Q. On page 56 Mr Coyne states:

"This heat pump competition has a tendency to reduce the average electricity use per customer for Newfoundland Power."

Please provide empirical evidence, including all data and worksheets, that support his assertion.

A. The impact on average electricity use per customer of the penetration of heat pumps in the space heating market is dependent on the primary space heating fuel used in the home. The addition of a heat pump in a home heated by electricity will decrease average electricity use per customer while the addition of a heat pump to a home heated oil or other space heating fuel will increase average electricity use per customer.

On April 1, 2016 Newfoundland Power filed a research report on mini-split heat pumps in response to Board Order No. P.U. 13(2013). A copy of the report is provided in Attachment A. The purpose of the report was to evaluate the potential for ductless Mini-Split Heat Pumps in the residential market in Newfoundland and Labrador.

The report provided a wide range of information on mini-split heat pumps and the potential impact on the residential space heating market in Newfoundland and Labrador. Table 2, on page 23 of the report, provides a summary of the customer energy usage analysis. The analysis indicated that the installation of a mini-split heat pump in an electrically heated home decreases average usage by 5,345 kwh per year. Conversely, the installation of a mini-split heat pump in a non-electrically heated home increases average usage by 5,494 kwh. Further, on page 12 of the report, the research indicated that prior to installing the mini-split heat pump, 73% of the respondents indicated the only fuel used to heat the home was electricity.

With approximately 68% of Newfoundland Power's residential customers using electricity for space heating and the majority of mini-split heat pumps being installed in electrically heated homes, the installation of heat pumps will tend to reduce average electricity use per customer.

Mini-Split Heat Pump Report
April 1, 2016

Mini-Split Heat Pump

Research Report

April 1, 2016

NEWFOUNDLAND POWER
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1.0 EXECUTIVE SUMMARY

The purpose of this report is to evaluate the potential for ductless Mini-Split Heat Pumps ("MSHP") in the residential market in Newfoundland and Labrador.

The report will focus on a number of key areas, including:

- An overview of MSHP systems,
- A review of existing research conducted by other utilities and government agencies in North America,
- An overview of the current residential MSHP market in Newfoundland and Labrador,
- Residential consumer awareness and experience with MSHP,
- Assessment of MSHP effectiveness and potential energy savings for residential customers, and
- Assessment of the potential impact of MSHP on both energy and peak demand on the electrical system.

The residential MSHP market in Newfoundland appears to be developing in urban centres, especially in the St. John's and surrounding area, while customers in rural areas may be challenged to find a qualified technician to install and service the equipment in a timely and cost effective manner. Consumer awareness and understanding of MSHP is low; however, customers who have installed MSHP reported high levels of satisfaction.

Evidence indicates that given the climatic conditions in most of Newfoundland and Labrador[1] the installation of a "cold climate"[2] or high efficiency MSHP, operated in an optimal manner by

[1] Research is insufficient to determine the effectiveness of MSHP in much colder climates in central Labrador.
[2] "Cold climate" refers to a system that is capable of producing 100% of its rated heating capacity at -20°C.

the homeowner, will result in lower energy costs.[3] To ensure the system operates properly, it should be installed and serviced by a qualified technician.[4]

Broader installation of MSHP will likely result in lower electrical energy usage, particularly during the colder months of the year.[5] However, analysis of weather conditions and metering data suggests that MSHP will likely contribute to higher electrical demand at time of system peak.[6] The findings of this local research are broadly consistent with research conducted by other utilities and government agencies in North America.

The following are the key recommendations arising from this report:

- Increase customer awareness of MSHP technology.
- Provide customers with information resources, including the importance of choosing a quality system and qualified installer, so they can make informed decisions.
- Identify qualifications for certified installers and make a list of these individuals and companies available for customers.
- Work with industry stakeholders to improve installer coverage in rural areas and encourage ongoing training for installers.

