EXPANDED USE OF ADVANCED WOOD HEATING IN VERMONT

A Roadmap to Reach the Target of 35% of Vermont's Thermal Energy Demand with Wood Heating by 2030.

PREPARED FOR
Vermont Working Lands Enterprise Board

BY
Renewable Energy Vermont and Biomass Energy Resource Center

ENDORSEMENTS

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ABOUT RENEWABLE ENERGY VERMONT

Renewable Energy Vermont (REV) represents businesses, non-profits, utilities, and individuals committed to reducing our reliance on dirty fossil fuels by increasing clean, renewable energy and energy efficiency in Vermont. Vermont's clean energy economy directly enables at least 19,080 jobs at 3,751 businesses, representing approximately 6% of Vermont's workforce. Together, we will achieve 90% total renewable energy (electric, thermal, transportation) before 2050. Learn more at www.revermont.org

ABOUT THE BIOMASS ENERGY RESOURCE CENTER

The Biomass Energy Resource Center (BERC) is a program of the Vermont Energy Investment Corporation (VEIC), a mission driven non-profit organization focused on developing and implementing market solutions to expand the use of energy efficiency and renewable energy. Since 2001, BERC has specialized in the design and implementation of programs that stimulate and support wood energy conversion projects. BERC has a long-standing reputation as a source of independent and impartial information and services for modern wood heating. More information at – www.biomasscenter.org

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Executive Summary

The State of Vermont has committed to meet 90% of the State's total energy demand from renewables by 2050. The 2016 Comprehensive Energy Plan (CEP) calls for an increase in the portion of renewable energy used to heat Vermont's buildings to 30% by 2025, through both efficiency and increased use of renewable fuels (including wood). More specifically, the 2016 CEP calls for doubling the use of wood heating in Vermont. Expanded use of advanced wood heat will help Vermont make measureable progress toward a number of key goals.

Developing local demand for cordwood, wood chips, and pellets will help create vital markets for low-grade timber from managed forests. Heating with local wood fuels reduces the economic drain on Vermont's economy. Factoring that only 22 cents of every dollar spent on heating oil or propane are likely retained in the local economy, and 80 cents of every dollar spent on wood are likely retained in the local economy,[1] an estimated net $70 million was retained in the Vermont economy in 2016 by Vermonters choosing to heat with wood rather than fossil fuels. Wood heat lowers and stabilizes energy costs and keeps dollars circulating in the local economy. Wood heat also creates and supports jobs in the forestry, wood processing, and transportation sectors.

This road map details how the 35% thermal energy target can be met with expanded use of wood heating and assesses the various strategies for achieving the target.

Based on the most recent year (2014) of US Energy Information Administration (EIA) data available, wood fuels (both traditional and AWH) met an estimated 21% of heating demand in Vermont in 2014.[2] Increasing the use of wood heating in Vermont from 21% in 2014 to 35% by 2030 would not only displace oil, but also propane and to some extent natural gas.

If wood heating is to increase from 2.5 million megawatt hours of annual thermal energy generation in 2016 to 4.3 million megawatt hours in 2030, significantly more advanced wood heating systems and pellet stoves will need to be installed across the residential, commercial, and institutional building market sectors.

To reach the 35% target by 2030, we would need to:

- Install 38,905 more wood pellet stoves (or about 30% of all single family homes)
- Install 10,519 more bulk pellet fueled boilers (or about 16% of all single family homes with centralized hydronic heat distribution networks)
- Install 2,574 more pellet boilers in small commercial buildings (or about 6% of that market segment)
- Install 221 more woodchip boilers in larger commercial/institutional buildings and district heating plants (or about 4% of that market segment).

[1] http://www.nebioheat.org/pdf/heatne_vision_full.pdf
[2] Value calculated using EIA data and data from the Vermont Residential Fuel Assessment (RFA), 2015.

A variety of barriers to further development of the wood heating market exist -- including capital costs, public perceptions, and lack of funding to support incentives. There are two key drivers that influence the extent to which the market will adopt a renewable energy technology:

- Market conditions (cost of competing equipment and fuels)
- Policy and regulatory (the various incentives available)

With currently low fossil fuel prices and limited market awareness, there is significant need for integrated programs to drive broader market adoption. However, in theory, there is a threshold for heating oil price when essentially no direct subsidy is needed to further stimulate market adoption. Sensitivity analysis performed suggests that if oil prices were over $5.00 per gallon for the residential market and over $4.00 per gallon for the commercial market, there would be no direct incentive needed to dramatically expand the use of wood heating. In the meantime, policies that direct funding toward program support, financial support, and regulations that aggressively push the market toward the adoption of renewable energy are essential.

Section 1 - Introduction

Vermont has a long history of heating buildings with wood. While heating homes with woodstoves has been common for generations, heating entire buildings with automated woodchip and wood pellet boilers in Vermont started in the 1980s. Since that time, there has been slow and steady growth of the use of automated woodchip and pellet fueled boilers in the commercial, institutional, and residential markets. Today, Vermont is home to the greatest concentration of installed advanced wood heating (AWH) systems in North America.

The State of Vermont has committed to meeting 90% of the State's total energy demand from renewables by 2050. The 2016 Comprehensive Energy Plan (CEP) calls for an increase in the portion of renewable energy used to heat Vermont's buildings to 30% by 2025, through both efficiency and increased use of renewable fuels (including wood). More specifically, the 2016 CEP calls for doubling the use of wood heating in Vermont. The analysis and discussions with stakeholders undertaken via this report further detail this target as achieving 35% of thermal energy demand by 2030. The focus of this report is on expanding the use of advanced wood heating as a replacement for fossil fuel heating sources, and is premised on promoting best in class technology, and encouraging local, sustainable forest management.

Wood heating comes in many forms. There are three main categories of wood fuels – cordwood, pellets, and woodchips. Cordwood is sold by volume and is used predominantly in the residential sector in stoves that provide point-source heat. Wood pellets sold in 40 pound bags are commonly used with pellet stoves that also provide point-source heat. Bulk pellets are now widely available to the residential and small commercial heating market and are most commonly used to fuel automated boilers that provide whole-building heating via hydronic (hot water) piping and emitters (radiators). Woodchips are used for larger commercial and institutional buildings or networks of buildings with central hydronic or steam heat distribution systems. Automated woodchip and pellet boilers are highly efficient with minimal emissions. Pellet stoves also feed fuel automatically and are thermostatically controlled. While traditional use of cordwood in stoves is a significant portion of the total wood heating sector today (and will remain an important portion of sector in the years to come), this roadmap explores the opportunity of meeting the 35% target by dramatically expanding the use of advanced wood heating (AWH- automated bulk pellet and woodchip fueled boilers) and best-in-class pellet stoves.

1.1 Background

In 2016, Renewable Energy Vermont, in partnership with VEIC, received a grant from the State of Vermont's Working Land's Enterprise Board (WLEB) to develop a road map document that further develops details around how the 35% thermal energy target can be met with expanded use of wood heating and assesses the various strategies for achieving the target.

The Working Lands Enterprise Initiative supports innovative entrepreneurs at the forefront of Vermont's Working Lands economy through technical and financial assistance to help growing businesses thrive. The program is made possible through the support of the state legislature, multiple state organizations and public/private donors.

The origin of the 35% wood heat target stems from a 2010 study commissioned by the State of Vermont's Department of Forests Parks and Recreation. The Vermont Wood Fuel Supply Study, 2010 Update, estimated that there are roughly 890,000 green tons of additional (beyond existing harvesting levels) low-grade wood grown annually on the ecologically appropriate and actively managed portion of Vermont's forestland[3]. That amount of additional sustained-yield forest resource capacity was estimated to be close to the equivalent amount wood fuel currently being used in Vermont for thermal energy (counting the cordwood, chips, and pellets consumed each year). At the time of the study release, the amount of additional forest resource capacity wood fuel was estimated to increase the percentage of thermal energy derived from wood from roughly 15% to 35% of the total statewide thermal demand. Then in 2016, the State of Vermont Department of Public Service released the Comprehensive Energy Plan (CEP) that called for doubling the use of wood heating by 2030. Subsequent refinement analysis and a more refined target of reaching 35% of Vermont's thermal energy from local wood fuels by 2030.

In 2016 the Clean Energy Development Fund (CEDF) commissioned a baseline study of wood heating in Vermont[4]. A short summary of the baseline report can be found in Section 2 of this document.

Recently, support for advanced wood heating as an effective strategy to help meet renewable energy and carbon emission reduction targets (when replacing fossil fuels) has grown. But there has also been increased interest in the local economic opportunities and benefits of AWH. Expanding the local heating market in Vermont offers creation of new jobs, keeps energy dollars in the Vermont economy, and helps develop local markets for low-grade wood harvested from private and public managed forestland.

Over the past two decades, traditional markets for low-grade wood have declined dramatically due to closures and reduced capacity of regional pulp and paper mills. Without local viable markets for low-grade wood, it is difficult to carry out periodic timber harvests in accordance with forest management plans. Good forest management sustains the forested working landscape.

1.2 Methodology

The REV and BERC team used the following approach to craft this roadmap:

1. Engage a diverse group of stakeholders including members of the wood heating and forest products industry, renewable energy advocates, economic development advocates, and state agency personnel.
    a. Present the outcomes of the 2016 Baseline assessment
    b. Clarify the target of 35%
    c. Define the boundaries of the 35% target
    d. Discuss and establish the guiding principals
    e. Present action plan for analysis
2. Perform analysis (starting with just AWH and then adding pellet stoves)
    a. Calculate the amount of thermal energy target to achieve goals
    b. Model the BAU trajectory for 2030

[3] https://www.biomasscenter.org/images/stories/VTWFSSUpdate2010_.pdf
[4] http://publicservice.vermont.gov/sites/dps/files/documents/Renewable_Energy/CEDF/Reports/AWH%20Baseline%20Report%20FINAL.pdf

   c. Quantify the difference
   d. Run scenarios on market adoption rates for different market sectors
      i. Calculate numbers of appliance installation needed
      ii. Assess the rationality of the numbers and make adjustments if outcomes are out of balance in proportion to the size of the total market segment in Vermont
3. Reconvene stakeholders
   a. Present analysis
   b. Gather feedback and input on the results and assumptions used
4. Revise analysis based on stakeholder input
5. Write up roadmap document
6. Present to stakeholders

Section 2 – 2016 Wood Heat Baseline Summary

In 2016, the State of Vermont, through the Clean Energy Development Fund, hired the Biomass Energy Resource Center to conduct a baseline assessment of the AWH and total wood heat market in Vermont.

This baseline assessment was compiled primarily from existing sources of data. Existing data was supplemented by information collected through interviews with key market players. The report was comprised of two primary sections: (1) AWH and (2) total wood heat. The section on AWH presents findings related to wood heating businesses, cumulative and annual installations, wood fuel consumption, trends in installations and consumption, and the overall economic impacts of AWH sector. The report also presented findings related to the portion of thermal energy met with all types of wood fuel and appliances (including AWH), as well as the overall economic impact of all wood heating.

2.1 Advanced Wood Heating

In 2016, there were two operational wood pellet fuel production mills located in Vermont[5] (and another two mills under development), dozens of woodchip fuel producers, three primary bulk pellet fuel delivery businesses, and 41 businesses offering the sale, installation, and service of AWH systems. Overall, the AWH industry contributed over $8.6 million in sales revenue for installers, and producers and distributors of pellets and woodchips in Vermont – with an additional $3 million to businesses located in the "region" (defined in this assessment as within 200 miles from the center of Vermont)[6]. The AWH industry directly creates 54 full-time equivalent jobs in Vermont, with an additional 10 jobs outside of Vermont.

Using data from a variety of sources, BERC estimates that there are approximately 480 advanced wood heat installations in Vermont. The majority are residential, but approximately 100 are commercial or institutional bulk wood pellet fueled systems and another 62 are commercial or institutional woodchip systems. Based on information gathered from installer interviews, BERC estimates that an additional 64 residential pellet systems are installed in Vermont annually, as well as an additional 9 commercial and institutional pellet systems. On average, one to two woodchip systems have been installed each year in Vermont in recent years.

BERC estimates approximately 8,000 tons of bulk wood pellets[7] and 79,000 tons of woodchips were consumed in 2016 in Vermont's advanced wood heat systems. By comparison, Vermont and regional pellet mills reported selling a total of 4,800 tons of bulk pellets to Vermont customers. This leaves the origin of a large amount of bulk pellets in question. The report provides likely explanations for the difference. Evidence suggests that three quarter of bulk pellets burned in VT are imported from outside Vermont.

