Municipal Energy Analysis Report:
Clean Energy Site Assessment

For

Pioneer Valley Regional School District, Massachusetts

October 31, 2017

Prepared by

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Executive Summary

Together with the Pioneer Valley Regional School District (PVRSD), the towns of Bernardston, Northfield, and Warwick has engaged with the UMass Clean Energy Extension (CEE) to (1) review municipal energy information in the MassEnergyInsight (MEI) platform, (2) identify potential focus areas for reducing energy usage in PVRSD schools, and (3) support the towns as they update their Green Communities profiles to include the regional schools. The goal of this effort is to enable PVRSD and its host communities to identify energy efficiency opportunities and secure and allocate efficiency funding.

On June 12, 2017, CEE staff, faculty, and student members of the UMass Clean Energy Corps – facilitated by school and town officials –conducted "walk-throughs" to identify energy efficiency opportunities in the following schools: Warwick Elementary School (WES), Bernardston Elementary School (BES), Pioneer Valley Regional School (PVRS), and Northfield Elementary School (NES). Additionally, CEE conducted a desktop analysis of PVRSD's MEI account. This analysis included municipal building information, energy consumption metrics, weather-normalized historical heating and electrical data, and benchmarks related to building performance. Findings and recommendations resulting from these investigations are summarized below.

PVRSD MassEnergyInsight Energy Account Overview

Below are key findings from the desktop review of PVRSD's MEI account:

- **Energy Usage Across All Schools**: All four schools are heated with oil, which is the most heavily consumed fuel type within the district and heating fuels account for 71% of total energy consumption (excluding Transportation fuels). Therefore, heating fuel reduction through improvements to building thermal characteristics and heating systems should be prioritized.
- **Pioneer Valley Regional School**: PVRS has the two largest heating fuel and electric account. Any efficiency gains at PVRS will have a significant impact on the District's overall energy budget. In addition, the school uses 3% more energy per square foot than the Massachusetts average school. PVRS should be therefore be given a **high priority** for energy efficiency assessments and retrofits. PVRS and NES both represent the greatest potential for reduction to the district's energy consumption based on annual consumption and energy intensity.
- **Electrical Demand Control Opportunities**: WES and PVRS both have an electrical load factor (i.e., the percent of actual electrical consumption in relation to maximum theoretical consumption) below 35% for the majority of their electrical periods. CEE estimates that 74% of the Warwick's electric periods and 80% of Pioneer Valley Regional School would benefit from demand control or energy storage devices to reduce peak load hours and, therefore, energy expenditures.
- **Energy Use Intensity**: Energy use intensity (EUI) expresses a building's energy use as a function of its size, in terms of energy per square foot per year. It is calculated by dividing the total energy consumed by the building in one year (measured in kBtu) by the floor area of the building. Generally, a low EUI signifies good energy performance. All of the schools are within one standard deviation of the average energy consumption per square foot for all schools in Massachusetts (Benchmark 2014). However, NES has the highest EUI, 41% higher than the Massachusetts average. This suggests that PVRSD should place a **high priority** on further examining NES for inefficient heating systems, occupant behavior, and/or envelope issues.

Summary of Recommendations from Walk-Throughs

On June 12, 2017, CEE staff, and members of the UMass Clean Energy Corps conducted walk-throughs to identify energy efficiency opportunities at WES, BES, PVRS, and NES. Findings from the walk-throughs are summarized below with a detailed focus on WES and preliminary findings at the remaining schools.

Warwick Elementary

CEE identified energy conservation measures (ECMs) in relation to projected costs and potential annual savings. The Payback Period is calculated for each retrofit. Retrofits to the fire suppression system has savings based on maintenance costs from 2017 alone. The total cost for all ECMs and respective savings and estimated payback period are included the **Table 1** below.

1. Removal of glycol and heating within vestibules
2. Envelope insulation and air sealing
3. Removal of dry fire suppression system
4. Add heat pump in the cafeteria
5. Modify thermostat controls

Table 1: ECM Summary

ECM	Cost	Savings	Pay Back (Years)
Insulation and Air Sealing	$21,086.00 *Town quote: $41,000*	$1,969.27	10.7 *With Quote:20.82*
Removal of Glycol and Vestibule Heating	$1,280.00	$4,281.02	0.30
Heat Pump in Cafeteria TES Tank	$2,633.00	$312.12	8.44
Modified Thermostat Controls	$140.00	-	-
Switch to Water Fire Suppression	$9,800.00	*$12,000 (Maintenance 2017)*	0.40
Total (Not including Fire Suppression)	$23,639.00 *With Quote: $45,053*	$6,562.41	3.6 *With Quote: 6.87*
Total (Including Fire Suppression)	$33,439.00 *With Quote: $54,853*	$18,562.41	1.8 *With Quote: 2.96*

Bernardston Elementary (Preliminary)

1. Remove glycol in heating system
2. Envelope insulation and air sealing improvements

PVRSD High School (Preliminary)

1. Insulation and air sealing perimeter connection
2. Ground source heat pump installation

3. Domestic hot water tank converted to thermal energy storage
4. Low-E film on south facing windows
5. PV solar panels over parking lot

Northfield Elementary (Preliminary)

1. Replace current boiler system
2. Air sealing and increased insulation

Next Steps

This report represents a primary collaboration between CEE, PVRSD, and its host communities – and may be developed further going forward. Analysis and recommendations at WES is the initial focus of this report as this school was determined to have the greatest near-term needs and opportunities. Future CEE technical assistance may include detailed analyses at the remaining PVRSD schools, pending consultation with the PVRSD energy team and an assessment of PVRSD's capacity for implementing recommendations.

It's important to note that the CESA is an energy "walk-through" that is designed to help building managers gauge the effectiveness of previously installed measures and identify new energy conservation opportunities. As such, *the CESA is not a certified energy audit*. While the CESA may be used to inform energy investments, a more detailed analysis for any given energy measure may be advisable. For example, the prices used for installed measures are based on averages and are not a complete estimate. Instead, they are meant to provide a rough "ballpark" estimate for costs and payback periods. For actual prices for installed measures, it is advisable to get three quotes from potential installers.

1. Introduction & Project Background

UMass Clean Energy Extension (CEE) has been engaged by the state Department of Energy Resources (DOER) to support municipalities in providing technical assistance in understanding and managing their energy consumption. The Pioneer Valley Regional School District (PVRSD) recently engaged with UMass CEE to review energy opportunities at several school buildings. Resulting from this initial meeting, CEE was authorized to access to PRVSD's MassEnergyInsights (MEI) account. Utilizing the MEI Data, the Municipal Energy Assessment (MEAR) provides a solid foundation to support a systemic approach to identification and implementation of energy projects. From the walk-throughs of key buildings, in depth descriptive and calculation based analysis was completed to prioritize retrofits for further investigation by certified auditors and/or contractors.

The purposes of this report are to:

- Identify energy requirements and energy usage intensities in PVRSD buildings (**Section 2**);
- Provide detailed building analyses to support further engineering studies and/or the solicitation of contractor quotes. (**Section 3**); and
- Discuss a range of technologies and strategies to manage energy consumption, including clean heating and cooling technologies, energy efficiency best practices, and strategies to reduce vehicle fuels (**Section 4**).

Next steps will include review of this report by the PVRSD energy committee meeting, and a subsequent discussion with UMass CEE to review results and ongoing projects. Please contact CEE with any questions at 413-545-8510 or energyextension@umass.edu.

2. MEI Account Analysis

The following inventory and analysis of PVRSD buildings and energy consumption is to give context to the recommendations from the CESA. There is an order of priority based on the potential retrofits that must be assessed in relation to the building's context in the district's total energy consumption. Before analysis of each individual building it is important to understand how improvements to a singular building will affect the district's total energy consumption. The metrics below look at total energy consumption by fuel type by account and by building as well as energy use intensity. From these metrics priority buildings, can be identified as those which have the largest energy usage and the highest energy consumption per square foot.

From the analysis,

- Northfield is the second most consumptive building and has the largest EUI indicating improvement to this building should be prioritized.
- The high school has the largest singular account heating oil, the building should be investigated for retrofits that can reduce this energy consumption through efficiency or conservation measures.

2.1 Inventory

As shown in **Figure 1**, oil is the most heavily consumed fuel type within the district (69%), followed by electricity (29%), and propane (2%).

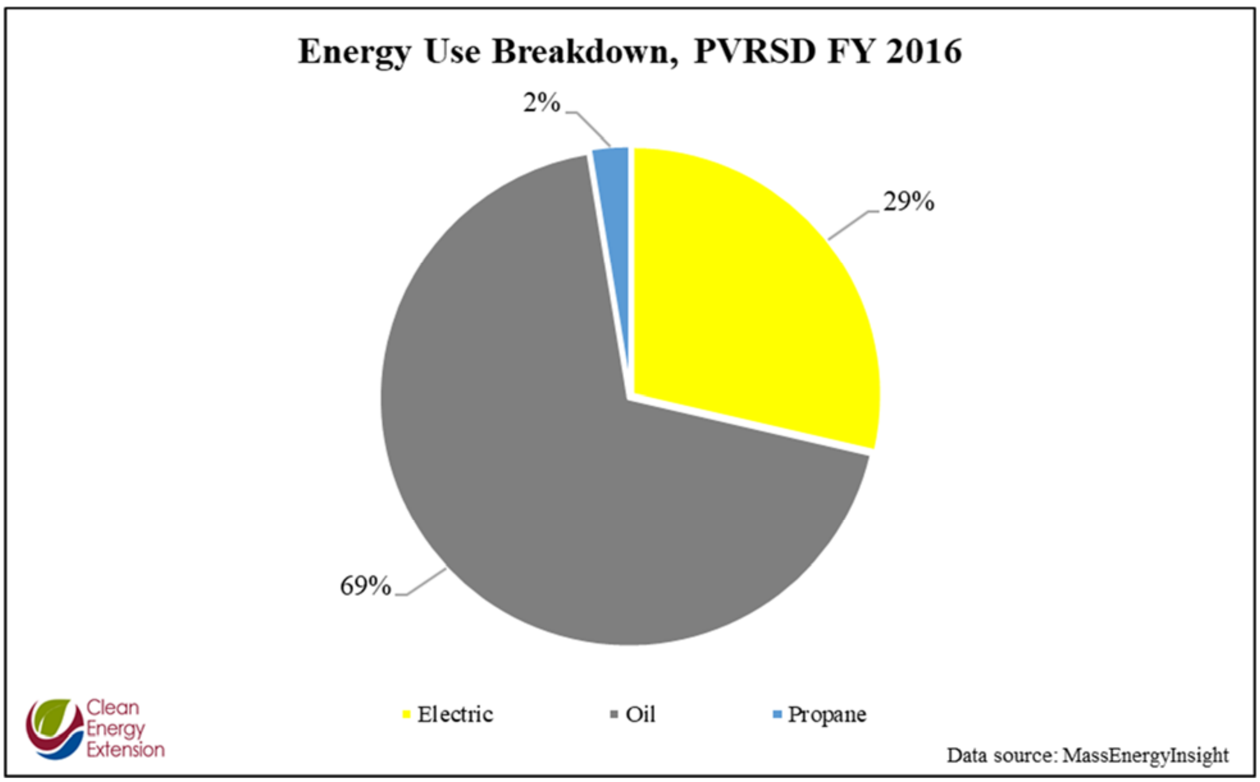


Figure 1: Total energy consumption by fuel type.

2.2 Total Energy Use by Account and Fuel Type

PVRSD's total energy consumption was analyzed on a "per account" basis. **Figure 2.2** indicates that the largest of PVRSD's accounts' (MS/HS - Oil) consumes twice as much energy than second largest account (MS/HS - Electricity). Three of the five schools are heated with Oil, while the other two use propane (**Figure 2.3**).

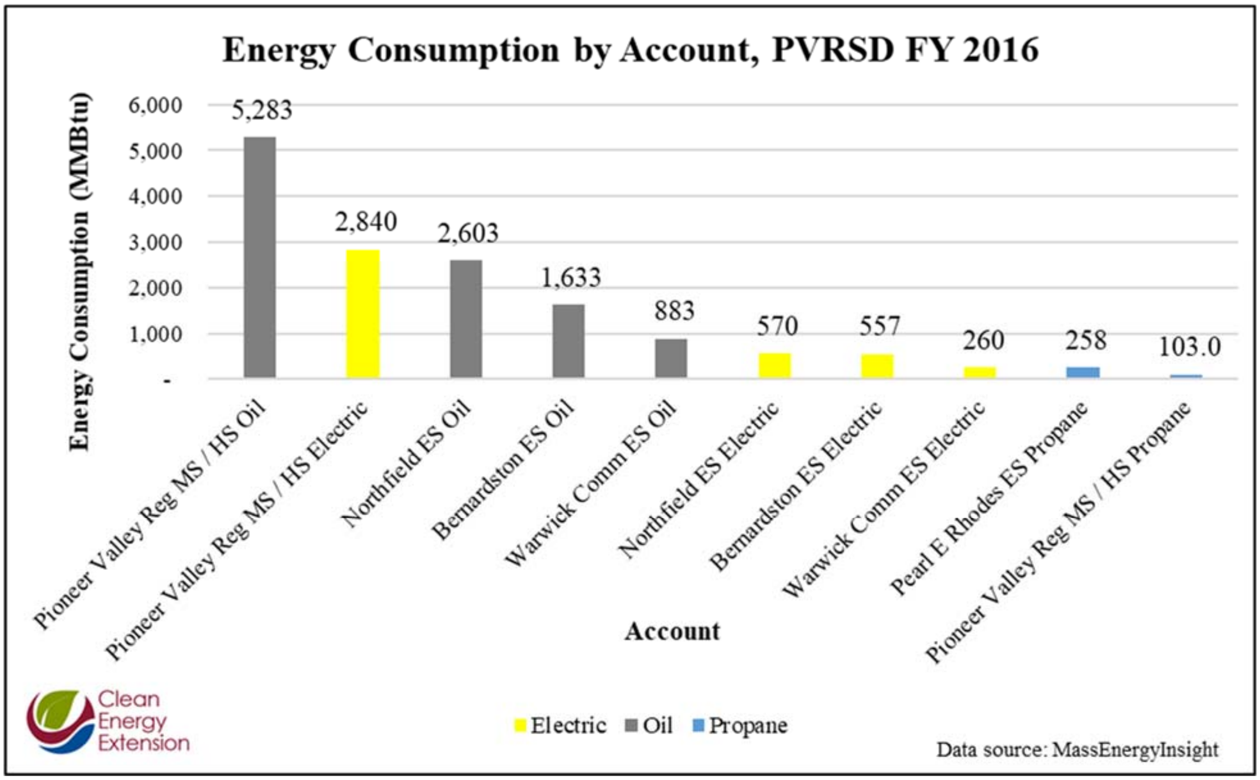


Figure 1: Top ten total energy consuming accounts - largest to smallest (by building and fuel type).