[3] Data indicates that both electric and non-electric space heating customers are installing MSHP. Customers with electric space heating reported reductions in their electricity bill while customers who use oil to heat their home reported increases in their electricity bill but lower oil bills.

[4] The sizing and location of the systems are important to ensure maximum efficiency is achieved. The technicians should receive training by the manufacturer of the system being installed, as well as meet Federal and Provincial requirements with respect to electrical and refrigeration certification.

[5] The decrease in electricity usage by electric space heating customers during the winter months is partially offset by increased electricity usage by previously non-electric space heating customers. There may also be slightly increased usage during the summer months for air-conditioning.

[6] System peak normally occurs during the coldest and windiest time of the year, and reflects use of electric space heating by 66% of Newfoundland Power's residential customers. Based on data from monitoring of homes with MSHP over the 2014-2015 winter season, load for the MSHP homes was higher than that for electric baseboard heated homes at times during system peak periods. MSHP installations in homes previously heated using non-electric systems also contribute to higher electrical system demand.

2.0 BACKGROUND

2.1 Overview of MSHP Technology

MSHP were first introduced in Japan in the 1940s/1950s. Today, MSHP are widely used in Asia and Europe. While the percentage of homes using the technology in North America is low, adoption of the technology is on the rise.

Typical System

MSHP systems are comprised of an outdoor compressor, or condenser, and one or more indoor air handling units which are connected by a conduit that houses the power cable, refrigerant tubing, suction tubing and condensate drain. The conduit passes through a small hole in the wall of the home, which makes it easy to install. The system does not require any ductwork and each indoor air handler has its own thermostat for individual temperature control. In addition to providing energy efficient space heating during the colder months and cooling during the summer, the systems provide dehumidification and improve air quality in the home. Figures 1 and 2 show a typical installation.

Figure 1
Indoor Air Handling Unit

Figure 2
Outdoor Compressor Unit

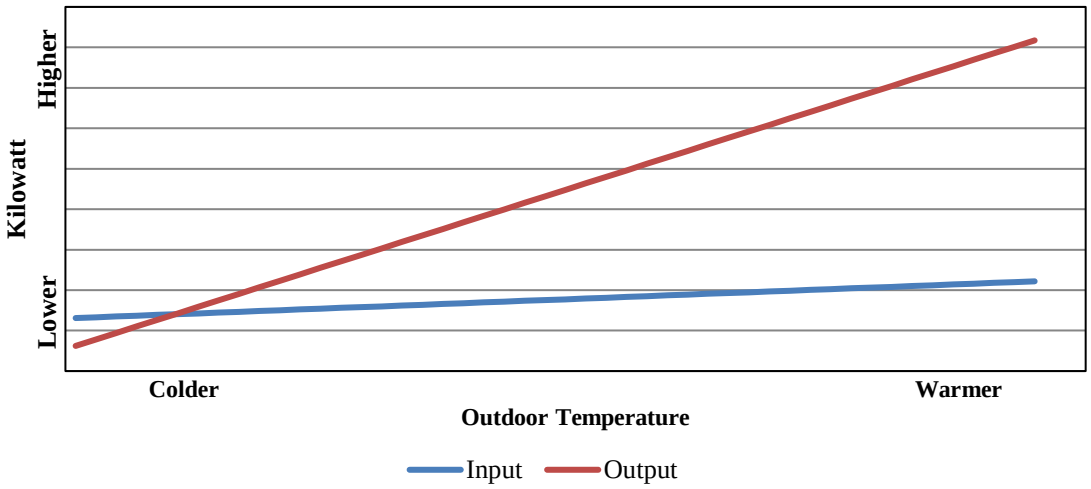
System Efficiency

The performance of the MSHP is directly related to the outdoor temperature. Recent technological enhancements have significantly improved the efficiency of MSHP systems.[7] Some products are now capable of maintaining higher heating efficiency at temperatures as low as -20ºC, while others produce very little heat at -10°C.[8]

[7] Enhancements have included inverter-driven variable speed compressors and fans.
[8] Given Newfoundland and Labrador's climate, MSHP would be primarily installed for space heating.

