MINI-SPLIT HEAT PUMPS

Opportunities for Demand Reduction and Energy Savings

April 20, 2016

This report was submitted to the Public Utilities Board, Newfoundland and Labrador, in response to rate applications for local utility companies. It's primary purpose is the demonstrate the effectiveness of mini-split heat pumps for decreasing peak winter demand and lower overall energy consumption on the island of Newfoundland. Secondary objections include providing guidance on equipment selection, sizing and operations.

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OBJECTIVES

Primary - Demand Reduction:

1. Demonstrate the potential for mini-split heat pumps (MSPH) to reduce peak winter demand on the Newfoundland islanded electrical system
2. Demonstrate that the winter demand peak loads with baseboard heaters for new energy efficient houses are twice the peak loads of older housing stock with electrical baseboard heaters and demonstrate that the peak load is worsened by the present strategy of using programmable thermostats with nighttime setback.
3. Propose an alternate demand reduction strategy to reduce peak demand from domestic hot water tanks

Secondary - Energy Efficiency:

3. Demonstrate effectiveness for MSHP system to effectively and efficiently provide whole home heat, without the need for electric backup
4. Provide recommendations on MSHP selection, sizing and operation
5. Provide recommendations on acceptable makes / models of MSHP for the island of Newfoundland
6. Comment on effectiveness of conservation programs currently offered by local utilities
7. Elasticity Impacts - MSHP Reducing Overall Energy Use and Peak Demand

MSHP - A Mature & Proven Space Heating Technology

MSHP's are a heating and cooling technology that was initially developed in the 1970's by Asian manufactures as a step up from the window air conditioner. The main vision was the same: provide spot cooling to homes and buildings where a more complete, whole-system approach was either unfeasible due to space or financial constraints, but ultimately serving as a much friendlier cooling - and now more common heating - solution.

Over the last three decades, continuous advancements in the technology have resulted in significant performance improvements, including:

- Increases in capacity
- Extended performance range, at the high and low end
- Variable speed fans and compressors and
- Automatic control features

MSHP have become widely adopted in Asia and Europe, and are quickly being adopted in the United States and Canada.

With improving functionality and performance, numerous utilities and government agencies in North America have studied MSPH systems over the last 10 years. Study after study demonstrates that the system meet or exceed performance and customer expectations. They are effective in reducing peak demand while improving energy efficiency. Many jurisdictions in the United States and Canada offer incentives for installing MSPH systems.

The 2015 report by ICF International, titled "Newfoundland Conservation and Demand Management Potential Study", was commissioned by both local utilities. This report notes the superior performance of MSHP systems. On the subject of demand reduction, while ICF chose to omit the demand reduction savings for heat pumps on Page 90 of this report, they state in Note 29 that this is a conservative assumption for the island of Newfoundland, and that many heat pumps in the St. John's region will continue to work in heat pump mode and not revert to electric heaters during the coldest winter days of this region.

Basic Assumptions Used In This Report

The technology is proven, with multiple manufactures providing quality systems that can:
1. Efficiently provide heat down to -20C and lower
2. At -20C, provide heat that is at least 200% more efficient than baseboard electric heaters

1. Island Peak Demand Reduction

Island peak demand occurs during winter months in the morning and evening. The primary cause is the widespread use of electric baseboard heaters and the increase in morning and evening use of space heating to counteract night and day time setbacks as people are sleeping or away for work and school. While these setbacks have some effect on lowering monthly heating bills (by lowering the average temperature of a house), the effects on peak demand results in excess generation and distribution that spend most of the year offline.

Peak demand on the island of Newfoundland is compounded by the following:
1. Common adoption of electrical baseboard heaters over the last 30 years as the primary source of home heating and also for domestic hot water
2. Lack of economic alternate heating options available in other jurisdictions, such as natural gas
3. The practice of oversizing electric baseboard heaters in new home construction, especially as home energy efficiency standards have continued to increase.
4. Promotion of night setback as a means to lower monthly energy bills
5. Adoption of central heat pump systems that have built-in electrical heaters that automatically cut in when rapid warmup is required and during low temperatures.

Items 1 and 2 above are well understood and will not be explained further.

With regard to baseboard heater sizing recommendations (item 3), you will not find any recommendations or rules of thumb or guidance on websites of the local utilities. Sizing is left up to the contracts. Common rules of thumb, dating back to the 70's, is that a house requires 10 |Watts of electric heaters per square feet of floor space (or 10kW/1000 square feet). An unofficial recommendation was found on one of the websites of a major Canadian homebuilding supplier, stating: "The average home requires a baseboard heater that provides 10 watts of power per square foot" with recommendations to increase this by 25% for poorly insulated homes and decrease this by 25% for newer, more efficient homes.

Modern homes typically have heat losses in the range of 3W to 5W per square foot at -20C. This represents 100-200% of unneeded, yet installed, heating capacity. When combined with night and daytime setback, the peak demand issue to grow larger, and is currently being solved by adding additional generation and distribution.

Electrical baseboard heaters are not intelligent devices. A 1000W heater can only be in one of two modes - complete off or completely on. The purpose of a thermostat is to regulate the room temperature by controlling how long the heater is on and how long the heater is off. For example, if a small room has a 1000W heater installed, and requires 500W of heat to maintain a room temperature of 21C, the thermostat will cycle the heater on and off (½ the time on, ½ the time off) to maintain this temperature. If the thermostat set point is changed (increased or lowered), the following will happen:

- If you decrease the room temperature to 18C, the room will require less heat to maintain 18C vs. 21C, say 50W less (or 450W). The thermostat will lower the room temperature by keeping the heater off until the new set point is reached (18C), and begin cycling on and off again to maintain the temperature at 18C.
- When you increase the room temperature from 18C back to 21C, the thermostat will keep the heater 100% on until the room reaches 21C, and then start cycling on and off to maintain the temperature at 21C.

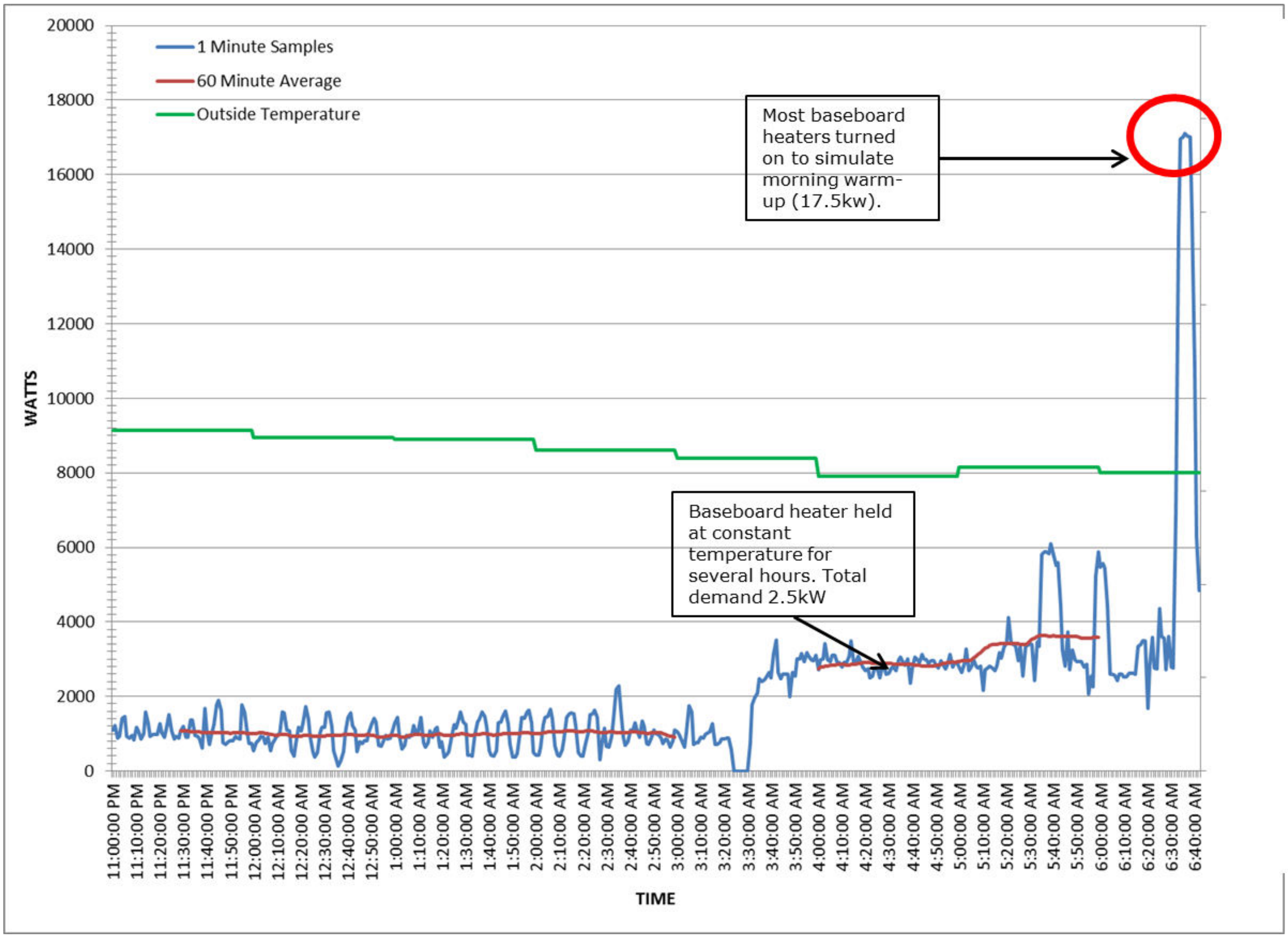
Newer electronic thermostats do the same thing, but they cycle more frequently to keep the room temperature more constant.

Expanding this one room example to a 2000 square foot house, with 20kW of installed heat, the following will typically occur, day after day:

Time of Day	Average House Set point (C)	Average Heating Load (kW)
Evening	21	10
Start Nighttime Setback	21->18	0
Overnight	18	9
Morning Warmup	18->21	20
Start Daytime Setback	21->18	0
Daytime	18	9
Evening Warmup	18->21	20
Evening	21	10

This example demonstrates a 100% peak demand over the average energy required to maintain a comfortable household temperature and is caused by a combination of excessive installed capacity combined with the widely accepted practice of using night and daytime setback.

The effect of excessive capacity of baseboard heaters and night setback has been demonstrated by our own test case. Testing is based on a 10 year old, 2 story home in the St. John's region, that is certified R2000. This home has approximately 4000 square feet of heated space, and was initially constructed with 20kW of baseboard heaters (or 5W per square foot, ½ the common rule of thumb). Heating requirements at -8C have been demonstrated to be 5kW of baseboard heaters (and calculated at -20C to be 7kW). As demonstrated in the following graph from April 2016, house temperatures are easily maintained with 4kW at 0C of electric baseboard heaters. When most thermostats are simultaneously increased to simulate at typical morning warm-up, the total heating load increases to 18kW's.



MSHP's counteract peak demand from baseboard heaters in two ways:

1. The installed peak demand of a MSHP will always be less than the installed peak demand of electric baseboard heaters to heat the same space. This is due to their ability to produce twice the amount of heat as an electric baseboard heater even at low temperature extremes.
2. Due to the improved efficiency of MSHP's, night and daytime setbacks serve no advantage to the consumer. Using night setback and the subsequent morning warmup will actually cause MSHP's to operate less efficiently.

The residential sector in Newfoundland uses 650MW for space heating (reference ICF Report

Exhibit E59), spread across 160,000 residential units. This gives an average unit baseboard heat peak load of 4kW. Conservatively assuming that MSHP will operate 200% more efficient than baseboard heaters, this indicates a 2kW demand reduction per residential unit. For this island as a whole, this represents a winter demand savings of 320MW.