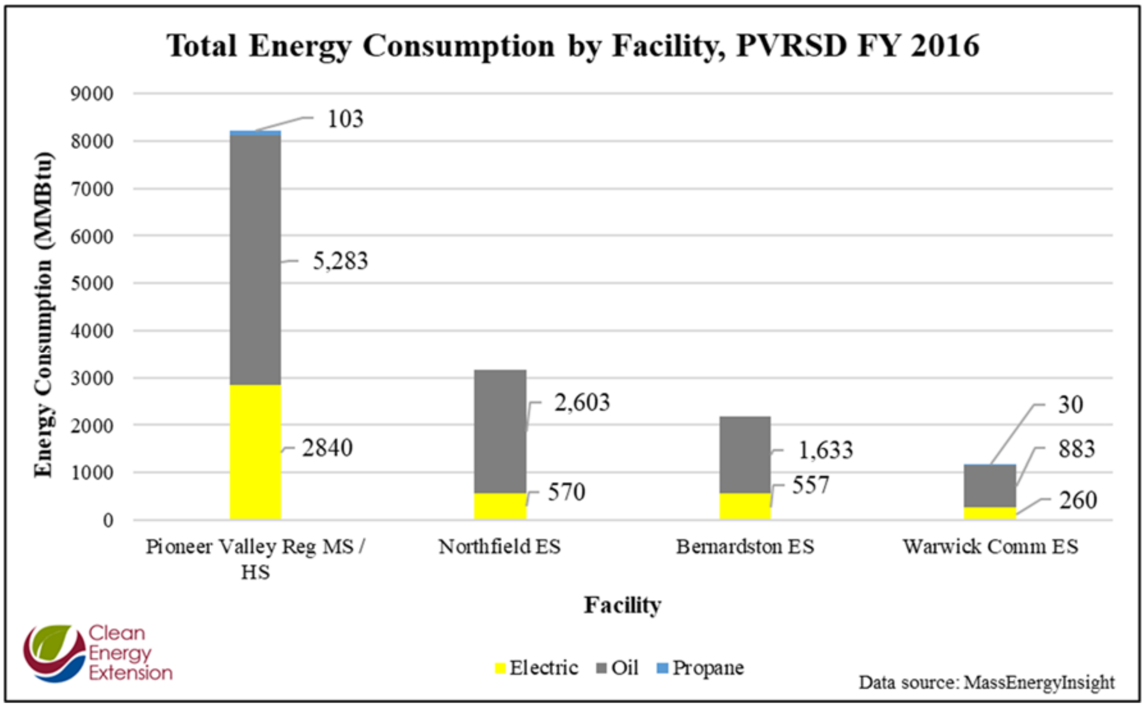


Figure 2: Total energy consumption for the four facilities that were investigated by fuel type.

2.3 Energy Usage Intensity

Energy Use Intensity (EUI) shows the energy consumption on a building area basis (typically kBtu/ft^2). By quantifying the EUI, the relative energy usage of a set of buildings can be more easily compared and ranked by energy performance, regardless of building size. EUI analysis can provide a clearer understanding of how well PVRSD's buildings are performing so potential energy efficiency studies and projects can be prioritized. **Figure 4** below shows PVRSD's municipal building energy use in Energy Usage Intensity (EUI).

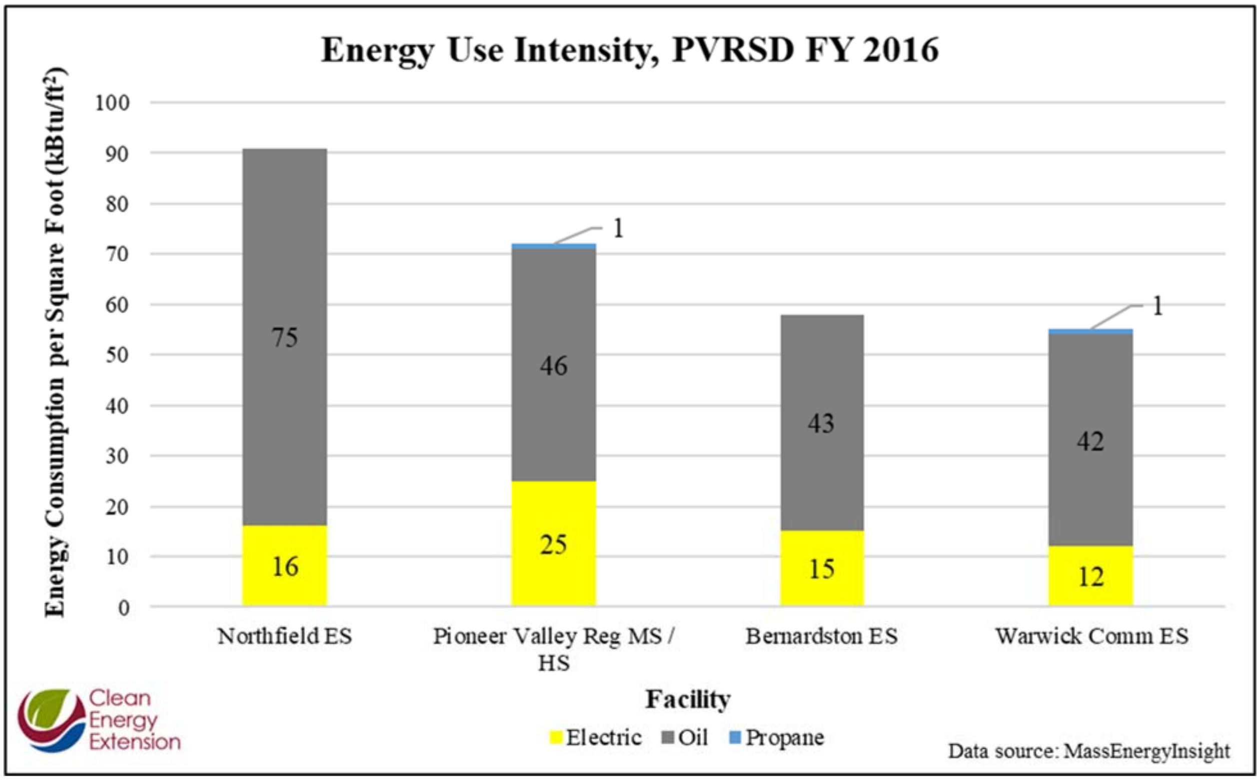


Figure 3: Energy Use Intensity for all buildings.

As represented in **Figure 4**, although the MS/HS is the largest energy consumer, it does not use the most energy per square foot. Since the buildings are all schools, the building's EUI can be objectively compared against each other. Northfield Elementary is the largest energy user per square foot and may suggest the following: inefficient systems, high energy load building, occupant habits, and/or envelope issues.

3. Clean Energy Site Assessment

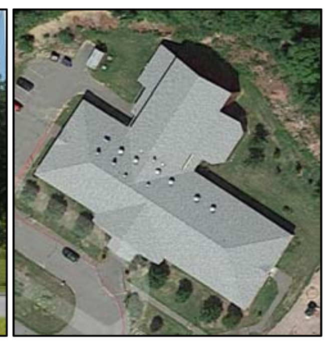
In partnership with Massachusetts Department of Energy and Resources (DOER), the Clean Energy Extension (CEE) offers Clean Energy Site Assessments (CESA) to municipalities. This service provides the district with building specific construction, infrastructure, and operation related Energy Conservation Measures (ECM) to reduce energy consumption and costs. The following information provided is an in-depth examination of buildings through the walk through which takes a systems analysis approach to building energy auditing, identifying integrated solutions to challenging problems. This helps CEE identify the most cost effective and creative solutions to save energy and improve occupant comfort. All calculations in bold are supported in the Appendices.

CEE's Thermal Performance Analysis (regression analysis of the building's heating fuel consumption and electrical consumption in relation to the weather conditions). This analysis looks to find any correlation between energy consumption and weather conditions. A high correlation can then be used to determine the balance point.

Balance point is a widely utilized indicator of gauging building heating performance, comparing fuel consumption to weather data. The balance point is the outdoor temperature at which internal systems turn on to heat the building. A building with a balance point that is higher than 60°F is a good candidate for lifestyle (e.g. keeping overhead garage doors closed) or structural changes (e.g. adding Insulation) that would decrease the building's heat loss through the envelope.

Our overall analysis (Thermal Performance Analyses) indicates that PVRSD's building stocks vary from the standard of 60°F by roughly 5°F - 7°F, indicating that they are good candidates for envelope improvement measures. Additional information on the statistical tests used to determine the balance points is in **Appendix C**.

3.1 Warwick Elementary

Overview

The Warwick Community Elementary School was originally constructed in 1999, with recent improvements to the roof and gym in the last five years since this reports creation (2017). The majority of the classrooms are located on the large rectangular corridor. The school is equipped with a small cafeteria, kitchen, and gym on the north side of the west wing. The building is also used for community programing outside of normal occupancy hours.

Despite the buildings relatively recent constriction, there have been significant maintenance issues with heating and fire suppression systems. Currently the building is heated with oil and in-duct hydronic coils that circulate and heat the air. Most of the heat supply duct-work runs horizontally (East-west) across the rectangular structure of the interior space. Much of the duct insulation has been damaged due to the frequent maintenance issues, where it gets hit when stepped over or knocked with equipment. The three ducts that supply heat to the three vestibules and to the cafeteria run outside of the envelope, requiring the system to use glycol. Teachers have voiced concerns in different parts of the building about significant temperature variation in rooms, and are found to be too cold or hot during the winter. Furthermore, there have been problems with the fire suppression system and heating system including leaking and/or broken valves. The Glycol in the system is corrosive and is a large contributor to the degradation of heating infrastructure.

Warwick Executive Summary - Key Issues and Recommendations

CEE recommends that PVRSD remove glycol from the heating system by draining the system and disconnecting heating to the vestibules and cafeteria. The cafeteria should be heated with a new mini split heat pump. The attic should have air sealing and increased insulation. The fire suppression system should be moved inside the envelope and converted to an entirely water based system. New thermostat controls should be added to classrooms which experience improper heating. The costs and savings of these recommendations are below and described in detail in **Appendix C**.

Thermal Performance Analysis

Warwick has a balance point of 64.79°F which is high for such a new building, indicating that the building's heating is highly sensitive to weather conditions and may have issues with its envelope. (**Figure R.1**, **Table R.1)**.

Demand and Load Factor Analysis

Warwick would benefit from Demand Control Measures (DCM) such as smart controls for lighting and appliances, battery storage, and lifestyle changes to reduce peak electricity consumption. CEE investigated the building's energy consumption in relation to its peak demand. The complete analysis contained in **Appendix C, Demand and Load Factor Analysis,** seeks to demonstrate if a building is using electricity in a way that will lead to high rates. CEE estimates that 74% of the building's electric periods would benefit from DCM.

Removal of Glycol and Heating within Vestibules

To ensure against the freezing of pipes in areas where the heating system (hydronic loop) leaves the building's envelope, the system is composed of a 50% glycol, 50% water mixture. Glycol has a higher viscosity, a lower heat capacity and conductivity, thus operating temperatures must be higher (heating). Pump speeds and energy requirements are higher than they would be if the hydronic fluid was only water.

Savings from glycol removal would likely amount to **$4,222.00**, the actual saving would likely be higher as maintenance costs (e.g. draining and refiling of the system) was not included in this estimate.

In order to remove the glycol, all of the heating system elements must be moved within the building envelope. Currently, four heating sections travel outside of the envelope: heating of the three vestibules and the cafeteria/kitchen. To 'remove' vestibule heating, the piping and water to air heat exchanger coils should be removed and termination plugs or crossover connections (depending on piping configuration) installed inside the thermal envelope for those sections of hydronic piping to effectively disconnect delivery of heat to the three sections. Ventilation air would still be delivered through the existing ducts. Labor estimates for this process and removal of glycol from the heating system is roughly **$1,280** with a payback period of **0.3** years. There will be additional electrical savings due to lower duct resistance where hydronic fin coils were removed and some heating oil savings from the removal of the vestibules and cafeteria from the main heating system. For simplicity, these credits are not accounted for in the above conservative payback calculation.

Envelope Insulation and Air Sealing

There is inadequate cellulose insulation on the attic floor, mechanical corridor walls and ceiling, as well as inconsistent insulation on ductwork in the attic. Within the mechanical corridor, the access hatches on the top and bottom are missing insulation and weather-stripping gaskets. There are also a significant number of holes and gaps that lead to movement of air in and out of the building (increased heat loss and energy consumption). The building's high balance point in conjunction with observations from the site visit point to a poor envelope that is causing heating systems to turn on at moderate temperatures.

Air sealing should be done under the insulation and at the wall to ceiling connection joints. At least 2" of foam board should be placed on the exterior of the mechanical access corridor particularly where the ceiling joists meet the attic. This can serve as insulation as well as an air barrier connecting down to the sheetrock provided it is properly sealed with foam or air sealing tapes. The dropped soffits and duct chases on exterior walls also need to be sealed. For the duct chases, dense packing with cellulose will probably be the easiest and least intrusive way to accomplish alignment of the insulation and air barrier layers.

The infiltration that occurs due to improper air sealing contributes to wind washing of the insulation and reduction of R-Value by roughly 20%. The school could save an estimated **$1,237.59** annually by minimizing the impacts of wind washing and bolstering the insulation(R-50). Improved air sealing would likely result in an annual savings of **$731.68**, through decreased energy consumption. Combined with wind wash reduction, the school district could expect to see an annual savings of roughly **$1,969.27**. The work noted above would cost roughly **$21,086,** with a payback period of about ten years (**10.7)**.

All ductwork, whether inside or outside of the attics envelope should be sealed with mastic, and re-insulated with much higher R-value insulation. This increased insulation would lead to a reduction of annual heat loss, and could easily be incorporated with the previously mentioned insulation and air sealing work.

We strongly recommend against investing in added insulation or air sealing measures if the "dry" fire suppression system remains in place. Inevitable corrosion in such a system will cause water damage to occur in the attic at some point. This will require ceiling drywall repairs and the removal of insulation. To protect the investment in attic envelope measures, the fire suppression system must be brought inside the thermal envelope and converted to a wet system

Removal of Dry Fire Suppression System

The building's fire suppression system is composed of two parts: dry and wet (water based). This allows for the system to exit the envelope, in the attic, and enter the classrooms without freezing during the winter. However, the dry fire suppression system has caused significant leaks in the north-west section of the building. In 2017 alone, the cost to remove and replace broken piping for the system was reportedly about **$12,000**. This type of maintenance negatively impacts attic insulation and ductwork.

If the school district moves forwards with moving the heating system within the envelope, so too should the fire suppression system, thereby minimizing maintenance and dual-system issues. The estimated cost of this system is **$4,800** for labor, $200 per hour for three full working days, and **$5,000** for materials. The total estimated cost is **$9,800**.

Add Heat pump in the Cafeteria

The cafeteria is another area where the heating system travels outside of the envelope. Again, to remove glycol from the system, the heating system must be disconnected from all sections that are outside the envelope. Once disconnected, an air source heat pump should be installed to more efficiently supply heating for this section of the building. The current heating of the cafeteria costs approximately **$972.12** annually. The initial cost of the heat pump would be roughly**$2,333** and **$300** for labor (prices may vary). The total cost would be **$2,633** and the annual savings would be **$312.12** for a Payback period of **8.44** years.

Modified Thermostat Controls

In some classrooms, students and teachers experience inconsistent heating and air flow that impacts class time and occupant comfort. It is suggested that a non-electric thermostatic valve is used in Ms. Hansens's room and potentially others. The use of these thermostats positioned in the correct locations (on an interior wall away for the hallway door and the heating supply) with a damper in the duct work allows the system to adjust constantly to provide consistent temperature and avoids uncomfortable air flows. This type of zonal control would cost approximately $140 for each room. Energy savings are likely to be small, but comfort control, which can strongly affect teaching and learning, would be greatly enhanced.

Calculations and supporting documentation for the above recommendations can be found in the **Appendix**.

3.2 Bernardston


Overview

The Bernardston Elementary School (BES) as shown above, is 38,360 square feet. BES has two levels with classrooms located in an L shape with the gym attached to the northeast wing on the upper level. The cafeteria and the kitchen are located in the lower section along with the mechanical room on the north end.

Two boilers supply hot water for domestic uses and for heating. The building is heated with hydronic hot water coils inside radiators and fan coil units. The heating system employs a water glycol mix as the pipes travel inside and outside of the envelope. There is an updated control panel, and two new variable frequency drives.

Based on inspection of the attic, there are several separated sections with varying levels of envelope quality. There is a large section that has inadequate insulation and lacks an air barrier. Many of the ducts and pipes are uninsulated leading to increased heat loss. To resolve issues identified by CEE in the building site visit and walk through, the following recommendations have been identified.

Executive Summary of Key Issues and Recommendations

Thermal Performance Analysis

Bernardston Elementary School has a low correlation between weather and heating fuel consumption. This could be a result of incorrect or skewed data, or points towards a heating system that does not respond correctly to weather conditions (**Appendix C Figure R.2**).

Demand and Load Factor Analysis

Bernardston does not receive peak demand values for their electricity consumption and as such, the load factor analysis could not be completed.