[5]One of the two mills operating in 2016 is no longer operational.
[6]The share of revenue from pellet and woodchip distribution for businesses located outside of Vermont was not estimated.
[7]For the analysis, BERC separated the production and use of bulk wood pellets from the production and use of bagged pellets. Bagged pellets represent the greatest share of pellet sales in Vermont and much of the bagged pellets are used in wood pellet stove and fireplace inserts. While these are not included in the analysis of Advanced Wood Heating systems, their use is important in understanding the market for wood pellets.

In the commercial and institutional sector, the rate of woodchip systems installations slowed down after 2009, due to a funding moratorium for the School Construction Aid program, administered by the Department of Education, which had provided funding toward the capital costs of woodchip system installations in schools. In 2010-2011, the rate of installation of commercial and institutional bulk pellet systems increased rapidly, exceeding the pace of woodchip system installations. This was primarily due to the commercial introduction of lower capital cost bulk pellet fueled heating systems and improved bulk pellet fuel delivery options. While woodchips are well suited for larger buildings, many smaller buildings have been able to take advantage of developments in the bulk pellet market. The result was an increase in bulk wood pellet installations in the school and multifamily housing sectors, as well as other commercial and institutional installations.

Quick Statistics - Advanced Wood Heating Sector in Vermont	
Operational pellet mills in 2016[8]	2
Expected operational pellet mills in 2018[9]	2
Combined capacity of pellet mills in 2016 (tons/year)	37,500
Combined capacity of pellet mills expected in 2018 (tons/year)	84,500
Residential systems installed to date	377
Commercial/institutional systems installed to date	162
Bulk pellet fuel consumed by Vermont systems (tons/year)	8,000
Woodchip fuel consumed by Vermont systems (tons/year)	79,000
Percent of total statewide heating	2%

Looking into the future, AWH is expected to continue to grow and become a more mainstream heating option. However, some periods of stagnation are expected as the sector faces difficulties related to the fluctuating price of competing fossil fuels and continuing changes in technologies (such as air source heat pumps). Traditional wood heat (mostly home heating with cordwood stoves) is expected to continue making-up a significant, but highly variable share of total heating demand in Vermont, with Vermonters burning more or less wood depending on the price of competing fuels, among other factors.

2.2 Total Wood Heating

Using the most recent year (2014) of US Energy Information Administration (EIA) data available, wood fuels (both traditional and AWH) met an estimated 21% of heating demand in Vermont in 2014.[10] Heating with cordwood or pellet stoves provides home owners a lot of flexibility to burn more wood and less oil and propane, and this, along with the national economic recession, are reasons for the current share of wood heat being twice as high in 2014 as it was a decade earlier, when oil prices were much lower.

[8]Note that the pellet mill located in West Windsor, Vermont was operational in 2016 and was shut down in 2017.
[9]Note that a second pellet mill is scheduled to open in the Northeast Kingdom in 2018.
[10]Value calculated using EIA data and data from the Vermont Residential Fuel Assessment (RFA), 2015.

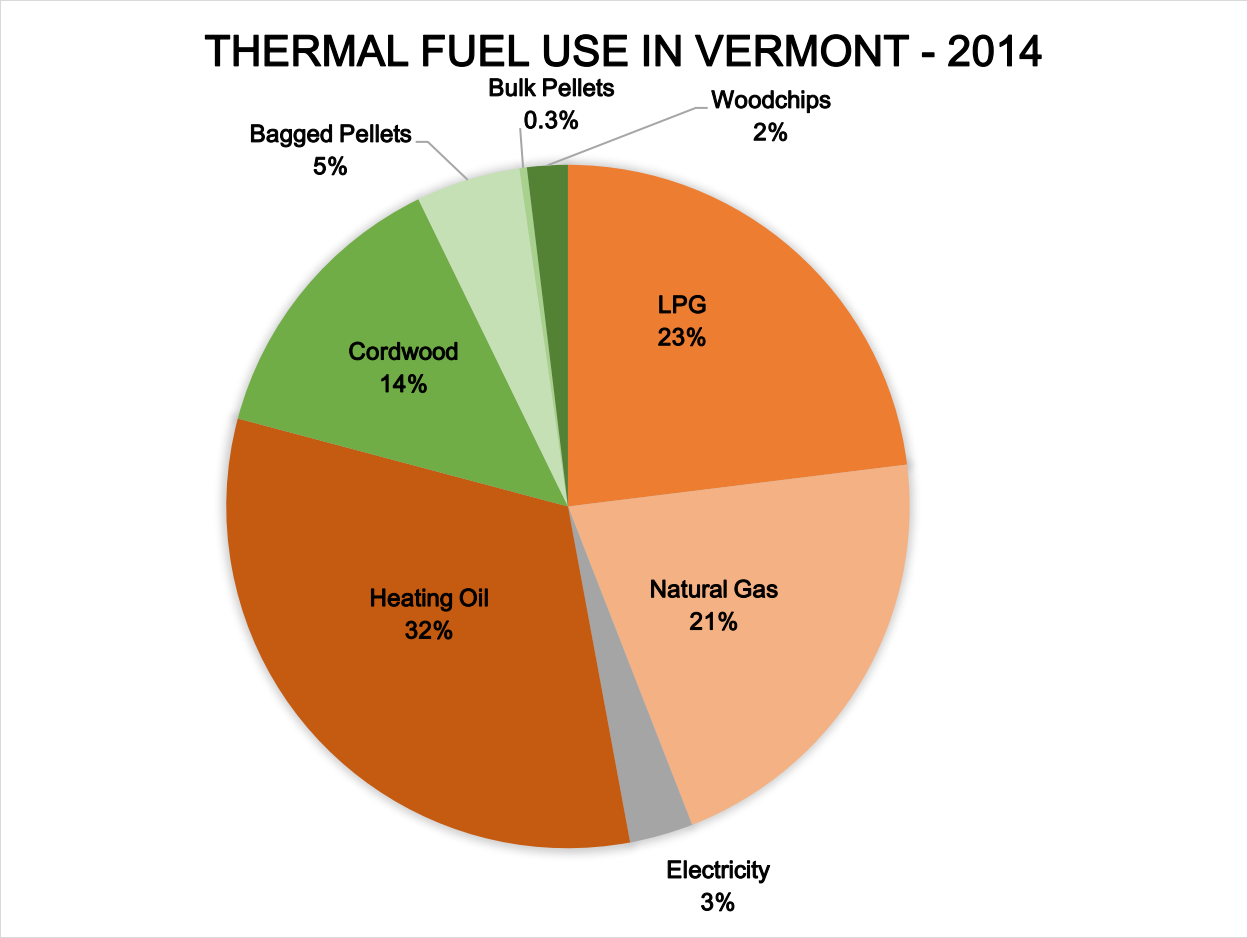


Figure 1 - 2014 Heating Fuel Mix for Vermont

The share of the total wood heat market occupied by AWH ranges from 0.5% for the residential sector to approximately 88% for the commercial and institutional sector. In the residential sector, approximately 65,000 households[11] heat with wood as their primary source of heat (20% of households heat with cordwood as primary fuel, 12% with pellets as primary and supplemental fuel), and only 377 are estimated to have an advanced wood heat system, which is equal to 0.6% of the number of households heating with wood.

[11]Vermont Residential Fuel Assessment, 2015

Table 1 - Quick Statistics on wood heating in Vermont

Quick Statistics - All Wood Heat in Vermont	
Number of homes heated in part with wood	96,951
Percent of homes heated in part with wood	38%
Firewood burned (cords/year)	347,000
Average firewood consumption per household (cords/year)	3.6
Households with pellet heating appliances	31,051
Households heated in part with pellets	12%
Bagged pellets burned (tons/year)	138,530
Bagged pellets produced in Vermont burned in Vermont (tons/year)	6,000
Percent of total statewide heating	21%

The annual revenue associated with cordwood fuel production and sale is approximately $85 million.[12] The annual revenue associated with the installation of wood stoves was not estimated as part of this baseline assessment. The fuel cost savings associated with heating with wood rather than with oil or propane were estimated at $31.5 million annually.[13]

Heating with local wood reduces the economic drain on Vermont's economy. Factoring that only 22 cents of every dollar spent on heating oil or propane are likely retained in the local economy, and 80 cents of every dollar spent on wood are likely retained in the local economy,[14] an estimated net $70 million was retained in the Vermont economy in 2016 by Vermonters choosing to heat with wood rather than fossil fuels. Wood heat lowers and stabilizes energy costs and keeps dollars circulating in the local economy. Wood heat also creates and supports jobs in the forestry, wood processing, and transportation sectors.

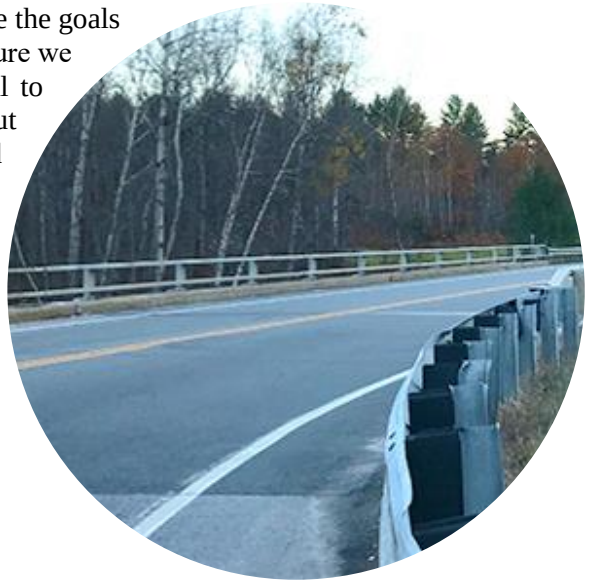
[12]Assuming $19/MMBtu and 4.5 trillion Btu of cordwood are consumed annually in Vermont
[13]Assuming that wood heat systems replaced the same proportion of oil and propane systems as the proportion of oil and propane systems present in Vermont overall.
[14]http://www.nebioheat.org/pdf/heatne_vision_full.pdf

Section 3 – Goals & Guiding Principals

Reaching 35% of Vermont thermal energy demand with wood fuel by 2030 is a numeric target, not a really a goal. Reaching the 35% target is a means for achieving the following specific goals that are the primary drivers for why the use of wood heat should be expanded:

- Enhance and sustain Vermont's forested working landscape
- Create new and retain existing jobs in the advanced wood heating and forest products sectors
- Retain local wealth and support Vermont's economy
- Lower and stabilize heating costs for Vermonters
- Meet broader renewable energy goals of 90% by 2050
- Meet carbon emission reduction goals by replacing fossil fuels

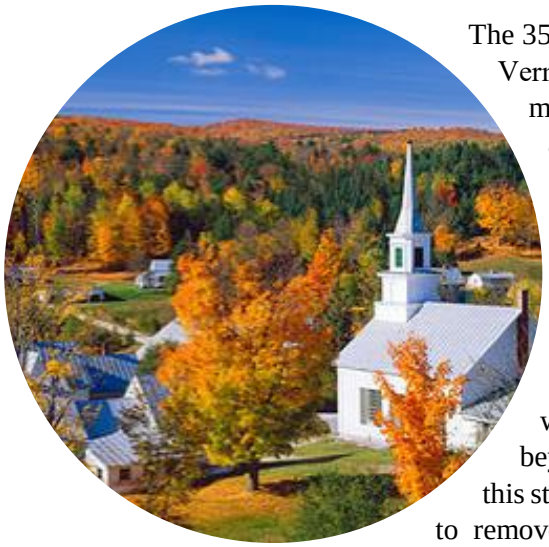
If the 35% target is to be met and wood heating expanded to achieve the goals above, guiding principles are needed to serve as "guardrails" to ensure we do not stray from the path. Although wood heat has the potential to deliver a multitude of benefits, many people hold concerns about expanded wood heating due to potential impacts on forest health and air quality.



Guiding principles to help ensure expanded wood heating delivers intended benefits include:

- Source wood fuel locally
- Encourage sustainable forest management
- Use wood fuel to directly displace fossil heating fuels
- Promote and use best in class technology (relating to efficiency and emissions)

Section 4 – Wood Heat Target for 2030



The 35% wood heat target is built on a foundation of knowledge regarding Vermont's forest resource capacity. Vermont's forests provide a multitude of ecological and economic values including providing clean air and water, habitat for wildlife, carbon storage, flood resiliency, recreation, timber products, and fuel for heat and power.