2. Newly Constructed Housing Increasing Peak Demand

New Canadian energy efficiency codes have been adopted for the city of St. John`s, Newfoundland. As a result, local utilities have cancelled incentives for insulation and windows for new house construction (and also cancelled incentives for older stock house window upgrades). Indeed, new houses do have much improved insulation levels and quality windows, where cities or towns have formally adopted these codes.

While newly built homes are typically more efficient than homes built in the 70’s and 80’s, they are also larger. Since official guidelines for sizing’s baseboard heaters do not exist, contractors continue to practice the outdated rule of 10W/square foot. Some use ducted air source heat pumps that reduce energy use, but these revert back to electric resistance heaters at low outdoor temperatures. At issue is the peak demand for these newer houses due to the electric heating load at these cold conditions. Larger homes that are more efficient may result is a levelling off of overall energy use, but it also results in an increased load of electric heaters, making a peak demand problem even worse. See Appendix C for a recent demonstration of a highly efficient 4000 square foot home that still has a peak heating demand of over 18kW.

One way to contain winter peak demand growth is to replace baseboard heaters with MSHP as their primary heating source for all new homes constructed, and adopt this requirement in local building standards. As well, use of centralized heat pumps should be discouraged by rate penalties or restrictions on the size of back up heaters.

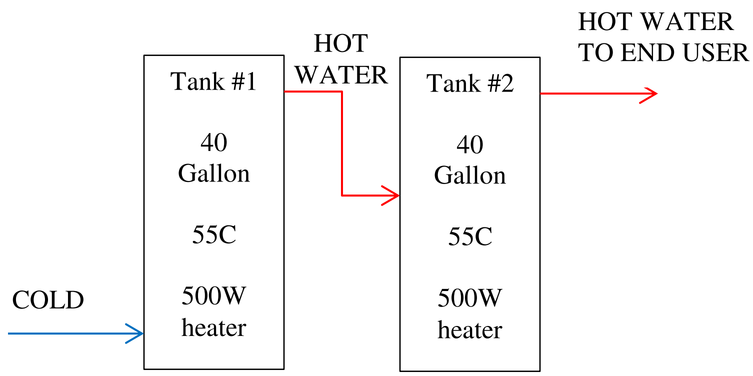
3. Hot Water Heating Peak Demand

The standard residential hot water tank has a 3000W heating element. When hot water is not being used, the element occasionally cycles on and off throughout the day, but only for short periods of time, to maintain the water temperature in the tank.

Similar to baseboard heaters, the peak demand for hot water is in the morning and evening. As soon as a small amount of hot water is used, the element will automatically turn on to heat the cooler water that is replenishing the tank. When this happens, the 3000W element comes on, and stays on, until the tank temperature is returned to its set point (typically 130F / 55C). For a standard 40 gallon tank, a 10 minute shower that empties ¼ of the hot water, will take approximately 50 minutes to heat back up. With 160,000 residences on the island, if 25,000 homes concurrently increased hot water demand in the morning and evening, this alone adds 75MW to the system demand at peak times (3kW per hot water tank x 25,000 hot water tanks = 75,000kW or 75MW). This is significant.

This demand can be reduced several ways:

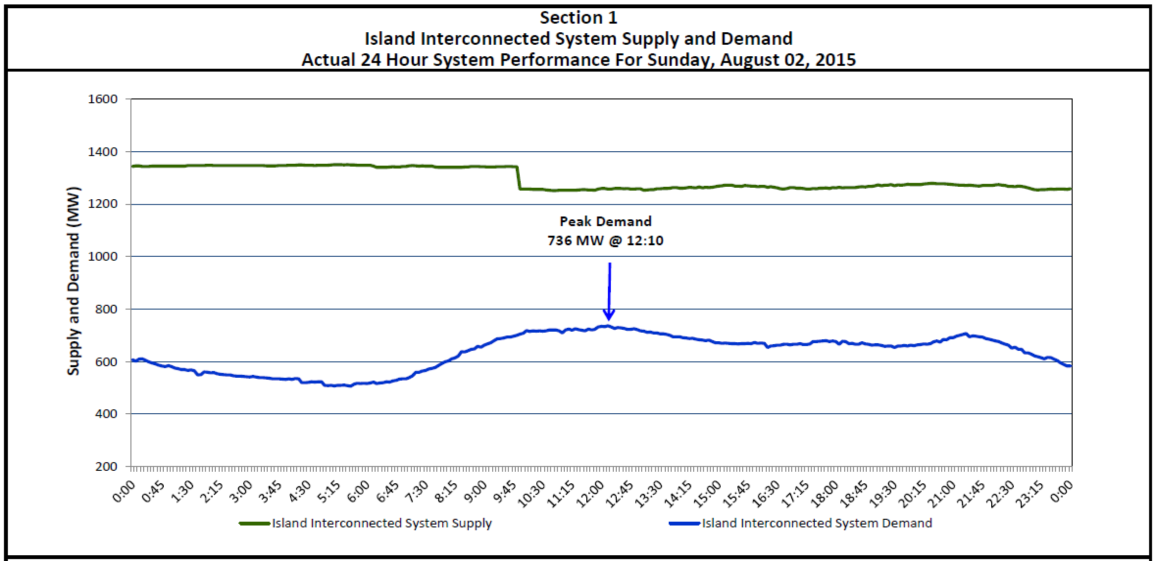
1. Promotional / educational programs by the utilities to encourage hot water usage outside of peak times
2. Installation of programmable timers on all hot water tanks to ensure heaters to not cut in during peak times. Since standard tanks are sized to handle several showers successively, there is no need to reheat the standard tank at peak times. Programmable timers would effectively transfers the reheat period to late morning / midday and late evening / overnight when demand from other loads are lower, helping to flatten out the peak.
3. Install two standard tanks in series, but each tank has a much smaller heater (say 500W instead of 3000W). This system would reduce the peak heating demand from 3000W per household to 1000W per household. End users would still have plenty of hot water for peak times - now 80 gallons vs. the standard 40 gallons. During non-peak times, the tanks would slowly return to its set point during the day.



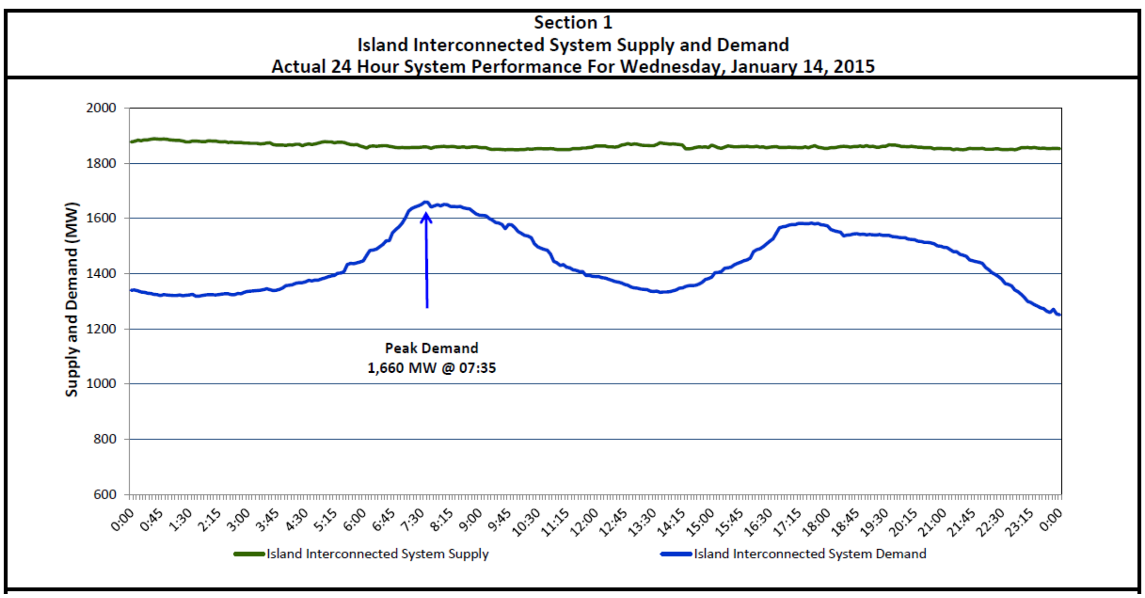
The most effective strategy, both for reducing peak demand and with customer satisfaction, would be to install two hot water tanks in series. As demonstrated above, this would reduce peak heating demand by 2/3 from 3000W to 1000W. Spread across the island, the peak savings would be in the range of 25-50MW.

Combined Effects

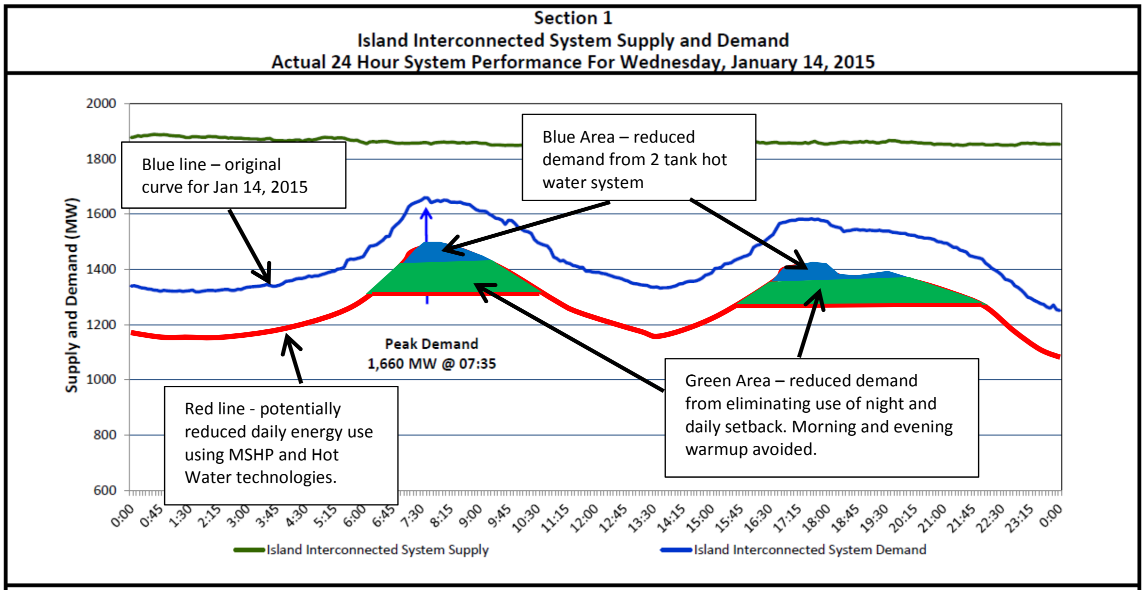
Below are two daily power usage charts for the island interconnected system from 2015. August 2, 2015 (27C daytime high) represents the island demand without heat. The average load is approximately 700MW.



January 14, 2015 (-6C daytime high, -16 daytime low) represents the island demand with heat plus peak demands in the morning and evening. The average load is approximately 1500MW, with peaks at 1660MW.



Making adjustments for average savings based on MSHP performance, elimination of night setback and introduction of a series hot water tank system as described above, the load curve for January 14, 2015 (and every winter day) would have the peaks chopped off, and the entire curve lowered, reducing the average demand by approximately 300MW and the daily peak demand by over 400MW, as shown below.