Remove Glycol in Heating System

Glycol should be removed from the heating system as it has higher viscosity, a lower heat capacity and conductivity, as well as needing higher pump speeds leading to decreased efficiency and higher operating costs. Glycol and its disadvantages are described in more depth in **Section 4.1** and **Appendix C.**

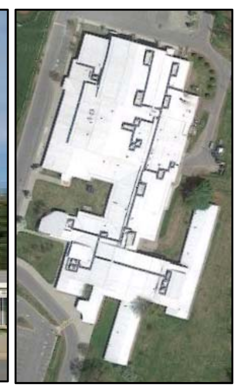
Note: To replace glycol with water, any area that pipes travel through must be well insulated to prevent freezing. And once glycol is replaced, water should be softened to prevent hard water mineral buildup.

Envelope Insulation and Air Sealing Improvements

Drastic improvements should be made to the envelope of the school. There are significant issues that must be addresses to reduce the building's heating fuel consumption. Some sections are missing air barriers or have inadequate insulation and blatant holes in the envelope. Foam boards with air barriers should be used to seal air gaps and additional insulation should be applied.

Supporting documentation can be found in **Appendix C**.

3.3 PVRSD High School



Overview

The Pioneer Valley Regional School is the largest building within the district and consumes the most energy **Figure 3.3.** However, the MS/HS uses this energy more efficiently than the Northfield Elementary which has the largest EUI **Figure 3.4**. The Regional School houses the middle and high school in the one-story building utilizing a hydronic heating system powered by two oil boilers. A third boiler is used exclusively to heat hot water for shower and sink use. There are new boiler controls for the primary heating boiler, and the secondary boiler is only used during the coldest days. The pumps which supply hot water to the building and oil to the boilers only run at one speed. The school gets its water supply from a well, this affords many opportunities for creative heating solutions. The domestic hot water boiler may be oversized for the amount of water used since students don't often shower at school. There may be an opportunity to replace this with a heat pump hot water heater. Furthermore, there are gaps in the air barrier between the walls and roof connection. Given the building's construction date, the roof insulation is about R-20 (current code requires R-50). The freezer may have a leak in the refrigeration, and should be further investigated.

Executive Summary of Key Issues and Recommendations

Thermal Performance Analysis

The Regional School has limited fuel consumption data but it is highly correlated to the weather conditions with a balance point of 68°F, indicative of issues with heat loss or system operation (**Figure R.3 Table R.2**). The school also has electrical consumption that is correlated to weather conditions **(Figure R.4 Table R.3).** It is recommended that PVRSD request an electrical and lighting energy audit through Eversource to reduces its electrical load and determine what systems are reacting to weather conditions.

Demand and Load Factor Analysis

This facility would have limited benefit from Demand Control Measures (DCM) such as smart controls for lighting and appliances, battery storage, and lifestyle changes to reduce peak electricity consumption. CEE has conducted an investigation of the buildings energy consumption for each data period in relation to its peak demand (**Appendix C),** and Load Factor Analysis. This analysis can indicate if a building is using electricity in a way that will increase rates. Currently, 80% of the building's electric periods would have limitedly benefit from DCM and 16% would have good potential. There is also a correlation between the peak electricity and weather conditions indicating that some of the building's electric systems are causing higher peaks when the temperature get colder.

Insulation and Air Sealing Perimeter Connection

The connection between the roof and the wall of the building along the perimeter has air gaps and requires improved insulation. A significant amount of heat loss occurs from this air flow and conduction. CEE recommends that two-part foam insulation be applied along the entire perimeter of exterior wall above the drop ceiling where the walls meet the roof, including encapsulating the steel beams, which conduct heat through the wall.

Ground Source Heat Pump Option Exploration

As the building has a well for domestic water, a ground source (water source) heat pump system might be able to use the existing well for an open loop ground water heat exchanger for heating and hot water. This sort of heat pump can have coefficient of performance (COP) between 3 and 5 (300% to 500% efficient) and uses electricity to move heat from the ground water to the building. It can also be used for cooling. Normally such a system is very expensive due to the need to drill many bore holes, but with an existing well, and a reinjection well, the installation cost is significantly lower. This system could replace roughly 90% of the fuel oil use with high-efficiency heat pumps that run on electricity. By reducing dependence on fuel oil and shifting to efficient use of electricity, the school district can increase its use of renewable energy.

Domestic hot water tank converted to thermal energy storage

The domestic hot Water tanks appear to be oversized, based on current demands. One or both of these tanks could be converted to Thermal Energy Storage for the proposed heat pump and/or boilers. This would reduce short cycling of the heating system and allow for scheduled heating of the tanks based on electricity demand charges and weather conditions for highest operational efficiency.

Low E Film on low performing Windows

For some larger windows, low-e film has already been installed on the outer panes to reduce unwanted solar gain. For some east and west facing windows low-e film for this purpose may help reduce unwanted solar gain and reduce cooling costs and classroom discomfort. For the majority of the windows, the low-performing (relatively high U-factor) double pane windows can be improved to perform with an apparent U-factor similar to 3-pane windows using an interior low-e film. Because radiant heat loss is a large portion of window heat loss, these films can be effective in many situations. However, because they work by actually reducing the surface temperature of the interior window pane, taller windows can cause occupant discomfort due to induced downdrafts near the windows. An evaluation using window configuration details should be done to determine in each case if low-e interior films are appropriate.

Solar Panel over Parking Lot

The parking lot is an ideal location for a possible solar canopy installation. The system could be set up as a parking lot cover array that would provide shade and electricity for the school. Not only could this significantly reduce electricity consumption, but could also serve as a focal point for the district's commitment to sustainability. The school also would benefit from this installation as it would help reduce its peak energy consumption, saving on electricity pricing rates. This is described in detail below and in **Appendix C,** Demand and load Factor analysis.

Supporting documentation can be found in **Appendix C**.

3.4 Northfield Elementary

Overview

Northfield Elementary school is comprised of three connected buildings of different periods, from 1910 to the 1980s. The two boilers in the oldest section serve the entire school. Oil boilers are old and require lots of maintenance. Northfield ES is the second largest energy user within the school district and has the largest EUI of all the buildings. An air compressor runs the pneumatic zone valves; the building's electricity consumptions is correlated to the weather conditions, increasing consumption as the temperature gets colder. This could be explained by the pneumatic value control. In the classrooms teachers, have identified heat distribution issues. The building's windows are quite old and leaky; the lighting and heating of the building would be greatly improved with the replacement of these windows. Certain historic preservation regulations could dictate how these alterations could occur.

Each section (3) has its own attic all of which, have air sealing issues along the perimeter at the connection between the wall and the attic. There must be improvements to the air sealing and additional insulation should be added. The primary issues for this building are the age and state of the heating boiler as well as the insulation and air sealing.

Executive Summary of Key Issues and Recommendations

Thermal Performance Analysis

Northfield Elementary does not have enough heating fuel data to accurately review its consumption. Based on the available data the correlation is low between energy consumption and weather conditions, **Figure R.5.**

However, the building electrical consumption is positively correlated with weather conditions. This correlation is likely due to heating system controls or pumps which turn on as weather conditions become colder.

Demand and Load Factor Analysis

This facility would have limitedly benefit from Demand Control Measures (DCM) such as smart controls for lighting and appliances, battery storage, and lifestyle changes to reduce peak electricity consumption. CEE has conducted an investigation of the buildings energy consumption for each data period in relation to its peak demand (see **Appendix C, Demand and Load Factor Analysis**). This analysis can indicate if a building is using electricity in a way that will lead to high rates. 52% of the building's electric periods would positively benefit from DCM and 48% would limitedly benefit.

Replace Current boiler system

The existing boilers should be replaced. A potential replacement option would be to introduce a pellet boiler system. There could be room within the building for the pellet hopper once the boilers were removed. Alternatively, based on the historic nature of the building, the hopper could be situated behind the building to reduce visibility along Main Street. Another option is to purchase all new oil boilers. However, installation of a pellet boiler is arguably a more sustainable fuel source, and would serve as another focal point for the school district.

Air Sealing and Increased Insulation

The separate sections of the building's attics would all benefit from increased insulation and air sealing. The air handler located in the attic of the newest building should be insulated and enclosed inside of the envelope. To prevent additional heat loss, the closet access to the attic in the resource room should be insulated.

Supporting documentation can be found in the **Appendix.**

4. Introduction to Clean Energy Technologies and Best Practices

Understanding baseline energy conditions, as analyzed and discussed earlier in this report, provides a strong foundation to develop and implement energy infrastructure improvements. The information presented in this section covers clean heating technologies, energy efficiency best practices, and strategies to reduce vehicle fuel usage. This information is provided solely to familiarize PVRSD with potential options, which will be discussed in more detail with CEE when this report is reviewed with PVRSD.

4.1 Clean Heating and Cooling Technologies

As a means to substantially reduce or eliminate the use of traditional fossil fuels, the heating and cooling of municipal buildings can be provided by or supplemented with established renewable thermal technologies such as air-source or ground-source heat pumps, solar thermal heating, and modern wood heating. The Massachusetts Clean Energy Center's (MassCEC) Clean Heating and Cooling programs offer rebates to support the installation of renewable heating, hot water, and cooling technologies at facilities across the Commonwealth. These technologies are generally more cost-effective to operate than traditional fossil-fuel systems and can reduce greenhouse gas emissions, all while maintaining a high level of comfort, automatic operations, and reliability. MassCEC has announced a $30 million commitment to these technologies through 2020. More information on the programs, technologies, and participating vendors can be found on the Massachusetts Clean Energy Center (MassCEC) website (http://www.masscec.com/government-non-profit/clean-heating-and-cooling), as well as in **Appendix A** of this report.

In addition to MassCEC, the state Department of Energy Resources is finalizing its Alternative Portfolio Standard regulation that will provide important incentive for the operation of clean heating technologies; and grants received by Green Communities may be applied to clean heating applications upon review with DOER.

Additionally, municipal buildings are often clustered together, which can provide the opportunity for district heating where one heating system can be used to heat multiple buildings. Where this is possible, this may reduce the capital and operational costs for new clean heating systems.

4.2 Energy Efficiency Best Practices

Energy efficiency can help lower energy bills, reduce emissions of greenhouse gas and other air pollutants, and increase energy security. These opportunities may include equipment upgrades and envelope improvements, as well behavioral changes, maintenance practices, and the use of automated controls. The capital required for these improvements can range from no-cost behavioral strategies to major investment retrofits, such as distribution or central heating system upgrades. Additional information on best practices is provided in **Appendix B** of this report.

4.3 Reducing Vehicle Fuel Usage

For some Massachusetts communities, vehicle fuel often accounts for as much as a quarter of total municipal energy consumption, and is often overlooked during efficiency assessments. While replacement of the most inefficient vehicles will provide substantial savings, these are several other ways to reduce fuel use:

- Right-size vehicles for their tasks
- Optimize vehicle routes
- Regularly check and maintain air pressure in tires

- Educate employees on vehicle idling protocol
- Evaluate hybrid or electric vehicles for major energy consuming vehicles such as high-mileage passenger cars and heavy duty municipal or DPW vehicles
- Consider fuel efficiency in all new vehicle purchases, including those that are exempt from Green Communities criterion 4 requirements

5. Next Steps

CEE is grateful to energy committee and town officials throughout PVRSD for their assistance in developing this Municipal Energy Assessment Report. It's important to note that *the CESA is not an energy audit and should not be used as a basis for energy investments*. Instead, the CESA is an energy "walk-through" that is designed to help building managers gauge the effectiveness of previously installed measures and identify new energy conservation opportunities. The findings and recommendations below are meant to assist the towns in identifying focus areas that should be examined in future detailed energy audits conducted by licensed auditors. Combined with existing town interests and efforts, the availability of potential municipal clean energy funding sources, and support from CEE and other agencies, PVRSD is well positioned to pursue clean energy opportunities across its municipal facilities.

As a follow-up to this report, CEE would be pleased to participate in a review meeting will PVRSD's energy committees and district officials.

Please contact CEE (413-545-8510, energyextension@umass.edu) with any questions.

Appendix A – Clean Heating Technologies Summary

In addition to traditional fossil fuels, the heating and cooling of PVRSD's municipal buildings can be fully supplied or supplemented with established renewable thermal technologies such as air-source or ground-source heat pumps, solar thermal, and modern wood heating. The following technology descriptions can be found on the Massachusetts Clean Energy Center (MassCEC) website, though is provided here for convenience. Additional information related to these, and other, clean energy technologies can be found at www.masscec.com.

Air-Source Heat Pumps

Air-source heat pumps (ASHPs) can provide cost-effective and energy-efficient heating and cooling for your building's space. While traditional systems burn fuel to create heat, a heat pump instead works by moving heat into or out of a space. Though they require electricity to operate, efficient ASHPs use 40-70 percent less electricity than traditional electric-resistance heating. Rebates of up to $210,000 are available.

Key Points

- Easy to install in existing buildings and compatible with any type of existing heating system
- Often installed to supplement existing heating systems
- Provide both heating and cooling in a single, efficient unit without the need to install ductwork
- Lowest up-front cost of any clean heating and cooling technology, and can be more cost effective to operate than traditional oil, propane, or electric heat

Modern Wood Heating

Modern wood heating systems use wood chips or wood pellets to produce heat, much in the same way traditional boilers or furnaces use oil, propane, or natural gas. Biomass heating systems can often integrate into existing heating systems, and can fulfill all of a building's heating and hot water needs. Systems are typically fully-automated, and require limited maintenance. Wood chip and pellet delivery is available in most parts of the Commonwealth. Rebates of up to $250,000 are available for commercial-scale systems and $27,000 for small-scale systems.

Key Points

- Typically installed in buildings with baseboard hot water heating, but furnace options are also available for buildings with forced air heating
- Can be more cost-effective than heating with traditional oil, propane, or electric heat

Ground-Source Heat Pumps

Ground-source heat pumps (GSHPs) can provide cost-effective, energy-efficient space heating and cooling, hot water and process heat by utilizing the nearly constant temperature underground to transfer heat between the ground and your facility. GSHPs are typically the most efficient type of heat pump. Though they require electricity to operate, efficient GSHPs can provide the same amount of heating for substantially less than traditional electric heating. Grants of up to $250,000 are available for commercial-scale systems and $25,000 for small-scale systems.

Key Points

- Great option for new construction, but can also replace existing forced air or hydronic heating systems

- High installation costs are offset by long-term energy cost savings compared with electric heat, oil, propane, or even natural gas heating plus highly efficient cooling

Solar Hot Water

Solar hot water systems use the energy of the sun to heat water for use in your home's hot water system. Solar hot water systems reduce the usage of traditional water heating fuels (such as oil, electricity or natural gas) and thereby reduce the amount you spend purchasing these fuels. Rebates of up to $100,000 are available.

Key Points

- Great option for both existing buildings and new construction
- Can reduce water heating costs and greenhouse gas emissions at your facility

Especially cost-effective for buildings currently heating water with oil, propane or electricity

Appendix B – Municipal Energy Efficiency Best Practices

The UMass Clean Energy Extension recommends that Green Communities and all municipalities consider the following energy efficiency best practices for municipalities.

Optimize Building Controls

Many buildings have building/energy management systems or programmable thermostats that are not operating to their full potential. These control systems need to be properly programmed and maintained in order to be effective in optimizing building operation and energy use. Energy efficiency opportunities may be identified by periodically retrocommissioning these systems, or reviewing temperature setpoints and schedules, comparing to building occupancy, making any necessary adjustments, and testing to make sure that the related equipment is operating as intended.

Control systems may record environmental conditions and operational parameters, and review of this data can be very helpful in maximizing the value of the system and identifying any performance problems with HVAC equipment.

For selected buildings, utility companies may be able to provide electrical billing data in 15-minute intervals, which can also be very useful in understanding electricity use patterns throughout the day/week and identifying opportunities to optimize building operation.

Some Green Communities have seen great benefits from these practices, some with the assistance of fault detection and diagnostic software or circuit-level monitoring by consulting companies. Utility pay-for-performance programs may provide incentives based on the achieved savings.

Install/Upgrade HVAC controls

Advanced controls can improve the efficiency of some HVAC systems without the substantial investments required to replace major equipment. These technologies include:

- Energy recovery ventilators or heat recovery ventilators use a heat exchanger to preheat or precool incoming fresh air by reclaiming energy from the outgoing exhaust air.
- Demand control ventilation (DCV) automatically adjusts the amount of outside air let into the building to optimize energy use while providing occupants with the right amount of fresh air.