Figure 3 illustrates the efficiency of MSHP systems during the heating cycle. As the temperature falls the ratio of energy output heat to input electricity consumption decreases.[9]

Figure 3
MSHP Efficiency



The energy usage impact of a MSHP installed in a home, regardless of the previous primary space heating system, is impacted by a number of factors.

1. Efficiency of the system. Some MSHP are capable of producing savings at very low temperatures while other systems stop providing savings at much warmer temperatures.
2. System configuration. The installation of more outdoor and/or indoor units can increase the potential savings.
3. Installation and maintenance. A properly installed and maintained system ensures the system operates as designed.
4. Operation of the system. To ensure maximum system efficiency and savings, the MSHP must be operated as the primary space heating system. This can be difficult to achieve given the thermostats for the MSHP and an existing system operate independently.

[9] Graph based on a typical MSHP operating at steady state. During the defrost cycle, the system does not produce heat; so the energy input will exceed the energy output. At very cold temperatures, the energy input of the system can exceed the energy output. The breakpoint will depend on a number of factors, including the make or model, system rating, installation, system location, and others.

5. Sizing and location of the MSHP. If the system is oversized relative to the size of the space, or located in an area such as a hallway, short cycling may result, reducing system efficiency.

2.2 North American MSHP Research

Over the past 10 years, a significant amount of research has been conducted on MSHP systems in the United States.[10] The following summarizes some relevant research findings.

Research has been conducted on the installation of MSHP in various residential structures, as well as small commercial buildings.[11] The primary focus of this research has been homes with zonal electric space heating; although, some research has been conducted on other space heating systems and fuels.[12]

Studies consistently show that the installation of a MSHP in a single-family electrically heated home resulted in energy savings ranging from 4,000 to 6,000 kWh per year.[13] In multifamily homes, savings were much lower at less than 1,000 kWh per year. These results indicate that the economics of installing a MSHP in a single-family home is much more favourable than in a multifamily home.[14] Monitoring of the systems over a longer period confirmed that customers continued to save energy.

Research also indicates that the installation of a MSHP generally increases peak demand on the electrical system.[15] This occurs regardless of whether the home's pre-existing heating system used electricity or other fuels.

[10] The organizations who have conducted U.S. research include Northwest Energy Efficiency Alliance (NEEA), Bonneville Power Administration (BPA), Northeast Energy Efficiency Partnership (NEEP), the U.S. Department of Energy (DOE) and other research institutions. To date, little research has been conducted in Canada.

[11] Residential structures include single-family, manufactured and multifamily homes.

[12] Other systems included electric forced air furnaces, standard air-source heat pumps, wood stoves, and propane space heaters and fireplaces. Other space heating fuels include furnace oil, kerosene, propane and wood.

[13] Based on the installation of a single indoor air handling unit. Results varied by location and primary heating system.

[14] The economics are dependent on the cost to install the system, energy savings and cost of electricity.

[15] EMI Consulting, *"Emera Maine Heat Pump Pilot Program"* evaluation report, November 2014.

For the most part, MSHP are viewed as an additional piece of equipment that can help reduce total energy costs but not eliminate the original space heating equipment in the home. Operation practices, including how the MSHP and the supplementary space heating equipment work together, can have a significant impact on potential energy savings. Baseboard electric heating systems have thermostats that provide zonal control in each room. Similarly, the MSHP have controls for each indoor handling unit. Studies have shown that greater energy savings are achieved when the MSHP is operated as the primary system and the zonal electric system is used only when the MSHP is unable to meet the space heating requirements.