In 2010, the State of Vermont's Department of Forests, Parks and Recreation commissioned a study to quantify the amount of forest resource capacity in Vermont to expand the use of wood energy from harvested low-grade wood.[15] The objective of this study was to calculate supply of Net Available Low-grade Growth (NALG) wood (wood that would be appropriate for use as fuel above and beyond current levels of harvesting) available annually in Vermont. For this study, the total forestland area was filtered using GIS data and software to remove inaccessible and ecologically sensitive areas of forestland not suitable for periodic harvesting. Forest inventory and composition data were applied to this filtered forested footprint and average annual rates of forest net growth were applied to the portion of the inventory deemed low-grade. Averaged amounts of current demand for low-grade wood were subtracted from this growth, giving the amount of NALG wood. This assessment was done in three "runs" – conservative, moderate, and intensive. The moderate run was intended to serve as the best representation of reality, while the conservative and intensive scenarios depict lower and upper limits, respectively. The following table provides the results of the study:

Table 2 - Results of the 2010 Vermont Wood Fuel Supply Assessment

Green Tons of NALG Wood			
	Conservative Scenario	Moderate Scenario	Intensive Scenario
Vermont	246,798	894,892	1,940,694

It is important to note that while the 2010 study is the most recent information available, it uses data that is now outdated. In the time since the study was performed, new information released by the US Forest Service on Vermont's forest inventory, composition, and rate of growth as well as more recent timber harvest data tracked by the State of Vermont suggests that the amount of NALG wood is considerably larger than the amount estimated in 2010. Nonetheless, 895,000 green tons of annual sustained-yield forest resource capacity has considerable energy value. Factoring for water content and average combustion efficiency of wood heating equipment, this amount of wood could displace the equivalent of approximately 56 million gallons of number 2 heating oil annually.

Increasing the use of wood heating in Vermont from 21% in 2014 to 35% by 2030 would not only displace oil, but also propane and to some extent natural gas. Of course, wood heating is not the only strategy for displacing the use of fossil heating fuels – weatherization and strategic electrification will also play major

[15] https://www.biomasscenter.org/images/stories/VTWFSSUpdate2010_.pdf

roles in decreasing our use of fossil heating fuels. This roadmap does not approach the expansion of wood heating in isolation of other factors.

What would it look like in 2030 if wood heat accounted for 35% of the total thermal energy sourcing for Vermont? How far would thermal efficiency go? How will increased use of heat pumps and expanded natural gas pipelines impact the overall picture? Analysis was performed that projected the anticipated fuel mix in 2030 if the 35% wood heat target were met and this analysis was cross-referenced against other recent energy planning modeling work to make sure the projections align with other forecasts.[16] Figure 2 below illustrates the projected heating fuel mix for 2030 where wood heating accounts for 35% of the total (adding the bagged pellets, bulk pellets, woodchips, and cordwood together). Figure 2 also illustrates the projected portion of heating fuel from oil, propane, and natural gas for 2030, while factoring the anticipated increases in weatherization and use of heat pumps.

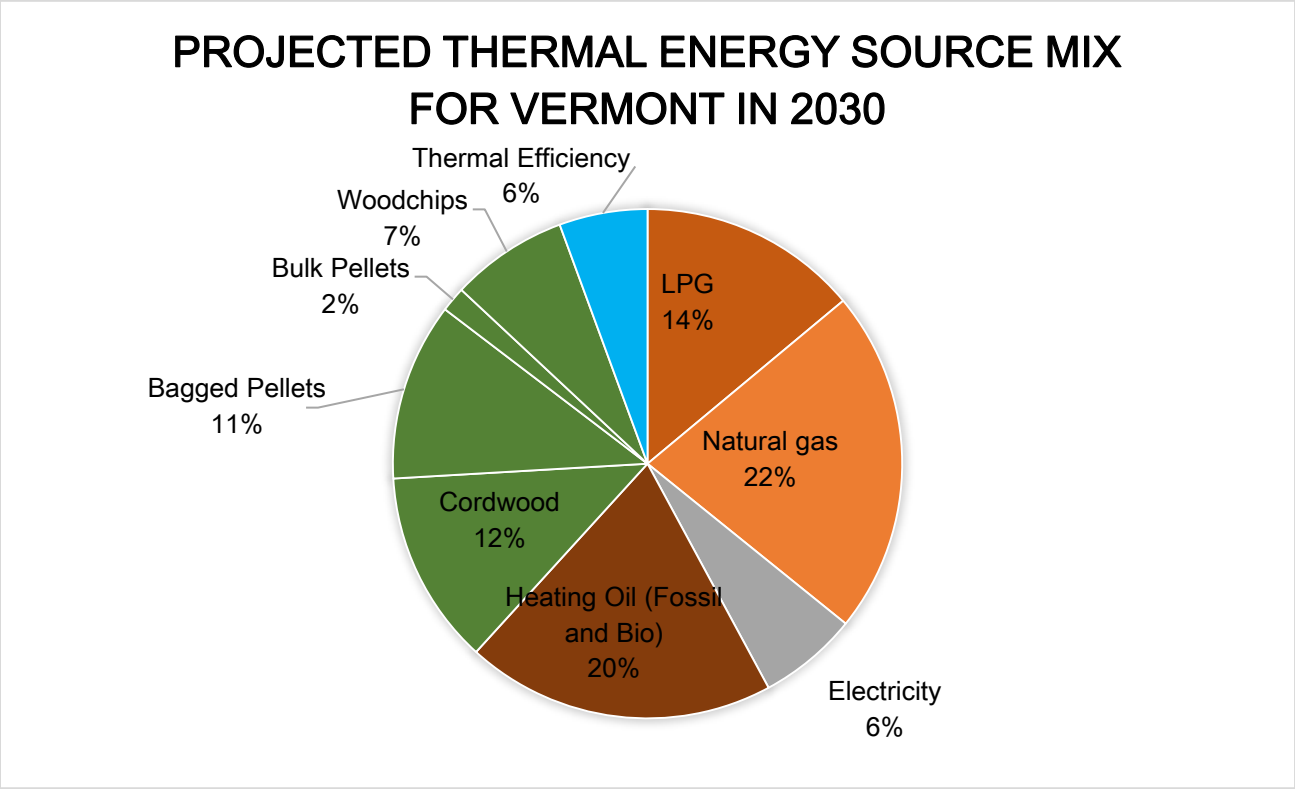


Figure 2- Projected thermal fuel mix for 2030

The projected heating fuel source mix depicted in Figure 2 factors the following assumed trends:

- Expected significant increase in the thermal efficiency of buildings. Weatherizing homes and buildings can dramatically decrease the need for heating fuels. There is a State of Vermont target of weatherizing over 80,000 homes in VT by 2020 to achieve 25% thermal energy savings in that sector.
- Expected dramatic increase in electric consumption for heating. Air source and ground source heat pumps are being broadly promoted and the numbers of units installed in Vermont is expected to increase dramatically in the next decade.

[16]Energy Action Network, Solar Market Pathways, and State CEP

- Expanded natural gas pipeline service and increased use of natural gas in select portions of the state such as Addison County.
- Level use of cordwood. While new cordwood stoves and boilers are being sold and installed, they often replace older and less efficient cordwood appliances – as a result the amount of cordwood fuel is expected to remain level.
- Dramatic increased use of bagged pellets for stoves, bulk pellets for automated boilers, and woodchips for larger boilers
- Significant decrease in heating oil and propane use

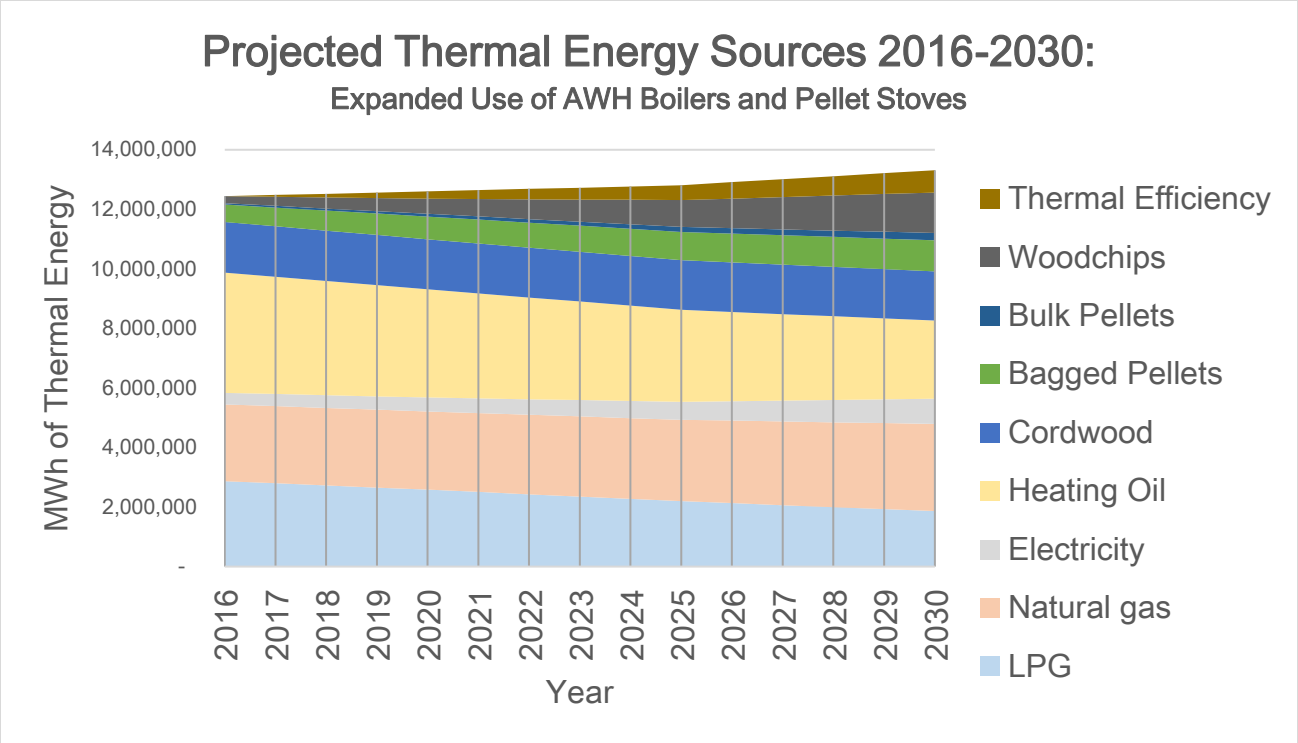


Figure 3 – Annual amounts (megawatt hours) of thermal energy generated from different sources 2016 - 2030

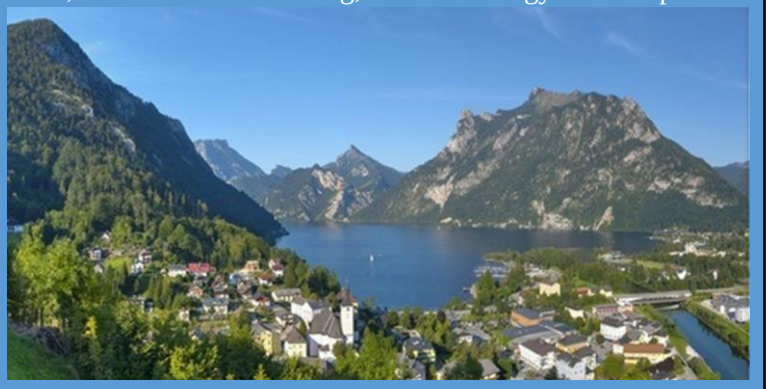
The area graph in Figure 3 depicts the annual amounts of energy from the different fuel types between 2016 and 2030. By the year 2030 wood heat derived from cordwood, bagged and bulk pellets, and woodchips will need to account for 4.3 million MWh of thermal energy.

LEADERS IN WOOD HEAT MARKET DEVELOPMENT -- UPPER AUSTRIA

Upper Austria is a small state located in North Central Austria with a population of 1.4 million. In addition to a strong economy with a mixture of manufacturing, tourism, agriculture and forestry, Upper Austria is a world leader in renewable energy. Upper Austrians have been hugely successful at establishing and growing a flourishing and robust modern wood heating market. The Upper Austrian Energy Agency developed a cohesive program which combines technology, business models, efficiency, environmental sustainability, and renewable energy, to create a streamlined implementation process. In addition to this coordinated approach, they have wood heat-friendly policies in place which encourage the stimulation of their modern wood heating economy.

With approximately half the total land area and forested land area of Vermont and more than two times the population, Upper Austria is already meeting over 40% of their thermal energy demand with wood fuels.