Integrate Energy Efficiency into Purchasing Decisions

Efficiency ranges widely for many types of energy-consuming equipment. Incremental costs range depending on the product type, but sometimes there is little to no added cost for high efficiency models of new equipment. Information about efficiency of many types of products – including appliances, commercial kitchen equipment, electronics, office equipment and more – is available from the ENERGY STAR program at http://energystar.gov/products and http://energystar.gov/purchasing.

Use Power Management Software on all Computers

The ENERGY STAR program offers free support on computer power management to reduce electricity consumption when computers are not in use, detailed at http://energystar.gov/powermanagement.

Implement an Energy Engagement Program

Some Green Communities have had success with programs that educate municipal employees, students and other building occupants about their energy reduction goals and encourage simple behavioral actions such as turning off lights, computers and other equipment when not in use.

Investigate Energy Efficiency Opportunities in Water and Wastewater Treatment Plants

Water and wastewater treatment plants are often among the highest energy consuming facilities in cities and districts. Our partner organization, the UMass Center for Energy Efficiency and Renewable Energy offers free, in-depth assessments of plants with annual energy costs of at least $100,000. The Center conducts a site visit with a thorough review of equipment and processes, then provides a detailed report with recommended energy efficiency opportunities, including estimates for energy and cost savings and implementation costs. More information is available at http://ceere.org/iac.

Appendix C – Supporting Documentation and Calculations

Warwick Elementary

Removal of Glycol and Heating to Vestibules

Glycol is mixed with water to provide freeze protection. However, it does so at the cost of increased viscosity, lower specific heat capacity, and reduced conductivity, making it roughly 15% less efficient as a working fluid for heat transfer applications. The reason for the excessively high boiler set point (200°F) is to compensate for the lower heat capacity and conductivity. The superior thermal characteristics and lower specific gravity of water also allows for lower pump speeds.

It is recommended that Warwick removes and replaces glycol in its heating system with water. This requires ensuring that the heating coils above the vestibules will not freeze by draining the hot water coils and heat ducts in the vestibules, replacing heat in those areas with ceiling cassette air source heat pumps.

To calculate the savings for the removal of glycol for the heating systems several factors were investigated. Given the capacity of the boiler and the annual energy consumption with an assumed short cycling percentage, the savings due to reduction of short cycling, boiler operation temperature, and an increase in pump efficiency was calculated.

Table C.1: Based on the maximum firing rate of the boiler the capacity. This value is supported by the regression analysis which gives the boiler capacity at 1,244.47 **Table R.1**. The max firing rate was used for the proceeding calculations.

Warwick Boiler Capacity	
Max Firing Rate (GPM)	7
Btu/Gallon of Oil	138,500
Capacity (MBtuh)	**1,163.40**

Table C.2: The reduced electrical and oil consumption was calculated given the different properties of a fully water based system that would reduce loads on the pumps, boiler temperature, and short cycling. The percentages were calculated from the average oil and electric consumption, suggesting an annual savings of **$4,222**.

Total Energy Savings from Glycol Removal					
	Gallons	**kWh**			
Current Energy Consumption	7,249	93,680			
Retrofit	**Gallons**	**kWh**	**MMBtu**	**Savings (%)**	**Savings ($)**
Short Cycling Reduction	1,595		221	22%	$2,392.17
Temperature Reduction	604		84	8%	$906.13
Pump Efficiency		5,132	175	5%	$923.71
			Total Annual Savings		**$4,222.00**

Table C.3: Savings incurred from disconnecting heating system to the vestibules were calculated by determining the cost to heat those spaces based on the conditioned area as a percentage of total heating fuel with a 30% reduction in heating load.

Removal of Vestibule Heating	
Square Footage of Conditioned Space	192
Gallons (Oil)	75
Annual Cost / Savings ($)	**$ 111.99**

Table C.4: The cost to shut of heating to the vestibules and remove glycol was calculated based on a day of work for a plumber working at $80 an hour.

Cost of Plumbing	
Hours	16
Rate	$ 80.00
Total Estimated Cost	**$ 1,280.00**

Envelope Insulation

Based on the current insulation levels within the roof, (6 inches of loose fill cellulose) the R-value was calculated given that loose blown cellulose has an average of 3.5 R per inch of depth. Due to the numerous air gaps allowing infiltration, the insulation is subjected to wind washing. Wind washing is proportional to air leaks, and is probably 10% at most. Regardless, the insulation is very uneven. Using the RESNET standard, it is a level 2 installation job. Leading to an assumed insulation loss of 20%. This infiltration also leads to heat loss, with an approximate 1 in^2 hole every 10 ft.^{2} the heat loss from this air movement was calculated (see **Table C.9).** If the attic space was air sealed and the insulation was loose filled to 12.5 inches the R-Value would increase to R-50. The "tunnel" walls should be insulated with fiberglass batts and then covered and sealed with rigid foam boards and PSA tape or 1-

part gun foam as needed to connect the air barrier to the drywall air barrier below. The roof of the tunnel could receive loose blown cellulose.

Table C.5: Heat loss from the roof of the building was calculated based on the HDD for Warwick, the area of the roof, and the R-Value of the insulation with the reduction due to wind washing of 20% (see **Table C.6**.)

Current Conductive Roof Heat loss	
Qcond = U * A * HDD * 24	
U-Value (Btu/ft²°F) = 1/R-16.8	0.060
Area (ft²)	16,778
Warwick HDD	7,180
Qcond (kBtu)	**172,094.34**

*Annual HDD determined from 3-year average (Site: KMAROYAL1 Windhorse Farm, Royalston MA)
TMY 3 file for closest weather station give HDD of 6,984

Table C.6: Reduction in heat loss was calculated for the attic with air sealing causing reduced wind washing.

Wind Washing	
Assumed loss of 20% R-Value	R-21 - 20% = R-16.8
Savings from Reduced Wind Washing	
Qcond Reduction = U * A * HDD * 24	
U-Value	0.048
Qcond with Retrofit (kBtu)	137,675.47
Current Q - Q Retrofit (kBtu)	**33,317.46**

Table C.7: Reduction in heat loss was calculated based on reduced wind washing and with increased insulation to R-50.

Savings from Increased Insulation and Reduced Wind Washing	
Qcond Reduction = U * A * HDD * 24	
U-Value for R-50	0.02
Qcond with Retrofit (kBtu)	57,823.70
Current Q - Q Retrofit (kBtu)	**114,270.64**

Table C.8: Annual savings from the reduced heat loss.

Savings from Increased Insulation and Reduced Wind Washing		
Savings (MMBtu)		114.27
Savings (Gallons Oil)		825.06
Savings ($)	**$**	**1,237.59**

Table C.9: Reduction in infiltration and exfiltration from the potential air sealing was calculated based on assumptions of a 1 square inch hole for every 20 square feet of attic space. CFM 50 was calculated and the annual energy usage was calculated using Residential Energy Dynamics AIM Infiltration Calculator. With an assumed boiler efficiency, the cost of this infiltration was determined.

Effective Leakage Area Calculation		
Gap width (in)		1
Gap length (in)		1
Building Roof (Square Feet)		16,788.00
ELA (in^2)		839.40
Infiltration Calculation		
CFM50 / 18 = ELA		
CFM50 = ELA * 18		
CFM 50		15,109.20
Annual Energy Usage (MMBtu)		83.00
Gallons Per Year		599.28
Savings from 70% Reduction		
Assumed Boiler AFUE - 86%		
Boiler Annual Energy Usage (Gallons)		487.78
Cost per Gallon	$	1.50
Annual Cost of Infiltration Losses	**$**	**731.68**

Table C.8: Cost of air sealing the attic is determined based on 20 hours of work at $75 an hour.

Cost of Retrofit Spray Foam Air Sealing		
Hours		40
Hourly Rate		75
Total Cost	**$**	**3,000.00**

Table C.9: Insulation is approximately 75 cents per square foot. Factoring in labor, total cost is approximately $18,086.50.

Cost of Insulation	
Cost per Square Foot	$0.75
Attic Square Footage	16,778
Material Cost	$ 12,583.50
Labor Cost	$ 5,500.00
Total Cost	**$ 18,086.50**

Cafeteria

To estimate the savings from switching to a heat pump for cafeteria heating, current operational costs was calculated (**Table C.10**). Cost was calculated based on the ft^2 of conditioned space as a percentage of the annual heating consumption. The cost of the new heat pump was sourced from Mitsubishi, with an installation cost of $300. The operational cost of heating with the heat pump was calculated using the Energy Start Life Cycle Cost Estimate for Qualified Air Source Heat Pumps (**Table C.11**). The savings from this retrofit was calculated based on the reduced operational cost of heating the cafeteria with the heat pump (**Table C.12**).

Table C.10: Current annual cost of heating the cafeteria.

Cost of Cafeteria Heating	
Square Footage of Conditioned Space	1500
Gallons (Oil)	648
Annual Cost ($)	**$ 972.12**

Table C.11: The initial cost and operational cost of the heat. The calculations are based on the model specifications and the Energy Star heat pump calculator.

Heat Pump Implementation and Operational Cost	
Mitsubishi MZ-GL18NA	
Initial price	$ 2,333.00
Installation	$ 300.00
HSPF	10
kWh	3664.54
Operational Cost	**$ 660.00**

Table C.12: Savings from switching to a heat pump system for the cafeteria based on annual operational costs.

Savings from Heat Pump Installation	
Current Heating Cost	$ 972.12
Heat Pump Operational Cost	$ 696.00
Annual Savings	**$ 276.12**

Modified Thermostat Controls

More information on the recommended thermostat control can be found by following the link below.

http://s3.supplyhouse.com/product_files/T104C1036-Submittal%20Sheet.pdf

Bernardston Elementary

Figure C.1: Top view of Bernardston with section identification.

Figure C.2: The attic on the new section (left two image) old section (right image).

Envelope insulation and Air Sealing improvements

The images in **Figure C.2** demonstrate several of the issues that were identified in the site visit. The first image shows ductwork that is outside the building envelope, sections of which lack proper insulation. The middle image demonstrates the complete lack of an air barrier in the southern New Section identified in **Figure C.1** by the black rectangle There is also only 6” of insulation in this section. The image to the right demonstrates one instance of the consistent lack of insulation on access hatches that are causing increased heat loss from the building and more expensive heating bills. In the eves, there is evidence of ice dams and a 1” copper pipe laying exposed in the attic which contributes to system inefficiencies. In the west wing of the building there is 10" of cellulose insulation and an additional 3" of fiberglass underneath. There are however significant air leaks coming from the vaulted ceiling in the foyer. To decrease heat loss from the building, the attic, in all sections of the building, should receive additional insulation and air sealing. It is highly recommended that air sealing take place before insulation is added as the unimpeded movement of air through insulation will cause a significant reduction in the R-Value of the insulation.

Remove glycol in heating system

The recommendations outlined for this building are the same as those originally introduced in **Section 4.1** under Warwick's executive summary. The removal of glycol from the hydronic heating system will reduce pump electrical costs and boiler fuel consumption due to lower operating temperature and a higher heat transfer coefficient.

Kitchen Appliances

The dishwasher leaks due to faulty booster pump, the plumbing also has degraded over the years from hard water. The freezer motor should also be upgraded.

PVRSD Pioneer Valley Regional MS/HS

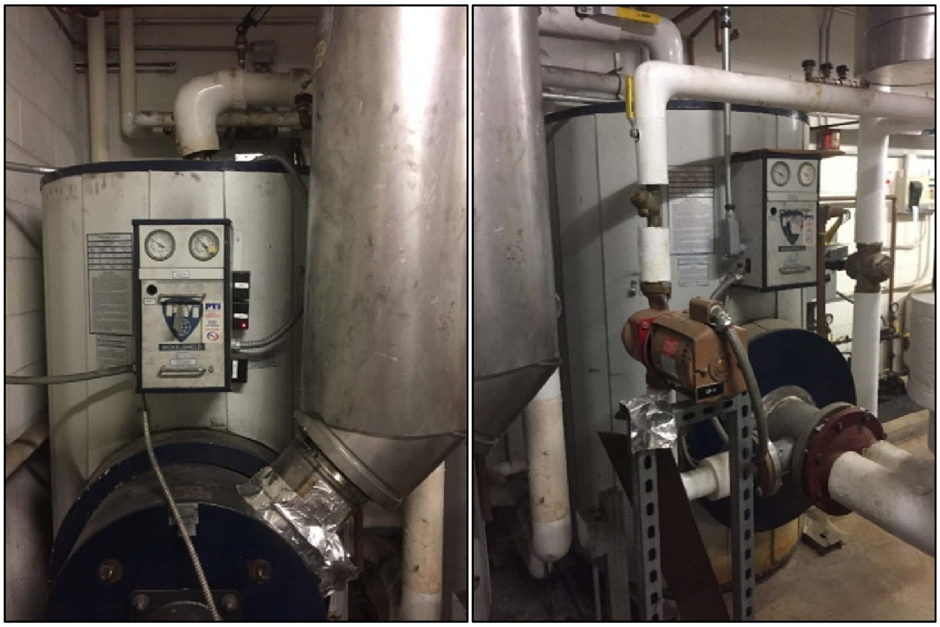


Figure C.3: The images above show the two hot water heater storage tanks for occupant use.

Figure C.4: Freezer condition with condensation on the door (Left image) and leak in the refrigerant line (Right image).

Domestic Hot Water tank converted to Thermal Energy Storage

The two tanks in **Figure C.3** store and supply all of the water for the building. These tanks could be converted into thermal energy storage and heating buffer tanks. Instead of the boiler firing up and running until it heats the building and shutting off, the boiler can heat up the water in these two tanks, run at a higher efficiency and reduce short cycling. The hot water that is stored in the two tanks could then be pumped to heat the building. At 500 gallons, each these tanks would supply significant thermal energy storage.

Walk in Freezer

The walk-in freezer displayed in **Figure C.4** has a refrigerant leak (shown in the right image) and has condensation on the door. This condensation means that cold air is leaking out of the freezer causing water in the air to condense on the door, this process in turn heats up the door increasing the heat loss from the freezer and the energy required to maintain the proper temperature.

Low E Film on low performing Windows

More information and one example of a climate control window Film is given in the link below

http://solutions.3m.com/wps/portal/3M/en_WW/Thinsulate_Window_Film/Home/Commercial/

Northfield Elementary

Figure C.5: Damper in the mechanical room is incorrectly weighted.

Figure C.6: Images above show the air gaps that are present in the north and south sections of the building

Figure C.7: In the north building, the left image shows the massive air leakage and deteriorated state of the envelope that was observed on the ceiling of the closet below the attic. The right image shows the depth of insulation in the attic.

Replace Current boiler system

The current boiler is extremely old has poor presets and operation. It suffers continual maintenance and requires experienced staff to operate properly. This boiler should be replaced with either a new oil boiler or potentially a modern wood heating system such as a pellet boiler. There is enough room outside to place a hopper for pellet storage. The combustion damper is also improperly weighted.

Air Sealing and increased insulation

In the north section of the building, additional insulation including cellulose and foam along the baseboard would help seal air gaps. The extra passive ventilation vent to the left of the stairs in the attic should be sealed and set up to be controlled with a motorized damper. This would give the custodial staff the ability to open and close the outside ventilation based on weather conditions. The central building houses the air handler room, however it is not properly insulated and draws in outside air. In the south building, there are large perimeter gaps that should have air sealing applied to decrease heat loss through the envelope.

Thermal Performance Analysis

Regression analyses compare historical energy consumption to historical weather conditions to determine the relationship between energy consumption and weather. From this comparison, the balance point can be calculated. The balance point is the outdoor temperature at which internal systems turn on to heat the building. For internally dominated buildings (e.g. office buildings) a typical balance point is 50°F. For envelope dominated buildings (e.g. traditional house) the typical balance point is 60°F. A building with a balance point that is higher than 60°F is a good candidate for lifestyle or structural changes that would decrease the buildings heat loss through the envelope. This analysis is useful to quickly identify buildings that would benefit from retrofits that could reduce the buildings energy usage per Heating Degree Day (i.e. increased insulation, improved air barrier). The regression analysis, utilizing fuel delivery data from MEI for the three buildings along with local temperature data, are shown on the following pages.