In addition to how the system is operated, the size and location of the indoor units are important. Short-cycling can result if the indoor air handling unit is oversized for the space, or installed in a poor location. This lowers the efficiency of the system, and negatively impacts comfort levels in the home.

Laboratory testing has confirmed that the heating effectiveness of certain high efficiency models has met, and under certain conditions exceeded, manufacturer reported data.[16] Examples of this included testing on Fujitsu and Mitsubishi models, which was completed in a broad range of operating conditions, including outdoor and indoor temperatures at various compressor and fan speeds. The high performance of the systems demonstrated the potential to deliver energy savings even at low outdoor temperatures.[17]

Overall the research results related to MSHP in North America have shown them to be an effective space heating technology.

[16] U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, "*Laboratory Test Report for Fujitsu 12RLS and Mitsubishi FE12NA Mini-Split Heat Pumps*", September 2011, Jon Winkler, Ph.D.

[17] Report prepared for DOE dated September 2011; report prepared for NEEA dated July 14, 2011.

3.0 NEWFOUNDLAND AND LABRADOR MSHP MARKET

To develop a greater understanding of the Newfoundland and Labrador MSHP market, information was gathered from suppliers, installers and customers.

3.1 Supplier and Installer Research

Information regarding the MSHP market in Newfoundland and Labrador from a supplier and installer perspective was compiled from information collected through a telephone survey of Electrical and Heat Ventilation and Air Conditioning ("HVAC") contractors, and a round table discussion with MSHP suppliers and installers.[18]

Suppliers and installers indicated that, while MSHP are relatively new to the province and consumer awareness of the systems is low, the market is growing.[19] All major MSHP brands are currently available in the province, primarily through suppliers and installers.[20] Recently, national retailers have been offering package deals for the installation of complete systems.[21] The systems can also be purchased by the homeowner over the internet.[22]

Many of the HVAC companies contacted were not active in the residential MSHP market. This was due to a number of factors including a robust and more profitable HVAC commercial market, or a primary focus on residential whole-house heat pump systems only some companies viewed MSHP as a side business, and installed systems only if time permitted. While many of these HVAC companies do not install MSHP in the residential market, they routinely perform in commercial installations.

[18] Contact was made with over 60 companies and approximately 30 suppliers/installers were identified. All suppliers/installers were invited to a round table discussion on MSHPs that was held on November 19, 2013. A total of nine suppliers and installers attended the meeting.

[19] Interest in the systems is growing mainly due to word of mouth.

[20] Suppliers indicated that they will only sell systems to qualified installers. A number of companies indicated that they both supply and install the systems. Most installers purchase systems from local suppliers.

[21] These retailers typically use local installers to install the systems.

[22] All systems should be installed by a qualified technician. Information on the internet may suggest MSHP installation is a "do it yourself" project. However, this is not consistent with Federal and Provincial requirements with respect to electrical and refrigeration work qualifications. Some installers indicated that they would not install systems purchased on the internet.

The majority of the installers identified during the survey were located in the St. John's area. These provide service primarily to customers on the Avalon Peninsula.[23] Many of these installers are primarily focused on residential markets. Installers were also identified in other urban areas, such as Gander, Grand Falls-Windsor and Corner Brook. However, few of these installers were primarily focused on the residential market. Customers in rural areas of the province primarily rely on installers from larger centres for installation and maintenance. They may therefore be at a disadvantage in getting systems installed and serviced in a timely and cost-effective manner.

Suppliers and installers indicated that not all MSHP brands and products are equal with respect to efficiency, quality and price.[24] Some models are capable of maintaining higher efficiency at outside temperatures as low as -20ºC, while other models can produce very little heat at -10°C.[25] The cost for the supply and installation of one outdoor compressor with one indoor air handling unit can range from $2,500 to $6,000.[26] Typically, systems can be installed in less than a day with very little tear up or need for electrical upgrades.[27]

Installers indicated that most customers install MSHP primarily to reduce space heating costs; although some install them to resolve a particular space heating issue or for cooling during the summer. The systems are most commonly installed in single detached homes with zonal electric space heating.[28]

Installers stressed the importance of sizing and location of the unit to ensure maximum savings and comfort. Under-sizing the system may limit potential savings and negatively impact

[23] Many of the installers indicated their core service area was the St. John's metropolitan area but if necessary they would go as far as Clarenville to install a system.

