong conservation ethic of keeping thermostats low almost to the point of discomfort. This mindset made it more difficult to consciously turn up the heat pumps to overcome the more passive thermostat load of the radiant slab, which burned oil throughout the winter without her immediate awareness.

In two other cases (Project 2 and Project 25), it was apparent that the home's solar generation capacity was not sized to accommodate the additional electric load of the heat pump. One of these homeowners kept the thermostat down to avoid having to pay an electric bill and complained that the house wasn't warmer; the other decided the heat pumps were not heating the house properly anyway, and were making his electric bill skyrocket, so he shut them off. Both of these homeowners might benefit from follow-up from their contractors to see if some of the apparent problems can be resolved, but both somehow mistakenly thought their PV system would completely power the heat pumps and heat the house.

It is also important to note that all of these pilot projects were completed in 2016 and 2017. Sometime in 2018, after these pilot programs, it was discovered, through a handful of heat pump monitoring studies, that many heat pumps were not operating at anything close to their nominal rated efficiency. Instead of being able to count on a coefficient of performance (COP) of well over 2.0, it was discovered that some heat pumps were delivering at COPs averaging as low as 1.0. This meant that actual energy savings delivered by these heat pumps in some cases was less than half what was actually projected.

There is still a lot to learn about heat pump placement, sizing, and system design. In one case, Project 23, a great deal of work has been done to address system problems including replacing multi-head systems with single one-to-one mini-splits. Continuous monitors that were placed on the heat pumps in this project indicate that one of them at least is still short-cycling heavily, and in general operating very inefficiently. It is not known whether this is because the unit is oversized, or if there is some other problem with the installation causing it to operate inefficiently. In Project 25, the overall conditioned space is 4,160 square feet, but the living space served by the heat pumps is only a little over one third of that. Yet two enormous multi-head systems were installed in this relatively small (and quite well insulated) space – with a total of 54,000 Btu per hour output. The system, on the one hand, is running very inefficiently, short cycling constantly, and running up kilowatt hours. and, on the other hand, can't keep up with the load because it constantly has to cycle off into stand-by and defrost mode.

Because of how they perform, heat pumps need to be sized differently from fossil fuel heating equipment. The standard way to size fossil fuel heating systems is to match the output to the coldest days of the winter – in Vermont, usually ten to fifteen degrees below zero. The system will simply call for heat less frequently on more average winter days without harming the efficiency. If heat pumps are sized in this way, they will operate very inefficiently on more average winter days, which, of course, are far more common. It has been suggested that the best way to design for non-fossil heat in Vermont may be to design the heat pump system for a more modal winter temperature range 20 - 30 degrees, and add some backup resistance heat to help cover the loads at much colder temperatures.

Solar PV

Solar got very positive reviews except in the two cases above where generation expectations were not met. Interestingly, in the first case, Project 2, the solar only slightly underperformed (due probably to below average insolation) and the electric load was also slightly lower than the contractor anticipated, so it is not clear where the homeowner's expectations were coming from. In many of the projects, solar was often not well matched with loads, and generation was insufficient to

meet them. This was in some cases due to lack of coordination between contractors, but in other cases due simply to limitations of rooftop space, or homeowner's financial resources. Insolation has been below average in the years since these pilot projects were completed, which has affected anticipated generation rates for some projects. Another factor for some was heavier than average snowfall in March (and even April in 2018).

The solar array in Project 25 also produced at only a .82 kWh:kW ratio – 4,500 kWh less than had been projected by the ZEN coordinator involved in the project. Since the homeowner shut off his heat pumps early in the winter and relied on oil, for most of both the 2017 - 2018 heating season and the 2018 - 2019 heating season, it is difficult to know how far short the solar would have fallen with the heat pumps included.

Another very significant factor – particular to group net metered projects – is that the division of an array's generation between participating meters is determined by a specified percentage of generation output. A credit on one meter does not go to the other – even if both accounts are owned by the same customer (unless a special arrangement is made with the utility, for which a substantial monthly fee is charged). The homeowner of Project 5, whose group net metered array was divided between her house and a detached barn on her property with a woodworking shop and an office (both used part time), had a very difficult time managing the distribution of her solar generation between the two meters. To avoid paying an electric bill when the shop and barn were being used substantially more than previously, she reallocated the distribution so that her house was receiving one percent of the power output from the array, and the barn was receiving 99 percent. This led to very skewed performance in her house over the winter of 2018 – 2019. The allocation was changed in the spring of 2019 to 25% house and 75% barn, and then again in July to 80% house and 20% barn. This change, along with increased usage of her heat pumps this winter, should significantly improve her project numbers in the future. It is not known how many other group net metered systems participating in the ZEN program have similar questionable proportionings of power resources.

Aside from these specific issues, most people had little to complain about with solar, although many opted to install less than they would need to cover their full energy load, and some commented on the high cost. Even those whose electric bills were not well covered by solar felt good about having it in their portfolio. “We love having solar on the house, feel good just seeing it there -- clean energy!” This is a comment almost everyone in the program would agree with.

Heat Pump Domestic Hot Water

Heat pump water heaters got great reviews with respect to hot water, but mixed reviews for other reasons. The Project 18 homeowner complained that the heat pump water heater did not provide the dehumidification he had hoped for. This was the same homeowner who complained of overheating in the summer. It may be that using his air source heat pump for AC might help both with overheating and dehumidification without substantially impacting his power usage. The Project 6 homeowner complained about the noise of her heat pump water heater, which came right up from the basement through the open plenum above her forced hot air furnace. She said it was terribly loud and went on typically for an hour and a half. Although she still relies on the furnace for heat, it might be possible to change the return air circulation for the furnace so that the noise is less bothersome. Again, opportunities abound for contractor follow-up.

Energy Bills, Savings, Financing

Participants in the program were generally very clear in their sense that they were saving significant energy from their projects. Cost savings, by contrast, were less clear, and were largely obscured, in their minds at least, by the cost of the project itself. For most, however, cost savings were frankly a secondary concern. This speaks in some way to the temperament of the “early adopter” who, by nature, is more interested in values other than cost. (If cost is the primary value, presumably everyone would be an early adopter.)

Those homeowners who could afford to pay for the project outright were generally happy with their dramatically reduced energy bills, and didn’t think in terms of payback. The return on investment was real and would return every year they owned the property, and possibly be a benefit at time of sale.

“I pay both the solar and the energy loan through my Green Mountain Power electric bill. I have paid \$21 so far this year in electricity – after 10 months. Because of the loan payments, I pay \$92 a month as a draft on my credit card, which gives me extra points on the card with no additional interest, since I am able to pay my credit card statement balance every month.” – Windsor County Homeowner

Those who financed were usually looking for a net cost they could afford to obtain what they considered to be very real benefits – a more efficient, more comfortable home, and reduced carbon footprint. “It may take as long as 20 years; but I’m taking it in the long term and pleased as punch,” said one homeowner. Another said, “Cost savings are not the highest priority; better performance of the house and being an environmentally responsible citizen are more important than cost savings.” A third said, “Replacement of intermittent fuel oil bills with regular loan payments makes budgeting easy.”

For some participants, however, there was a strong interest in proving the value of their projects – at least to themselves. “Savings expectations have been met, with the exception of the added consumption of the EV,” said one. “I pay both the solar and the energy loan through my Green Mountain Power electric bill. I have paid \$21 so far this year in electricity – after 10 months. Because of the loan payments, I pay \$92 a month as a draft on my credit card, which gives me extra points on the card with no additional interest, since I am able to pay my credit card statement balance every month,” said another.

With regard to savings, there was a lot of equivocation. As mentioned above, this is partly because of the large personal investment in the cost of the project up front. Some focused on this quite a bit: “I’m not saving money now because of such a big up front cost (paid for in cash). It depends on how you account for the money (no real savings), but saving money wasn’t a motivator because we’re just trading costs (expenses vs investments).” Another expressed: “I expect there will be cost savings; right now there certainly is not; expect it to be a benefit in the future.” But others, especially one of those who refinanced, saw it differently: “Savings is less important than more manageable monthly costs: a slightly lower mortgage payment and one cord of wood annually.”

Many homeowners were unclear about the true nature of their savings. One, whose only comment was “Expected lower bills; gain is no frozen pipes; but not financial gain”, actually reduced her energy bills from \$378 per month to \$54 per month.²⁴ Another said, “[Our contractor] did calculations at the beginning of the project. I thought it would be closer to zero energy. Surprised that we are way off on the energy balance.” The contractor’s entries for this project in EUSAVE did project 92% energy savings, and actually only 71% was achieved initially. This was because the multi-head heat pump system installed to displace 650 gallons of fuel oil, operated at a COP somewhere between 1.2 and 1.8 rather than the 2.5 – 3.0 COP that it was nominally given and that was reflected in the EUSAVE calculations. It was therefore requiring quite a bit more energy than could be provided by the rooftop solar array. The homeowner has more recently taken steps to correct the situation by buying an additional 5.78 kilowatts in a community solar array, which will increase his fossil and grid reduction to between 86 and 90 percent depending on insolation values.

Generally speaking there is a lot of confidence among this group of homeowners – about the overall value of the project they undertook – whether financial or social. As one said, “Anticipated savings were a large motivator; cost of oil fluctuates and can go high; we didn't want to be paying a fuel bill during retirement”. And another: “It was morally the right thing to do.”

Contractor Assessment & Comments

There were 16 contractors who undertook the training to become Zero Energy Now contractors or coordinators. Of these, 14 submitted project data into EUSAVE and CLEAR, and nine of these actually completed the thirty-five jobs qualified under the two programs. Twelve other contractors in affiliated trades (solar PV, heat pump, and biomass energy technicians) participated in the program (and the trainings) as “In Network Partners”. Virtually all of these contractors had strong philosophical missions in their businesses that were well aligned with the goals of the Zero Energy Now program. They attempted to bring their own sense of responsibility and expertise into projects in the interest of advancing those goals, as well as those of the homeowners involved. As mentioned above, however, there were also contractors who had completed portions of the work even before the Zero Energy Now contractor became involved, and there were other projects that were essentially completed entirely by other parties, and were brought into the program by a ZEN coordinator simply because they qualified. This was done primarily to increase the number of completed projects within the narrow time frame before the program deadlines.