A Memorandum of Understanding between Vermont and Upper Austrian was signed in 2013, which called for on-going collaboration regarding the advancement of wood heating in each respective state. This "sister state" relationship has grown over the past few year and was strengthened further during a delegation visit in 2015 and again in 2016 to discuss enhanced trade, information sharing, and strategy development.



Section 5 – Getting to 35% by 2030

If wood heating is to increase from 2.5 million MWh of thermal energy generation in 2016 to 4.3 million MWh in 2030. Significantly more AWH systems and pellet stoves will need to be installed across the residential, commercial, and institutional building market sectors.[17]

Each year new AWH equipment is installed in homes, businesses, and public buildings across Vermont. However, analysis performed for this study indicates that at current rates of sales and installations of pellet stoves and automated pellet and woodchip boilers, the 35% target will not be met. Figure 4 below depicts the current "business as usual" trend for AWH and pellet stove equipment sales and installations in Vermont.

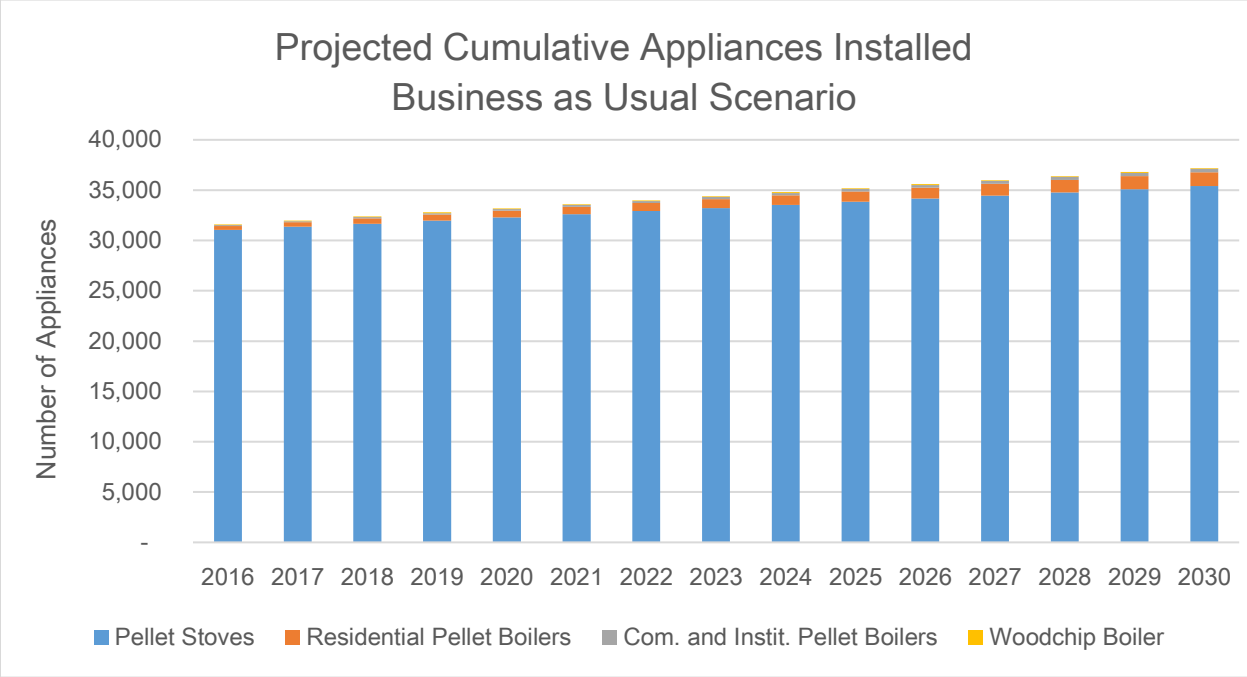


Figure 4 – The projected number of wood heating appliances installed under the business as usual scenario

Given current market conditions (i.e. low price of fossil heating fuels) and the level of incentives available, there is very little increase in wood heating. Figure 4 above shows the projected number of appliances installed between 2016 and 2030 under business as usual conditions. However, this graphs shows the number of systems – not the amount of thermal energy generated. Figure 5 below illustrates the same business usual projection, but reports the amount of thermal energy generated and compares that against the amount of thermal energy generation from wood fuels (pellets and woodchips for AWH and pellet stoves, not considering cordwood) that would be needed to reach the 35% target.

[17]It is important to note that residential of cordwood stoves accounts for a large majority of thermal energy generated from wood fuels in Vermont today. However, to meet the 35% target for 2030, we assume that all the increased use of wood heating will come from automated fuels like wood pellets and chips for use in best in class equipment including boilers, furnaces, and stoves. While cordwood plays a critical role in meeting our 2016 and 2030 thermal energy requirements, all wood heat market growth is expected to come from bagged and bulk pellets and woodchips. The projections depicted in this section assume the cordwood consumption will remain level between 2016 and 2030.

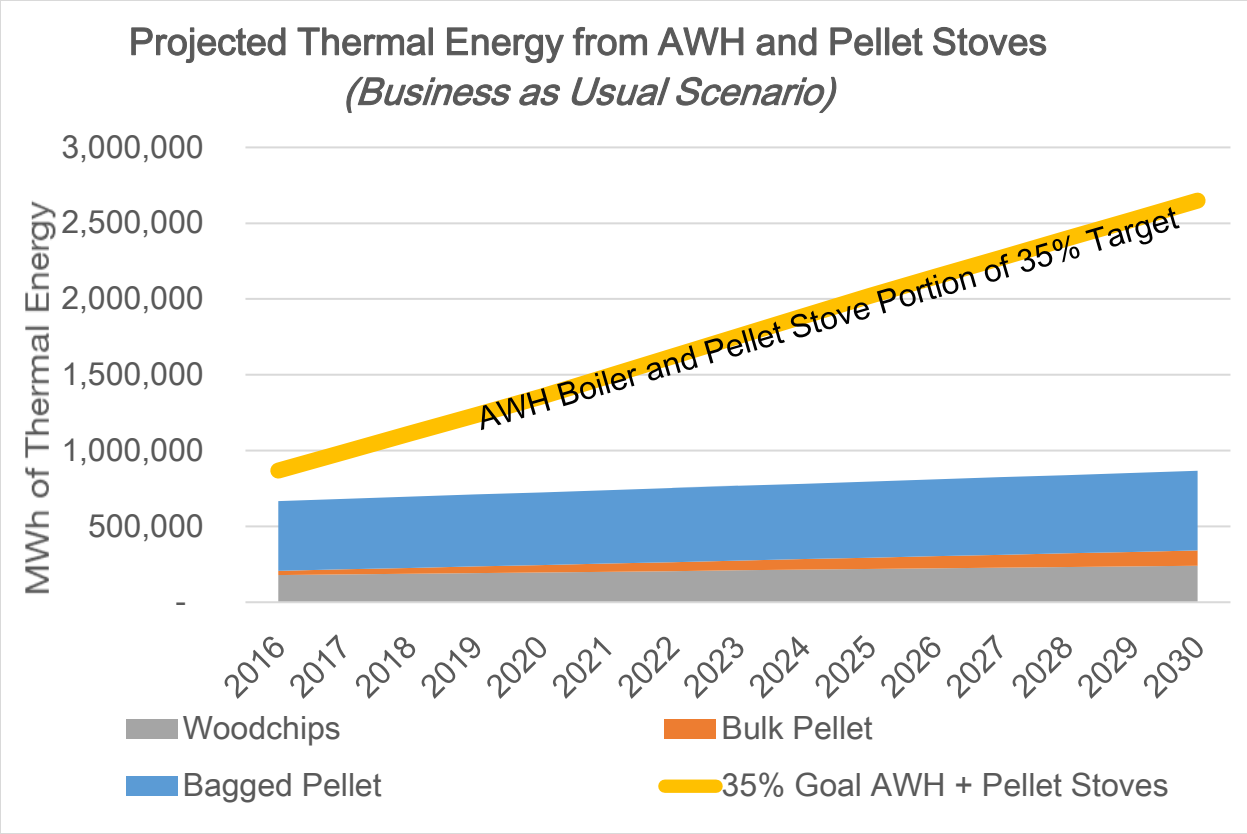


Figure 5 - Business as usual thermal energy generation projection for pellet stoves and AWH boilers

Figure 5 above clearly illustrates the considerable gap between the current rate of new wood heating system installations and the rate necessary to meet the 35% target. Each year, the gap widens and at our current pace we will fall far short of meeting the target in the year 2030.

Further analysis was performed to better understand how the 35% target could be met. Figure 6 shows the number of wood heating appliances (AWH and best-in-class pellet stoves) that would need to be installed to meet 35% of thermal energy by 2030.

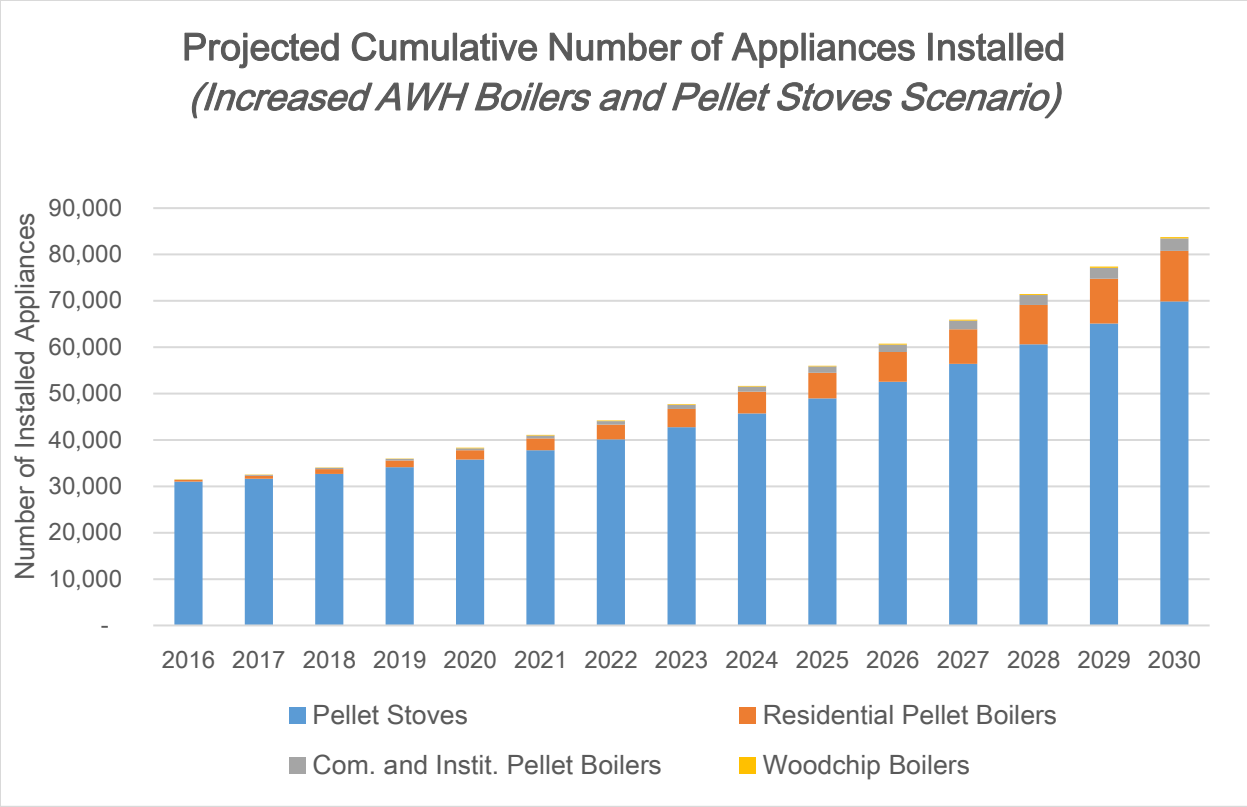


Figure 6 - Projected number of installed appliances needed to reach 35% target

Figure 6 illustrates the number of units needed to reach the 35% target, but it is important to note that, while the number of pellet stoves is a large portion of the number of units needed, the fewer larger commercial pellet and woodchip boiler systems will generate a large amount of thermal energy.

Table 3 - Number of wood heating units needed to meet 35% target

Year	Cumulative Units Installed in 2016	Cumulative Units Installed by 2030	Additional Units to Install by 2030
Pellet Stoves - Bagged Wood Pellets	31,000	69,905	38,905
Residential Pellet Boilers - Bulk Wood Pellets	377	10,896	10,519
Commercial Pellet Boilers - Bulk Wood Pellets	94	2,668	2,574
Commercial Woodchip Systems	61	282	221

Figure 6 and Table 3 show the number of combined appliances that would need to be installed to reach the 35% target. By 2030, we would need to:

- Install 38,905 more wood pellet stoves (or about 30% of all single family homes)
- Install 10,519 more bulk pellet fueled boilers (or about 16% of all single family homes with centralized hydronic heat distribution networks)
- Install 2,574 more pellet boilers in small commercial buildings (or about 6% of that market segment)

- Install 221 more woodchip boilers in larger commercial/institutional buildings and district heating plants (or about 4% of that market segment).