Warwick Elementary

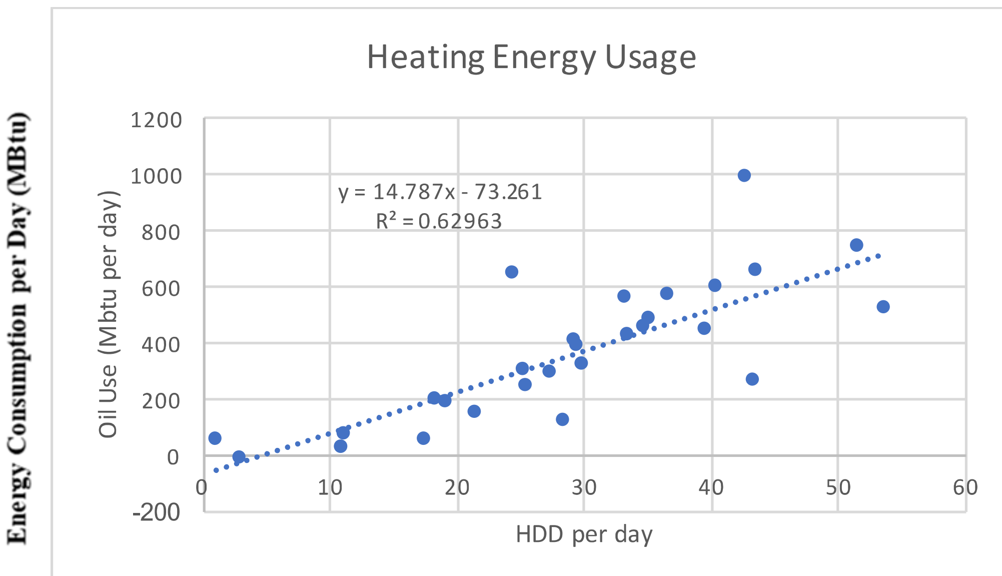


Figure R.1: Regression plot of total energy consumption per heating degree day. R^2 of 0.62.

Table R.1: The baseload, balance point, correlation and heating sizing of the building is calculated and displayed in the table below.

Baseload, PVRSD Warwick Comm ES Oil (Gallons)	
Intercept	**15th Percentile**
-73.26	12.92
Correlation	
R^2	**Pearson**
0.62	0.784
Slope (energy unit/°F)/intercept (energy unit)	1.10
Balance Point (°F)	64.8
Heating Sizing (MBtuh)	1244.47

Bernardston

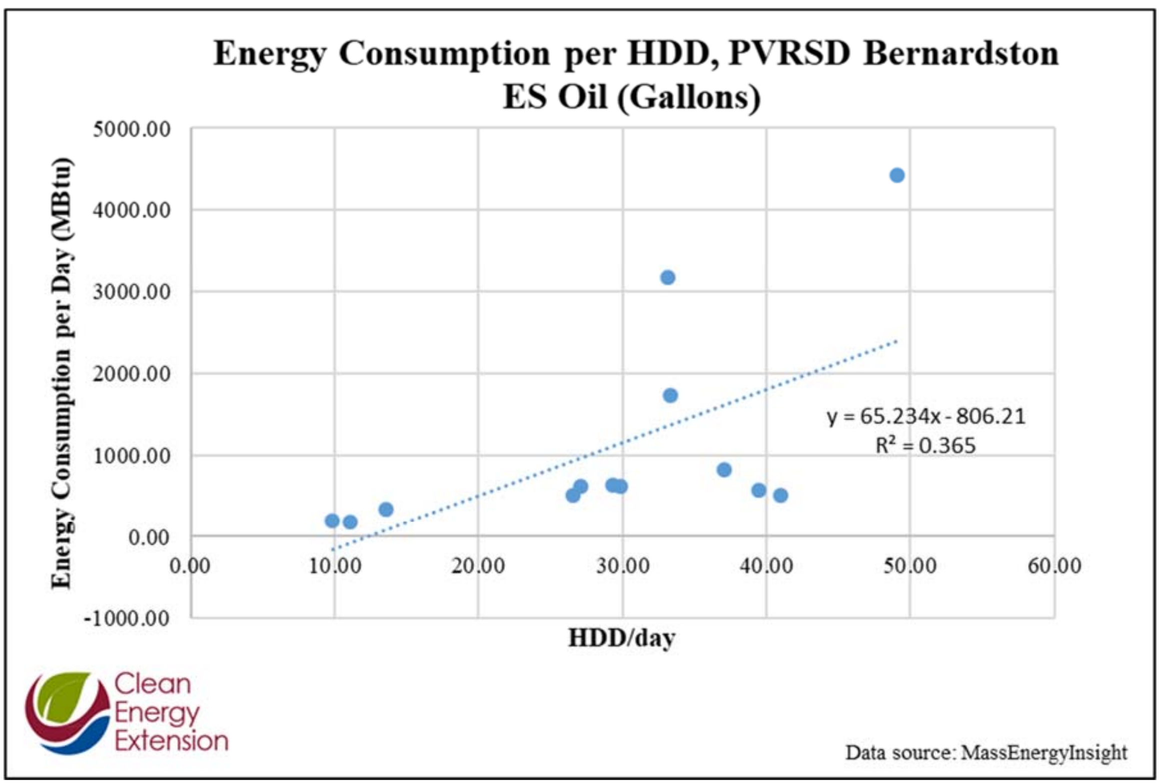


Figure R.2: Regression plot of total energy consumption per heating degree day. Low correlation.

Pioneer Valley Regional MS/HS

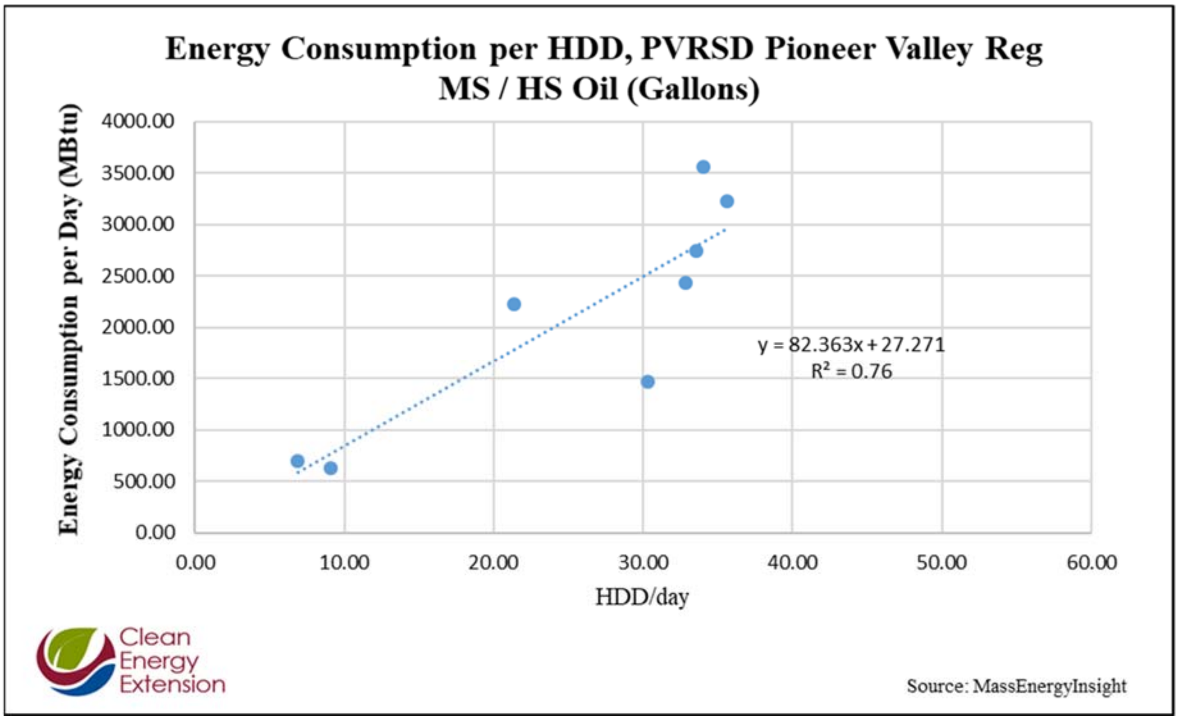


Figure R.3: Regression plot of total energy consumption per heating degree day. High correlation but limited data.

Table R.2: The baseload, balance point, correlation and heating sizing of the building is calculated and displayed in the table below.

Baseload, PVRSD Pioneer Valley Reg MS / HS	
Intercept	**15th Percentile**
1.97	53.06
Correlation	
R^2	**Pearson**
0.760	0.872
Slope (energy unit/°F)/intercept (energy unit)	5.95
Balance Point (°F)	68.02
Heating Sizing (MBtuh)	6720.83

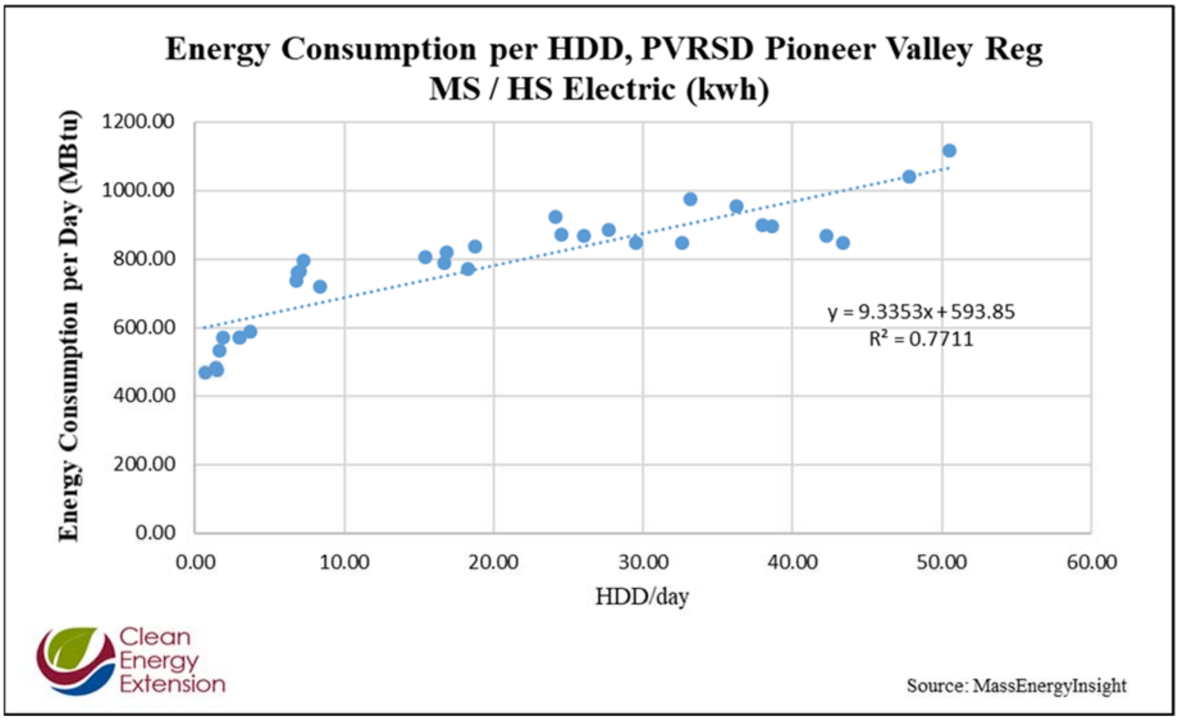


Figure R.4: Regression plot of total energy consumption per heating degree day. High correlation demonstrating that the buildings electrical systems are effected by weather conditions.

Table R.3: The baseload, balance point, correlation and heating sizing of the building is calculated and displayed in the table below.

Baseload, PVRSD Pioneer Valley Reg MS / HS	
Intercept	**15th Percentile**
1764.16	1680.00
Correlation	
R^2	**Pearson**
0.745	0.863
Slope (energy unit/°F)/intercept (energy unit)	25.26
Balance Point (°F)	65.01
Heating Sizing (MBtuh)	703.31

Northfield Elementary

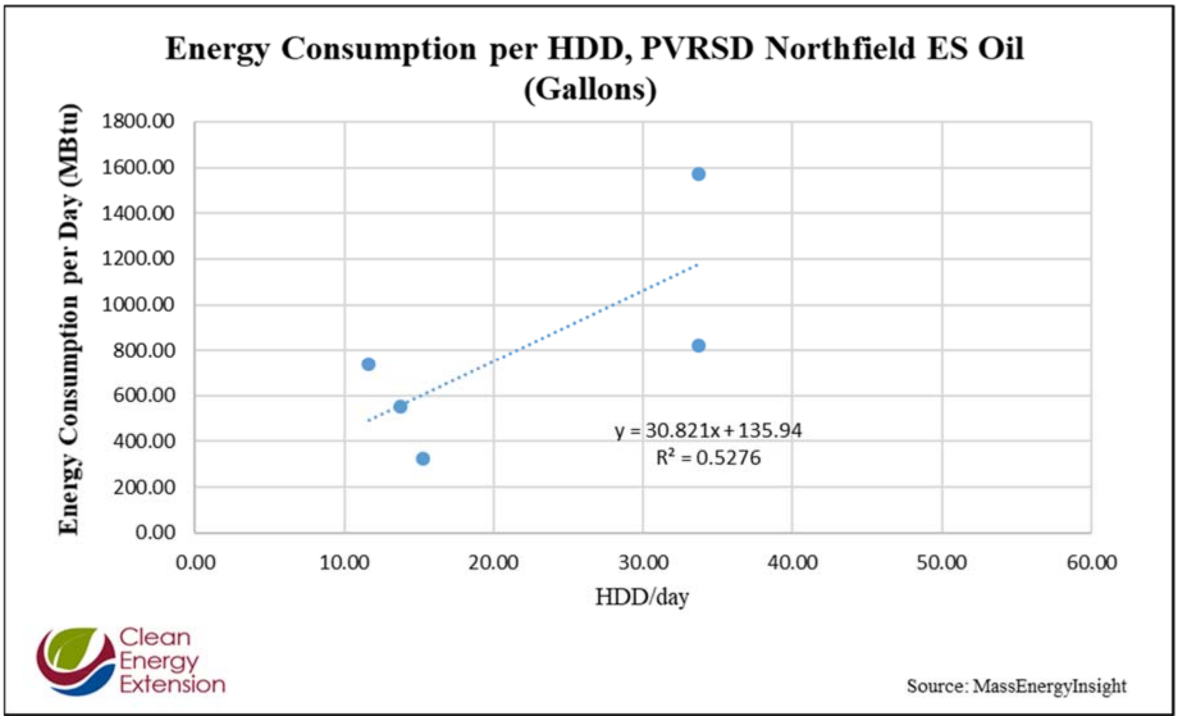


Figure R.5: Regression plot of total energy consumption per heating degree day. As demonstrated by the graph above there is not enough data for the to be accurate.

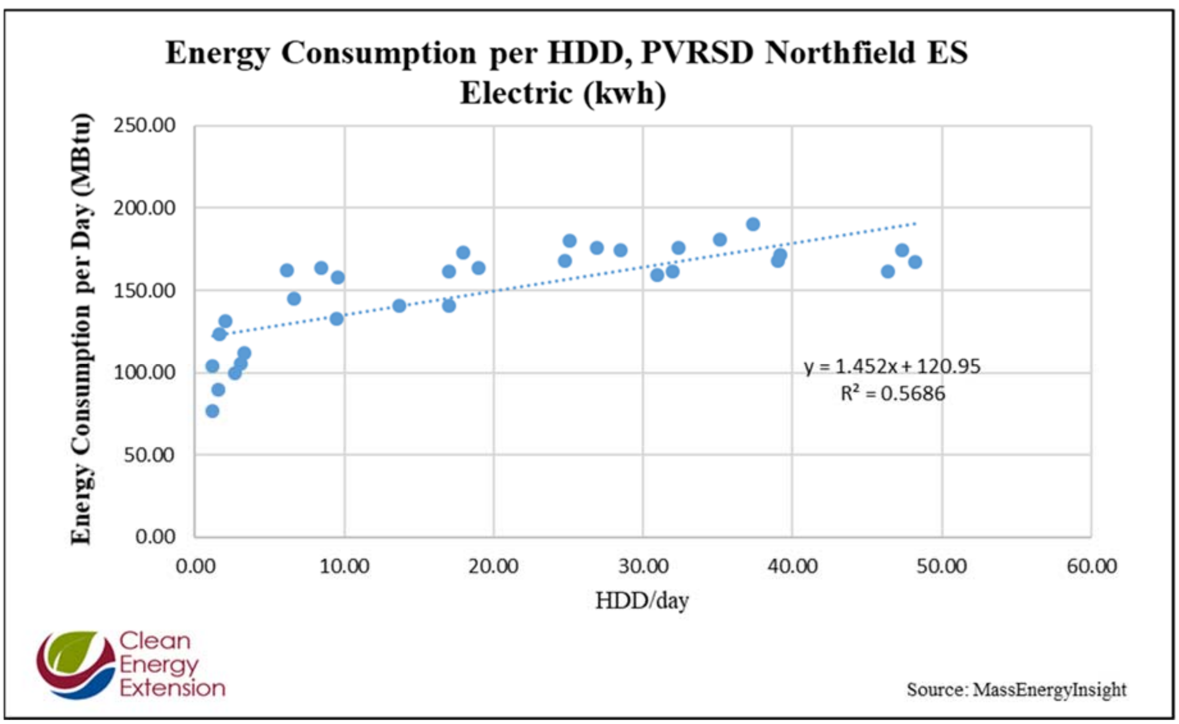


Figure R.64: Regression plot of total energy consumption per heating degree day.