[24] Depending on the brand, the warranty can range from one year to as much as seven years on parts and labour.

[25] One supplier/installer indicated that some systems are unable to produce heat at temperatures below -10°C.

[26] Information provided by suppliers and installers as part of the telephone survey. Costs can be higher depending on the distance between the outdoor compressor and indoor air handling unit. The most common installation consists of one outdoor compressor with one indoor air handling unit. However, the number of installations with multiple indoor air handling units is increasing.

[27] An electrical system upgrade may be required for homes with smaller or outdated electrical panels, common in older homes or those heated with non-electric sources.

[28] To a lesser extent homeowners heating with oil and wood are installing the systems. One supply/installer described the MSHP systems as the "new wood stove". It is not uncommon to see systems installed in garages, sheds or cottages.

comfort, while oversizing may cause the system to short-cycle and negatively impact the overall efficiency of the system. Installing the unit in a small room or in a hallway can result in similar problems. The system performs best when the units are placed in larger rooms or in open concept designed homes. Due to potential vibration issues, installers also preferred that customers mount the outside compressor on a stand instead of on a wall.[29]

Concerns were raised by suppliers and installers regarding systems being installed by homeowners and other unqualified individuals. Improper installation can reduce efficiency and potential savings, customer comfort and overall satisfaction. It can also reduce the life of the system, and may void the manufacturer's warranty. Since the installation involves working with electricity and high pressure refrigerants, safety is an issue. Often, qualified installers are called in to troubleshoot and make adjustments.[30]

Suppliers and installers were asked what utilities could do to assist in the development of the MSHP market. Three areas were identified. First, they suggested the utilities could help with increasing customer awareness and knowledge by promoting the systems; for example, by placing information on the company or takeCHARGE websites. Secondly, offering incentives to install the systems. Finally, it was suggested that utilities provide financing for the systems.[31]

Overall, comments from suppliers and installers of MSHP about the product were very positive; however, some negative issues were identified. One of the first companies to bring MSHPs to the province indicated they were no longer involved in the business due to problems with the equipment and consumer complaints.[32] It is believed a number of factors are to blame, including lower quality systems, inexperience with the installation of the systems and overselling of the

[29] Systems are typically very quiet except on initiation of the defrost cycle.

[30] Many installers are reluctant to troubleshoot installations completed by the home owner or other unqualified installer due to potential liability should the system not perform as expected or fail due to damage which occurred during the initial setup.

[31] Many of the suppliers and installers at the meeting were unaware that Newfoundland Power currently provides financing for MSHP that are installed by qualified installers.

[32] The issue was that systems were unable to provide an adequate amount of heat during colder periods.

benefits of the systems to customers.[33] Installers and suppliers agreed that the negative experience related to these systems created a challenging market which has since been overcome.

3.2 Customer Research

In assessing the current and future potential of MSHP in the local market, this research examined the level of customer awareness of MSHP technology and obtained feedback from customers who have the systems installed in their homes.

Consumer Awareness

Customer surveying indicated that 1.8% of respondents had a MSHP installed in their home.[34] These results indicate that, at the end of 2013, less than 4,000 of Newfoundland Power's customers had a MSHP installed in their home.