Based on the number of wood heating appliances shown in Figure 6 and Table 3, Figure 7 below illustrates the amount of thermal energy these appliance would generate and how they would add up to reach the 35% target.

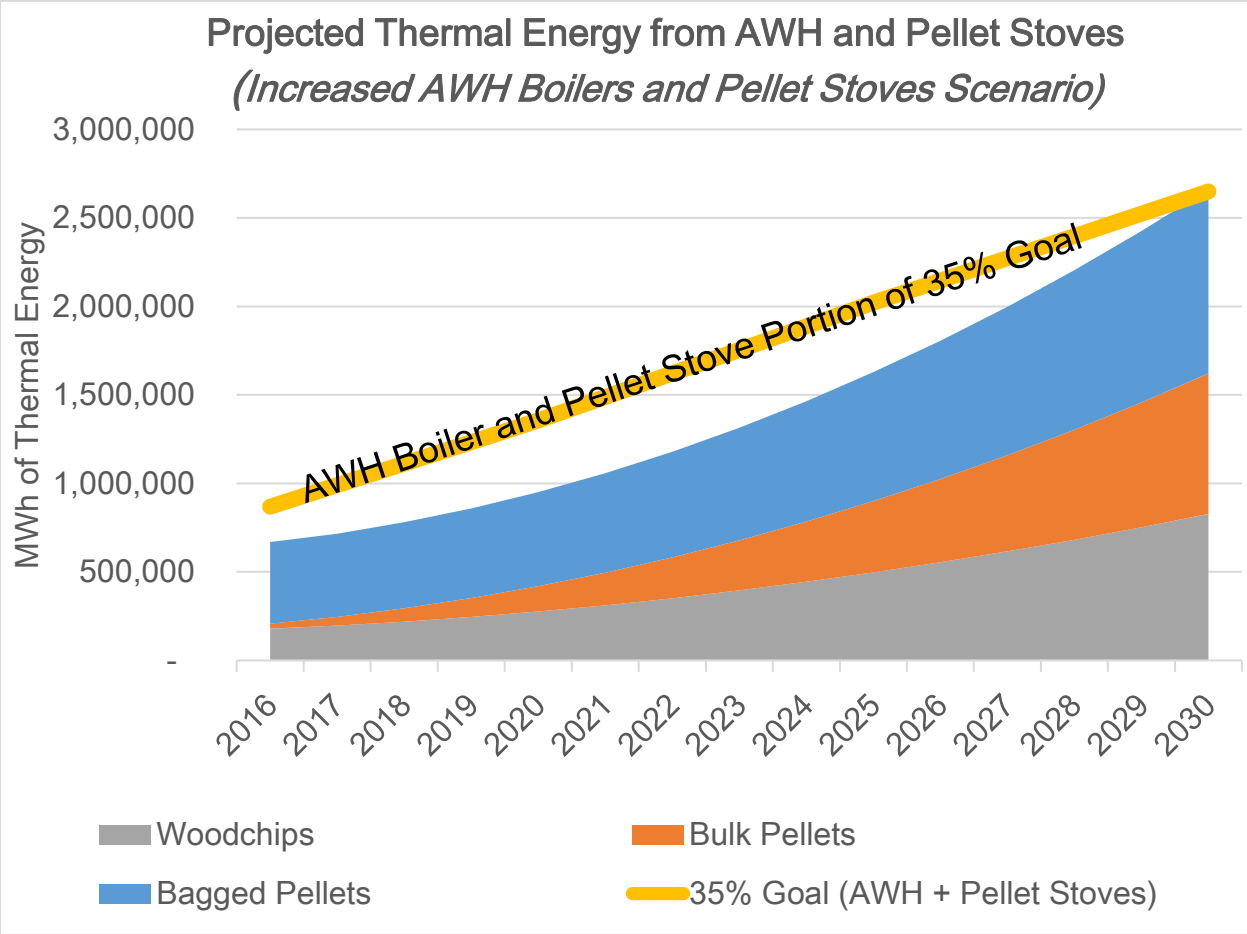
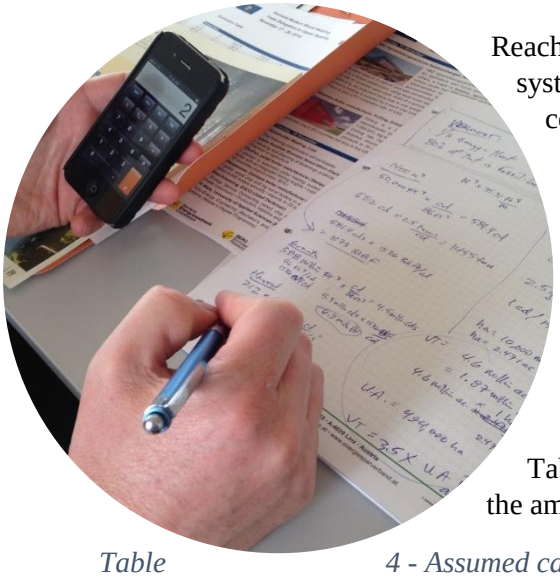


Figure 7 - Amount of thermal energy needed to meet 35% target by 2030.

It is important to reiterate that the projection of thermal energy in Figure 7 is not a forecast or prediction of what will happen in the future—it is simply a depiction of how much thermal energy would need to come from wood fuels (AWH and best-in-class pellet stoves) in order to meet the 35% target.

Section 6 - Investments and Benefits



Reaching the 35% target will require installing thousands of more heating systems fueled with wood pellets and woodchips and that will require considerable investment. So, how much investment would be needed to reach the goal and would those investments pay dividends over time? Basic financial cost-benefit analysis was performed to determine the total capital investment and to calculate the likely financial performance. In reality, the cumulative investment cost necessary to reach the 35% target would be staggered over multiple years between now and 2030, but for simplicity we assessed the costs and benefits by rolling all the equipment into a single investment made at one time.

Table 4 below provides the estimated capital investments for installing the amount of various wood fueled heating equipment.

Table 4 - Assumed capital costs used in life-cycle analysis

Wood Heating System	Assumed Average per Unit Capital Investment	Incremental Number of Units needed	Capital Investment (2018 Dollars)
Pellet stoves	$3,500	38,905	$136,167,500
Residential pellet boilers	$20,000	10,519	$210,380,000
Commercial pellet boilers	$70,000	2,574	$180,180,000
Large woodchip systems	$1,500,000	221	$331,500,000
TOTAL			**$858,227,500**

$858 million is a significant investment, but would generate a multitude of financial and environmental benefits. Average historic prices of wood fuels are less than those for heating oil and these lower fuel prices are what generate financial savings and drive a return on investment.

Life-cycle cost analysis was performed on a scenario to convert the target number of buildings over to wood heating. The combined investments (debt service, fuel, and operation and maintenance) of wood heating over a 30-year period were compared against a business as usual scenario where that target number of buildings continue to heat with fossil heating fuels. The analysis factored the cost of fossil heating fuels, the cost of wood heating fuels, and the rate of price escalation over time for both fossil and wood heating fuels.

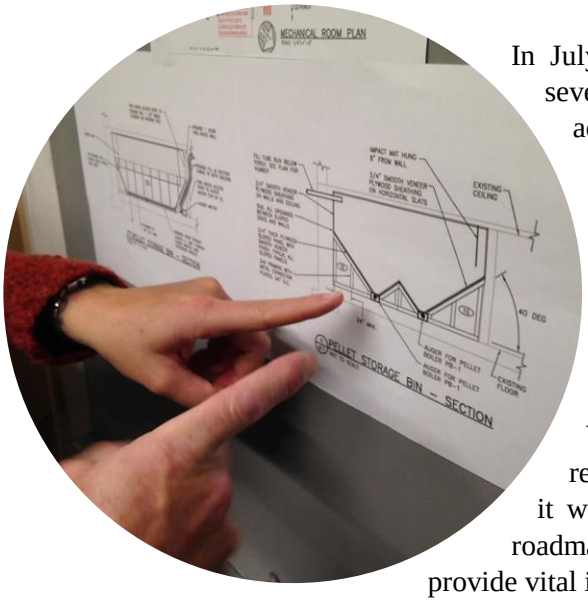
The results of the cost-benefit analysis suggest that such an investment would save Vermonters nearly $1 billion (in 2018 dollar value) over the 30-year period. This equates to approximately 5% rate of return on the investment.

Beyond the financial benefits to Vermonters and the economy, there are numerous other benefits that would be generated by expanded use of wood heat as a way to reduce fossil heating fuel use. Meeting the 35% target by 2030 would:

- Reduce Vermonter's consumption of heating oil and propane by over 60%[18]
- Replace or add another 900,000 green tons of annual local market demand for low-grade wood to help sustain Vermont's forested working landscape
- Avoid $112 million in annual energy expenditures exported from the Vermont economy[19]
- Avoid 350,000 tons of net greenhouse gas emissions annually[20]

[18]Based on displacing 56 million gallons of the 90 million gallons of heating oil used in Vermont in 2014.
[19]Based on 80% dollars spent on heating oil are exported from Vermont economy and $2.50 per gallon average price.
[20]Factoring 161 lbs/MMBtu CO_2 emissions for heating oil and 29 lbs/MMBtu net CO_2 emissions for wood fuel.

Section 7 – Strategies for Achieving the Goal



In July of 2017, Renewable Energy Vermont, in partnership with several other organizations and agencies released a 5-year industry action plan for achieving increased market adoption of advanced wood heating in Vermont.[21] The plan was endorsed by numerous other businesses and organizations and presented a list of recommended action across several categories including:

- Policy and regulation
- Outreach and marketing
- Education and training

While the 5-year action plan provides clear, actionable recommendations for making real progress toward the 35% target, it was not intended to be a comprehensive, long-term plan. This roadmap document aims to build upon the 5-year action plan and provide vital information necessary for meeting the 35% target by 2030.

A variety of barriers exist to further development of the wood heating market. Presented below is an overview of key market drivers affecting development of advanced wood heating, discussion of key barriers to further market development, and suggestions for a range of policy solutions that could address the barriers.

7.1 Barriers to Market Adoption of Wood Heat

Capital Costs

Perhaps the single largest barrier is the upfront capital cost for wood heating equipment. The purchase and installation costs for automated, self-feeding wood pellet and woodchip systems range from two to five times the cost of fossil fuel heating systems. A typical installed cost for a modern, efficient, bulk fueled residential pellet boiler is roughly $19,000 whereas a comparable oil system may cost approximately $8,500.[22] Pellet stoves provide an excellent lower cost option, but only provide partial home heating, require daily fuel loading, and typically require buying fuel in 40-pound bags.

Despite the compelling potential heating fuel savings, borrowing funds for the purchase and installation of wood heating systems can be a long and complicated process for both the residential and commercial customers.

Public Perceptions

Modern, efficient, clean burning, automatically-fed wood heating systems are not widely understood by the general public or in the heating, ventilating, and air conditioning (HVAC) industry in the US. Lasting impressions remain of older wood heating systems. Key areas where there continue to be misconceptions about the potential impacts of expanded wood heating are:

- System performance and reliability;
- Emissions;
- Forest sustainability; and

[21] http://www.revermont.org/wp-content/uploads/5-Year-Action-Plan.pdf
[22] Based on recent direct communications with numerous pellet and oil boiler vendors.

- How wood heat solutions compare against other heating options.