Table R.4: The baseload, balance point, correlation and heating sizing of the building is calculated and displayed in the table below.

Baseload, PVRSD Northfield ES	
Intercept	**15th Percentile**
351.79	326.05
Correlation	
R^2	**Pearson**
0.609	0.780
Slope (energy unit/°F)/intercept (energy unit)	4.25
Balance Point (°F)	65.01
Heating Sizing (MBtuh)	118.23

Demand and Load Factor Analysis

Load factor is the ratio of energy used in a given period divided by the total energy that could have been used for that period, based on the peak demand for the period and the total number of hours for the period. This is a measure of how consistent a buildings energy usage is. A building with a high load factor is very consistent as the peak demand is relatively close to the average hourly energy consumption. If the load factor is low, that means that the building has a peak that is significantly higher than the average hourly energy consumption. For buildings where the electric rate for a period is set by the peak demand use, a low load factor results in a high expense. This building would benefit from controls set to limit the peak demand or energy storage to evenly distribute the load.

The Demand is the peak demand consumption in kWh for that period, and shows the fluctuations in peak demand from season to season. The max theoretical consumption is the demand for that given period times the total number of days in that period times 24. The Load Factor displays the calculated load for each period of provided data.

The Demand Frequency gives the percentage of periods that the facility is operating above a specific threshold to display un even distribution in the graph.

The Load Frequency gives the amount of time that the facility is operating above a specific load level.

Based on the relationship between load factor and HDD we can see if high peak demands are related to variations in weather, a strong correlation with a positive slope may indicate inefficient systems related to heating.

Load Factor	>75%	50% - 75%	35% - 50%	20% - 35%	10% -20%	< 10%
Benefit of Demand Control	Limited Benefit	Possible Benefit	Depends Upon Return	Good Potential	Excellent Potential	Must do

Warwick Elementary

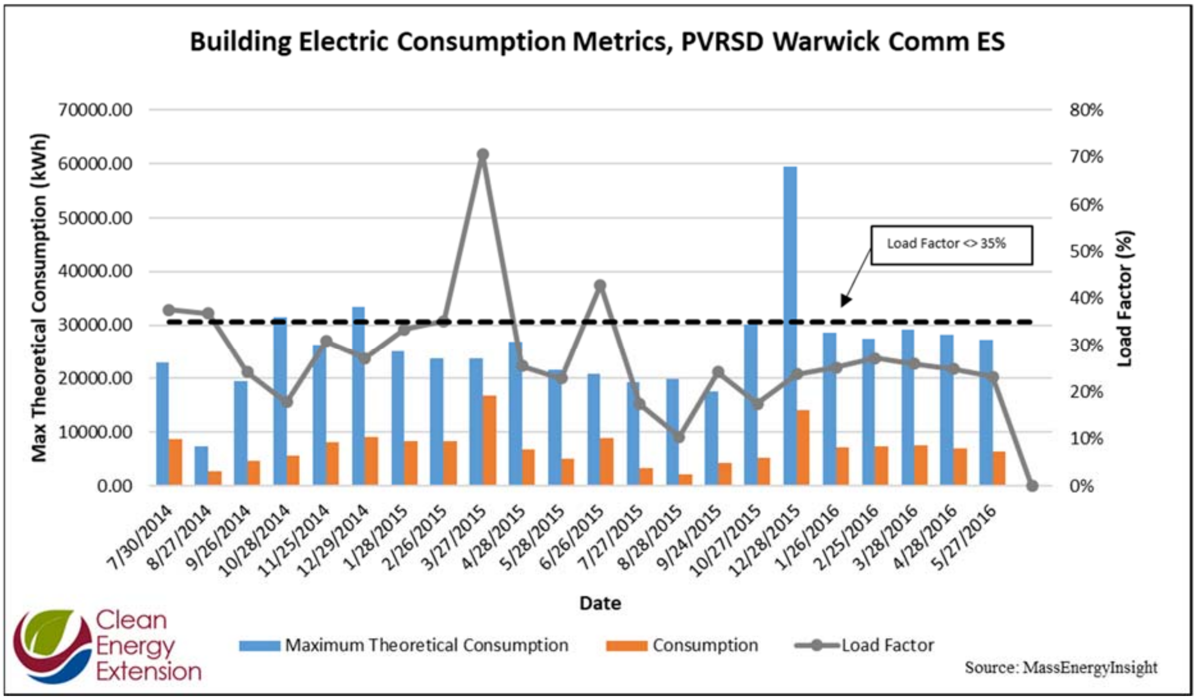


Figure L.1: Max theoretical consumption is displayed (Blue) next to the actual consumption (Orange) and the load factor (grey). The dotted line denotes the 35% load factor threshold.

Table L.1: Based on the facility demand the following metrics were determined to assess the variations in the facility's peak demand and energy consumption.

Demand, PVRSD Warwick Comm ES	
Average	34
Standard Deviation	7
Range	30
Min	11
Max	41

Table L.2: Based on the calculated load factor the following metrics were determined to assess the variations in the facility's peak demand and energy consumption.

Load Factor, PVRSD Warwick Comm ES	
Average	29%
Standard Deviation	12%
Range	60%
Min	10%
Max	71%

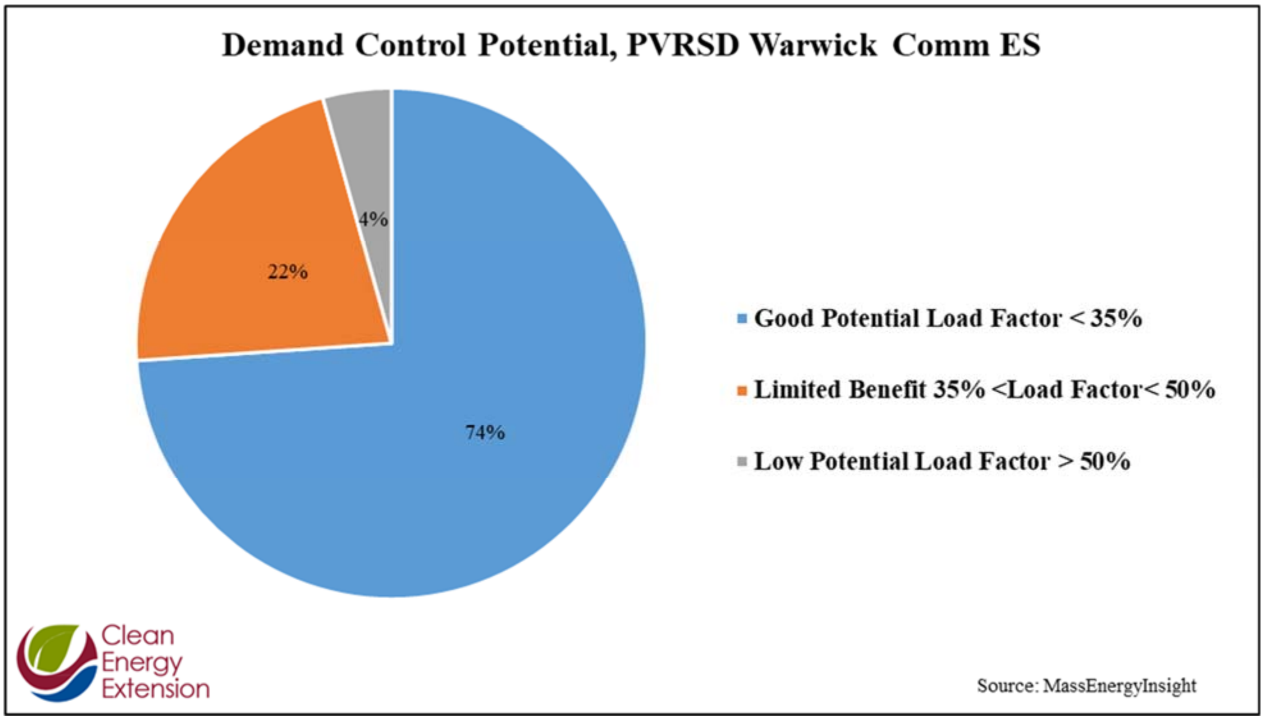


Figure L.3: The load factors for all periods were divided into three categories based on their suitability for demand control options. 74 % of the time Warwick has good potential for demand control measures.

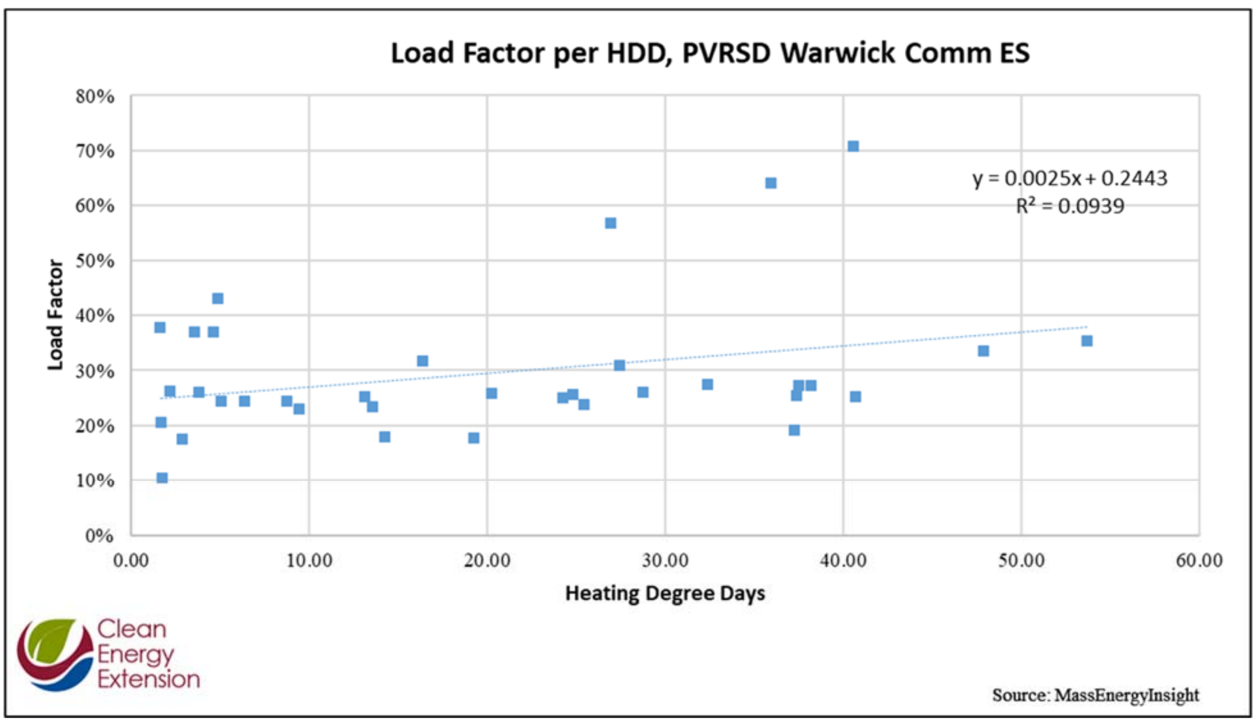


Figure L.4: Load factor is compared to the weather conditions for each period based on the HDD. For Warwick, there is no correlation between load factor and HDD revealing that the peak demand for the building is not effected by weather conditions.

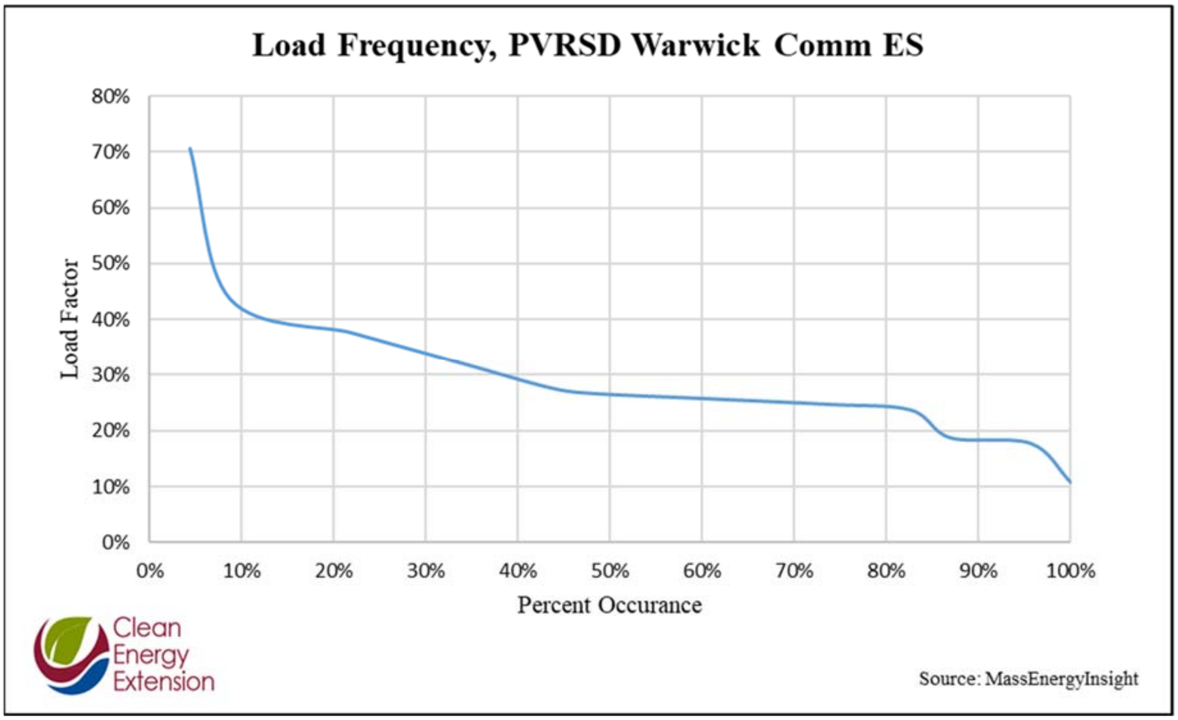


Figure L.5: Percentage of periods that the facility operates above a specific load factor.