Only 4.5% of respondents indicated they were "very familiar" with a MSHP with another 9.1% indicating they were "somewhat familiar" with the systems.[35] The majority of customers, 77.5%, had never heard of a MSHP. Respondents in St. John's and the Eastern Region were more likely to be "very" or "somewhat familiar" than respondents in the Western Region.[36] Older respondents tended to be less familiar with the MSHP.[37]

Respondents were asked how likely they were to install a MSHP if the system paid for itself within 5 years through reduced heating costs. In total, 19.8% of respondents were "very likely" to install a system while another 37.0% were "somewhat likely." [38]

[33] When the systems were first introduced, consumers mistakenly believed the systems would provide enough heat to replace their primary space heating system. While MSHP may produce heat during most of the heating season, another heating system is required during colder days.

[34] Several questions were included on Newfoundland Power's 3rd and 4th quarter Customer Satisfaction Surveys in 2013. Approximately 800 Newfoundland Power residential customers were surveyed by telephone in each quarter.

[35] Prior to asking the question, the surveyor described a MSHP system in detail.

[36] 16.1% in St. John's and Eastern versus 8.5% in the Western Region.

[37] 20.0% of respondents aged 18 to 34 were "very familiar" or "somewhat familiar" with MSHPs compared to 8.4% for respondents over 65 year of age.

[38] These results also varied by region and age of respondent.

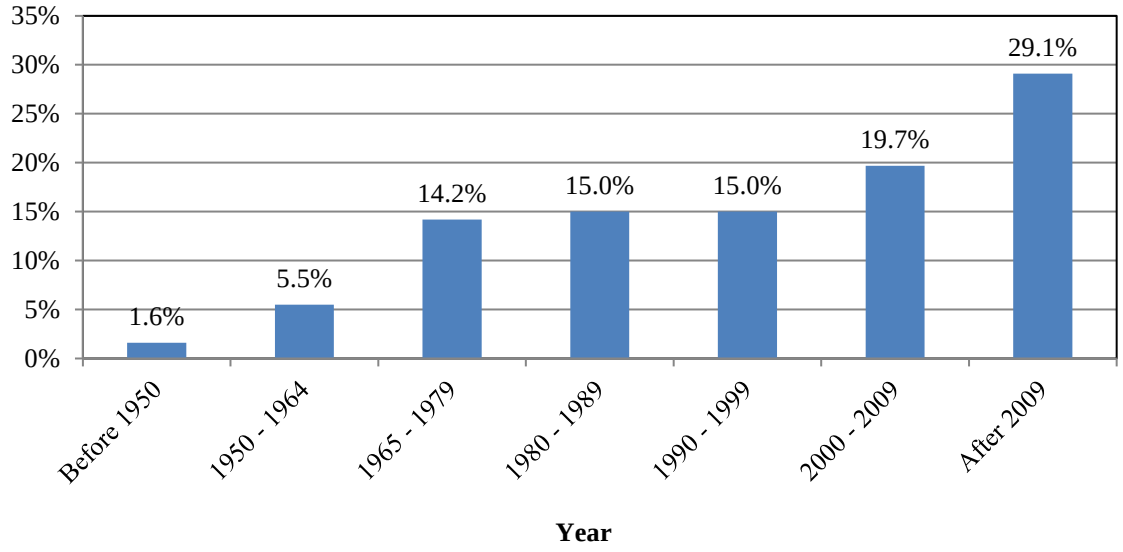
Customer Experience

A web-based survey was used to obtain feedback from customers with residential MSHP experience.[39] In total, 128 MSHP customers participated in the survey.

About the Home

Respondents indicated that 84.4% of MSHP were installed in single detached homes, 7.8% in multifamily structures, and 3.9% in cottages and garages. Systems were primarily installed in larger structures, with 71.7% having 1,300 square feet or more. As shown in Figure 4, MSHP are primarily installed in newer structures, with 48.8% installed in structures built after 1999.

Figure 4
Age of Structures with MSHP



Prior to installing the MSHP, 73.0% of the respondents indicated that the only fuel used to heat the structure was electricity, while 6.3 % indicated oil and 2.4% wood. A further 18.3% of respondents indicated they used multiple fuels to heat the structure.