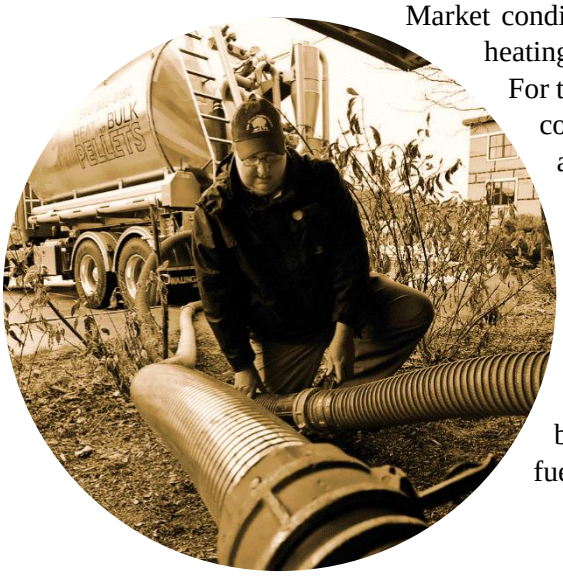
Lack of Funding to Support Incentives

The thermal energy sector operates in an open and competitive market and is not regulated in the same way as the electric and gas utility industries. As a result, the regulatory framework and mechanisms that used to implement energy efficiency and renewable energy progress, and requirements for electric and gas utilities do not typically apply to propane and heating oil suppliers. The thermal energy sector, as a result, lacks a regulatory structure and related regulatory mechanisms to incentivize thermal efficiency and renewable energy use compared to the electric sector.[23] Policies and programs designed to reduce consumption of fossil fuels through thermal efficiency measures and the use of renewable energy face the challenges of securing funding sources and political difficulties in applying charges on fuels not regulated by the state Public Utility Commission that oversees the natural gas and electric sector.

7.2 Market and Policy Drivers for Overcoming Barriers

There are different drivers that influence the extent to which the market will adopt a renewable energy technology:

- Market conditions (cost of competing equipment and fuels)
- Policy and regulatory (the various incentives available)



Market conditions have a significant impact on the rate of adoption of wood heating and these market conditions are difficult to predict and control. For this reason, this roadmap document does not predict which specific combination of actions will trigger the necessary amount of market adoption to achieve the 35% target by 2030. However, further exploration of how changes to both market conditions and energy policy can prove extremely useful in determining strategies for stimulating market adoption.

Market Drivers

Fossil heating fuel prices and volatility is one of the greatest market factors that impacts interest in wood heating. Figure 8 below, illustrates the price history and trends for fossil and wood fuels in Vermont over the past 25 years.

[23] http://www1.eere.energy.gov/wip/solutioncenter/pdfs/fundingforenergyefficiencyprogramsforunregulatedfuels.pdf

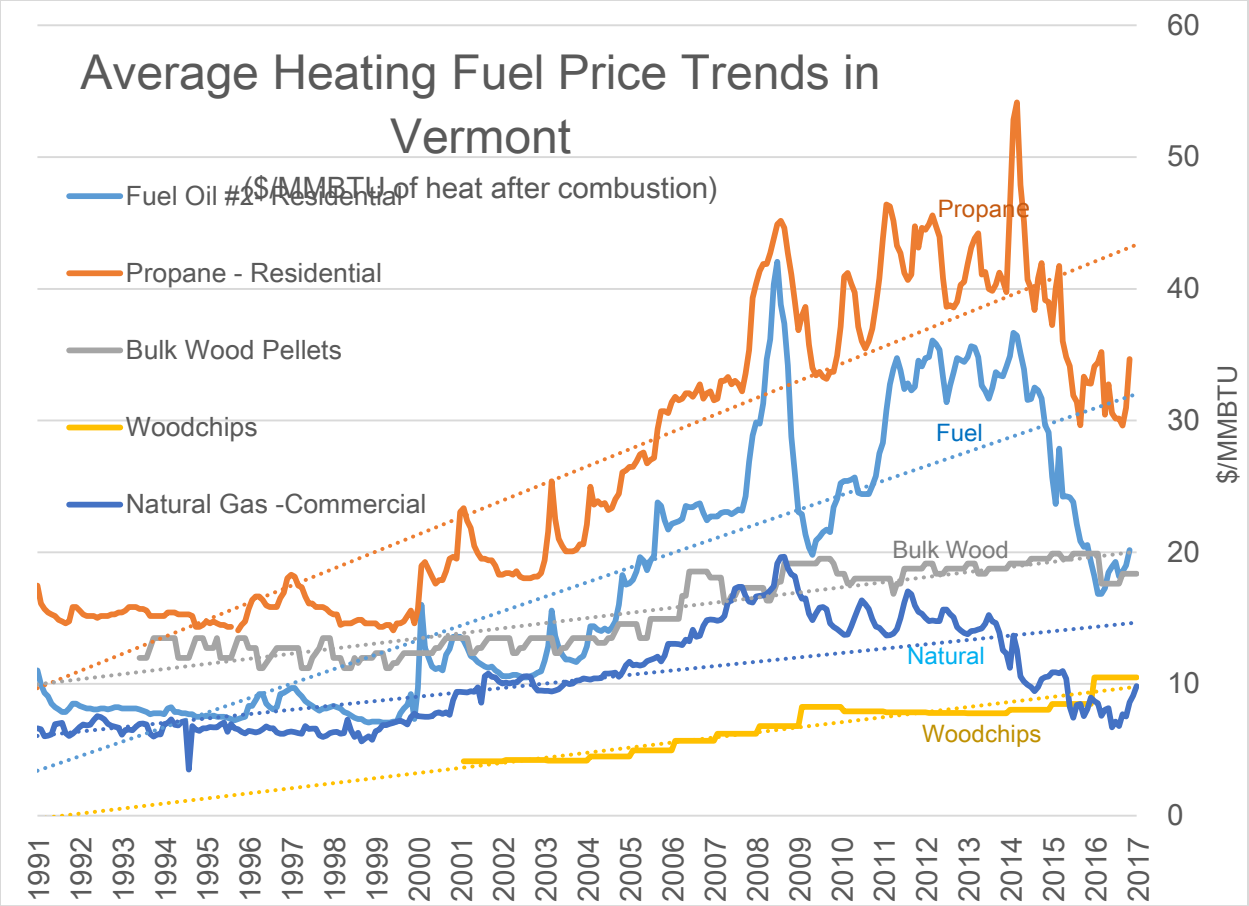


Figure 8 - Heating fuel prices in Vermont over the past 25 years

As can be seen in Figure 8, the price of oil and propane have been very volatile, while wood fuel prices have remained comparatively stable. In addition, the prices for oil and propane have increased more rapidly on average then rate of price increase for wood fuels.

Although there was a short period of time in 2015-2016 when oil prices dipped lower than pellet prices, over time it is expected that local wood fuel prices will remain lower than heating oil and propane. In general, there is a high level of market uncertainty about the short-term forecast of fossil fuel pricing, but there tends to be greater market consensus that long-term trends for fossil fuel prices will rise faster than local wood fuels.

Policy Drivers

To optimize the effectiveness of policies aimed to advance wood heat, ideally policies should be developed in a way that seeks to directly address the key barriers discussed above. Presented in Table 5 are examples of policy options (or solutions) for addressing the key barriers.

Table 5 - Policy options for overcoming barriers

Barrier	Potential Policy Solution
High capital costs of wood heating equipment	• Federal 30% tax credit proposed by BTU Act • State income tax credits • Eliminate state sales tax on wood heating equipment • State funded rebate programs
Lack of public awareness	• Support education, outreach, and training for architectural, building construction, HVAC contractors, heating fuel dealers, insurance, real estate, and engineering professions • Adopt policies such as "lead by example" programs by state and local government • Provide program support services to show case "best in class" projects using modern, efficient wood heating technologies
Lack of regulatory framework for thermal sector	• Develop comprehensive "total energy" approach including electrical, thermal, and transportation energy • Expand/revise Renewable Energy Standard Tier 3 to more directly support wood heating. Consider adopting a Thermal RPS approach used in New Hampshire.

The potential policy solutions provided in the Table 5 above are just a limited list of the possible strategies that could be used to drive expansion of the advanced wood heating market in Vermont.

There is a broader range of strategies that need to be developed and implemented in combination: legislative and regulatory approaches are essential, but need to be combined with financial as and programmatic support as part of an integrated approach.

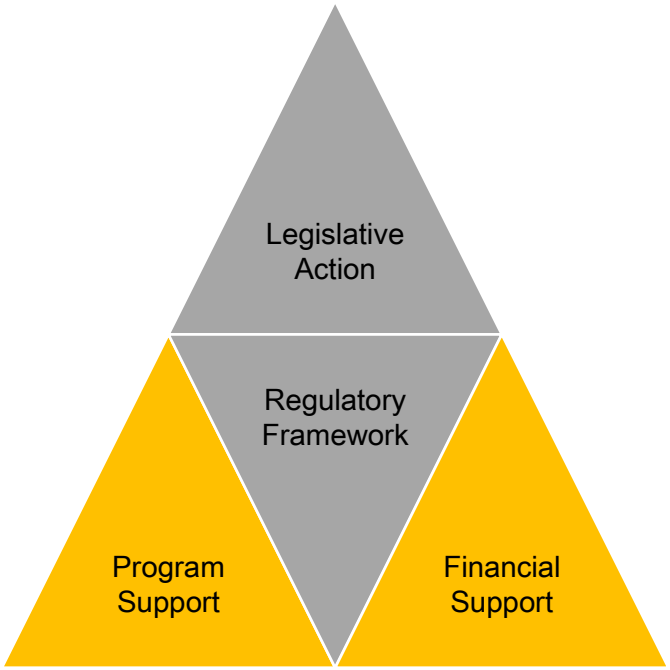


Figure 9 – An integrated policy framework for expanding advanced wood heat in Vermont

The integrated policy framework illustrated in Figure 9 consists of the following components:

- **Program Support**. Programs that provide technical support and education to the market are essential.
- **Financial Support**. Rebates and incentives on equipment. Financing programs to improve financing options (lower interest rates, longer terms, etc.)
- **Regulatory Framework**. Strong, clear, and consistent regulations can help expand market adoption and stimulate private investments in the wood heat sector. Regulations on air quality, forest management, boiler efficiency and emissions, and safety requirements can be set high and still help stimulate the market and industry in Vermont. Regulatory approaches can also be taken to set mandates for the use of renewable energy in Vermont. In essence, Vermont's Renewable Energy Standard is such a mandate on electric utilities regarding how much of their electric supply should come from renewable sources. However, there are examples in Europe where mandates are commonly integrated into building code requirements for the use of energy efficiency and renewables. Upper Austria, for example, has a requirement since 2008 that all new or renovated private buildings larger than 10,000 square feet in size must use renewable energy for space and hot water heating.[24]
- **Legislative Action**. The action needed to develop the necessary program, financial and regulatory components.

This integrated approach is similar to the approach used by the Upper Austrian energy agency (Oberösterreich Energiesparverband), an international leader in the use of advanced wood heating. The OÖESV advocates the "carrot, stick, and tambourine" approach in which the stick refers to legal approaches (fuel quality, emissions, and efficiency standards as well as building energy code mandates), the carrot refers to financial incentives (grant programs, etc.), and the tambourine symbolizes the education and outreach needed to build further market awareness as well as the programs that provide technical assistance to the market.

Besides promotion and education to increase interest in advanced wood heat, there are three primary mechanisms that can improve return on investments for advanced wood heat systems:

1. Increased market prices of fossil heating fuels;
2. Decrease prices of wood fuels; and
3. Decrease the capital costs of AWH systems.

While higher market prices for fossil heating fuels will definitely help stimulate the rate of market adoption of advanced wood heating, generally, public policy has been historically focused on either lowering the cost of wood fuels or lowering the capital costs of purchasing and installing advance wood heating systems. There have been several policies aimed at lowering the cost of wood fuel in the last two decades, however these policies are widely considered as less effective at stimulating market demand than policies that focus on lowering the capital costs. For example, several policies used to subsidize wood chip and pellet prices to consumers have resulted in only lowering the fuel costs for the existing wood fuel consumers, but did not effectively cause any more new systems to be installed. Also, wood fuels are typically already less expensive than fossil fuels – further subsidy on the fuel is less effective than policies aimed at lowering the high capital cost barrier. For this reason, lowering the capital costs is the primary focus of the discussion in the sections ahead.

There are several ways to lower capital costs that have been offered in the past:

[24] http://www.energiesparverband.at/fileadmin/redakteure/ESV/Info_und_Service/Publikationen/Biomass_heating_2010.pdf

- Grants
- Rebates
- Income tax credit
- Sales tax exemption
- Finance programs to provide lower interest rates and longer finance terms

7.3 Assessment of Policy and Market Drivers

In effort to understand how the market may respond to either changes in market conditions or changes in the public policy aimed to support the adoption of advanced wood heating, sensitivity analysis was performed on typical residential and commercial scale projects. This analysis explores the financial performance of typical projects in response to market changes of oil prices and the capital costs for the wood heating system.

Typical Residential Installation of a Wood Pellet Boiler

An analysis was performed to understand the tipping point conditions needed to accelerate market adoption rates. There are many variables that impact the overall financial performance of an investment to install a pellet boiler, but the top two are price of oil and the level of capital cost subsidy.