Six of the contractors who completed projects were interviewed as part of this study. (Of the contractors not interviewed, one was the author of this study, and the other two were unavailable.) There were 24 questions that comprised the interview.²⁵

Two contractors of the six interviewed had been instrumental in the development of the ZEN program, and one of them had already completed several ZEN type projects. This contractor had been trying to promote the ZEN concept in various venues – notably within the BPPA membership at large, and also at Efficiency Vermont’s Better Buildings by Design conference for several years. His

²⁴ There is more to this story, as some of the changes she made were done on her own before the ZEN project, and there were some fuel values entered incorrectly in the CLEAR tool by her contractor, which may have confused her expectations.

²⁵ See Appendix

strong sensibility was that weatherization was not doing enough to fight climate change, and that the really important metric that should be guiding all of our efforts was greenhouse gas reduction. (It is interesting to note that the discussion around the goals of Act 62 has now shifted its focus to this same metric.)

As a weatherization trade organization, BPPA was also attempting to promote the Zero Energy Now pilots as an opportunity for weatherization contractors to develop bigger projects that would help them to build stronger businesses, and expand the reach of their services.

Weatherization jobs are not easy for a homeowner to afford. Even with Efficiency Vermont incentives – except for very poorly insulated homes with high air leakage, or less expensive “low hanging fruit” opportunities – the return on investment for weatherization improvements is generally between two and five percent, and the payback can be decades long. While there are enormous benefits in comfort, and significant energy and greenhouse gas savings, money-conscious homeowners will continue to live in their leaky, poorly insulated homes for years without making any investments in efficiency. Alternately, after reluctantly spending the money on an energy audit, and using the contractor’s loss-leader investment in the project, they will hire a different, no-nonsense, no-discussion insulation contractor to blow a few inches of cellulose into their attic for a price that they like – to virtually no effect whatsoever. It will give them a feeling that they are being a responsible homeowner and that they are doing something to make their house more efficient and to contribute to society, but will subtly reinforce their sense all along that energy investments are not worth the money.

This is the hard reality that the weatherization industry has been living with for most of the past twenty years. One of the goals of the Zero Energy Now program, therefore, has been to build business for BPPA contractors and their affiliates, and to build value in and broaden the reach of the weatherization trades in general. As observed above, weatherization financials – payback and return on investment – are not that strong, not strong enough, in any case, to drive jobs. With Zero Energy Now, these financials become slightly better. The real benefit, however, is in the significant *avoided energy costs*, which are substantial enough to provide room for financing, or, for those who don’t need to finance, the simple benefit of no longer paying energy bills. This is important because it creates a much higher value for the weatherization contractor’s work – especially one who has gone to the trouble to learn about building science and apply it carefully in his work.

Zero Energy Now contractors who were BPI certified and involved in the Home Performance with Energy Star Program were generally adept at the Building Science component of ZEN, but many had at least something to learn about tying in the other ZEN components – the solar, or advanced heating systems. The ones who had the least background in these other ZEN components had to rely fairly heavily on the expertise of their subs who sometimes did not fully understand the ZEN goals. For the ZEN projects that had been begun before a ZEN contractor came on site, it could be challenging to get the non-ZEN contractors to redirect their goals to make the project conform to ZEN standards. These projects sometimes produced good results, and sometimes did not. At least one Zero Energy Now contractor was primarily a solar contractor, and not from a building science background. She had strong associations with several BPI certified contractors, however, and was quite successful at providing full service ZEN projects to a number of her clients. One reason for her success was that she considered herself to be an “integrated” energy contractor, and was quite comfortable designing systems that included air source or geothermal heat pumps with solar energy and weatherization. The main difference with ZEN from her point of view was that the weatherization was required.

Instead of simply recommending weatherization, she would specifically arrange the contact with the BPI contractor. She pointed out that the \$5,000 incentive made this requirement an easy sell.

This contractor was one of two participating in the program that routinely provided – either in-house or through closely managed subcontractors – all three essential components of a ZEN project. These two contractors had far more sales in both pilot programs than any of the others. They were both exceptional salesmen, and their higher sales numbers were likely due to their experience in selling the whole ZEN product and their confidence in the professionalism of its installation by their employees or subcontractors. For other contractors, developing this professionalism with new subs was part of their learning curve.

All Zero Energy Now contractors and in-network partners were expected to attend trainings hosted by BPPA and Energy Futures Group, the ZEN program administrator. These trainings were designed to introduce the contractors to the program mechanics and requirements, the modeling tools used in each program, and some additional business and sales trainings hosted by a sales consultant, Mike Rogers of Omstout, who was hired to help get contractors motivated and jump start the program sales. This also provided an opportunity for contractors in all of these trades to get to know one another and develop potential partnerships with other contractors interested in the same goals.

Most BPI certified contractors already had strong motivational inclinations related to the goals of Zero Energy Now. They saw ZEN as an opportunity to build their businesses, to develop larger projects, and to expand their capacities and opportunities in a field that had the potential to achieve dramatic benefits for homeowners, the community at large, and the environment. The step up to Zero Energy Now was the step up to potentially larger jobs with higher rewards both for homeowners and for contractors.

ZEN's potential value to business is one thing. Turning it to account is another. Because of its high cost, Zero Energy Now is not an easy concept to sell, especially on short notice, when not a lot of people have done it, and when there is a deadline of only a few months to sign a contract and get all the work done. All of these things contributed to the challenges the program had in developing serious projects. Contractors could talk up the program, try to build interest in it with new contacts or with old customers with whom their trust relationship was strong, but it was also difficult for these contractors to invest time in this process when it had to compete with other work that was quicker and easier to sell, and more reliable as a source of income. When Zero Energy Now was first brought to contractors as a concept in an effort to set the program goals and the funders expectations, contractors were very optimistic, thinking that this had all the components of an essentially "almost too good to be true" product that customers would rush to embrace. But "almost too good to be true" in most people's experience is risky, prone to scams, something that is taken on slowly and cautiously, not rushed into. Furthermore, for the contractor, the steep learning curve just in sales, in understanding and applying the modeling tools, the responsibility of getting the client to take on a project largely on faith, and then coordinating unfamiliar components, and with unfamiliar contractors, under a tight deadline, was extremely daunting. One contractor described it as "a perfect storm of a startup business selling a Cadillac in two months' time – complex product, high customer service, impossible time frame."

In spite of all this, the contractors surveyed really embraced the program. The concept itself had such high value that many were willing to take on the learning curve required, adjust their expectations with respect to short term profits, and think of the program as a longer-term effort that they could support – an investment in the potential and reputation of their businesses, rather than

an immediate profit-turning strategy. This was alluded to repeatedly in their comments. One saw it as “a continuation of what I’ve been doing: building energy efficient, affordable housing in Vermont”. Another said, “ZEN is another tool in the toolbox to help a homeowner get to where they want to go in terms of improving their home.” A third said, “It fits right into what we want to do, and is consistent with and amplifies our mission.” A fourth, one of the two that sold all the components of ZEN in-house, saw the value of the program itself to drive sales: “I think we’re a leader in the state on doing these projects. It doesn’t hurt our experience to be aligned with a program.”

The sales process for most contractors also depended on their prior experience with selling the various components. For the two that routinely sold all of the ZEN components, the complication was in trying to tie it all together and get it completed in the tight time frame required by the pilot programs. For the contractor whose primary focus was solar sales and heat pumps, the incentive provided all the impetus she needed to get people interested in pursuing weatherization. She pointed out, however, that her “Usual clientele is relatively affluent, so could absorb a large cost project quickly, but the tight time frame would not have been possible for more moderate income people.”

Another point shared by many contractors was that a lot depended on how clients were introduced to ZEN and what were their own interests and motivations with respect to their homes. “People come into home energy improvements at different points,” one said. “For people already interested in doing solar, it was easy to sell the benefits of weatherization and heat pumps. If they were coming into it through weatherization, it was much more of a lift to get them to consider solar – many questions would come up – where to put it? Is the roof strong enough? Do trees have to be taken down? Also... [there was the]... much higher cost to contemplate without already being motivated in that direction.”

Almost all homeowners involved in the program had become interested in at least one component of the program before learning about ZEN, and most who participated had already made a commitment to solar. The solar component was usually the most expensive of the three, so if a client had already taken that on, the other components – especially with the added incentives – were an easier sell for the contractor. This could also be problematic, however, as the solar component – if it was already completed – was not necessarily designed for specific compatibility with the other components with respect to the load required. Since the 2016 pilot required that the post-project energy portfolio be only 50% renewable, many of the projects qualified, but they didn’t necessarily deliver the best cost value, and the best results in fossil and grid energy savings.

In general, the complexity of the sales process – the tying together of all the components, the discussion of the various incentives, the concerns about timing and scheduling the work, the questions about solar capacity, and siting – limited the number of actual sales that could be achieved in such a tight time frame. Unless the homeowner was fairly far along in the process in their own minds at least, they would have difficulty absorbing and processing the details presented and see through the substantial costs to embrace the full benefits of what a ZEN project could offer. Contractors, most of whom are pretty intuitive in their sales process, were sensitive to these difficulties, took them in stride, and did the best they could with those homeowners who were most responsive.

Incentives

The incentive for the first pilot was \$50 per million Btus in projected fossil and grid energy savings – up to a maximum of \$5,000.

The Zero Energy Now and Solar Bonus pilot programs would not have been possible without incentives. Only a substantial bonus rebate would have drawn potential customers towards such a large and complex project, and then driven them forward towards completion in such a tight time frame.