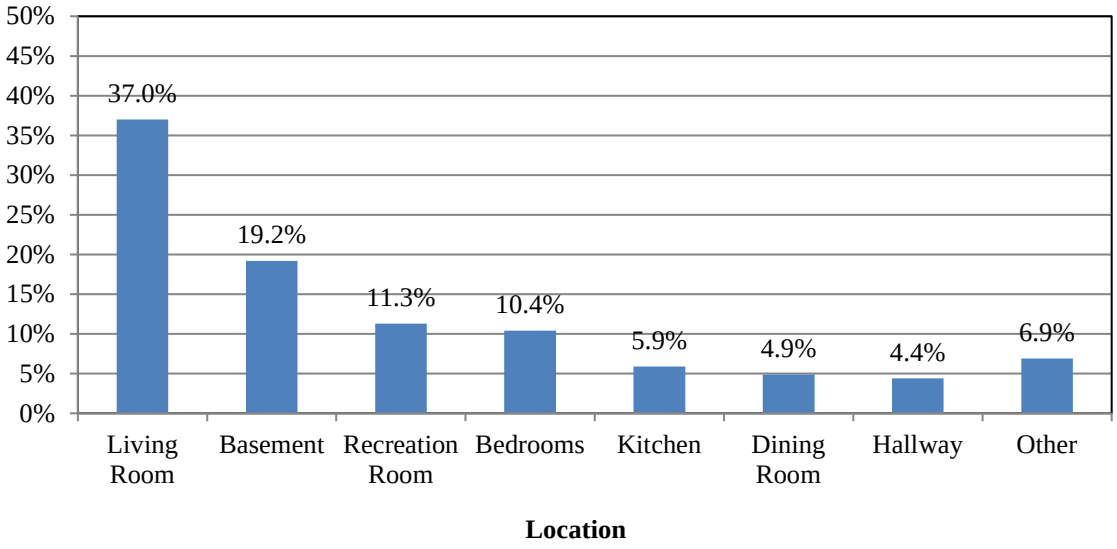
[39] A survey was made available on the takeCHARGE website. A number of strategies were used to promote participation, including printing messages on customer bills, use of social media, referrals from suppliers and installers, and encouraging Newfoundland Power and Newfoundland and Labrador Hydro employees and their families to participate. A number of random draw prizes were offered as an incentive to participants.

About the MSHP Installed

The survey results indicate that approximately 20 different brands of MSHP are installed, with the top five brands accounting for 58.4% of all installations.[40] Installations ranged from a single outdoor compressor with a single indoor air handling unit to two outdoor compressors with as many as five indoor air handling units. 82% of structures reported having one outdoor compressor, with 18% having two outdoor compressors. The most common configuration was a single outdoor compressor with a single indoor air handling unit. However, 29% of systems included more than one indoor air handling unit.

Figure 5 shows the location of the indoor air handling units. The most common location is the living room, followed by the basement.