4. MSHP - Whole Home Performance

Formal studies from other jurisdictions, demonstrate long term performance of entire homes using MSPH systems. Lab testing in 2011 by the US Department of Energy demonstrated the ability of \MSHP's to be nearly 200% more efficient than resistance heaters at temperatures well below -18C. Another study was issued in 2015 by the US Department of Energy titled "Long-Term Monitoring of Mini-Split Ductless Heat Pumps in the Northeast". This report involved three years of study on the eight houses in Massachusetts. Several key findings include:

- There were no cases where there were issues with equipment sizing or lack of capacity, which indicate that cold-temperature heat pumps are a viable strategy as a single heat source in cold climates.
- When MSHP's operate using night temperature setback, the following warm-up period results with the unit running at maximum capacity, and its least efficient state.

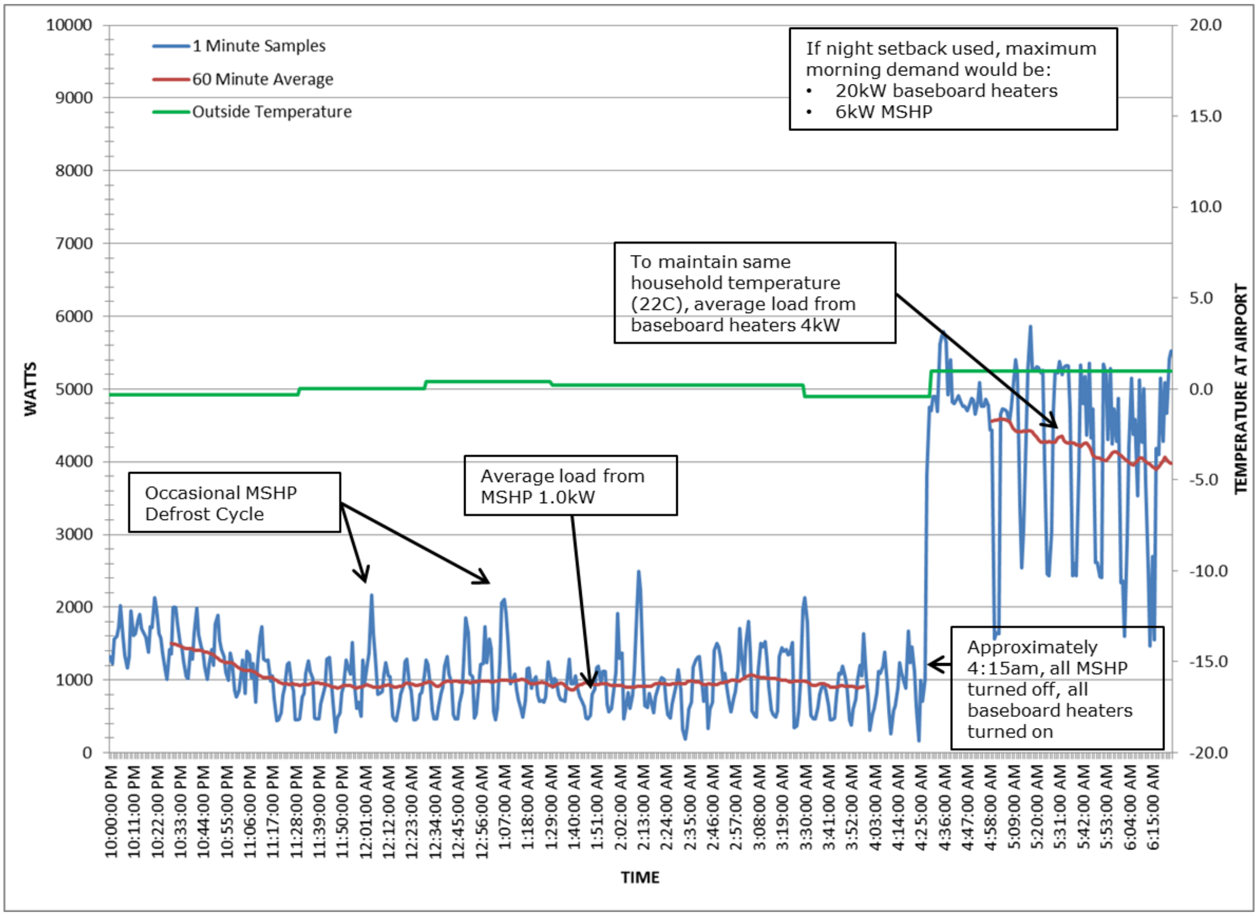
Whole home formal studies from Newfoundland utilities do not exist. Personal knowledge of existing, long term whole home installations include:

- Single level home in the community of Bishop's Cove, Conception Bay. House is 30 years old, approximately 1000 square feet. This home has been heated by a single unit (one outdoor compressor, one indoor "head") for approximately 6 years. This unit is rated for -18C, has never shutdown for cold temperatures, and baseboard heaters have not been used since it was installed. Night setback is not used. Annual heating costs are estimated to be less than $300/year.
- Single level home in the community of Petty Harbour. House is 40 years old, approximately 700 square feet. This home has been heated by a single unit (one outdoor compressor, one indoor "head") for approximately 5 years. This unit is rated for -18C, has never shutdown for cold temperatures, and baseboard heaters have not been used on the main level it was installed (electric heat still used in the unfinished basement / crawlspace). Night setback is not used. Annual energy consumption has decreased by approximately 25%. Winter energy

consumption has decreased by approximately 35%. Payback with 3 years, with incentives from the federal and provincial governments (payback would have been 5 years without incentives). Note that both the federal and provincial incentives have since been cancelled.

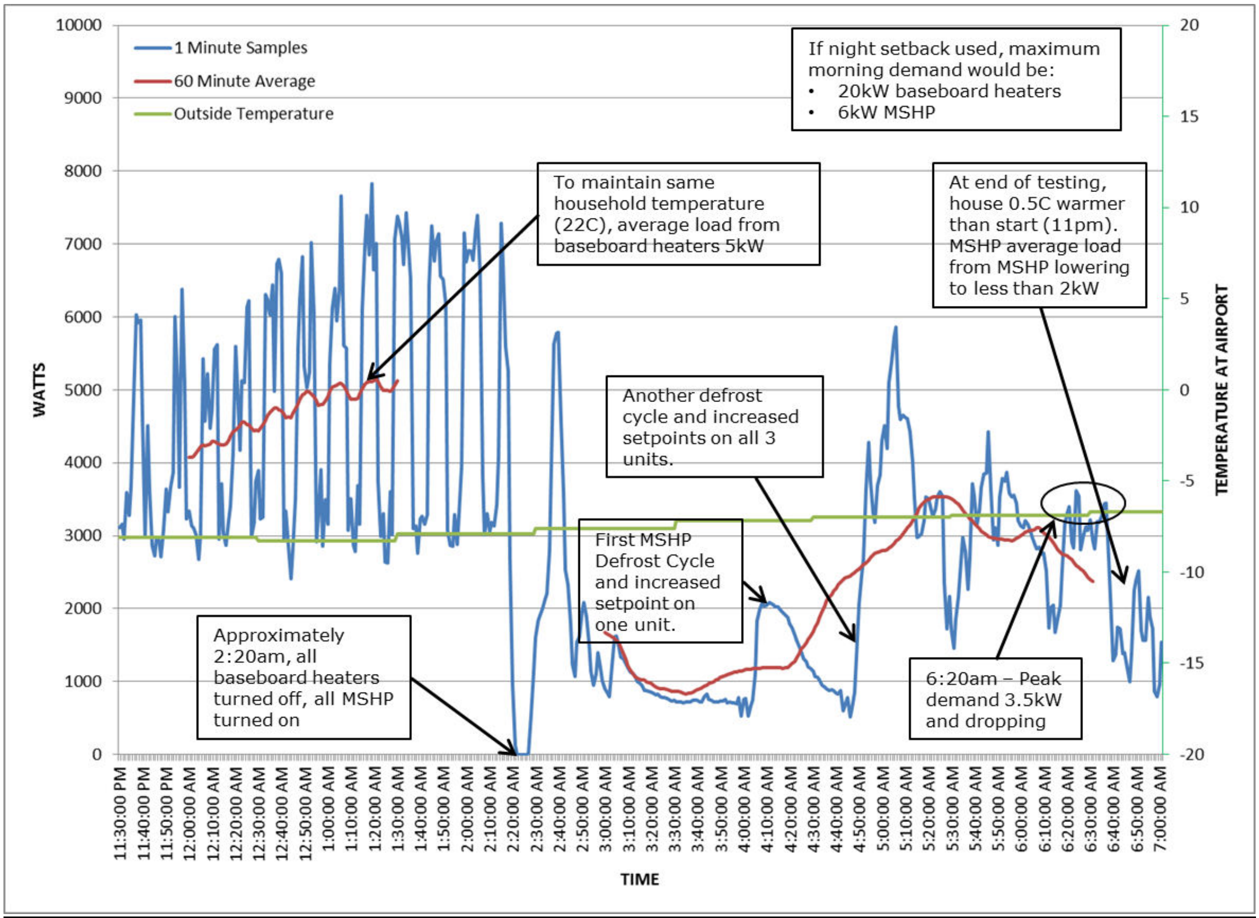
- Larger 2 story home in the St. John's area. House is 10 years old and is more energy efficient than a standard home due to its R2000 certified construction. This home has been heated by three multi-units (three outdoor compressors, each with two indoor units) for approximately 3 years. These units are rated for -15C, has never shutdown for cold temperatures, and baseboard heaters have not been used since they were installed. Night setback is not used. Since MSHP have been installed, the entire house has been maintained at 22C, including the basement and attached garage, increase whole house comfort levels. Annual energy consumption has decreased by approximately 15%. Winter energy consumption has decreased by approximately 25%, while eliminating night setback and increasing comfort levels.

Recent testing of property 3 listed above (2 story home) has demonstrated just how effective and efficient MSPH are. The following graph is based on data collected for the night of April 7, 2016, with an outdoor temperature of 0C. The test was conducted overnight, when all loads in the house are turned off, including major appliances (fridges, freezers, hot water tank, etc). The house is heated with all MSHP's operational for until 4:00am. The average demand was 1kW or 0.25W/square foot. At approximately 4:15am, all baseboard heaters are turned on to maintain the same house temperature (22C). The average demand jumped to 4kW (or 1W/square foot) to heat the exact same space. All measurements were taken at the panel, coming in from the meter. In this example, the MSPH system was lightly loaded, and demonstrates the ability to use 4 times less energy to heat the same space as electric baseboard heaters.



And below is another direct performance graph from an evening at -8C, recorded the night of April 6, 2016. This graph demonstrates:

- Household heating demand was 5kW (based on electrical baseboard heater load)
- MSHP load during simulated warmup (by increasing set points of each heat pump) never exceeded 6kW, which was 2kW below the peak demand of the baseboard heaters
- Early in the morning, MSHP average load was continuing to trend down and likely would have settled out at less than 2kW.



See Appendix C for a brief study case for this R2000 house conducted April 2016.

<u>Typical Payback</u>

Exhibit 6 of the ICF report states that the typical single family detached home uses 13613kWh/yr to heat their home with electric baseboard heaters. Installing a MSHP system in this typical home with an average performance factor of 3 (3 times more efficient that electric baseboard heaters), would give an average savings of 9066kWhr/year. At $0.106/kWhr for electricity, this represents a $961 annual savings, before tax ($1105 after 15% tax).

A typical single detached house in Newfoundland is approximately 1100 square feet. A house of this size would require two MSHP systems, with an installed cost of approximately $7000. Payback for the above described system would be 6.3 years ($7000/$1105), not including interest charges.

At pre-Muskrat Falls energy rates, over a 20 year equipment life for the MSHP, the total savings would be approximately $15,000, not including interest charges.