Most contractors recognized the value of the incentives. “For customers, the bundle of incentives was huge and very important. We would not be able to do any significant program without something to draw people in,” one said. They recognized that they were helpful in getting people interested in the program, and especially helpful in getting the homeowner to actually “opt in” and move ahead with their project.

There were some complaints about the structure of the incentives – that there were several different incentives, from different sources, obtained differently, etc. This was confusing and complicated for the contractor to explain and for the homeowner to absorb. The incentives also tend to attract people who are motivated only by an easy rebate opportunity, and it was important to weed out people who were not serious about pursuing the goals of the program. This is not necessarily easy, and several contractors performed “dead-end audits” at little cost that were not followed up on.

Contractors had lots of ideas on how incentives could be improved. One suggested that they “have a sliding scale based on income, and also be correlated to the specific work done – e.g. level of weatherization, or heat pump installed in case it is not done all at once – and can be given out partially.” This contractor also went on to suggest “some kind of certificate of recognition aside from the incentive, which would help to motivate wealthier homeowners who don’t need the incentive.” Some were concerned that the incentives would be abused unless the homeowner were serious about reducing fossil fuel. “You should get a percentage of it right off based on projections,” one said, “but some portion that only comes once your fuel usage is verified after a one full year.” Another suggested, “A big bonus for ripping out the fossil fuel equipment altogether.”

Virtually all the contractors said that it was important to provide incentives for the contractor (as well as the consumer) especially early in the program, to help with the cost of the “learning curve process”. Many appreciated the \$400 bonus for each job completed in the 2017 pilot, and commented on how helpful it was in defraying some of the costs of the lengthier sales process and reporting requirements associated with the program.

With respect to incentives, it is important to note that all of the components of Zero Energy Now exist in the marketplace – without the program. Trained contractors familiar with building science and proper installation of the ZEN components can, and in some cases continue to, do ZEN projects that are not identified as such. The incentives – and the specific standards required to earn them – are, in fact, one of the key things that defines the program and distinguishes it from a haphazard, market-based use of the same components in a manner that may or may not be effective. *The incentives, therefore, provide an absolutely critical structural element of the program – a powerful*

accreditation – that drives both consumers and providers (i.e. contractors) toward a strategy that is truly effective in delivering greenhouse gas reductions. Without these incentives, the program has to compete with every other contractor or approach – proven or otherwise – in the marketplace that claims to provide a worthwhile product for the consumer.

In general, all the contractors interviewed found the program's overall mission very compatible with their own; sales were more or less daunting depending on their experience selling the specific components of the program; and all of them recognized that the tight time frame and the substantial learning curve surrounding the specific program mechanics and the modeling tools cut into any potential profits coming directly out of the pilot projects they undertook. Most of them saw the long term potential of the concept, and the general value to their businesses. Remodeling contractors who have become BPI certified have always recognized a beneficial relationship between their work as remodelers and their work as weatherization specialists. One contractor says he doesn't touch a house unless the homeowner is going for net zero – whether in a new or an existing home. Still others said that they would be interested in ZEN as part of the repertoire of the services they offer.

Neither pilot provided enough exposure to the program components and mechanics for most contractors to overcome the learning curve associated with them. The modeling tools were initially cumbersome and took some getting used to. Many contractors complained about EUSAVE, for example, but only two contractors completed more than three projects in it, and it is hard to say whether they would have come to respect it more if they had had more exposure. The training in it was inadequate in any case. The sales process was quite involved, and most customers require more time to absorb and contemplate a project of the magnitude of Zero Energy Now. Even if the salesman was experienced and sensitive in his or her approach, in many cases it was not enough to bring a homeowner into the program – unless they were already most of the way there.

Most contractor complaints were focused around the limited time frame for sales and completion of projects and the lengthy learning curve associated with a program that was essentially over and done with just as they were getting a handle on it. While some were uncertain whether they would be interested in participating in a future Zero Energy Now program, most spoke very positively of the potential for the program.

“No inherent overarching negative; at the time it was trickier for us to take on than it would be now, although we would still be looking very closely at whether the program, however it is set up, could be an asset for our business.”

“It was a big lift on time and software, training, for a limited return during the pilot.”

Scalability

All the contractors interviewed were asked about scalability. The question really depended on the nature of the contractor's business. Many Zero Energy Now contractors were first and foremost builders, who became involved in weatherization and Home Performance with Energy Star through their interest in building science and a desire to apply it both in new construction, and in remodeling older homes. Many of these saw weatherization as a compatible point of entry into potentially broader remodeling work opportunities, and longer term relationships with customers. Others were

small weatherization contractors, very involved in the work itself, and interested in continuing to function essentially as an artisan shop dedicated essentially to weatherizing one house at a time. Neither of these business structures are scalable to the extent that a broad reaching Zero Energy Now program would require. The only way to substantially increase the number of ZEN projects done by this type of contractor would be to increase the number of contractors.

At least two businesses who participated in the Zero Energy Now program were large enough to have a sense of the scalability of the program, and were structured in a way that could expand under a clearly defined business model. One of them was involved as a fully participating Zero Energy Now contractor. The other participated only as a subcontractor to the solar-based ZEN contractor mentioned above. He did none of the sales work with the homeowner (except to complete an audit), none of the work with the modeling tools and none of the coordination with other subs, although he did participate in the training.

The first contractor was enthusiastic about the potential for growth. “We would take it on right up to our capacity. We haven’t been overloaded yet,” he said. He also indicated that the program itself would add value to his business by providing a structure that would help motivate clients and build enthusiasm around the ZEN product, allowing him to expand his business in a way that would specifically accommodate ZEN projects.

The second contractor was not interviewed. He has historically been reluctant to accommodate the additional work involved in program participation (e.g. Home Performance with Energy Star), suggesting that his time involved in audits and obtaining incentives is more costly for the customer than the incentives provide in project savings. This reflects an attitude that is a significant hazard for ZEN or for any program. As ZEN attempts to scale up, the cost/benefit ratio to contractors will have to continue to be competitive with – and really more attractive than – other business alternatives and opportunities that are available to those contractors in the same marketplace.

A future ZEN program will have to be designed in such a way that it can be functionally contained within the business models of a wide variety of contractors, and, in particular, function well with larger contracting companies that have the structural flexibility and capacity to scale up. A large scale ZEN program will require several of these large contractors, who likely provide all the ZEN components in-house, functioning within the state to provide the bulk of its services. It will also, however, require smaller contractors who do ZEN either full or part time on a smaller scale. These smaller contractors are important because they make up the bulk of the building community in Vermont. For ZEN to succeed, the concept – and especially the building science behind it – has to be intensively imbued in this building community. Engaging a wide variety of builders and contractors in ZEN projects is the best way to get them interested in building properly in the first place.

Program Development and Administration

Zero Energy Now as a concept had been undertaken successfully in individual projects by a number of contractors. At least one and possibly two contractors who participated in the program were essentially committed to net zero building in all their work, one going so far as to say he wouldn’t touch a house where the ultimate goal was not net zero. A third contractor, whose company routinely performs all the essential components of Zero Energy Now (i.e. weatherization, heat pumps, and solar PV), generally follows the client’s lead in his sales process. He will suggest

opportunities for combining some of the ZEN components to added benefit for the client, but has to take care not to lose the sale he is developing by suggesting additional options that are simply confusing to the client or add expense that the client is not interested in taking on. *In order for ZEN as a concept to be taken up in a big way by Vermont homeowners, it has to be sold as a concept to Vermont homeowners. It has to be out there in the marketplace for them to discover. Zero Energy Now as a program, therefore, is essential to the success of Zero Energy Now as a concept.*

The essential functions of a program and its administration are to:

- Develop the concept as a program and define its key goals and characteristics;
- Develop awareness and recognition of the program in the marketplace;
- Find, motivate, and train contractors to provide the program service;
- Evaluate quality and make appropriate adjustments;
- Develop strategies for growth and expansion to meet evolving program goals.

BPPA was very lucky to receive a grant of almost \$700,000 through Green Mountain Power's CEED fund to bring a full-fledged Zero Energy Now program to the market in less than a year.

Administratively, this was an enormous undertaking. The bulk of this work was achieved through the efforts of Energy Futures Group, Inc. (EFG). Working closely with the BPPA Board, EFG developed the essential criteria of the ZEN program, developed a marketing strategy, developed training for contractors, oversaw the development of modeling tools that could design and qualify specific ZEN projects, developed a system for handling client referrals and the day to day administration of the program, coordinated the handling and administration of incentive funds, and carried out all the reporting requirements related to the CEED grant and its administrators at Green Mountain Power.

As suggested in earlier sections, there were relatively few complaints from contractors or customers about the administration of the program. The main difficulties for everyone involved all related to the tight time frame the CEED grant required. This difficulty manifested most significantly in the relatively small number of projects that were completed, and in the failure of some projects to perform as well as expected.

With respect to specific administrative elements of the program, some were more successful than others, and much can be learned.

Product Delivery

The essential structure of the program worked quite well. A primary program contact point was established with a phone number and email address. This was based at Capstone Community Action in Barre. Inquiries were referred to a short list of up to three BPI certified Zero Energy Now contractors based on geographical proximity. The potential client was given these contractors' contact information, and the contractors themselves were given the client's contact information. It was left to each of these parties to make contact appropriately, and coordinate from there.

With regard to specific project administration, this "general contractor model" was quite effective as an essential product delivery mechanism in that contractors are inherently skilled at organizing a work scope of diverse elements and coordinating their execution in a timely and efficient manner. They are used to working with subcontractors, sequencing elements of the work carefully, and

helping the homeowners anticipate and accommodate the various intrusions of the work in their homes. They, more than anyone else, have the administrative capability to see the project through.