For a typical 3-bedroom home in Vermont consuming 800 gallons of heating oil per year, the following assumptions were made:

Table 4 – Assumptions for a typical single-family home

Parameter	Assumed value
Capital costs	$19,000
Amount financed	80%
Finance term (years)	10
Interest rate	5.00%
Pellet fuel price per delivered ton	$240

Simple payback, internal rate of return, and other financial performance indicators are useful, but the simplest indicator where a black and white threshold exists is cash flow. Does a project save the building owner money in the first year after all the costs are factored (including O&M and debt service) compared to the costs to heat with fossil fuels?

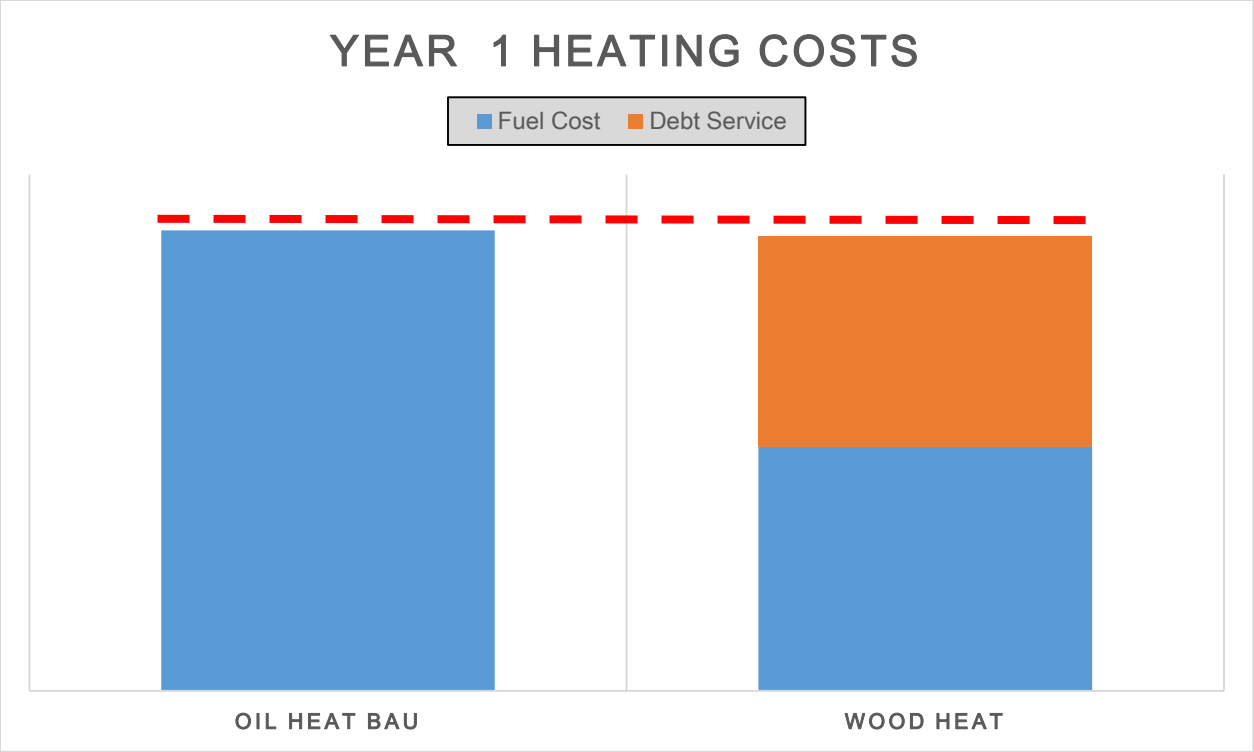


Figure 10 - Conceptual breakeven threshold when market adoption will accelerate

To get to a breakeven or better scenario, the combined annual costs of wood pellets and debt service must be below the dotted red line of the cost to heat with oil.

Figure 10 below illustrates the year one cash flow performance of installing a residential pellet boiler at different prices for heating oil assuming a flat $6,000 boiler rebate level.

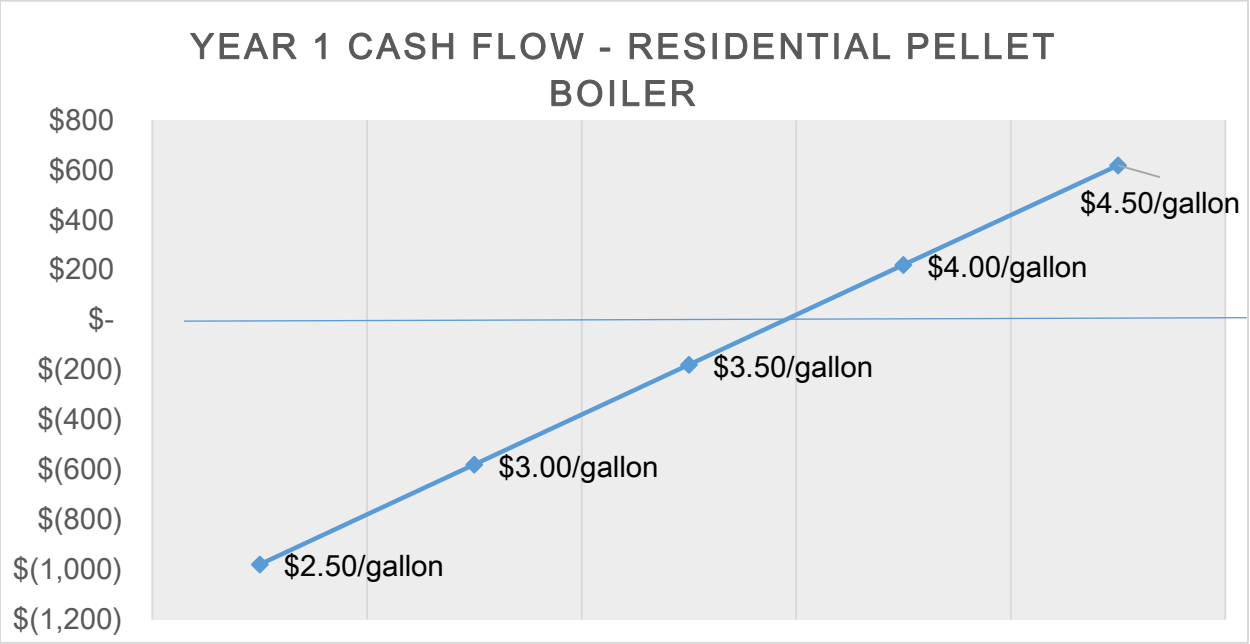


Figure 11 – Year one cash flow impact of varying heating oil prices with fixed $6,000 incentive level

Oil price has a big impact on the economic performance of the investment in a wood heat system. A small percent of the prospective market will install wood heating systems without regard to financial performance. However, to achieve mainstream market adoption rates needed to achieve 35% by 2030, oil prices will be to be above $3.75 per gallon to tips the scales.

In addition to the price of oil, the amount of capital cost subsidy also has a significant impact on the financial performance of a pellet boiler investment. In 2018, currently there is a $6,000 ($3,000 from Efficiency Vermont and another $3,000 from the State of Vermont's Clean Energy Development Fund[25]) available for residential pellet boiler rebate for installations in Vermont. Using the same assumption for a typical 3 bedroom home, consuming 800 gallons of heating oil per year, analysis was performed to determine the impact of increasing the rebate level.

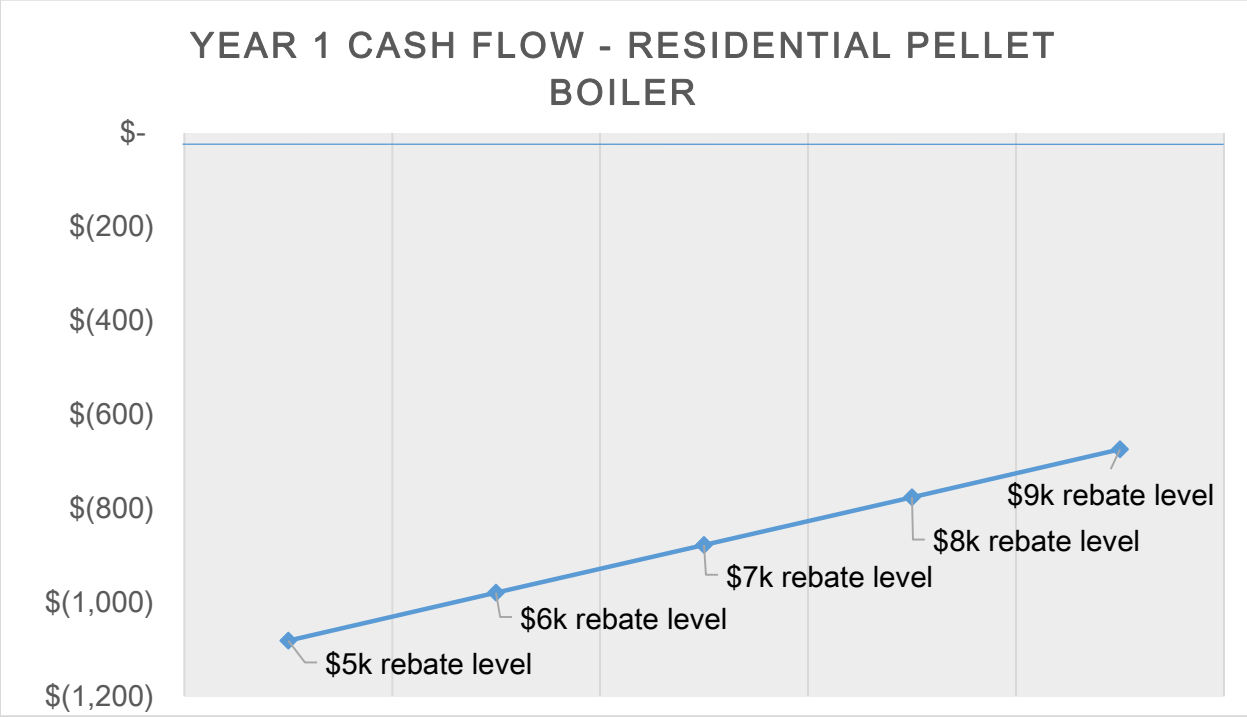


Figure 12 - Year one cash flow impact of varying incentive level with fixed $2.50 per gallon heating oil price.

Figure 11 above clearly conveys that even at the $9,000 incentive level, a typical project is cash flow negative in year one. At $2.50 per gallon for oil prices, rebate levels would need to be over $15,000 to trigger year-one savings.

Larger buildings have more demand for heating fuels and typically can save more money each year by switching to wood heating than smaller single family homes. We performed the same analysis for larger commercial sized buildings, assuming more heat demand, a large pellet boiler, and higher capital costs.

For a 15,000 square foot commercial building in Vermont consuming 5,000 gallons of heating oil per year, the following assumptions were made:

[25]Note that remaining CEDF funds are expected to be depleted in the second quarter of 2018 and it remains uncertain if future funding sources will be found to replenish the fund.

Table 5 – Assumptions for 15,000 square foot commercial building

Parameter	Assumed value
Capital costs	$54,000
Amount financed	80%
Finance term (years)	10
Interest rate	5.00%
Pellet fuel costs	$240

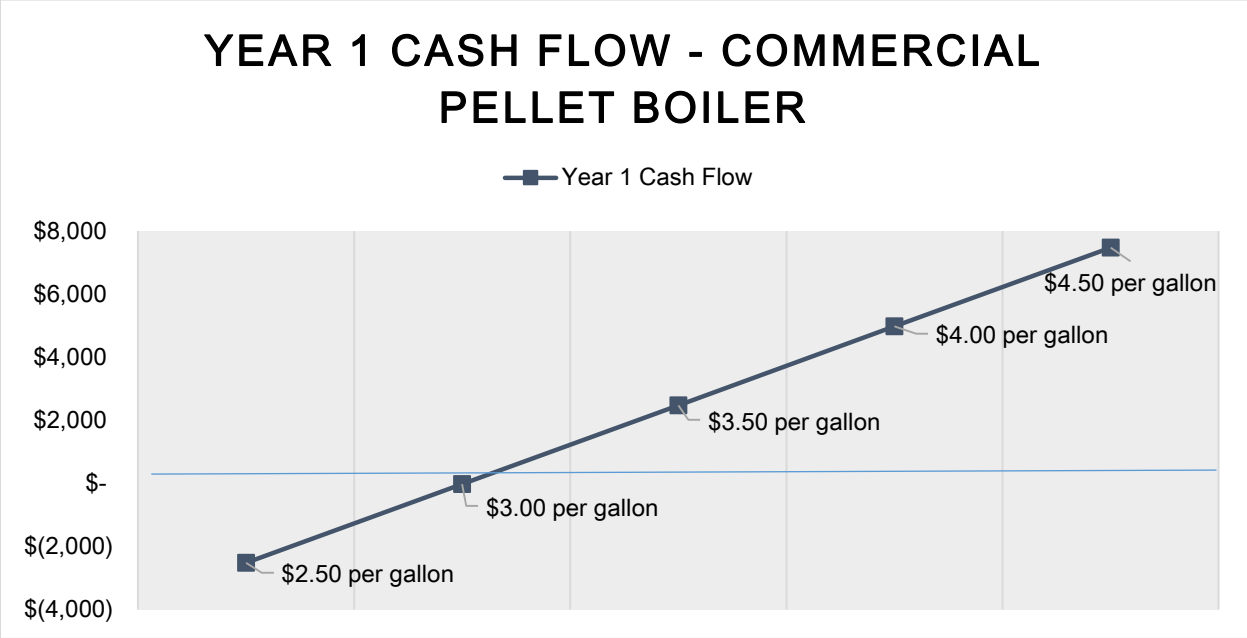


Figure 13 - Cash flow analysis measuring the impact of market prices for heating oil on the economic performance of switching to wood heating factoring 15% level of subsidy toward lowering the capital cost.