Once Muskrat Falls is online, with power rates at $0.20/kWhr, payback would be 3.4years, not including interest charges.

At post-Muskrat Falls energy rates, over a 20 year equipment life for the MSHP, the total savings would be approximately $33,000, not including interest charges.

All of the above payback and savings assume quality units are installed, sized to perform efficiently at cold temperate extremes (so no baseboard heaters are used), and are operated in automatic modes. The importance of this is discussed further in the next section.

4. MSHP Selection, Sizing and Operation

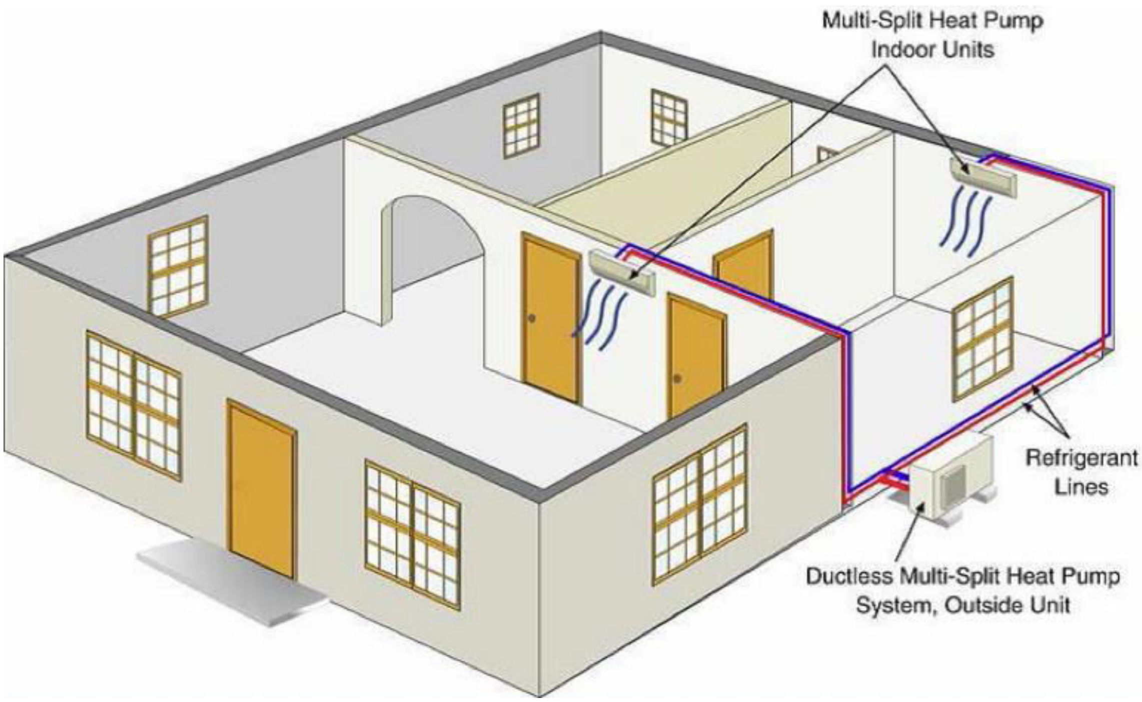
System Selection

These systems are available in many different configurations:

- One outdoor unit serving one indoor unit
- One outdoor unit serving two or more outdoor units (shown below)

The exact configuration will depend on the size and layout of a house. Some general guidelines include:

- If your basement is developed and used regularly, start from the basement and work your way up.
- If you don't intend to heat your basement, start by installing units on the main floor.
- Focus on placing the indoor units so they serve larger rooms in the house
- Heat rises so a second story should have no more than one unit, and that unit located in a hallway
- Units are typically too high in capacity for heating an individual bedroom
- If air conditioning is an important feature, a 2 story home will need at least one indoor unit on the second level for dehumidification and cooling.
- Outdoor units are very quiet and should not be a noise issue for the homeowner or neighbours
- Units should not be installed directly on the ground, to prevent being frequently covered by snow.
- If possible, install outdoor units in sheltered locations to improve performance and life expectancy. Note the required clearances for adequate air circulation.
- Consider installing a wind guard, especially if the unit is predominately exposed to easterly or westerly winds. South side installations provide the best overall performance.
- Consider installing units in attics to provide enhances protection and performance in extreme weather conditions. In these cases, allowance must be made for water drainage during defrost cycles.
- Outdoor units will frequently drain water during winter defrost cycles. They should be installed in a location where ice build-up to not present a hazard or damage. Ice build-up on the ground does not cause issues, but should be avoided near steps and pavement.



<u>System Sizing</u>

- Typically contractors are sizing units based on two irrelevant factors
    - Tons of cooling (e.g. 1 or 1-½ ton unit) – these are air conditioning terms and not relevant to the heating capacity of the unit at low temperatures. Heating is by far the primary reason for installations in Newfoundland.
    - Performance at standard temperatures – which are based on 8C.

  When a contractor quotes a 1 ton unit, they are quoting the units air conditioning capacity at 8C – a useless fact when specifying a unit for heating in January.

Using the above selection criteria often results in undersized units, that offers lower than expect energy savings and likely have insufficient heating capacity at extreme low temperatures.

To ensure proper unit sizing for heating, units should be sized based on the following criteria:

- Outdoor units have a minimum operating temperature of -15C, with -20C or lower should be considered for central Newfoundland.
- Size unit(s) to provide full heating load plus 25% margin at -15C

While this method will provide excess capacity during the shoulder seasons (fall and spring), it will provide:

- Exceptional efficiency and performance during the bulk of the heating season
- Sufficient heating capacity while consuming ½ the power of electric baseboard heaters at low temperature extremes.

During the shoulder seasons, surplus capacity can be reduced by turning some units off, such as upstairs units or units serving sunny side / south facing rooms.

<u>Operation</u>

- Each unit will come with a remote control. The primary function of the remote is to set the temperature of the indoor unit and select the mode of operation (heating or cooling).
- Remotes typically have other features, such as:
    - Quite mode
    - Power mode
    - Manual speed control
    - Manual direction control of the air flap
    - Night setback
    - Motion sensors that automatically setback temperatures when rooms are vacant
    - On/off timers(if used for night setback)

  It is strongly recommended to avoid using the features. They will decrease the efficiency of the unit, by making it work harder to maintain or achieve temperature set points, and can be detrimental to the overall energy efficiency of the unit.
- Temperature control varies from manufacturer to manufacture. Some sense the temperature at the remote, and adjust the output of the indoor unit based on the temperature sensed at the remote, similar to a conventional baseboard heater thermostat. Other manufacturers use a remote to set a temperature, but the room temperature is actually sensed from the air returning to the indoor unit.

- Indoor units need a drain connection for air conditioning operation
- Indoor units need a small, reusable filter removed and cleaned several times a year, particularly in winter time
- Outdoor units do not need any maintenance. After large snow storms, they should be checked to make sure they are not surrounded by snow.

6. Acceptable Makes & Models

The Take Charge program recently started offering financing assistance for ratepayers that install MSHP systems (as well as more traditional central or ducted heat pump systems). While a quality unit is very important, there are many of them on the market but the financing criteria on the Take Charge website makes almost all makes and models ineligible for financing programs (due to the required efficiency factor). Limiting customer selection will have a negative effect on the uptake of this program.

Nova Scotia provides a comprehensive list of acceptable makes and models, and should serve as a basis for an approved Newfoundland list. Units listed by Nova Scotia qualify for incentives from provincial programs in Nova Scotia.

http://www.efficiencyns.ca/tmpimages/minisplits.pdf

Newfoundland utilities could adopt this list, or modify it based on region of installation. For example, the list could be more restrictive for central Newfoundland, where winter temperatures are lower.

7. Effectiveness of the Take Charge NL Program

Insulation rebates have been effective in reducing overall energy use. TV ad campaigns have brought attention to available programs by making the topics of conservation and efficiency funny and entertaining. However, when comparing the local programs with other jurisdictions in Canada and the United States, the program has done little in comparison to reduce peak demand.

In 2007, the Newfoundland and Labrador Government had a plan to change our culture. It came from the Energy Department, and its catch phrase was that we develop a CULTURE OF

CONSERVATION. Soon after our power companies rolled out its TAKE CHARGE plan and studies were commissioned for 5 year plans for improved customer efficiency measures. Nearly a decade later, in Newfoundland, we have resorted to rotating outages to deal with power system failures and insufficient capacity to meet a rising peak demand. Just this past winter we experienced a energy supply problem, caused by low rainfall, requiring millions of dollars more to be spent on thermal generation at Holyrood. An aggressive conservation policy in Newfoundland (where 85 percent of our energy comes from renewable island hydro) could have helped achieve 98 percent clean renewable energy and significantly reduced thermal generation. Efficiency measures, primarily at the customer level (for large end-use electric space heating and domestic hot water) should have been the prime target, and could have actually reduced overall customer energy bills.

Our neighbour, Nova Scotia, has actually transformed itself with Efficiency Nova Scotia. In particular, for space heating it promotes mini-splits as a HEATING REVOLUTION. By 2011, uptake peaked, with the help of significant rebates, to 20,000 units installed in one year. The uptake was so great that they have now reduced the rebate to about half. Meanwhile, New Brunswick, whose winter peak demand is also high, provides a rebate for high efficiency units that assist with bringing down their system peak demand. The mini-split technology has been proven to operate reliability well below -18C, while providing demand reduction. Coefficient of Performance is about double that of baseboard heaters.

See Appendix A for a detailed comparison between Efficiency Nova Scotia and the Take Charge rebate program, and efficiency measures offered.

8. <u>Elasticity</u>

In economics, elasticity refers the degree to which individuals (consumers/producers) change their demand/amount supplied in response to price or income changes. Higher prices naturally gives a result of lower sales. The relationship is defined by the elasticity factor, (example, if the price goes up 100 percent and the sales drop by 50 percent, then the elasticity factor is 50 divided by 100 for a factor 0.5. A low elasticity factor of 0.1 or 0.2 suggests the sales are little effected by price increases. A high elasticity factor, of 0.5 or higher suggests the commodity is significantly linked to the price.

The commodity of electricity is subject to this elasticity effect. This effect varies in various jurisdictions and countries. There are various studies available on the internet showing what the influences are on elasticity of electricity. There are minor influences like the economic well-being of customers, whereby growing average incomes of individuals then to offset electricity price increases, and so maintain a low elasticity factor. The dominant elasticity factor for electricity is the availability of alternatives for that commodity, in this case electricity. In most of North America electricity for space heat is NOT the prime end use. Space heat is most often provided by natural gas, oil, pellet stoves, or wood stoves. In those jurisdictions, where space heating is provided by electricity, the elasticity is influenced by the availability of alternatives for space heat, and the result is that in those areas, the elasticity factor is very high, 0.5 or higher. This results from the customers' ability to switch from one heat source. This requires electricity providers to be competitive or lose market share, and reduced sales.

Due to a robust economy and lack of competition for heating sources, local utilities have enjoyed the benefit of a relatively low elasticity factor for electricity. Newfoundland Power`s Mr. Henderson (PUB transcript of April 12, 2016, page 122) indicates an elasticity factor of 0.2. Going forward, Newfoundland Power, in discussions with Newfoundland Hydro, has indicated an elasticity factor rising from 0.2 to 0.3, this being a 50 percent increase from the current level. See Appendix B for PUB transcript covering recent discussions with Newfoundland Power and potential impact of widespread adoption of MSPH on local utility companies.