Follow-Up

The hazard of relying on general contractors to take full responsibility for the ZEN project, however, is that their responsibility ends, traditionally, when the job is complete. Their primary focus is selling the job initially and then getting it done cost effectively, in a way that is satisfactory to the homeowner. Zero Energy Now, however, has a critical performance expectation – i.e. savings, both in energy and dollars – that extends beyond homeowner satisfaction, and well beyond the end of the job. The essential measure of the job's success in this regard doesn't appear substantively until months or years afterwards. It is then assumed to extend indefinitely. This added performance standard carries significant financial risk, which, unless redirected or assumed by some other entity, is borne entirely by the homeowner. This performance standard is also critical for financing. Without the proven cost savings, funds will not be available to pay down the debt.

The pilot programs provided a "savings guarantee" funded by Green Mountain Power that would pay the difference between modeled savings and actual savings for a period of one year if the modeled savings were not achieved. This helps to sell jobs, perhaps, but provides only limited protection to the homeowner, and perhaps raises that question in a particularly scrutinizing homeowner during the sales process. Contractors are cautious about warranting their work as repair costs can be expensive, and most do not really have reserves to cover those costs.

It is essential that these added performance risks be kept as minimal – as close to zero – as possible. This will require significant precision and accuracy in the modeling process – both in the tools themselves and in the way the data is gathered and entered into them. It will also require high quality workmanship and careful attention to detail in the weatherization, and careful sizing and installation of heat pump systems and other equipment to ensure efficient operation.

The homeowner, too, has a continued responsibility to use the home's energy resources appropriately. If, for example, a certain amount of cord wood is included in the assumed energy package for the home (and modeled as such), then the homeowner is not being responsible to the modeled goals of the project unless that cord wood is utilized accordingly.

It was also clear, from our interviews with homeowners, that the savings in many cases are not immediately apparent. Some believed they were saving energy, some did not; and this impression was not necessarily connected in any way with their actual savings or energy use. Some homeowners also were not using their equipment effectively to achieve best performance or savings, and some were trying to save money by avoiding using their heat pumps and keeping thermostats down to uncomfortable levels when they had solar power to spare and could have turned up their heat pumps at no cost.

Because a Zero Energy Now project involves the introduction of many new systems in a home which may be unfamiliar to the homeowner, proper commissioning of these systems, and some training in their use by the homeowner, is absolutely critical. This is not necessarily a one-time deal, but may require on-going attention in some cases. Getting these systems fine-tuned to perform optimally is likely to take some period of time. A properly trained homeowner may be able to do most of this on their own, but it is likely that some kind of follow-up and performance review by a program

professional – at various times, till up to two years after job completion – will be a critical part of the program service. The job is not done essentially, until the savings have been verified, and any significant anomalies resolved as much as possible. The contractors necessarily should be involved in this – as a matter of protecting their reputation, as well as providing good service to their customers. However, the program also has an interest in this follow-up as it will provide important data that can be used to enhance overall program performance in the future. This follow-up will have to be budgeted in, either as a program cost or a contractor cost, or shared in some way by each. This is also a standard part of quality assurance, which is important as a support both to homeowners and contractors, and to enhance the reputation of the Zero Energy Now program.

Contractor Recruitment and Training

Many BPI certified contractors were drawn to Zero Energy Now as an opportunity to broaden their sales and participate in a program that delivered really deep savings for their customers. There was no specific obligation to complete jobs, and the only requirement was attendance at one mandatory all-day training. Once jobs were completed, there were some reporting requirements, and, again, because everything had to be completed and reported by the end of the year – both in HERO with Efficiency Vermont, and in EUSAVE or CLEAR with the pilot programs – the reporting task became a little intense for many as the deadline approached.

The training itself was essential, and was very well planned. It included a basic introduction to the mechanics of the program, a review of critical program requirements, an introduction to the modeling tools, and also included a sales training by a sales consultant specializing in selling weatherization.

Some contractors appreciated the sales training, and others found it redundant and useless. (One problem was that many of the contractors had seen this consultant's presentation before, and he did not take steps to adapt it in any specific way to the Zero Energy Now program, which was disappointing.) While this part of the training received mixed reviews, several contractors took advantage of direct one-on-one support from this consultant, who joined contractors at on-site sales visits, or listened in on phone calls with clients. These one-on-one support efforts, though not taken advantage of by many, received very high praise among those who participated.

The training relating to EUSAVE also was insufficient for many contractors, and did not effectively close the gaps in their learning curve with that tool.

The training also provided an important opportunity for the group as a whole to get together, share their interests in the ZEN goals and program, compare notes and experiences, do a little networking, and share contacts with one another as contractors in the same or related trades.

In addition to the training, the administrative staff at Energy Futures Group made substantial efforts to reach out to contractors and provide support as needed. They were readily accessible, and worked diligently to accommodate contractors' needs and questions. They also took steps at regular intervals to check in with contractors to monitor progress in program sales and project development, and to offer support. In the 2016 pilot, they hosted a second voluntary training for a half day in September (that was very well attended) to provide more training on the software tools, and some additional sales training. Some contractors also shared their own experiences with program sales

over the course of the summer, provided valuable suggestions, and helped to rally what at that point had been somewhat flagging interest and participation in the program.

As both programs were essentially pilot programs, and they were under significant pressure to complete projects, carefully considered adjustments in program requirements were made. In the 2016 program, after it became apparent that much of the clientele most interested in the program had, in many cases, already made weatherization improvements, and contractors were concerned about being able to achieve an additional ten percent, it was decided to recognize adjustments already made by offering an “Alternative Paths” option for meeting this requirement.²⁶ This allowed the contractors to breathe a little easier, but, as it turned out, only one project opted to qualify under the “Alternative Paths” option. The rest of the 22 projects completed that year qualified under the original 10% envelope improvement requirement. In 2017, adjustments were made very late in the year to the incentives (a “kicker” bonus of \$500 was added, and the \$1,000 cap taken off the original (per watt of solar) incentive), and an extra outreach with a bonus was made to solar contractors – whether inside or outside the program – to connect the program with homeowners that might be interested in pursuing its opportunities and incentives. This strategy certainly helped to get some projects into the program very late in that year.

Marketing and Sales

Zero Energy Now did not have a large marketing budget, and with the limited time frame, it was difficult to figure out how to make best use of limited funds. It was decided to hire a marketing consultant to develop a basic approach and some of the language of our outreach materials, and to develop a direct sales presentation that contractors could take to local community events hosted by local energy committees. The most substantial marketing efforts were a live press event in June of 2016 featuring Mary Powell of Green Mountain Power and Vermont Congressman Peter Welch, an article which appeared in the *Green Energy Times*, and an outreach Power Point presented by contractors at various energy events throughout the spring, summer, and fall of 2016. Brochures promoting the program were also distributed as much as possible. An unfortunate lack of coordination with Efficiency Vermont’s website managers prevented the program from being promoted or linked in any way on their website until very late in the year, and Green Mountain Power did not want Zero Energy Now competing with other programs they were offering at the same time – eVolve Panton and eHome – so they were unwilling to actively promote Zero Energy Now in any of their marketing or outreach, even with their qualifying customers. Although Zero Energy Now had its own website, for some reason it was not easily searchable, and for most of 2016, the only searchable appearance of Zero Energy Now on the web was through NeighborWorks of Western Vermont – a participating contractor with a strong web presence. This did reach some people.

How homeowners learned about Zero Energy Now:

From a contractor they already knew:	8
From an energy event:	3
From Green Energy Times:	2
From an energy audit:	1
From GMP at Home Show:	1
From other sources:	6

²⁶ See appendix.

Beyond these, the most successful outreach efforts for Zero Energy Now were by contractors themselves, either with new contacts or former customers.

It is uncertain how many inquiries came into the information/contact number hosted by Capstone. 59 projects were initialized in EUSAVE, indicating that at least that many were passed along to ZEN contractors. How many of those resulted in site visits, audits, work scopes, or proposals is not really determinable, but the ratio of inquiry/entries to finished jobs does not seem unusual, especially given the high sticker price.

As a contractor participating in the 2016 program, I entered five potential projects into EUSAVE. For three of them, I completed work scopes based on extensive site visits; one, I spoke to the homeowner off site, but didn't complete a work scope or an audit; and the last was an extended family member whom I was working with informally and who opted out on pre-conceived assumptions that the program was unaffordable to them before I had a chance to complete an analysis.

The one whom I spoke to off site was someone I had consulted with at his house on energy issues before, and knew to be temperamentally skeptical and hesitant about taking on major work of any kind. I was therefore unwilling to invest time in a major sales effort. (I heard anecdotally that he was hoping I would sell the program to him more enthusiastically – “in the way that Suncommon salespeople do”. I would agree that I failed to do that, but remain skeptical that it would have been worth my time.)

One of the homeowners for whom I completed ZEN proposals could meet the standards of the program by doing only weatherization and either a solar installation or a heat pump water heater, as she already heated her house exclusively with a wood stove. She opted out of the solar installation because the solar contractor I brought on site told her that she didn't have enough solar capacity there to obtain payback from the project in less than nineteen years, and she opted out of the heat pump water heater because the smallest one she could get was 50 gallons, and she, as a single woman living alone, did not need more than 25 gallons. My observation that the 50 gallon heat pump water heater would use less electricity than a 25 gallon resistance water heater was not sufficient to change her mind.

The second client for whom I completed a proposal also declined to participate in the limited timeframe. This left one project actually completed, and, ironically, it was one of those in which all the components were completed by other contractors before I got on site. My role was entirely administrative.

I suspect that each of these anecdotes is familiar to every contractor in the program, and that even their details are similar to what was commonly experienced in the process of trying to sell a difficult, expensive, and complicated project in a very short time.