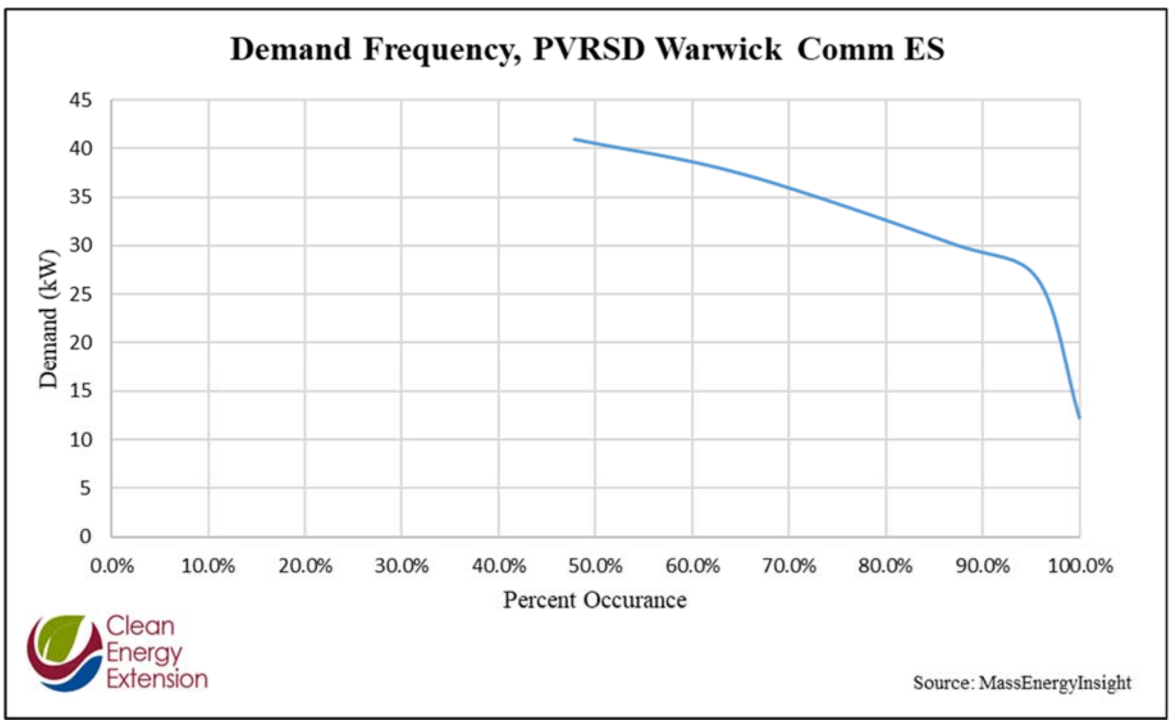


Figure 5: Percentage of periods that the facility operates above a specific demand threshold.

PVRSD Pioneer Valley Reg MS / HS

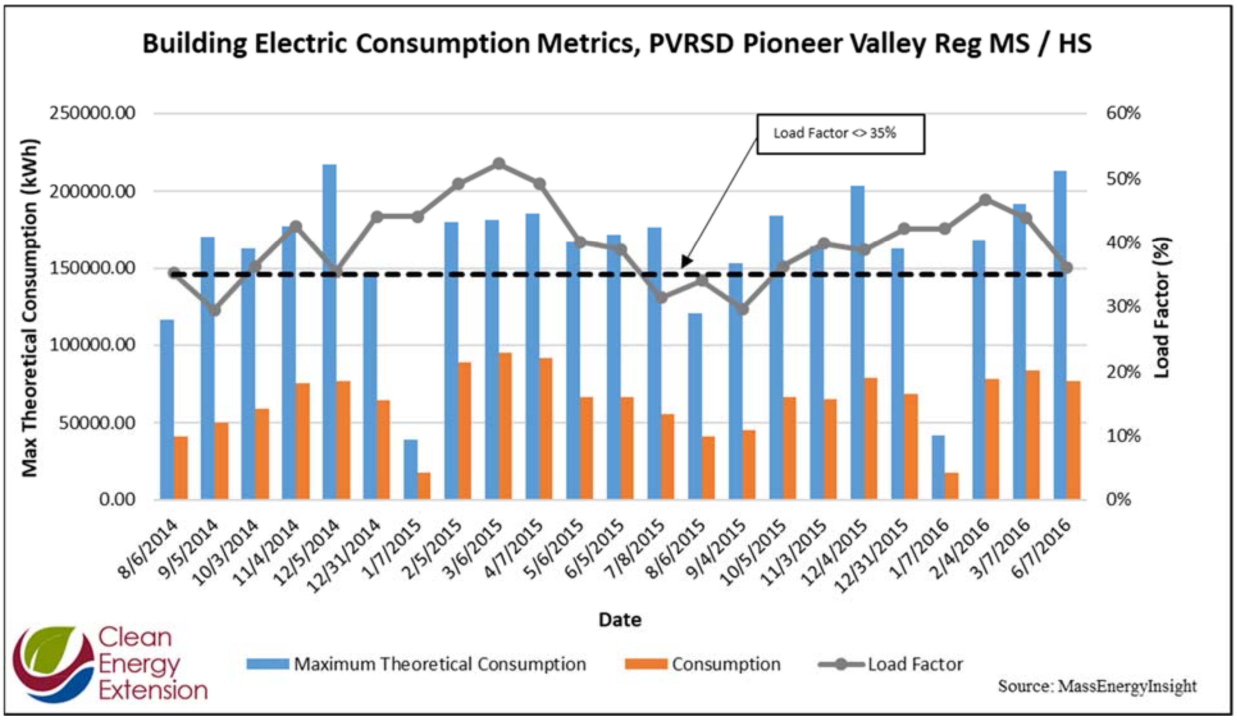


Figure 6: Max theoretical consumption is displayed (Blue) next to the actual consumption (Orange) and the load factor (grey). The dotted line denotes the 35% load factor threshold.

Table L.3: Based on the facility demand the following metrics were determined to assess the variations in the facilities peak demand and energy consumption.

Demand, PVRSD Pioneer Valley Reg MS / HS	
Average	239
Standard Deviation	25
Range	130
Min	162
Max	292

Table L.4: Based on the calculated load factor the following metrics were determined to assess the variations in the facilities peak demand and energy consumption.

Load Factor, PVRSD Pioneer Valley Reg MS / HS	
Average	40%
Standard Deviation	6%
Range	23%
Min	30%
Max	52%

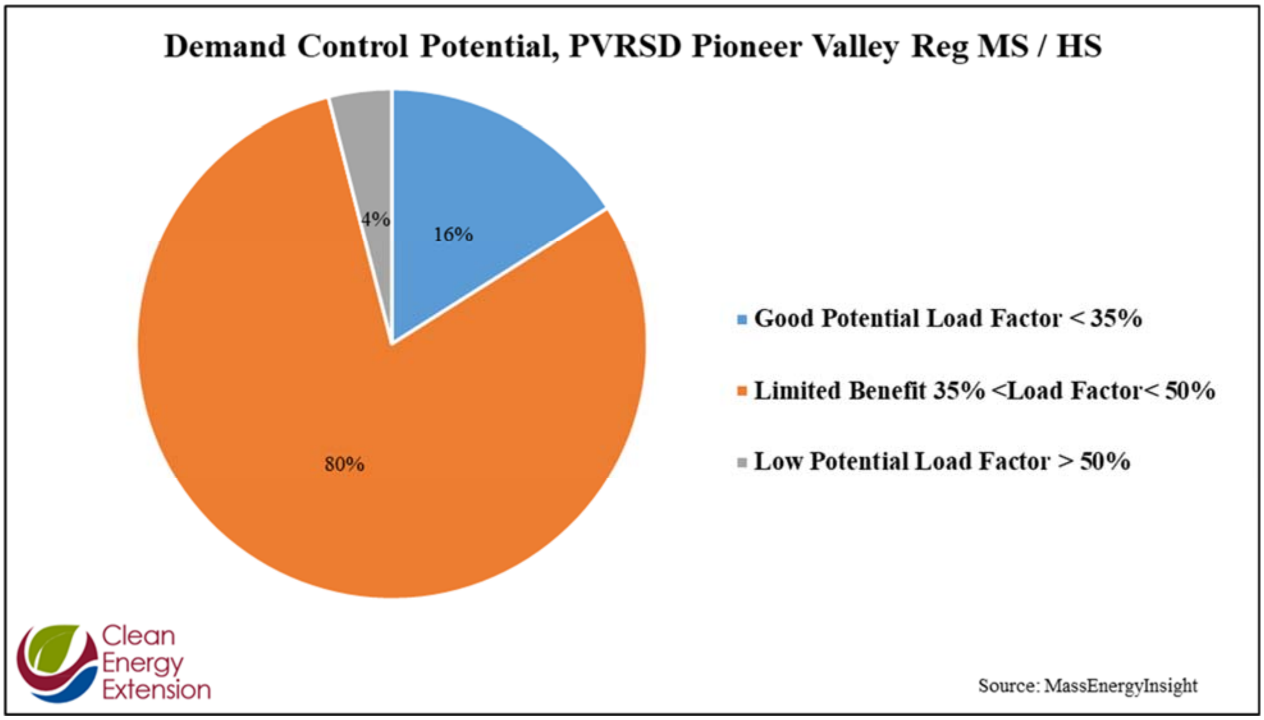


Figure L.8: Load factors for all periods were divided into three categories based on their suitability for potential for demand control options. Pioneer Valley Regional MS/HS has very consistent demand compared to consumption and only 16% of periods have good potential for demand control measures.

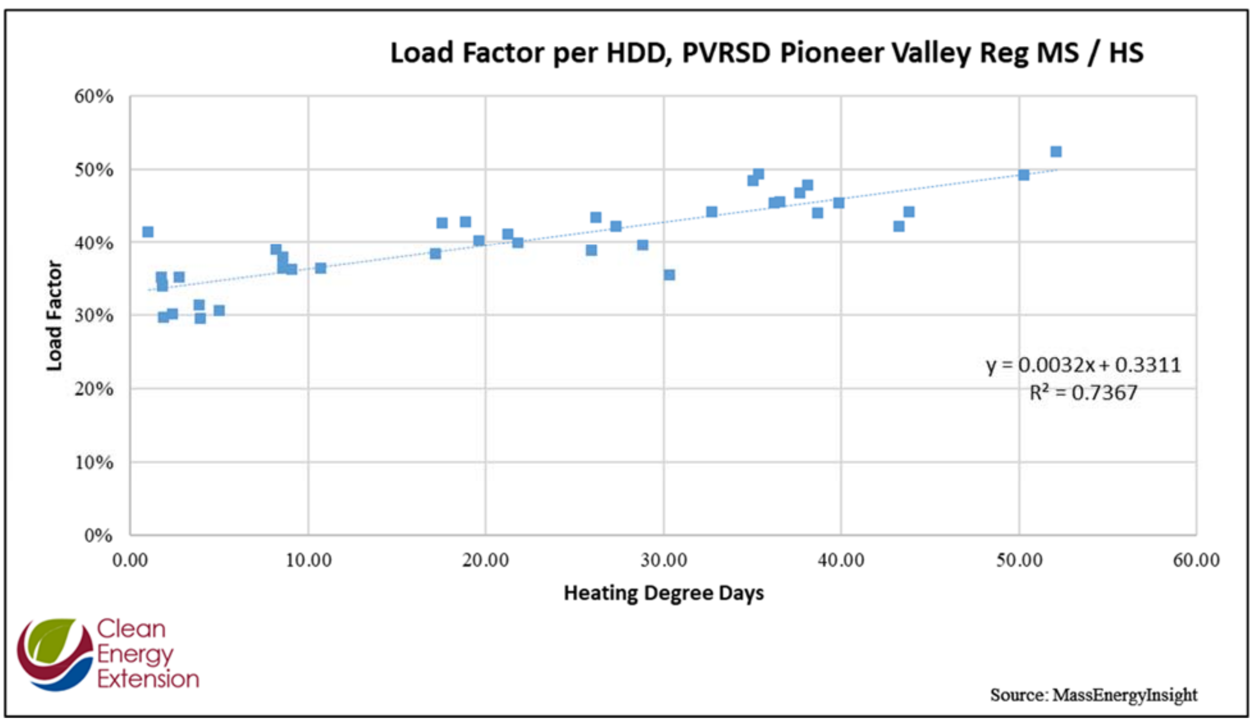


Figure L.97: Load factor is compared to the weather conditions for each period based on the HDD. For Warwick, there is no correlation between load factor and HDD revealing that the peak demand for the building is not effected by weather conditions.

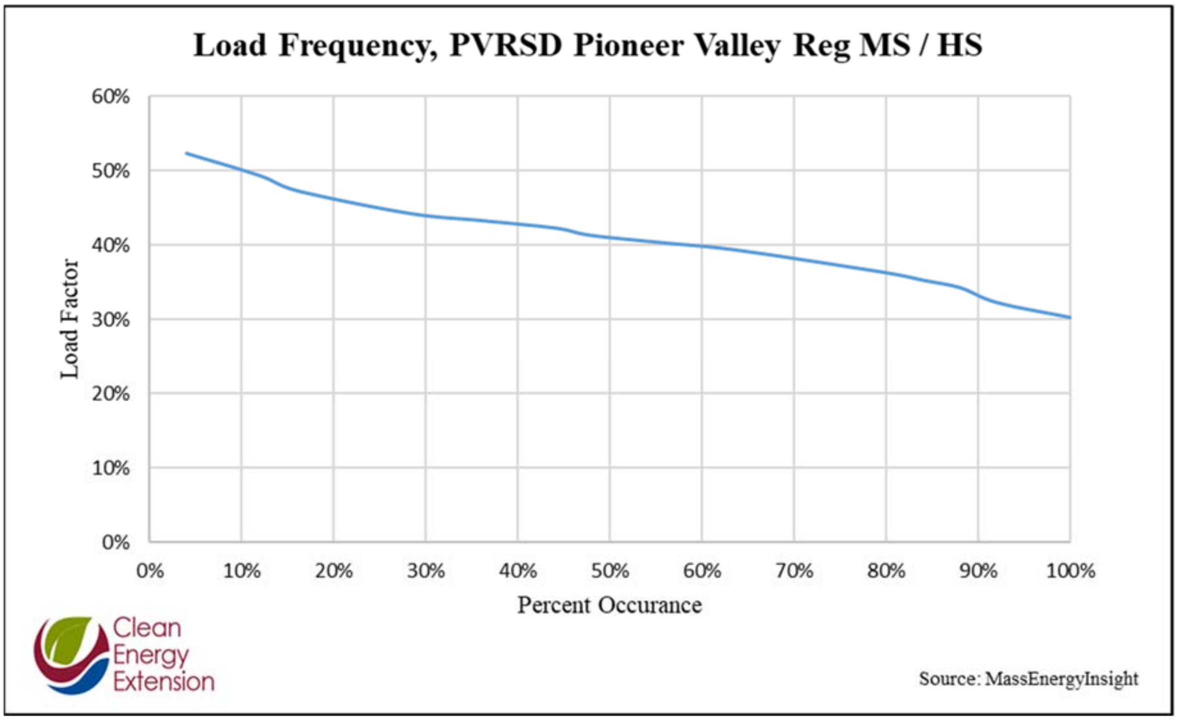


Figure L.10: The percentage of periods that the facility is operating above a specific load factor.

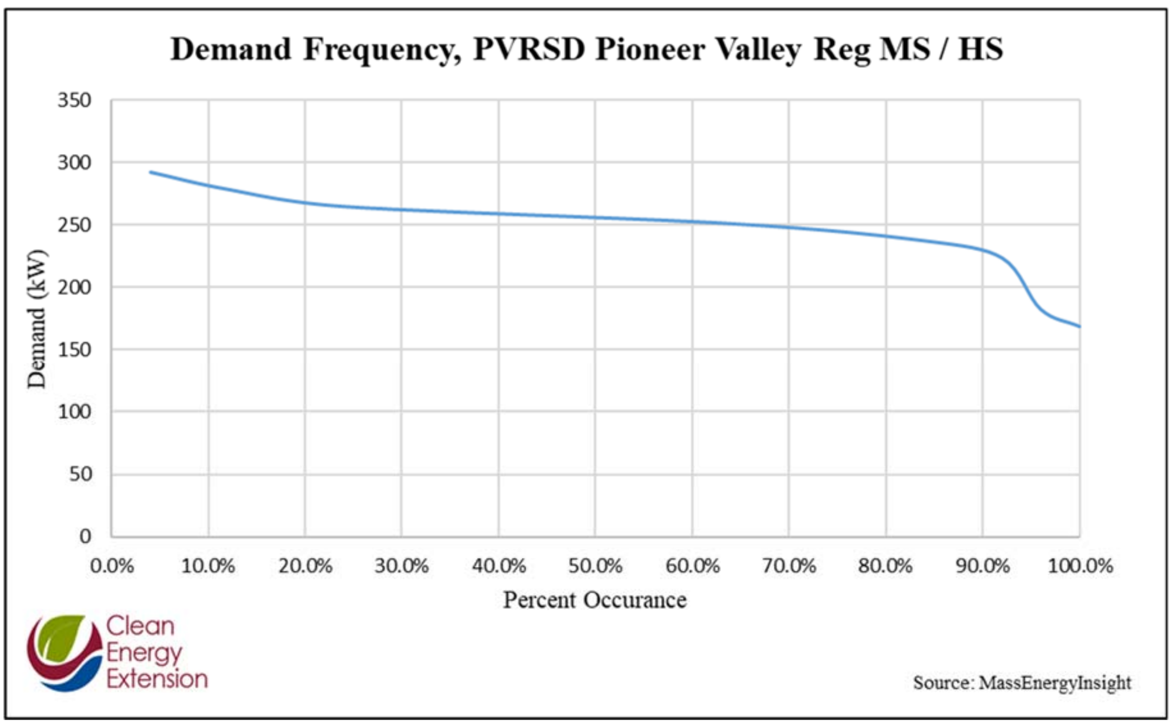


Figure L.11: Percentage of periods that the facility is operating above a specific demand threshold.