Mini-split heat pumps are a cost effective alternative to baseboard heaters and electric backup duct heaters in central heating systems. Properly sized and installed to replace all the baseboard load, they provide a COP of 3 on average (a energy use reduction for heating of 66 percent) Newer more efficient models are increasing this COP to 3.5 average (a 72 percent reduction). Pay back at present is about 7 years. Post Muskrat Falls (with potential rates of 19.8 cents per kWh) payback will be less than 4 years. This is without rebates. For a typical house (1100 square feet), savings, assuming a 20 year life, will be about $15,000 at present rates, and would rise to over $30,000 post Muskrat Falls rates.

The effect on elasticity for electricity sales can be dramatic with the uptake of mini-splits. Elasticity of 0.5 or more may be likely. In the past, local economist David Vardy has opined that an elasticity of 0.5 should expected, his opinions may be independent of heat pump technology. Given the dramatic efficiencies of mini-splits for our climate, and the choice of this alternative, elasticity would be expected to jumps substantially higher than 0.3, to 0.5 or higher. The effect may be somewhat reduced by more conversions from oil and wood to mini-splits.

Mini-splits have a potential for peak load demand reduction. Peak demand reduction can slow the need of future new generation and distribution assets and save on transmission losses. It also reduces thermal generation costs during wintertime. To this extent it can positively impact elasticity effects for electricity going forward, to help restrain a high elasticity factor. Maximum demand reduction requires a coordinated and holistic strategy of best practises to maximum the mini-split technology benefits. The present market for heat pumps results in ducted central systems that offer no demand saving at peak times, and mini-splits that are generally undersized and so offer little if any peak demand reduction to the power system. Such a market will do little if anything to reduce peak demand. Indeed, central systems are promoted by contractors as they find them more profitable, with little consideration to maximize energy savings, and no consideration for the issue of system peak demand.

Conclusions

1. The monitoring of the R-2000 house demonstrates the large savings for both energy and demand reductions at -8C conditions under field conditions. This data supplements prior US Department of Energy laboratory testing in 2011 to conditions as low as -25C , as well as many North American installations for climate conditions for temperatures equal to or colder than St. John's, Newfoundland region. Testing method was by direct comparison of heat load only, by switching in the middle of the night from MSHP to baseboard heaters, with automated monitoring at 1 minute intervals and calculation of 1 hour average loads, all while maintaining a constant household

temperature.

2. The R-2000 house testing demonstrates the large increase in peak load by the simulated reset of the programmable thermostats.

3. Dual hot water tanks connected in series, with much smaller heating elements, can be a cost effective strategy to reduce peak load. It offers no energy savings.

4. The R-2000 test house, under operation since 2014, demonstrates that whole house heating, without triggering backup baseboard heaters, provides high comfort levels throughout. This is an effective strategy for all new houses for optimum cost effective efficiency and power system benefits.

5. Efficiency Nova Scotia's incentive program and mini-split standards and model selections should be adapted for Newfoundland, with substantial mini-split rebates to encourage uptake from the present relative low level.

6. Mini-splits can severely impact the elasticity factor for electricity, as a low cost alternative for space heating. This is to the benefit of the home owner as well as the power company. Power company benefits include reduced peak demand, future infrastructure cost savings, reduced transmission losses, savings on thermal generation, and a reduction on the water reservoir during years of low rainfall.

7. Rebates and low interest loans for mini-splits should be designed to permit payback in 5 years or less so as to be attractive for low and mid income families.

8. Rebates could be issued to contractors, subject to and prorated according to actual reduction of the customer's yearly energy bill: to assure quality equipment, proper sizing, good installation, customer instruction for proper operation. This also allows utility administration costs to be low, to permit passing of tests as a cost effective measure, having already been indicated as the most significant measure for energy savings, and suitable for immediate installation by the ICF study of June 2015.

About the Author

Winston Adams is a semi-retired business man with 40 years of experience in the commercial heating and cooling industry in Newfoundland and Labrador. Formally trained as an electrical engineer, Winston also worked early in his career with Newfoundland Hydro as a substation designer. Winston has had a professional and personal interest in efficient heating technologies for some time. Winston took an interest in MSHP approximately 10 years ago as they started to appear in commercial designs. Noticing their superior performance, he has installed MSHP in his own properties, and assisted family and friends with similar installations. Winston has no commercial interest in the sales of MSHP's. He can be reached at 709-726-6512.

Appendix A

Efficiency Program Comparison

Program Component	Rebates / Criteria	
	Efficiency NS	Take Charge
1 mini-split heat pump, tier 1	$400	not available
1 mini-split heat pump, tier 2	$500	not available
1 mini-split heat pump, tier 3	$700	not available
extra head (multi-unit)	$150	not available
central ducted heat pump	$1750	not available
air to water heat pump	$1750	not available
geothermal heat pump	$2500	not available
HFPF mini-split energy factor, single head	9	10
HSPF mini-split energy factor, multi head	8	9
charge for energy adviser	$99	
approved mini-split contractors	yes	not available
rebate maximum for residential	$3950	$1175
low interest loan rate $2500-4999	2%,5 years	7%
low interest loan rate $5000-14,999	1% ,5 years	7%
low interest loan rate $15,000-25,000	0%, 5 years	
maximum insulation rebate	$3950	$1000
wood pellet stove	$800	not available
wood pellet boiler, furnace	$1750	not available
heat pump water heater	$350	not available
solar water heater	$1250	not available
drain water heat recovery	$300	not available
heat recovery ventilator	$300	175
misc. insulation	$200	
old fridge credit and free pickup	$300	not available
new home efficiency rebates	$2000	not available
small items, lights, thermostats	$3-$75	$10
fridge, freezer, TV, washer	0	$100, $100, $30, $100
business	$500,000	$50,000
feasibility study for business	$15,000	$5000
scope study for business	$1,000	not available

Appendix B

Excerpt from PUB Transcript April 12, 2016

The following including direct transcript quotes and additional comments to put context to the quotes.

Sales of electricity by Newfoundland Power were robust up to 2014. The PUB transcript of Apr 12, (page 109), The Consumer Advocate Mr. Tom Johnson states it to be a 2.3 percent sales growth. Mr. Henderson of Newfoundland Power advises the economy was week during the 1990s and sales growth then was below 1 percent, average about 0.6 percent growth. Since the year 2000, with improved economy electricity sales went up. But that for the next 5 years, in terms of customer income, ``is worse than it was through the 1990s. So, that kind of gives me pause when I`m looking forward as to what we`re going to be facing over the four or five years.......the big turnaround we`re seeing is that while housing starts is declining, our average use is declining, and it`s been quite a long time since we`ve seen that, and I don`t even think in the early 1990s we saw negative growth, but so far this year, you know, we`re kind of scratching our chin and keeping our fingers crossed that we get the amount of growth that we see in the forecast that we have here, and there is downside risk and we`re seeing that in the current forecast...... there are customers that are dual-use, basically they have the option of electric versus oil, and you know, we`re starting to think the drop off in load that we`re seeing is possibly as a result of dual-fuel switching, you know, giving up using their electric heat in whatever form they have and moving back over to oil.

Mr. Johnson asks ``is there anything about how you`ve gone about forecasting that would make us think that you're ability to forecast going forward would be any less reliable than how you forecasted in the past``. Mr. Henderson replies: ``No there`s nothing...... I suppose you could say there`s a trend underneath it. Other than that, we don`t see anything within the methodology that would suggest the forecasts are going to be inherently off, right. We do know that one of the elements of the load forecast which really hasn`t been an issue in the past is our elasticity forecast.

On this, in 2011, the Manitoba Hydro International study done for the PUB pointed out that neither Newfoundland Power nor Newfoundland Hydro used best methods of end-use research to aid forecasting, and made a recommendation to to end- use research. This appears to be very significant issue when there is an uptake of heat pumps on the system, especially mini-splits units.

The evidence presented earlier in the day by David Adams proved substantial COP of such systems...a COP on average of a good installation of 3.0 and higher, and high reduction of peak loads for the tested temperature of -8C, with substantial reserve heating capacity. As to this sort of data, Mr Henderson himself acknowledges his role to estimate the potential impact of various technologies on energy use and system peak demand, and says Newfoundland Power did it`s own detailed study of miini-splits in the Newfoundland context, and acknowledged that the units could have a COP as high as 4.5, and that there are now around 5000 installed in Newfoundland, about 1000 being installed each year and that the number is growing, and that an average home can have savings of about 5000 kilowatt hrs per year, about 600 dollars in saving...and that customer demand is already growing and will increase further with anticipated increases in electricity rates.

Mr Johnson asked if their report was an authoritative piece of work, that is to say that these mini-splits are not going to be valuable from a system peak point of view.

(This author believes it seems reasonable to inquire whether Newfoundland Power is missing forecasting data by not doing proper end-use research on this important end-use: electric heat. The following excerpt may be instructive):

Mr. Henderson, in response to the Consumer Advocate, says :``NO , You know these devices are always changing and improving with time........it`s actually , from a utility perspective, it might even have a load building effect......we don`t expect to attribute any demand savings to that technology coming into our marketplace.......Since coming on stand, I looked under the hood of it you know, I recognize in hindsight that there might be some flaws in regard to the interpretation of it. As a result, i think the assumption where we stated this can be expected to contribute to a higher overall peak for those putting in mini-splits into baseboard heating. I think is overstating what might happen.......I guess ideally you`d love to be in there, as an engineer, had all the money in the world, I`d love to be able to do what Dave adams did for every single home through the coldest winter period and hope that you get a severe winter peak this winter, it`s about one in five years, where the combination is such that a peak is quite a bit higher then what it otherwise would be and that`s what we got to size the system for, so as a result, you know, ideally I`d love to be able to do what David did, collect that kind of data, probably collect even the data that Winston Baker put in his questions, which is a huge amount of data on the operation of each one. As an engineer, I`d love to have that data and I`d love to have it operating through these really cold periods that happen, you know, every once, every five years, but those types of studies can be expensive, you may have to wait for that time period, you know, and maybe you`ll get the results out if it.

We wouldn`t necessarily be looked upon too highly if we`re not doing what`s least cost for our customers, and as a result, we will deem it our spending.............obviously this is a very important end use, electric heat is a big end use for us and making sure we are doing the right thing by customers is what i think the public utilities board would expect, so we`ll continue to monitor it and do what we can to make sure things go and get installed, but to offer heat pump----you know, discounts and all that sort of stuff is, might be a little bit far to go...........

However Mr. Henderson states that: ``what we are going to see in the future is something dramatically different..... given the change in technologies that`s going on and opportunities for customers to save money, you know, off their bills, you know, they all constitute a fair bit of of uncertainty as to where we`ll be in six or seven years time.`` Mr. Henderson is questioned further by counsel Mr. Green: ``So, you really can`t offer an opinion at this point in time where as to what the impact might be.`` Mr. Henderson replies : ``That`s correct``.

The Chairman of the PUB takes up the issue asking Mr. Henderson: ``You`re telling us that I understand that these customer initiatives-basically, you don`t think they`re going to reduce peak demand.`` Mr. Henderson replies : When you consider mini-splits going into Newfoundland Power service territory ..... I think it`s 65 percent electric and everybody else, let`s say. We recognize that this is an advantage to everybody, so as a result all customers are liable to be installing it. Those who are installing it that currently don`t use electricity for heating may use electricity for heating. Those with baseboard heating will switch over to this. This may or may not, in and of itself, get decreases. There certainly might be depending on the quality of the installations and all that stuff we kind of talked about earlier. So, as a result, on average, to me there`s certainly risk that it`s going to actually increase peak even though it`s reducing --- well, I`m not sure what the energy is, I`d have to think about it more, but , yeah, there`s risk that this technology coming to the market is not necessarily going to do anything to reduce peak``.