Reporting Requirements

Both pilot programs required a substantial amount of paperwork, both for the contractors, and (especially) for the administrators. Time related to learning how to use the modeling tools has already been discussed. Most of the rest of the reporting was relatively straightforward, once the details were properly entered into the tools, but there were sometimes changes or coordinating elements of the work, which required some follow-up of some kind. For contractors the most

compelling reporting requirements were certifications that the work was complete, that the client had qualified for his or her incentive, and that the proper forms were signed and submitted, allowing them to receive their incentives. Again, all of this required a certain learning curve under the pressure of a precipitous deadline, but there were few complaints from the contractors.

Economic Benefits of the Program

It is estimated that 78% of our home energy dollars leave Vermont.²⁷ As long as we are dependent on these fossil fuel sources, we can expect an average of \$2,700 per household to leave the state each year, much of it going to places either within or beyond our U.S. borders where economic, social, and environmental devastation are a fact of life. Fossil based energy development, whether by mountaintop removal mining in West Virginia, tar sands processing in Alberta, or wealth engineering in Saudi Arabia is a major precipitator of political instability, social disequilibrium, economic inequality, and environmental destruction. Large scale hydroelectric or nuclear generating facilities, while not emitting carbon into the atmosphere, bring their own significant hazards, no less destructive than fossil based energy.

Part of the intent of the Zero Energy Now Program is to mitigate the ongoing destructive tendencies of our industrial scale energy economy, by replacing the flow of dollars out of Vermont in service of that economy with substantive investments in the local Vermont economy. ZEN does this in four specific ways:

1. Weatherization and energy upgrades in our houses – providing high-paying local jobs, and local business development specific to investing in and maintaining our existing homes and neighborhoods.
2. Small-scale biomass heat, supporting our local farm and forest economy. (This is very much under discussion and contention at the moment, but it is still essentially a local conversation driven by local, non-industrial scale, interests, and can be sorted out at that level.)
3. Locally sited renewable electricity – keeping us aware of and involved in (the sometimes difficult) choices regarding our energy use, and mindful of how much we need.
4. Financing through local credit unions and banks which are then able to provide capital to other local enterprises and help build the Vermont economy – again at a scale which suits Vermonters.

The 35 projects of the pilot programs of 2016 and 2017 directly engaged over 30 businesses, and each project required the following worker days to complete the project:

Weatherization:	2-3 workers	3-5 days	6-15 worker days;	Wage: 16 - 30
Heat Pump Installation:	1-2 workers	1-2 days	1-4 worker days;	Wage: 20 - 40
Solar Installation:	2-5 workers	3-5 days	6-25 worker days;	Wage: 16 - 40
Wood heat installation:	2-3 workers	2-3 days	4-9 worker days;	Wage: 16 - 40
Other incidentals:	1-2 workers	1-4 days	1-8 worker days	Wage: 16 - 40

²⁷ Energy Action Network 2018 Annual Progress Report

In addition to those employed directly on site, the program drew upon suppliers across the state for materials and system components.

It is not difficult to see how an expansion of the ZEN concept will require a direct and substantial expansion of the local Vermont economy and workforce, just to get projects completed. Indeed it is likely to require an influx of workers and possibly business owners to meet the large scale need.

This study is not set up to properly analyze how a ZEN program would impact the farm and forest economy. Other estimates have been done to indicate how various levels of commitment to wood heating can impact both the environment and the forest economy. This too, as we have been hearing about lately, requires a nuanced discussion of costs and benefits, both economic and environmental.

Siting of local renewable electricity installations are also a public concern. One of the challenges of the ZEN concept is its reliance on the capacity of renewable generation to directly offset home electricity use. The potential for this on a large scale is largely dependent on the suitability of individual house sites and properties for matching-scale renewable energy installations. Not every rooftop is sized sufficiently or situated effectively to take advantage of needed solar exposure. Space and/or solar penetration on individual properties may be limited as well.

Group net metering and community solar installations are therefore critical to the expansion and viability of the ZEN program at scale. Without ready access to locational options for renewable energy, this component, critical to ZEN's success, will not be available to many homeowners.

It is important to point out, again, that even if the grid were completely green, or utilities individually could offer a completely green energy option to homeowners, without "buy-in" to a renewable installation – allowing the homeowner to effectively zero-out their electric bills – the value economics required to make the ZEN project viable and financeable for homeowners will not be possible. Off-site renewable installations of any kind and in any location that are considered to contribute to a Zero Energy Now project must therefore be financially connected to a specific homeowner or a specific home. They cannot be owned by utilities or other investors seeking merely to profit off of these installations, and then sold at utility rates to the ZEN homeowner. For ZEN to work, the return on investment must go directly into the homeowner's household economy, and *the homeowner must own the generating capacity that effectively powers his home.*

There are a lot of interests and issues at play in this discussion – more than can fully be addressed in this study, and more than have probably been fully addressed anywhere. This will be an ongoing discussion that gets larger and more complex as the competing concerns of electricity generation, distribution, storage, and brokering evolve, especially if the imperatives of climate change are made to bear in a way that has economic consequences. If ZEN is to be an effective strategy for meeting our climate goals, however, its economic viability within the broader economics of electricity generation and distribution will have to be recognized and maintained. *To the extent that regulators and policymakers have the capacity to make this happen, they should take notice.*

A further benefit of the Zero Energy Now program is its broader strengthening of middle class investment in their existing homes and communities. By moving dollars that would otherwise be sent out of state and out of the country, into reinvestment in their homes, they are also investing in

the local investment community itself. These include local banks, local credit unions, local philanthropic institutions, and the state government – all of which are heavily invested, through expanded capitalization, in the local economy. By providing an investment opportunity that is essentially a reallocation of household resources away from a simple living cost and into a solid home improvement that adds value to the home, reinvigorates neighborhoods, and strengthens communities, ZEN provides structural reinforcement and depth to local community vitality at multiple levels.

Finally, by giving them an opportunity to substantially reduce their carbon footprint and mitigate the effects of climate change, Zero Energy Now empowers homeowners to do something truly effective in improving their lives and their children's lives, and to bring about a world that is more stable, more peaceful, and more optimistic in the long term.

Conclusion

It is difficult to conclude this study; the information obtained to date begs for so much more information. Each project studied was essentially as unique as the house on which the project was completed and the household members that lived there. What is apparent from each and every project – even the ones that failed to deliver the desired results – is that they all performed spectacularly on some level or other. In compiling the five poorest performing projects, I was bracing myself for discovery of some significant compounded failure, and although this was sometimes found, some significant success was found right alongside of it. What comes out of this observation, more than anything else, is a recognition of the tremendous potential of the Zero Energy Now concept and the potential, through careful development of a new program, to effectively resolve some of the anomalies and contradictions that surfaced in the less successful projects of the pilots.

What has been demonstrated

In all but a few cases the pilot programs obtained deep, deep energy savings, and probably could have gone deeper if program designers had been a bit bolder in setting their standards. The average energy savings of almost 64% included some very low performing projects, most of which had to do with poor communication of program goals and/or homeowner intentions, or simply poor communication of how best to use heat pumps to take over the primary heating loads in the house. In other cases, there was a clear misconception of project intentions by the heat pump contractors, who, in at least three cases, never properly understood that heat pumps were to be utilized as a primary heat source through the winter. Both of these issues can easily be addressed through better project management within a more reasonable project time frame.

Cost savings were also very deep, allowing for substantially increased financing capacity on virtually all projects. Positive cash flow financeability is possible, and may be more broadly feasible with better project design, and a clearer understanding of project parameters vis-à-vis available savings opportunities and the homeowner's financing capacity. An effective modeling tool may be able to find the best mix of project components, savings, and financing options to generate the best cash flow benefit for the homeowner.

The general contractor model worked quite well at delivering the ZEN product, even under very strict deadlines and time constraints. In general, the jobs that were in the program were completed in a professional manner, and homeowners respected the quality of the work done and the professionalism of program personnel. There is a lot to be said for the pride and prestige of the participating contractors and their employees, and the program was well represented by these contractors.

Incentives were critical to driving interest and participation in Zero Energy Now. They provided an impetus for homeowners to learn about the program in the first place, and then to take the leap of faith necessary to sign up for the significant work and cost involved. Incentives also provided an endorsement or accreditation that gave the program recognition both among homeowners and contractors, and distinguished it from other market-based products or claims.

What must be addressed

Homeowner Education & Job Performance Follow-up

Virtually all homeowners will need some kind of training in heat pump technology and using them effectively to manage the heating loads in their homes. This kind of equipment is fundamentally different than the standard fossil fuel based heating systems most people are familiar with, and different than wood stoves or gas space heaters, which put out a lot more heat. It is likely that there will be some fine tuning of equipment, and general follow-up needed to make sure the various systems are performing as expected and operating at peak efficiency. Follow up will also be needed to ensure that biomass systems are being used as modeled, and, if not, to adjust savings (and perhaps financing) expectations accordingly. The same applies to any fossil fuel equipment that remains active in the house.

Follow-up will also be essential for verifying efficacy of modeling tools and of program standards and other parameters. There is no doubt that there will be room for continued improvement of these, especially as technology and weatherization strategies evolve, as the cost of fuel changes, and as homeowner priorities change with all of the above. This will be especially true in the early years of the program, and in the early ramp-up phases.

Marketing & Sales Strategy

Although the essential components of Zero Energy Now have been around for a long time, and are reasonably well known in the marketplace, Zero Energy Now – as a program that combines these component technologies to radically reduce fossil fuel usage – is *not* an easy concept for any homeowner to embrace. It is complicated, intrusive, and expensive. A marketing and sales strategy that fully addresses the complexity of Zero Energy Now's systems approach, and helps to overcome the hesitancy and reluctance that are natural even for homeowners with strong environmental inclinations will be critical to the success of any future program. Early adopters, including those who have already purchased some – or perhaps even all – of the components of Zero Energy Now, will need to be engaged to take up Zero Energy Now projects. They are the best-positioned candidates both to make appropriate adjustments or improvements to what they have so that deeper savings can be achieved; and – in those cases where their system is already performing as it should – to provide testimony on its value and success.