Only a very small percent of the prospective commercial market will install wood heating systems without regard to financial performance. However, to achieve mainstream market adoption rates needed to achieve 35% by 2030, oil prices will be to be above $3.00 per gallon to tips the scales for the commercial market.

Currently, the incentives for commercial wood pellet heating is unclear. For the past two years, the Clean Energy Development Fund offered commercial rebates. However, those limited funds are expected to run out in early 2018. Using the same assumption for a 15,000 square foot building consuming 5,000 gallons of heating oil per year, analysis was performed to determine the impact of increasing the rebate level.

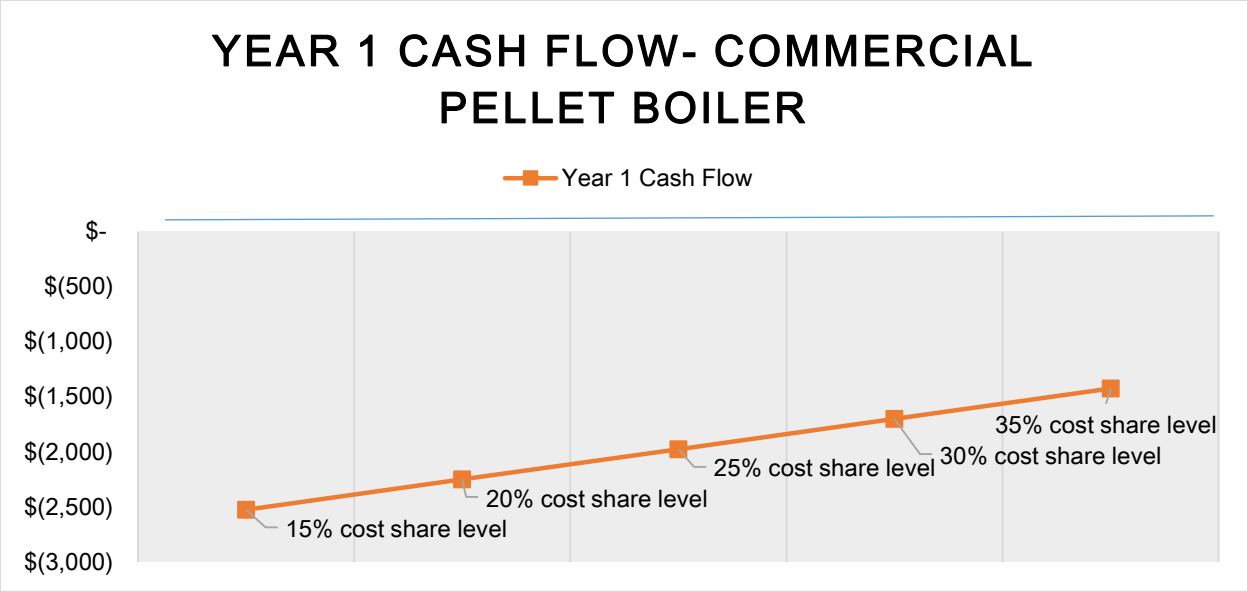
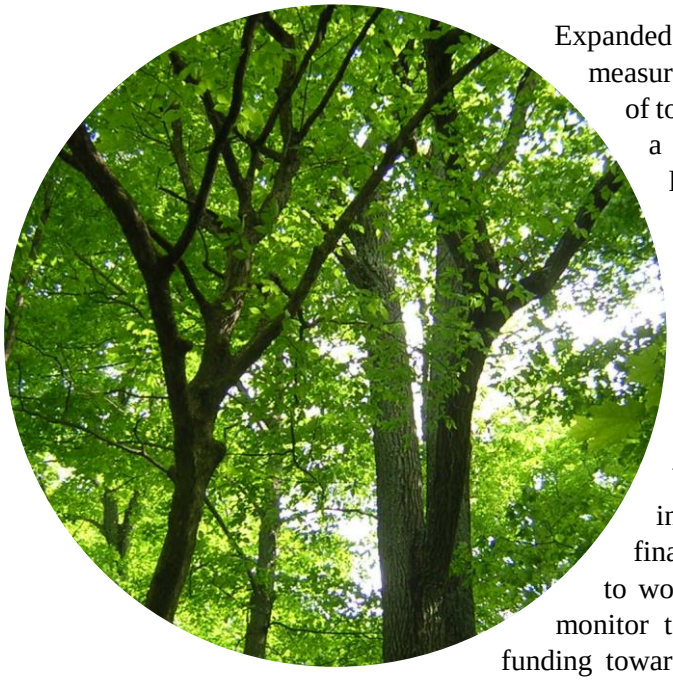


Figure 14 - Cash flow analysis measuring the impact of cost share subsidy level on the economic performance of switching to wood heating factoring $2.50 per gallon heating oil price.

Section 8 - Conclusions



Expanded use of advanced wood heat will help Vermont make measureable progress toward a number of key goals including – 90% of total energy from renewables by 2050, carbon emission targets, a stimulated economy, increased jobs, and a vibrant working landscape.

The 35% wood heat target is achievable, however it will require thousands more stoves and boilers to be installed over the next 12 years. Oil and propane prices have a major impact on the extent to which the market adopts advanced wood heating technology.

To stimulate advanced wood heating system adoption in Vermont across residential and commercial markets, an integrated approach combining legislative, regulatory, financial and programmatic approaches is needed. Policies need to work in tandem with sustainable harvesting rates and need to monitor to ensure forest health. Additionally, policies that direct funding toward program support, financial support, and regulations that aggressively push the market toward the adoption of renewable energy are essential. Financial support offerings aimed at lowering the first cost of equipment are critical, but other financial initiatives that help lower interest rates and extend finance terms are also effective. When fossil fuel prices are low, more incentives are needed. When fossil fuel prices rise, less incentive toward the capital costs will be needed. In theory, there is threshold for heating oil price when essentially no direct subsidy is needed to further stimulate market adoption. Sensitivity analysis performed suggests that if oil prices were over $5.00 per gallon for the residential market and over $4.00 per gallon for the commercial market, there would be no direct incentive needed to dramatically expand the use of wood heating.

While it is impossible to predict the right combination of policies and programs that will be necessary reach the 35% target under fluctuating market conditions, Table 6 below presents best estimates of combined market conditions and policies necessary to bend the curve toward achieving the 35% target.

Table 6- Description of milestones presented in Figure 15 and the estimated factors needed to achieve adequate market adoption rates

	Milestone Year	Cumulative Number of Systems Installed				Minimum market oil price needed	Key policy action needed
		Pellet Stoves	Residential Pellet Boilers	Small Commercial Pellet Boilers	Large Woodchip Systems		
Milestone 1	2018	32,705	1,021	252	75	$2.75	Sufficient funding to support 20% incentive level on residential pellet boilers
Milestone 2	2020	35,805	1,951	479	94	$3.25	Sufficient funding to support 35% incentive level on residential and commercial pellet boilers, woodchip systems, and pellet stoves
Milestone 3	2022	40,145	3,167	777	120	$4.00	Sufficient funding to support 35% incentive level on residential and commercial pellet boilers, woodchip systems, and pellet stoves
Milestone 4	2025	48,980	5,529	1,355	169	$4.50	Sufficient funding to support 25% incentive level on residential and commercial pellet boilers, woodchip systems, and pellet stoves
Milestone 5	2028	60,605	8,534	2,090	232	$4.75	Sufficient funding to support 20% incentive level on residential and commercial pellet boilers, woodchip systems, and pellet stoves

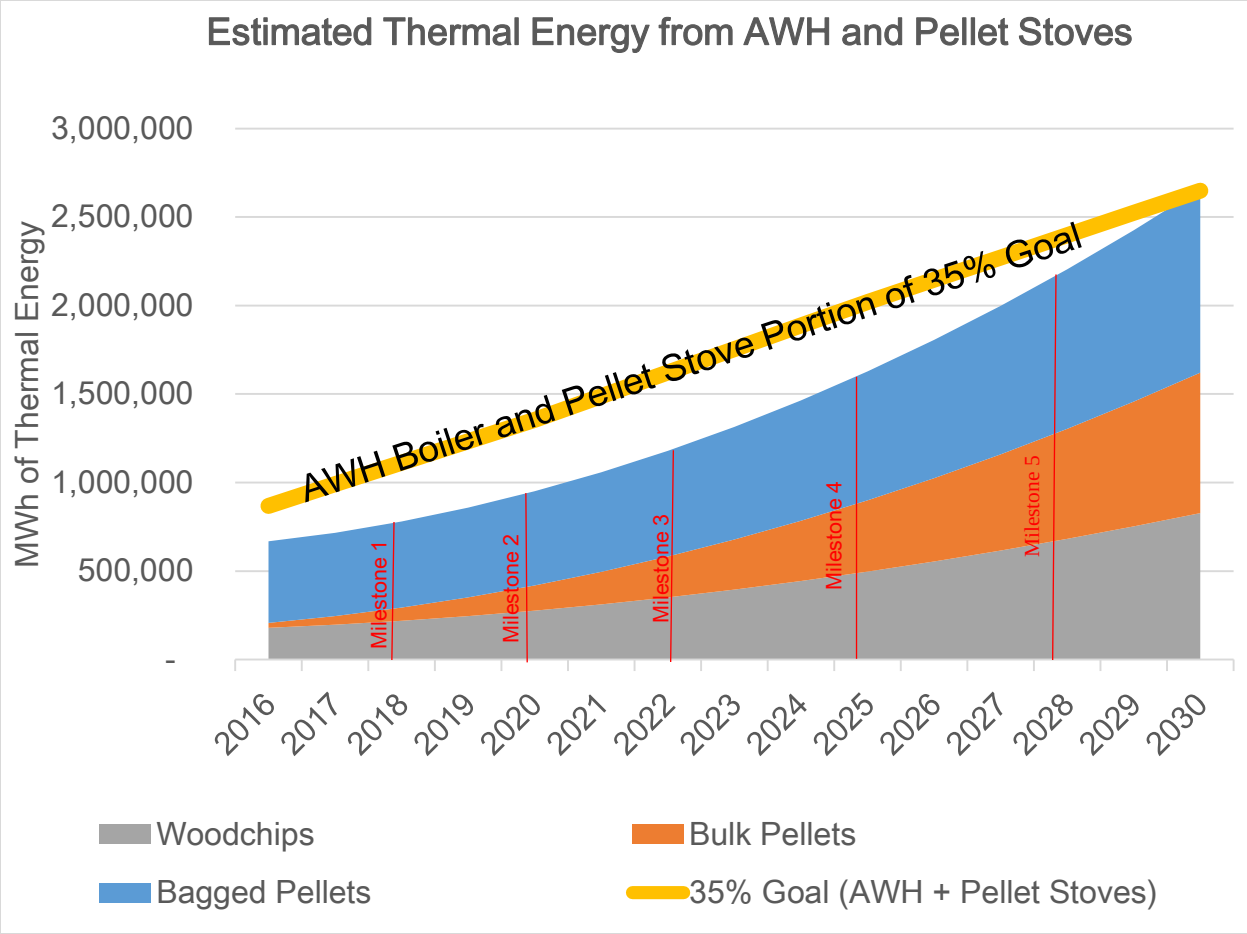


Figure 15 - Area graph depicting the amount of thermal energy from AWH and pellet stoves with key milestones included