Chairman Wells asks further : So basically what we`re saying is that the collective cost, the fixed cost, which are rising apparently considerably, are not going to be impacted at all by these improved efficiencies in energy delivery.`` Mr. , Henderson replies: If there`s a lot of fixed costs, and the costs are very small, the higher the load, the lower the price, you know, you got that dichotomy coming up. ``

Chairman Wells: And Muskrat Falls is, of course, a high fixed cost, isn't it. Mr. Henderson replies : A huge fixed cost, yeah, and Hydro`s reported estimate based on 9 billion dollars of investment is, I think, a price somewhere in the order of 19.9 cents, you know, within a few years--

Chairman Wells: ``Let me stop you right there. Now that 9 billion, does include IDC, interest during construction. Mr. Henderson replies: ``Yes``. .... Basically, the numbers that Hydro (Newfoundland Hydro) ---the number of 9 billion you will find in a footnote to a report that was done by the Oversight Committee, and it`s in a footnote in which the full document they talk about the construction cost, which is what Hydro is using, which doesn`t include IDC. The 9.03, I think include the IDC.

Chairman Wells: And that`s as of---well, whenever that was produced.`` Mr, Henderson replies: That was last fall I, think.

Chairman Wells: ``And they`re two years behind.... do you know how far they`re behind schedule, is there any public information on that``. Mr. Henderson replies: ``I haven`t actually studied the most current information. All I would be aware of is that there`s pressure in particular on the plant as to when it`s going to be installed. Hopefully, next week we`ll have some more answers on that.``

Chairman Wells: The people taking up these ---making these conversions, heat pumps, et cetera, I mean, they`re at the higher end of the income scale, are they,, do you have any data. It seems to me to be the case....the top 1 or 2 percent in the income distribution stream would be the ones who would be taking advantage of these subsidies or rebates or switching over. Do you have any data on that, do you know.`` Mr. Henderson replies: `` I really don`t know..... but anyway, we don`t have any particular information to suggest anything. We have this financing program out there. I suspect the fellows who are quite wealthy will be able to get a better financing rate somewhere else. For those people who have less ability to purchase these things , they may want to take advantage of it because it might represent a better way for them to pay for it, it`s on their bill, you know, it`s amortized over 5 years and it might make it work for them because presumably they`ll get some offsetting energy saving to do so. We are offering it out there, so as it is would enable a broader group of participation in the getting these things in place.``

Chairman Wells: ``Do you have any information, any studies done on, as costs increase, on ability to pay. Like it seems to me that the forgotten consumer in this whole thing are the people at the bottom end of the income scale, the people at the first percentile and the second percentile, the lowest income, they`re not in a position to take advantage of these rebates but they`re going to have to pick up all the costs, including if there are subsidies, for instance, or rebates, as taxpayers they will be paying for this , but they`re not going to be able to to avail or be in a position to avail``

Mr. Henderson replies: ``That`s right``.

Chairman Wells: `` Especially if they`re older people, I mean, the long run for me is six months, I put away my winter boots, am I going to need them again I said to the crowd inside. I mean, what we`re seeing in Newfoundland with the ageing society, or demographics is that`s the most rapidly rising part of the population who would be not be interested, I`m not interested in an energy system that I might get my money back in 10 years, even if it`s a good investment a 10 year timespan, you know, people are not going to do that.``Mr. Henderson replies: Well these heat pumps at that point in time might get down to, if prices go as high as Hydro is estimating to be, you know, the payback on that will be within five years, so you might have a chance for that.``

Chairman Wells: `` I like him``

Mr. Kelley, Q.C. `` You asked the question, Mr., Chairman``.

Chairman Wells: ``I like candour``

Mr. Henderson: `` Anyway, there`s absolutely no question that one of the big challenges to the price increases that are going to be seen is that the economy is doing poorly, the support for low income people, who this is a real affordability issue, is a major concern, and , you know, I don`t know what the solutions will be for that, but I guess it`s going to , depending on how it turns out, it`s going to be a real matter for the politicians and society to deal with``.

Appendix C

April 2016 Study Case

MSHP vs Baseboard Electric

Direct Performance Comparison
April 2016

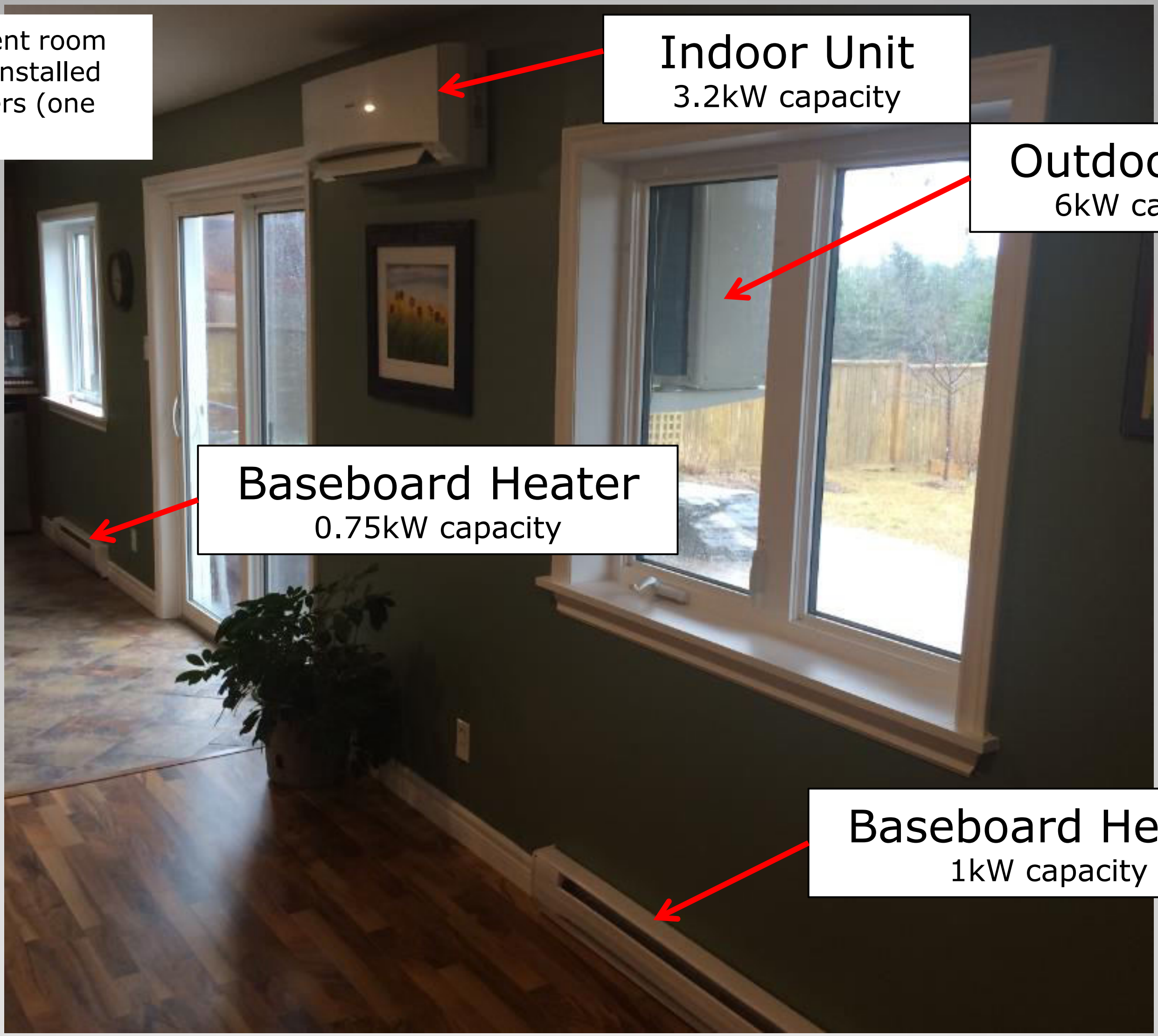
David Adams, P. Eng.

Overview of Study Case

- 10 year old home, registered R2000 construction, located in St. John's region
- 2 story, approximately 4000ft^2
  - Entire house temperature maintained at 22C, day and night, including developed basement and in-house garage (20C for garage)
  - Night setback not used since MSHP installed
- Initially built with baseboard heaters (20kW installed)
- Retrofitted with MSHP in Nov 2012 with additional units installed in Nov 2014.
  - 3 outdoor units, each with 2 indoor heads
  - Panasonic CU-2E18NBU outdoors, CS-E12NKUAW indoors
  - Baseboard heaters not used since Nov 2014
- Summer air conditioning available
- Installed MSHP heating capacity
  - 18kW rated (8C), 3 x 6kW
    - 20200Btu of heating each
    - Rated input 1.6kW each for COP of 3.75 at full load
  - Capacity reduces to 9.3kW @ -15C, 3 x 3.3kW
    - Rated input 1.4kW each for COP of 2.2 at full load
- Maximum installed heating demand
  - 20.0kW - Baseboard heaters
  - 4.8kW – MSHP (3 x 1.6kW)

Heating Equipment Comparison

This is a basement room with 2.75kW of installed baseboard heaters (one not shown)



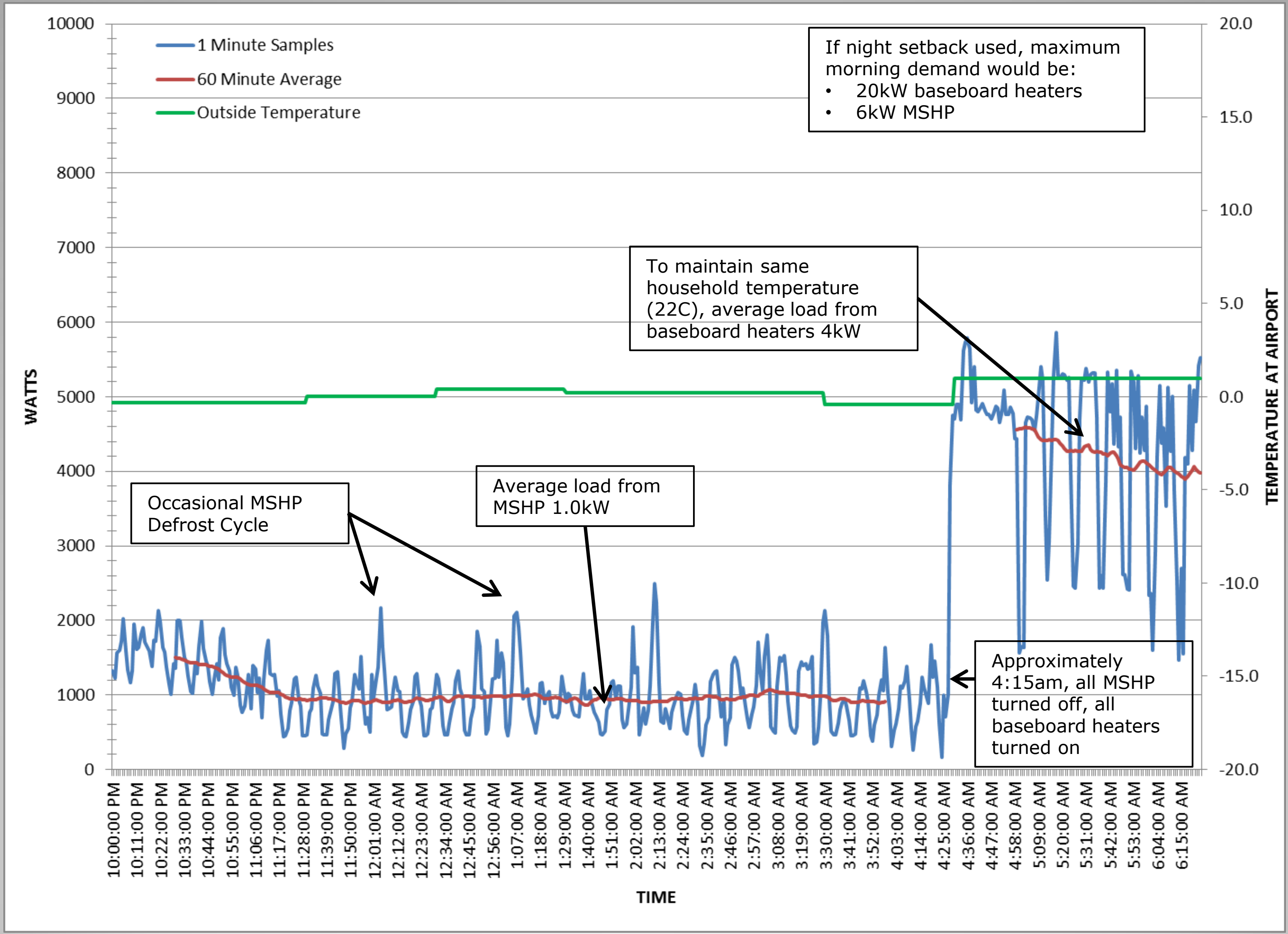
Control of Heaters

- MSHP operated in full auto mode. The following features are not used:
  - Quiet mode
  - Manual indoor fan speed control
  - Manual control of indoor louver direction
- Night setback not used for MSHP or electric baseboard heaters
- Electrical baseboard heaters controlled from electronic thermostats