What is still unknown

Modeling

Modeling in the pilots both was – and was not – remarkably accurate. While this was not necessarily due to the modeling programs themselves, the problem speaks to the multiple questions that remain about the capacity of a program such as this to forecast the actual savings capacity of a project or likelihood of its savings outcome in a way that can be utilized as a metric for financing, or provide, in

aggregate, an effective actuarial parameter for a savings guarantee. Is the modeling conundrum genuine – like the weather, subject to too many variables to forecast accurately? Or can it be resolved simply by a better understanding of homeowner goals, and greater clarity about program expectations and work scope design? This is an area where more study would be extremely beneficial. Unlike other programs, such as Home Performance with Energy Star, ZEN modeling – in order to succeed – requires direct, specific correlation between its projections and its results.

Scalability

Scalability and overall adoption of the program remain significant unknowns. Both will depend on the proven success of early phases of the program. It is one thing to have detailed data for 24 projects. We will need detailed data for hundreds, and eventually thousands, of projects before we can declare the program truly effective as a robust strategy to get our existing thermal infrastructure off of fossil fuels and 90% renewable by 2050 or any other date.

Improved Program Mechanics – The Challenge of a Future Zero Energy Now Program

Redefining the Program Goal

The first Zero Energy Now pilot established the 10-50-50 standard²⁸ as the program threshold. Beyond that, it incentivized fossil fuel and grid sourced electric reduction at \$50/MMBtu up to \$5,000. Aside from these two guiding program determinants, there was no structure to the concept, other than the goal implied in the program name – zero energy, now. This was partly because the concept had not been fully tested, and program designers were reluctant to set the thresholds too high.

As the chart below – listing projects in order of financeability – indicates, data collected for this study suggests that there is no defined correlation between project cost and savings, and that there are only imperfect correlations between any two factors contributing to a project’s success. A project that achieves 45% savings, for example, does not cost half as much as one that achieves 90% savings. While certainly driving down energy costs leaves funds available for paying off a loan, the best strategy for driving down those energy costs, or the best strategy for obtaining a low monthly out-of-pocket cost, varies substantially from job to job and cannot be tied to any specific factor or strategy.

Nor is it necessarily easier or harder to finance. For financeability, there is certainly an upper limit on project cost; none of the most expensive projects were financeable through energy savings. But it is hard to pinpoint where that limit is for any particular project, or what specific elements of the project define that “sweet spot” where optimal savings meets optimal affordability.

²⁸ See pages 13-14.

This means that, on some level, defined standards like the ones established for the first pilot only make sense if they allow the flexibility necessary to achieve the much more important goal of getting the home off of fossil fuel as much as possible, in the most affordable way possible. Combining these two essential program goals is the only way it will be possible to meet Vermont's Comprehensive Energy Plan goal of 90 percent renewable by 2050. Savings is required to meet the goal, and affordability is required to bring it to scale.

Table 5 - Correlation between Financeability, Savings, and Other Program Metrics

Project Number	Finance-ability	Net OP/mo 20 yr @ 5 1/4%	Pctge F&G Energy Savings	Pctge Cost Savings	Pctge Cost Savings Correlates to Finance-ability?	Net Project Cost with Incentives	Project Cost a Factor in Finance-ability?	Pctge of Consumption Renewable	Pctge Renewable Correlates to Finance-ability?
2	High	(\$145.19)	87.53%	85.60%	Yes	\$26,498	Yes	71.25%	Yes
3	High	(\$91.97)	95.23%	84.04%	Yes	\$16,142	Yes	93.80%	Yes
6	High	(\$32.06)	70.86%	71.21%	Yes	\$21,708	Yes	64.13%	Yes
33	High	(\$7.27)	69.18%	60.82%	No	\$22,909	Yes	65.64%	Yes
18	High	\$17.49	90.79%	63.45%	Yes	\$23,924	Yes	95.40%	Yes
32	High	\$22.98	64.30%	51.53%	No	\$20,766	Yes	73.26%	Yes
1	High	\$29.50	60.25%	38.90%	No	\$19,169	No	32.24%	No
35	High	\$33.15	72.48%	74.66%	Yes	\$33,679	Yes	56.19%	No
28	Med	\$64.58	32.93%	48.20%	No	\$39,171	Yes	30.27%	No
20	Med	\$67.69	59.26%	51.09%	Yes	\$25,743	Yes	31.03%	Yes
10	Med	\$74.35	86.60%	75.69%	No	\$25,524	No	65.98%	No
11	Med	\$80.78	49.33%	55.16%	Yes	\$37,305	Yes	27.32%	Yes
5	Med	\$87.16	27.03%	24.97%	Yes	\$25,013	No	42.70%	Yes
4	Med	\$98.48	54.86%	85.99%	No	\$34,254	No	49.98%	No
24	Low	\$103.12	30.81%	40.53%	Yes	\$25,882	No	57.18%	No
14	Low	\$109.37	50.08%	54.45%	Yes	\$33,572	No	34.51%	Yes
9	Low	\$120.20	14.46%	32.77%	Yes	\$27,757	No	35.82%	Yes
16	Low	\$128.24	71.11%	48.59%	Yes	\$40,097	Yes	55.49%	Yes
19	Low	\$146.85	94.92%	89.90%	No	\$43,209	No	87.93%	No
8	Low	\$214.21	65.63%	43.63%	Yes	\$48,180	Yes	45.91%	Yes
21	Low	\$266.00	73.63%	75.29%	No	\$100,875	Yes	54.33%	Yes
25	Low	\$296.81	47.30%	40.57%	Yes	\$71,236	Yes	29.41%	Yes
23	Low	\$519.39	67.87%	46.49%	Yes	\$86,838	Yes	56.48%	Yes
17	Low	\$751.23	98.02%	95.75%	No	\$147,600	Yes	95.23%	No

A New Program Approach

Proper delivery of a Zero Energy Now project starts with a qualified and trained contractor meeting with a client who is motivated by a strong desire to minimize their fossil fuel consumption. To get to that point, significant contractor training will have to occur, and significant marketing will have to be developed to draw potential customers into the program. These are straightforward elements of any program development process. We know how to do this.

From that point, however, the contractor must design a specific work scope based on the opportunities in the house, and apply the various ZEN strategies and components in a way that provides the greatest energy savings and the greatest cash flow benefit within the homeowner's financing choices. This is the unique opportunity that the Zero Energy Now approach provides, and around which any future Zero Energy Now program must be developed. This approach is not fully developed, or even understood at this point.

The project budget will emerge from the dynamic interaction between these two essential factors – deep energy savings and affordability. It is a moving target that will have to be “modeled” in the context of the specific work scope elements themselves. This can only be done with a modeling tool that has the ability to consider and to manipulate both the work scope elements and the cost and financing elements in a dynamic tandem – to find the best energy and carbon saving strategy available, within the means of the homeowner. Program specifics – goals, strategies, and incentives – must be designed to accommodate these specific criteria, or else the effect will be haphazard and scattershot, with highly variable results.

Building Program Accreditation

The defining elements of Zero Energy Now in the first pilot were

- its name and the concept that goes with it – that it is possible to get existing homes to zero or near zero fuel consumption;
- the standards or thresholds that had to be met in order to qualify; and
- the specific financial incentive associated with it.

Without these three things, it would not have been possible for a customer to know the difference between *Zero Energy Now* and a random similar offering by another contractor. Having this definition was also important because it provided prestige, accreditation, and confidence in the product – both for the homeowner contemplating a Zero Energy Now project, and for the contractor attempting to build out his business by developing his capacities to sell and deliver ZEN jobs.

A similar program accreditation with all of the above elements in place will be critical to the success of a future program in the same way.

It will also require something else – repeated, and repeatable, success on a growing scale.

This is the substantive challenge we must face as we look to build the future of *Zero Energy Now*, and its potential to decarbonize Vermont's existing housing stock.

Appendix

A-1

Heating Degree Days & Periodic Fuel Usage Records

Fuel usage for liquid fuels (propane, kerosene, and fuel oil) was quantified by measuring from fill-up to fill-up. The fuel delivered on a given date was assumed to reflect the fuel used since the last fill-up. Since these dates tended to be irregular, and since delivery was more frequent in the winter – when the number of heating degree days are the highest and each 24 hour day may have many heating degree days, a strategy of assumptions had to be developed to quantify these consistently, if not perfectly. The essential assumptions were as follows:

- a) The HDDs for the particular day the fuel was delivered were included with the period *following* the delivery. If 200 gallons of fuel oil were delivered on January 5, 2014, all of the HDDs for that day, January 5, were correlated to the fuel usage corresponding to the next delivery of fuel oil, which might be the following month or more after. This was done simply for the sake of consistency.
- b) Fuel usage for liquid fuels was correlated to annual HDDs by attempting to find two deliveries in two different years as close to the same calendar date as possible. This could be for a period of any number of years, although usually it was one to three years. These raw fuel usages were then “annualized” by establishing the “Date of the Nearest Annual Period” which would be the calendar date exactly matching the one from the previous (one to three) years. The actual “fuel usage per degree day” was then established by counting the total actual degree days between the actual specific dates of delivery, and then dividing the actual fuel usage in that period by that number. The fuel usage per degree day was then applied to the number of degree days between the actual date of delivery and the date of the nearest annual period to obtain an actual annual degree days total tied to specific fuel usage. This could be one specific year, or an average of two or more years. Generally it is assumed that an average of several years is a better measure of fuel usage than one, so where that was possible, the average was taken. A weather-normalized fuel usage can then be determined.
- c) Not all fuels have similar dates of use. A house might have fuel oil as their primary fuel, and then use a propane space heater in one part of the house. Although uses of these different pieces of equipment and fuels might vary, if an annualized usage for each of them can be determined, annual heating degree days can be applied to each piece of equipment and its fuel, and a meaningful weather-normalized annual usage can be derived.
- d) The different heating fuels and their annual HDD correlated usage can be assembled and quantified proportionally by how much of the home’s total heating load is served by the individual heating source and fuel. If the load MMBtus of a particular fuel make up a particular percentage of the home’s total heating load, that same percentage can be applied to that fuel/heating unit’s annual HDD total. While the total HDDs assembled in this manner will not exactly match a specific annual period, they will be matched to that fuel/heating units specific annual period, and the proportions will match. This allows a weather-

normalized annual fuel usage for all the various fuels to be correlated to an HDD total that reflects the actual usage of those fuels. This can then be correlated to any other weather-normalized period. It does help if the different fuels can be annualized to reasonably close calendar dates, so that the annualized degree days for each correspond as much as possible to the same year, but this is not necessary because the recorded fuel usage is directly tied to the specific HDD record. The HDD year reflects the actual fuel used in response to those HDDs accumulated.