Northfield Elementary

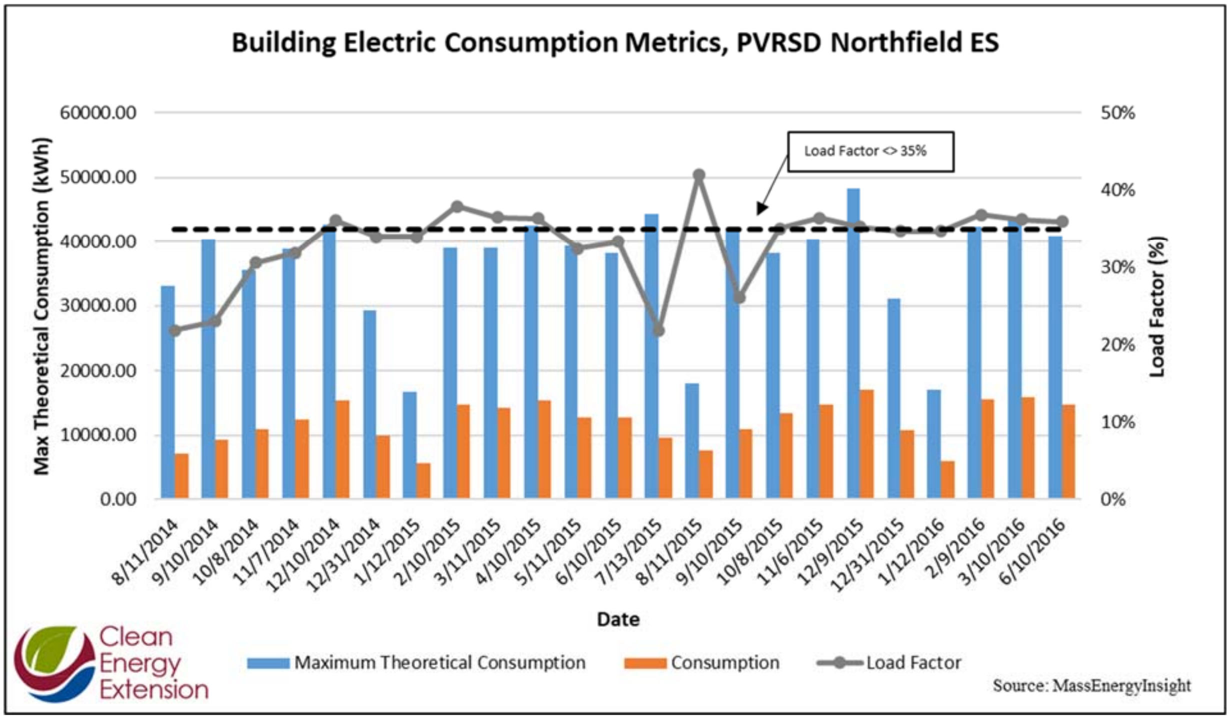


Figure L.12: Max theoretical consumption is displayed (Blue) next to the actual consumption (Orange) and the load factor (grey). The dotted line denotes the 35% load factor threshold.

Table L.5: Based on facility demand the following metrics were determined to assess the variations in the facilities peak demand and energy consumption.

Demand, PVRSD Northfield ES	
Average	56
Standard Deviation	7
Range	37
Min	26
Max	63

Table L.6: Based on the calculated load factor, the following metrics were determined to assess the variations in the facility's peak demand and energy consumption.

Load Factor, PVRSD Northfield ES	
Average	33%
Standard Deviation	5%
Range	20%
Min	22%
Max	42%

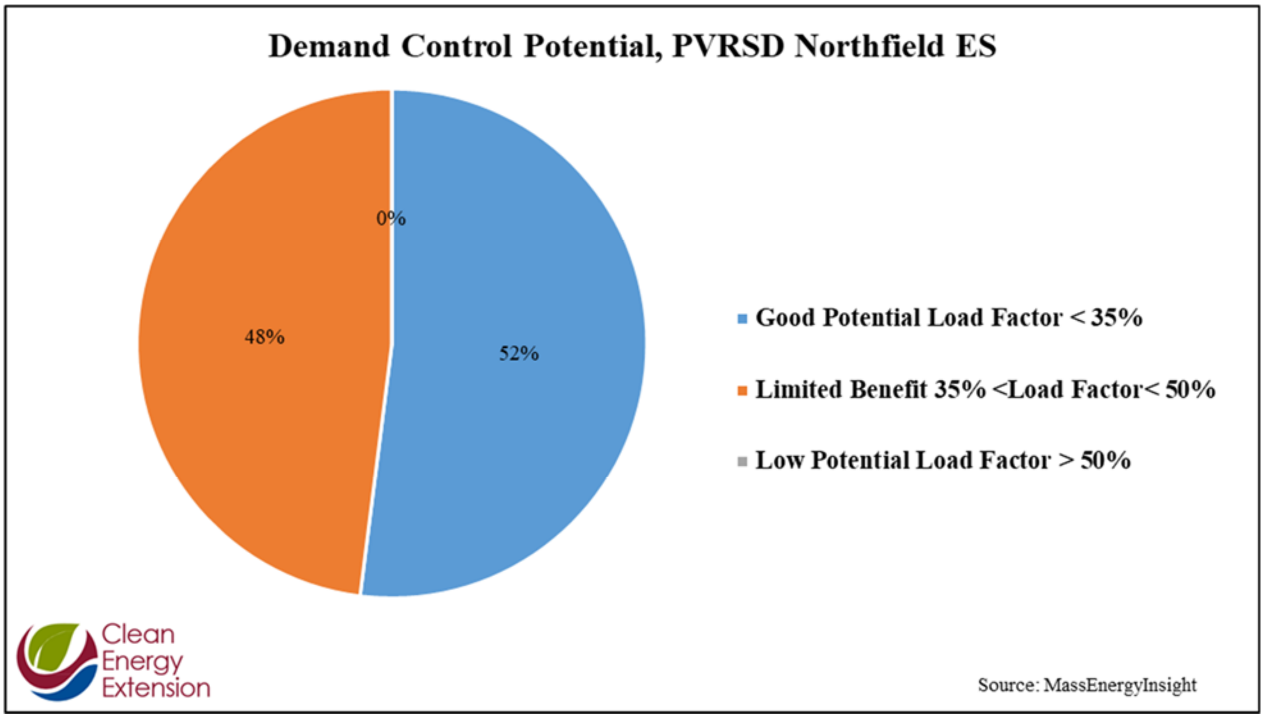


Figure L.13: Load factors for all periods were divided into three categories based on suitability for demand control options. Northfield has highly variable max theoretical consumption to actual consumption, about half of the time Northfield would benefit from demand control measures.

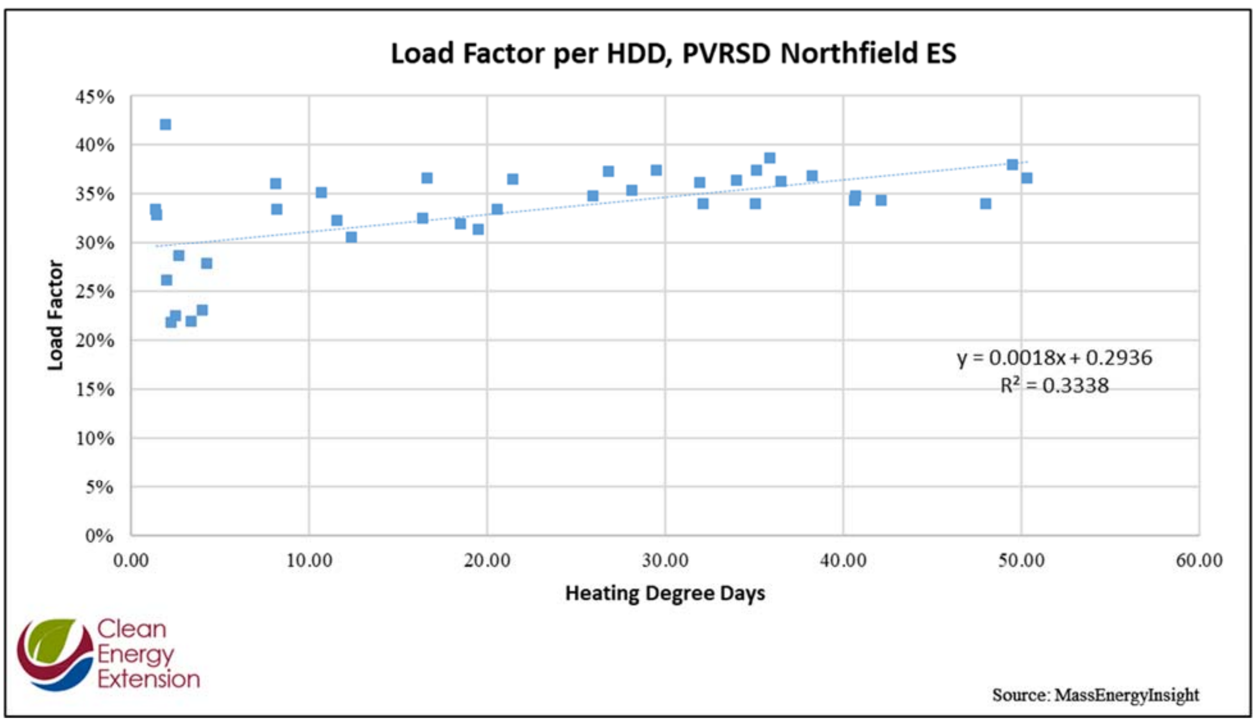


Figure L.14: Load factor is compared to weather conditions for each period based on the HDD. For Warwick, there is no correlation between load factor and HDD revealing that the peak demand for the building is not affected by weather conditions.

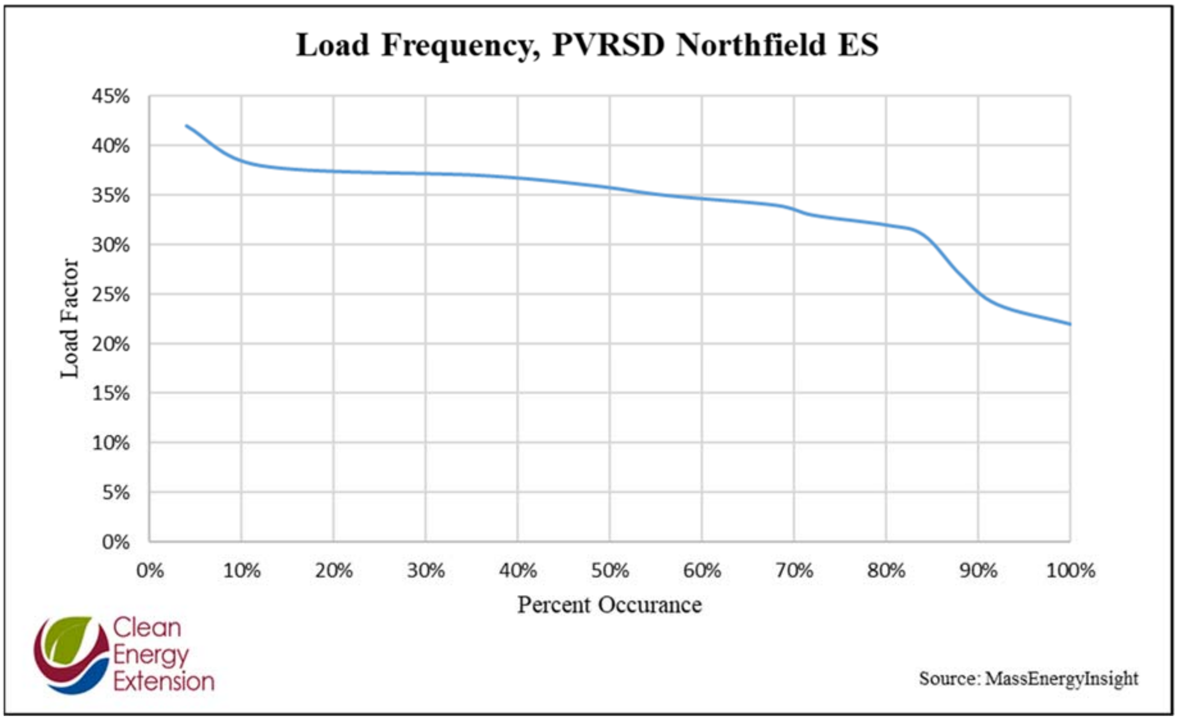


Figure L.15: Percentage of periods that the facility is operating above a specific load factor.

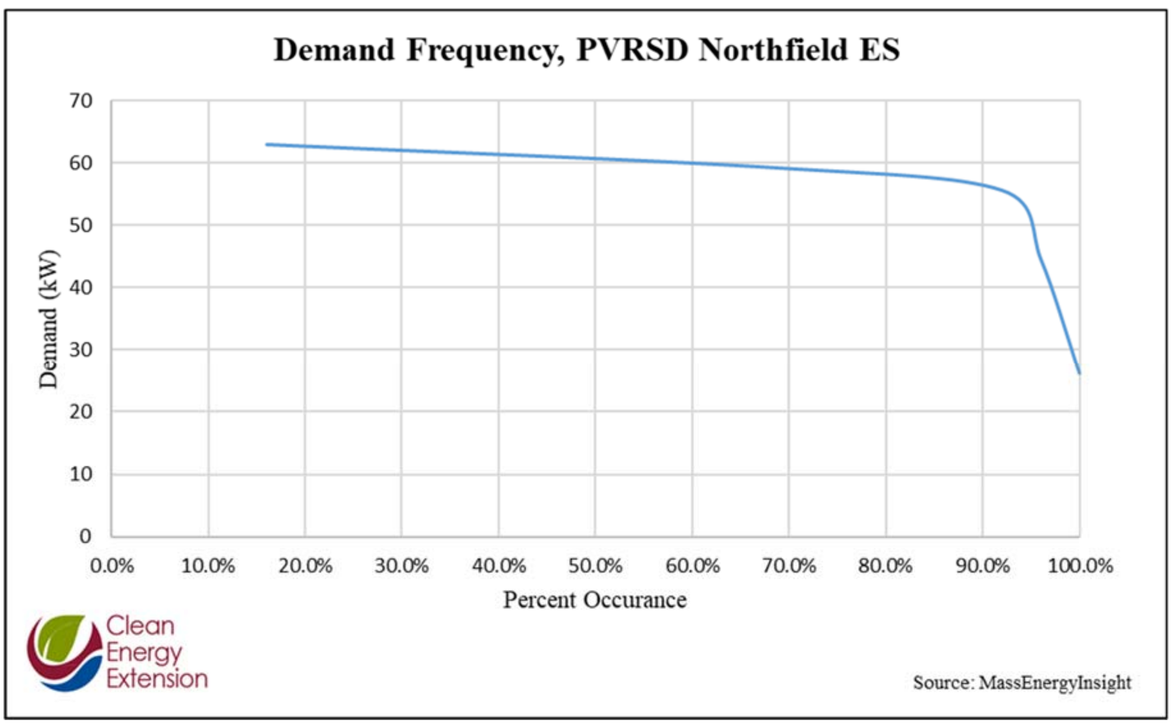


Figure L.16: Percentage of periods that the facility is operating above a specific demand threshold.