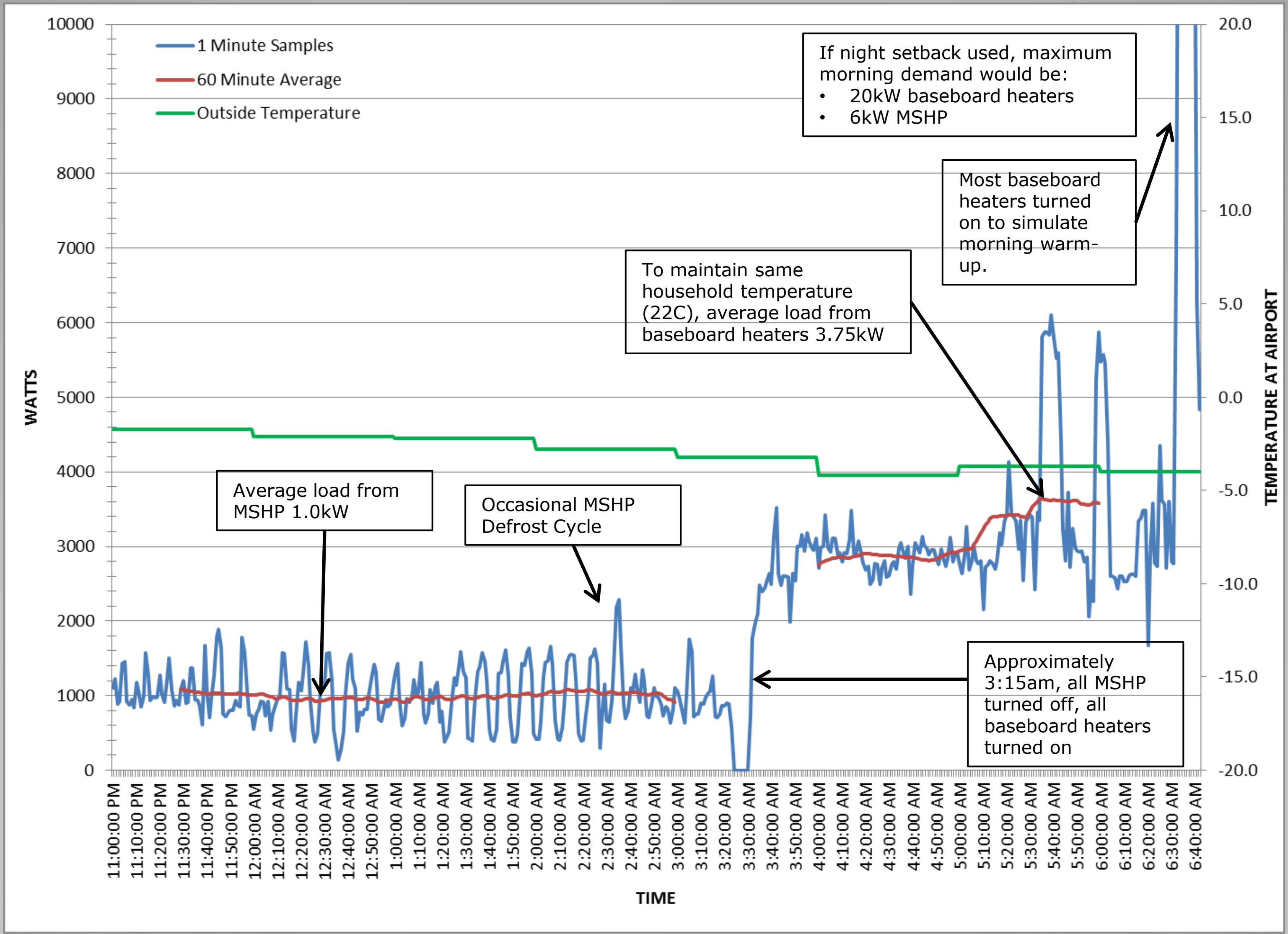
Testing Setup

- Home power monitoring system from Efergy
  - Measures current at main panel breaker (both wires) and multiplies by system voltage
  - System records power at 1 minute intervals
- Testing conducted at night (11pm-6am)
  - No effect from sun or household activities
  - All major appliances off, including hot water tank
- Heating 100% from MSHP for part of the night then switched to 100% electric baseboard heaters for the remainder
- Tests conducted during April:
  - Night of 7th — 0C overnight (heaters first, then MSHP)
  - Night of 11th — -3C overnight (heaters first, then MSHP)
  - Night of 6th — -8C overnight (MSHP first, then heaters)