- e) Some fuels such as cord wood really have to be estimated. For purposes of this study, cord wood was annualized from July 1 to July 1 every year, but other annualized dates could have been chosen that better correspond to the dates used for the other fuels. It was assumed that, with cord wood, there are so many variables that cannot be realistically quantified – variability in Btu output of wood, efficiency of equipment, usage habits of the homeowner, and actual ability to estimate quantities realistically – that precision is largely arbitrary.

A-2

Locally Available Loan Products

The following table shows a sampling of various loan products – their rates and terms that were available locally in Vermont in July 2018. The loan product providing the lowest monthly payment was found to be VSECU's Long Term Home Equity – a 20 year term at 5.25%

Current Loan Rates & Options				Term							
Loan Product	Fixed/Variable	Avg Fin Costs	Loan Maximum	3 Years	5 Years	10 Years	12 Years	15 Years	20 Years	25 Years	30 Years
VSECU Unsecured											
Heat Saver			\$ 35,000.00								
Income Level											
Below 59,350				0.99%	0.99%	2.99%		2.99%			
59,351 - 89,040				2.99%	2.99%	3.99%		3.99%			
Above 89,040				4.99%	4.99%	5.99%		5.99%			
Energy Improvement			\$ 40,000.00	5.40%	5.40%	5.40%		5.40%			
20 Year Energy Improvement			\$ 60,000.00					6.40%			
ITC Loan			\$ 60,000.00				5.40%				
VSECU Home Equity											
Loan to Value Ratio			Less than 80% of Equity		2.74%	3.75%		4.50%			
Loan to Value Ratio			Between 80% & 90%		3.74%	4.75%		5.50%			
VSECU Long Term Home Equity											
Loan to Value Ratio			100% of Equity						5.25%	6.75%	6.75%
NeighborWorks											
Energy Loan			Undisclosed		4.99%	4.99%					
Opportunities											
Heat Saver											

A-3

Questions for Homeowner Interview

Circumstantial Questions:

- 1) Is survey complete?
- 2) Is this home group net metered?
- 3) Is wood burned in this home?
- 5) Fuel dealer

Open ended interview questions:

- 1) How did you hear about the ZEN program?
- 2) Why did you want to do a ZEN project?
- 3) Now that you've lived in your home for a while after project completion, what changes are you happy about?

may include comfort, energy costs, mechanical issues (heating system now works properly, no more frozen pipes, it's great having AC, etc.); leaving it open; let them lead with what they think is important
- 4) Are you dissatisfied with any of the changes in your home?

may include comfort (ex. bedrooms are cold), operations (heat pump didn't work well in cold weather), or monetary (bills aren't as low as I expected) etc.; leaving it open; let them lead with what they think is important
- 5) Are there any factors that may have impacted total energy use since project completion such as changes in number of people living in the home, thermostat set points, new electric vehicle, etc.?
- 6) How was your experience working with the contractors on the energy upgrades? Anything that worked particularly well or was challenging?
- 7) Did your heat pump installer or HPwES contractor coach you on how to operate your heat pump for best efficiency and heat delivery?
 - What strategies did you use to operate your heat pump efficiently and for best heat delivery?
 - Do you have remaining questions about how to operate your heat pump?

8) Were there non-energy related projects happening at the same time as the energy upgrades? (ex. new siding, kitchen remodel)

9) What would have made the project easier?

10) Thinking back to when you were first considering participating in the ZEN program, what information was most helpful to you?

What additional information would have been helpful to know before starting your project?

If There Is Time:

11) Are you planning further energy improvements? If so, what are they and when will you undertake these improvements?

12) Financing

13) Savings attitudes

(survey)

14) Expanded conditioning

15) Different thermostat settings

16) Using hp for AC in the summer; had AC before?

17) Appraisal

A-4

Questions for Contractor Interview

- 1.) How did you become interested in the ZEN/Solar Bonus Program? Did you view it as a
 - Short term sales opportunity?
 - Long term sales opportunity?
 - Mission related opportunity?
- 2.) Had you done ZEN type projects before the ZEN program, or was this concept new to you?
- 3.) What do you consider to be your primary work as a contractor, and how did the ZEN concept fit into it?

- 4.) Was the ZEN concept an easy fit for your contracting business or was the concept new to you? If new, did you conduct any research or training prior to participating?
- 5.) Did you find the sales process easy and logical, or was it a heavy lift for you as a contractor?
- 6.) Were the clients motivated, or did you have to work to motivate them (and how)?
- 7.) Did the ZEN program provide added value to your business?
- 8.) How much additional time did the ZEN program add to the following specific parts of your contracting work:
 - Pre-contract estimating and sales
 - General Contracting/administration
 - Audit/software/reporting
 - Client education & follow-up after project completion
- 9.) Were you able to recover your additional time and expenses in your billing for the ZEN job?
- 10.) Was your participation in the ZEN program profitable? Were you able to make the ZEN project work within what you would consider your typical profit margins?
- 11.) The ZEN pilot programs of 2016 and 2017 were funded through a program that required a very tight project completion timeline and deadline. If this timeframe were more relaxed would that make it easier to design, sell, and complete ZEN projects?
- 12.) Would clients in general be more receptive to undertaking a ZEN project if it could be spread out over time? How much time? How much can ZEN be phased?
- 13.) How did the ZEN rebate incentives affect your sales process?
 - Was it critical – i.e. could the project have happened without it?
 - Was it sufficient to drive the sale of the work scope?
 - How should limited incentive funds be used in a future program?
- 14.) Have you received any feedback from your ZEN clients, on how the improvements have performed?
 - Energy savings?
 - Comfort?
 - Value?
- 15.) What was your sense about the ZEN/Solar Bonus trainings? With respect to:
 - Software tool
 - Sales training
 - Program mechanics

- 16.) Did your role as a ZEN coordinator work for you and your business model?
- 17.) If someone outside of your business were to design and coordinate the ZEN components of the work – including the audit and essential design of the project, financing options, software tools and reporting – would that be inherently problematic to your business model?
- 18.) If you wished to retain that function within your business, would you be willing to take substantial time – say two to four days – for training related to software use, specific design considerations, and work scope development?
- 19.) What about ZEN’s potential for scaling? If the ZEN program were able to be expanded substantially to become a large-scale offering across the state, how much ZEN project work would you be willing to take on?
- 20.) If a ZEN program became a successful part of your business would you be willing to contribute a portion of your marketing budget to promoting the program?
- 21.) Was there anything about the ZEN program or the way it was structured that was particularly valuable or beneficial to your business?
- 22.) Was there anything about the ZEN program or the way it was structured that was particularly problematic for you or your business?
- 23.) Do you have any particularly clear thoughts or ideas for how the program could be improved?
- 24.) If you could change one thing about the ZEN program for the future, what would it be?

A-5

Alternative Paths to the 10% Envelope Load Reduction Requirement

In an effort to make the original Zero Energy Now program more accessible to homeowners who had already completed a weatherization upgrade, or who lived in a newer, more efficient home, it was decided that the 10% threshold for weatherization could be waived under certain specific circumstances. These specific circumstances became known as the “Alternative Paths to the 10% Load Reduction”. These are listed in the chart below:

10% Heat Load Reduction Alternative Paths

If a building has no additional cost-effective building shell energy improvement measures and therefore cannot meet the 10% heat load reduction standard, it can still participate if it meets one of the following standards, after first completing a BPI energy audit (including a blower door test), which is required for every project:

1)	30 kBtu/ft ²	Maximum Energy Intensity. Calculated using the average fuel consumption over the previous two (2) years for space heating and the intentionally conditioned square footage of the building.
2)	Home Performance with ENERGY STAR Program Participation & 20% air leakage	The building has completed a Home Performance with ENERGY STAR (or Building Performance) Program project and also achieved at least a 20% air leakage reduction level.
3)	RBES or CBES Certificate	The building has achieved a 2011 Residential Building Energy Standards (2011 RBES) (or Commercial Building Energy Standard, 2011 CBES) or later certificate.
4)	HERS Index of 76 or less	The building has scored a Home Energy Rating System (HERS) Index of 76 or less by a certified Energy Rater. A score of 76 represents the HERS compliance number required in the 2011 RBES.
5)	ACH50 < 4	The building has a maximum measured Air Changes per Hour of less than 4 at 50 Pascals (ACH50), following BPI standards.

It is important to note that, without the load reduction provided by improving the envelope, meeting Test 2 of Zero Energy Now will be that much more difficult. Likewise, any envelope improvement undertaken, even if it is below ten percent, will help reduce fossil fuel usage and may need to be included in the work scope to help meet Test 2.

A-6

Mechanical Efficiencies

Mechanical System Default Efficiencies

- 1) Whenever available, use listed and rated system efficiencies for heating (AFUE) and hot water (EF) equipment. Google make and model number to find the efficiency rating.
- 2) When efficiency information is not available, use the default tables 303.8.1(3) and (4) below, taken from the RESNET Mortgage Industry National Home Energy Rating Systems Standards, (January 2013) and the Northeast HERS Alliance Manual (2007).
- 3) To find the age of a piece of equipment, go to <http://www.buildingcenter.org/content/hvac-production-dateage>
- 4) Total system efficiencies should consider the distribution system efficiency plus the heating system efficiency.
- 5) To determine total system efficiency, multiply the heating system efficiency by the default distribution system efficiency in Table 303.4.1(4).
- 6) To determine the efficiency of an indirect-fired hot water system (set up as a zone off a boiler), multiply the boiler AFUE x .75 (per REM/Rate).
- 7) For tankless coil system efficiencies, see table below.
- 8) Electric resistance baseboard heat is 100% efficient (AFUE 1.0).

Table 303.4.1(4). Default Distribution System Efficiencies for Inspected Systems ^(a)

Distribution System Configuration and Condition:	Forced Air Systems	Hydronic Systems ^(b)
Distribution system components located in unconditioned space	0.80	0.95
Distribution systems entirely located in conditioned space ^(c)	0.88	1.00
Proposed “reduced leakage” with entire air distribution system located in the conditioned space ^(d)	0.96	
Proposed “reduced leakage” air distribution system with components located in the unconditioned space ^(d)	0.88	
“Ductless” systems ^(e)	1.00	

Table 303.8.1(3) Default Values for Mechanical System Efficiency (Age-based)*

Mechanical Systems	Units	Pre-1960	1960-1969	1970-1974	1975-1983	1984-1987	1988-1991	1992 to present
Heating:								
Gas Furnace	AFUE	0.72	0.72	0.72	0.72	0.72	0.76	0.78
Gas Boiler	AFUE	0.60	0.60	0.65	0.65	0.70	0.77	0.80
Oil Furnace or Boiler	AFUE	0.60	0.65	0.72	0.75	0.80	0.80	0.80
Air-Source Heat Pump	HSPF	6.5	6.5	6.5	6.5	6.5	6.80	6.80
Ground-Water Geothermal Heat pump	COP	2.70	2.70	2.70	3.00	3.10	3.20	3.50
Ground-Coupled Geothermal Heat Pump	COP	2.30	2.30	2.30	2.50	2.60	2.70	3.00

Cooling:								
Air-Source Heat Pump	SEER	9.0	9.0	9.0	9.0	9.0	9.40	10.00
Ground-Water Geothermal Heat Pump	EER	10.00	10.00	10.00	13.00	13.00	14.00	16.00
Ground-Coupled Geothermal Heat Pump	EER	8.00	8.00	8.00	11.00	11.00	12.00	14.00
Central Air Conditioner	SEER	9.0	9.0	9.0	9.0	9.0	9.40	10.00
Room Air Conditioner	EER	8.0	8.0	8.0	8.0	8.0	8.10	8.50
Water Heating:								
Storage Gas	EF	0.50	0.50	0.50	0.50	0.55	0.56	0.56
Storage Oil	EF	0.47	0.47	0.47	0.48	0.49	0.54	0.56
Storage Electric	EF	0.86	0.86	0.86	0.86	0.86	0.87	0.88

* **Exception:** Where the labeled equipment efficiency exists for the specific piece of existing equipment, the labeled efficiency shall be used in lieu of these minimum input constraints.

**TABLE 303.8.1(4) Default Values for Mechanical System
Efficiency (not Age-based)***

	Units	Rating
Heating:		
Gas Wall Heater (Gravity)	AFUE	0.72
Gas Floor Furnace	AFUE	0.72
Gas Water Heater (Space Heating).	AFUE	0.75
Electric Furnace	HSPF	3.413
Electric Radiant	HSPF	3.413
Heat Pump Water Heater (Space)	HSPF	5.11

Electric Water Heater (Space)	HSPF	2.73
Cooling:		
Electric Evaporative Cooling	EER	30
Gas Absorption Cooler	COP	0.40
Water Heating:		
Heat Pump	COP	2.00
Instantaneous Electric	EF	0.87
Instantaneous Gas	EF	0.75
Solar (Use SRCC Adjustment Procedures)	EF	2.00

* **Exception:** Where the labeled equipment efficiency exists for the specific piece of existing equipment, the labeled efficiency shall be used in lieu of these minimum input constraints.

Northeast HERS Alliance
Table 4.6 (35): Recommended Energy Factors for Tankless
Coil Hot Water Heaters

Bedrooms	Occupants	Energy Factor
2	3	0.45
3	4	0.50
4	5	0.55
5	6	0.60
6	7	0.65

Definitions:

AFUE	Annual Fuel Utilization Efficiency	Seasonal efficiency for combustion space heating equipment (0 - 1.0)
EF	Energy Factor	Seasonal efficiency for water heaters (0 - 2.0+)
COP	Coefficient of Performance	Season efficiency of a heat pump; the ratio of heating or cooling provided to work required
HSPF	Heating Seasonal Performance Factor	Seasonal efficiency of heat pump heating; the ratio of BTU heat output over the heating season to watt-hours of electricity used, measured in BTU/watt-hours.
SEER	Seasonal Energy Efficiency Ratio	Seasonal cooling output during a typical cooling-season divided by the total electric energy input during the same period measured in BTU/watt-hours.

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Existing Wood Efficiencies

The following chart is a listing of existing wood efficiencies that were prescribed when assessing efficiency of existing wood-fired heating systems:

Estimated Seasonal Average Efficiency for Existing Wood Heat Systems (To Be Used When Establishing Existing & Improved Equipment Performance)

Appliance	Fuel	Age	Estimated seasonal average efficiency
Indoor Boiler	Pellets	new	82%
	Pellets	1-10 years old	80%
	Pellets	10+ years	75%
	Cordwood	New (with thermal storage)	78%
	Cordwood	1-10 years old	65%
	Cordwood	10+ years	55%
Outdoor Boiler*	Cordwood	1-10 years old	50%
	Cordwood	10+ years	40%
Furnace	Pellets	new	78%
	Pellets	1-10 years old	75%
	Pellets	10+ years	65%
	Cordwood	new	76%
	Cordwood	1-10 years old	63%
	Cordwood	10+ years	52%
Stove	Pellets	new	75%
	Pellets	1-10 years old	70%
	Pellets	10+ years	70%
	Cordwood	new	70%
	Cordwood	1-10 years old	65%
	Cordwood	10+ years	60%

*Please note: The efficiencies of existing outdoor wood boilers are lower than what is provided as their peak ratings, due to the how these systems are operated over the course of the heating season (as compared to performance in a controlled laboratory setting).

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Standards for New Wood

**Required Efficiency and Emissions Standards for New Indoor Wood Heat Systems
(To Be Used to Determine Which Systems May Receive a ZEN Incentive for Indoor
Wood Heating*)**

Appliance Type	Required Minimum Peak Efficiency Rating on HHV Basis	Required PM 2.5 Emissions Limit
Pellet Boiler	85%	0.08 lbs/MMBtu
Pellet Furnace	85%	0.08 lbs/MMBtu
Pellet Stove	78%	2.0 grams per hour
Cordwood Boiler (with <u>required</u> thermal storage)	75%	0.15 lbs/MMBtu
Cordwood Furnace	75%	0.15 lbs/MMBtu
Cordwood stove	75%	2.0 grams per hour

*Only Indoor Equipment May Receive a ZEN
Incentive.

Participating Contractors – 2016 & 2017 ZEN Pilot Programs

General Contractors

5 Star Energy Tech, Bruce E. Landry, Barre, 479-3575
Build Basic Green LLC, Bruce Merritt, Hartland, 436-2200
Building Energy: White River Junction Location, Brent Mellen, 359-7550
Building Energy: Williston Location, Nik Ponzio and Russ Flanigan, 859-3384
Caleb Contracting, Jim Bradley, Cambridge, 644-8756
Common Sense Energy, Allan Bullis, Burlington, 846-7592
Energy Co-op of Vermont, Paul Fleckenstein, Colchester, 860-4090
Energy Wright, Phil Mulligan, Chelsea, 685-7784
HEAT Squad, Melanie Paskevich, West Rutland, 797-8610
Integrated Solar Applications, Andy Cay, Brattleboro, 257-7493
Montpelier Construction, Malcolm Gray, Barre, 479-5882
Murphy's Zero Energy Building, John Unger Murphy, St. Johnsbury, 748-5800
New Frameworks Natural Design, Jacob Deva Racusin, Burlington, 782-7783
New Leaf Design, LLC, Thomas S Perry, Hinesburg, 482-5323
Peachtree Builders, Richard Nelson, Windsor, 674-6005
Reiss Building and Renovation, Chuck Reiss, Hinesburg, 482-3295
Weatherization Works/Solar Works, William Morrissey, Pawlet, 268-0028

In-Network Partners

Businesses providing solar, wood heat and efficiency work for the General Contractors above

DC Energy Innovations, Ben Gordesky, North Hero, 372-9514
Farnum Insulators, Chad Farnum, Dummerston, 387-5005
Gary MacArthur, Gary MacArthur, Brattleboro, 257-7026
Grassroots Solar, Bill Laberge, Dorset, 325-2281
Integrity Energy, Amos Post, Bethel, 763-7023
Pellergy, Andy Boutin, Montpelier, 371-0098
Same Sun of Vermont, Michael Elliott, Rutland, 775-7900
Solaflect Energy, Cody Berwick, 649-3700
SunCommon, James Moore, Waterbury Center, 882-8144
Sunwood Biomass, David Frank, Waitsfield, 496-6666
USA Solar Store, David Bonta, Proctorsville, 226-7194

Program Administrators

Richard Faesy, **Energy Futures Group, Hinesburg, 482-2812**
Gabrielle Stebbins, **Energy Futures Group, Hinesburg, 482-5001**

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* Active at time of pilots, but now retired from Board.

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