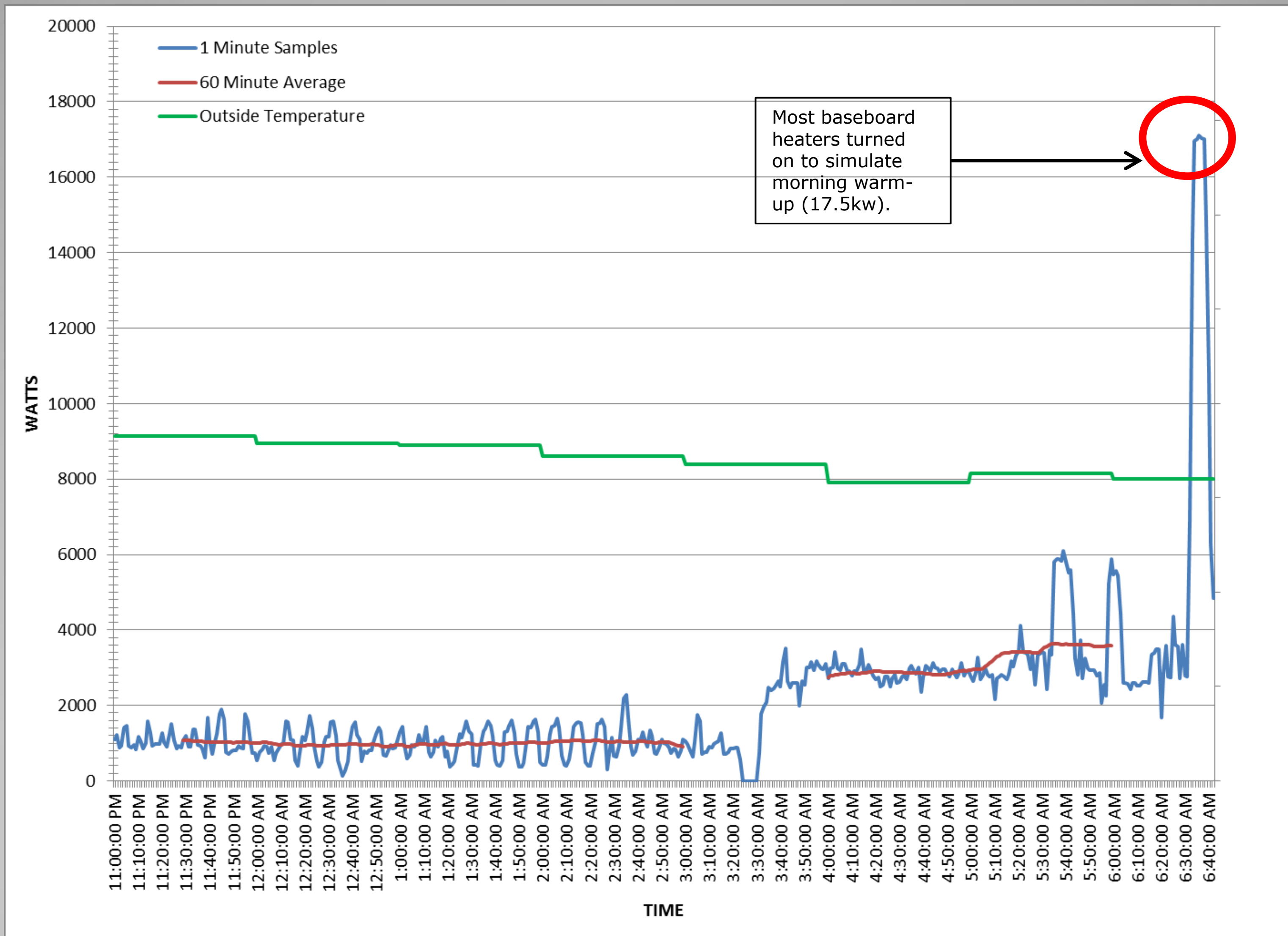
0C Performance Graph



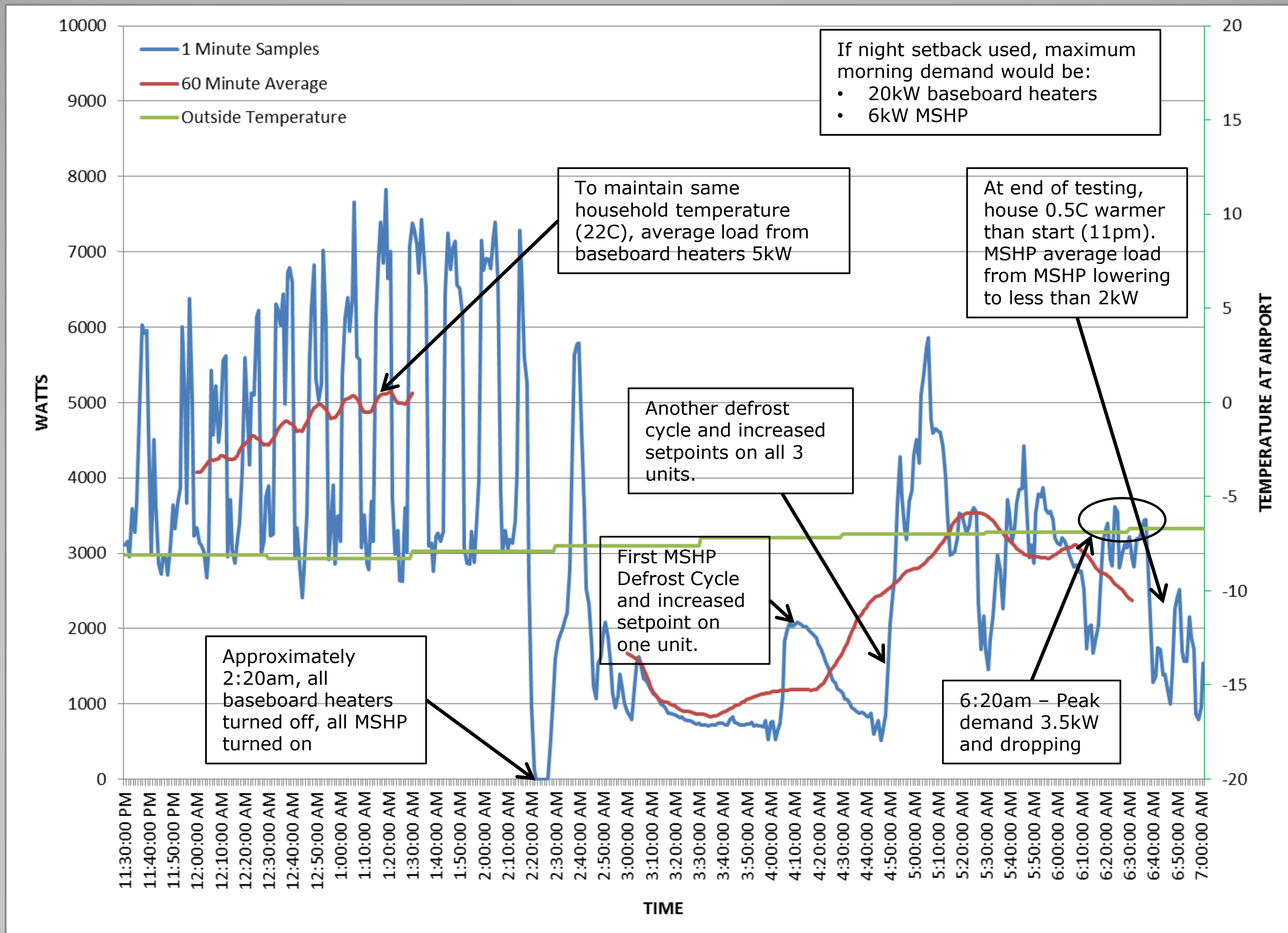
-3C Performance Graph



Morning Warmup



-8C Performance Graph



Results Summary

- Heating requirements to maintain entire house at 22C (red line)

Outside Temperature	Wind Speed (km/hr)	House Heating Requirements	Baseboard Heater Load	MSHP Load	MSHP COP
0C,	25-40	4.0kW	4.0kW	1.0kW	4.0
-3C	5-25	3.5kW	3.5kW	1.0kW	3.5
-8C,	40-55	5.0kW	5.0kW	2.0kW	2.5

- Peak Demand (blue line)

Outside Temperature	Baseboard Heater	MSHP	Demand Savings
0C	5.9kW	2.5kW	3.4kW
-3C	6.0kW	2.5kW	3.5kW
-8C	7.8kW	3.5kW*	4.3kW

* 3.5kW taken at 6:20am after house temperature increased to 22.5C.

Conclusions

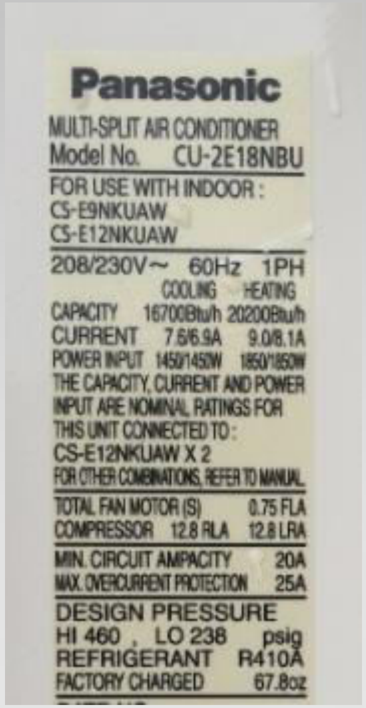
- MSHP whole house systems can be installed to heat house efficiently by sizing units for low temperature extremes:
  - 2:1 – MSHP COP at low temperature extremes
  - 4:1 – MSHP COP at 0C
- Performance at 0C:
  - 75% lower – MSHP energy use vs electrical baseboard
  - 60% lower – peak demand of MSHP vs electrical baseboard heaters
- Maximum MSHP heating demand always lower than electric baseboard heaters
- Defrost cycles have little effect on system efficiency, household comfort
- Night setback should not be use with MSHP system

Backup Material

- MSHP Nameplate
- MSHP Specifications
- MSHP Operating Curves
- Efergy Metering System

MSHP Nameplate

- Outdoor unit

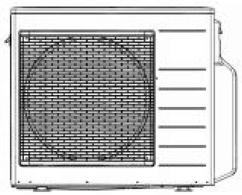


MSHP Specifications

Order No: PHAAM1111120A1

Service Manual

Air Conditioner



Outdoor Unit
CU-2E18NBU

Please file and use this manual together with the service manual for Model No. CS-E9NKUAW CS-E12NKUAW, Order No. PHAAM1111087C1.

⚠ WARNING

This service information is designed for experienced repair technicians only and is not designed for use by the general public. It does not contain warnings or cautions to advise non-technical individuals of potential dangers in attempting to service a product. Products powered by electricity should be serviced or repaired only by experienced professional technicians. Any attempt to service or repair the product or products dealt with in this service information by anyone else could result in serious injury or death.

⚠ PRECAUTION OF LOW TEMPERATURE

In order to avoid frostbite, be assured of no refrigerant leakage during the installation or repairing of refrigerant circuit.

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Panasonic

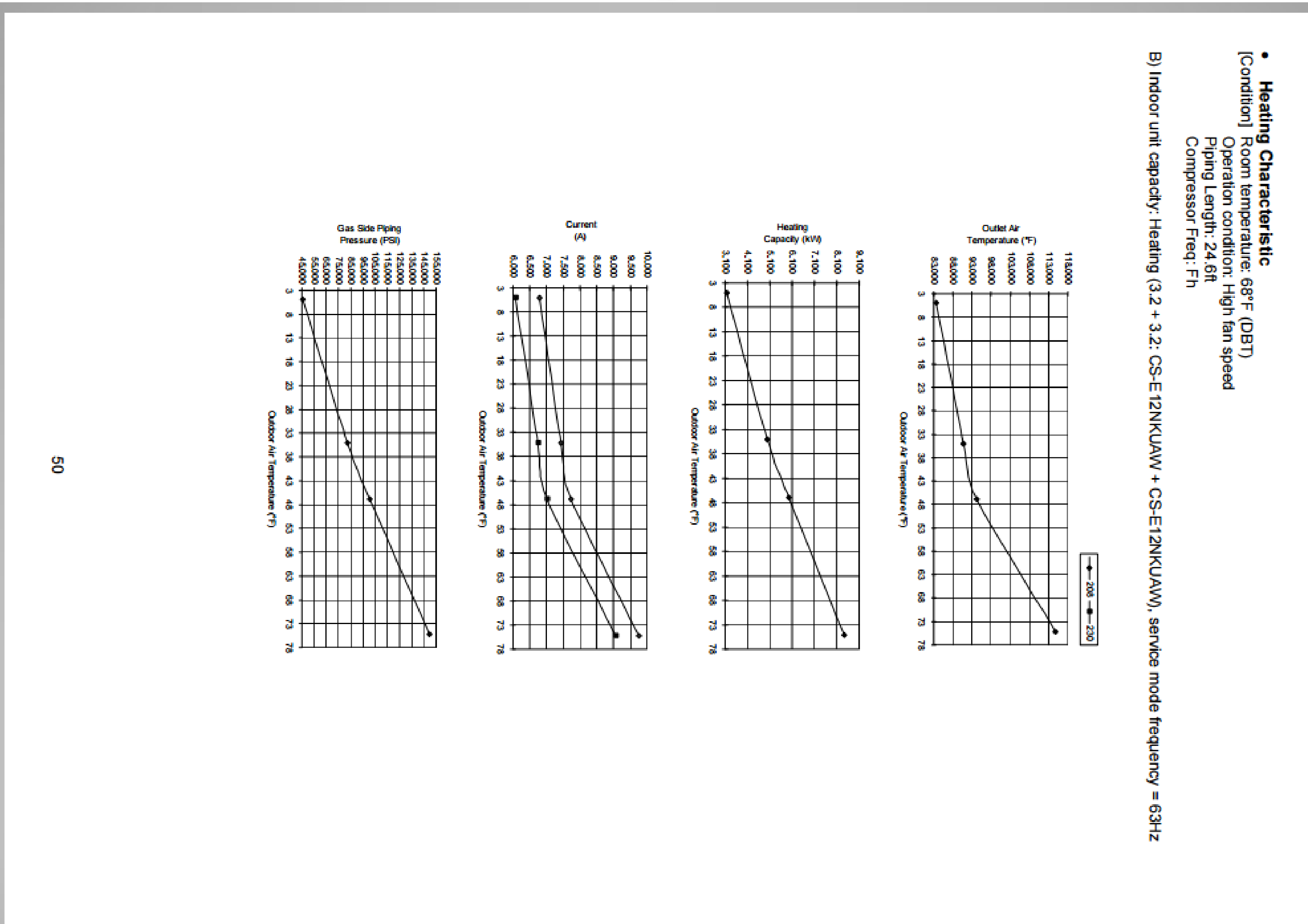
2. Specifications

2.1 CU-2E18NBU

Item			Unit	OUTDOOR UNIT
Indoor Unit Combination				3.2kW + 3.2kW
Power Source				1 Phase, 208 – 230V, 60Hz (Power supply from outdoor unit)
Cooling Operation	Capacity		kW	4.89 (2.10 – 5.86)
			BTU/h	16700 (7200 – 20000)
	Electrical Data	Running Current	A	7.6 - 6.9
		Power Input	kW	1.45 (0.39 – 1.84)
		EER	W/W	3.37 (5.38 – 3.18)
			BTU/hW	11.50 (18.45 – 10.85)
	Noise	Sound Pressure Level	dB-A	48
		Sound Power Level	dB	62
Heating Operation	Capacity		kW	5.94 (2.11 – 7.20)
			BTU/h	20200 (7200 – 24600)
	Electrical Data	Running Current	A	9.0 - 8.1
		Power Input	kW	1.85 (0.42 – 2.29)
		COP	W/W	3.21 (5.02 – 3.14)
			BTU/hW	10.90 (17.15 – 10.75)
	Noise	Sound Pressure Level	dB-A	49
		Sound Power Level	dB	63
Maximum Current			A	13.6
Starting Current			A	9.0
Minimum Circuit Ampacity			A	20
Dimension	Height		mm (inch)	795 (31-5/16)
	Width		mm (inch)	875 + 95 (34-15/32 + 3-3/4)
	Depth		mm (inch)	320 (12-5/8)
Net Weight			kg (lb)	69 (152)
Connection cable				3 + 1 (Earth) ø1.5 mm^2
Pipe Length Range (1 room)			m (ft)	3 – 25 (9.8 – 82.0)
Maximum Pipe Length (Total Room)			m (ft)	50 (164.0)
Refrigerant Pipe Diameter	Liquid Side		mm (inch)	6.35 (1/4)
	Gas Side		mm (inch)	9.52 (3/8)
Compressor	Type			Hermetic Motor
	Motor Type			DC Brushless (4-poles)
	Rated Output		W	1.30k
Air Circulation	Type			Propeller Fan
	Motor Type			DC Brushless (8-poles)
	Rated Output		W	60
Fan Speed	High		RPM	570
Heat Exchanger	Type			Plate fin configuration forced draft type
	Tube Material			Copper
	Fin Material			Aluminum
	Row/Stage			2/36
	FPI			19

5

MSHP Operating Curves



Efergy Power Monitoring

- http://efergy.com/ca/