Figure 5
Location of Indoor Air Handling Unit



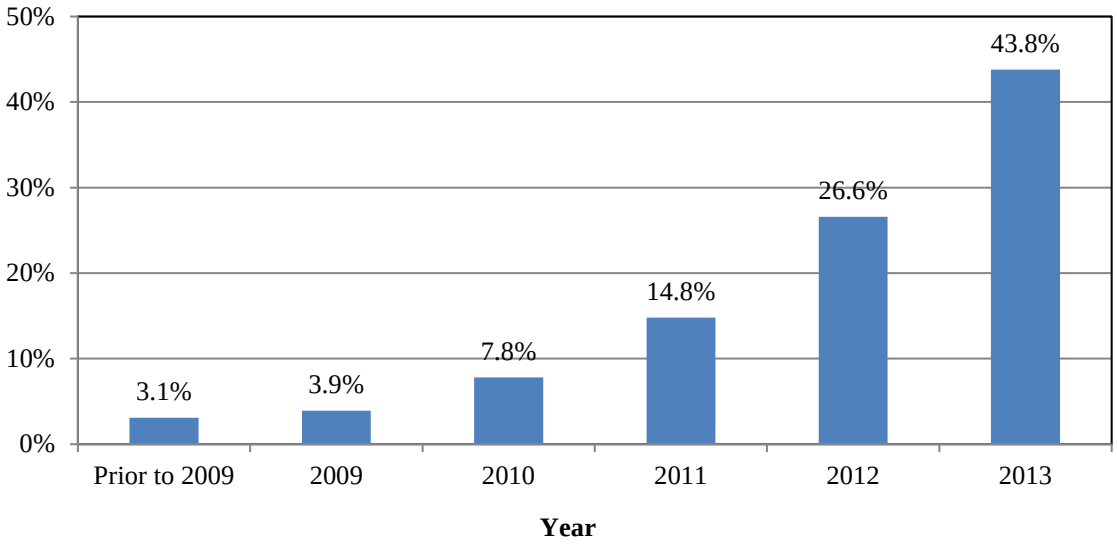
The cost to install the systems ranged from approximately $2,000 to over $7,500. The cost of the system is influenced by the brand of the system and its configuration.[41]

[40] Daiken 15.9%, Kerr 15.9%, Fujitsu 11.4%, Mitsubishi 7.6% and Samsung 7.6%.

[41] One of the installations cost over $7,500 and consisted of two outdoor compressors connected to five indoor air handling units.

Figure 6 provides information on when the systems were installed. The chart clearly shows growth in the MSHP market.

Figure 6
Year MSHP Installed



About Installation and Servicing

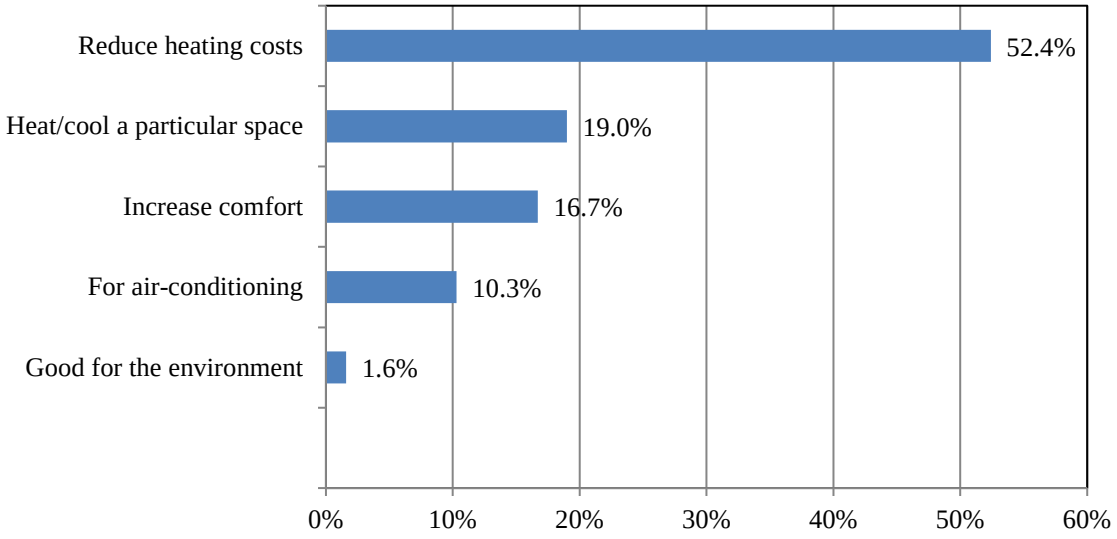
Over 98% of respondents indicated their MSHP were installed by a qualified installer, with 10% of respondents reporting problems during system installation and setup. Approximately 40% of respondents indicated they scheduled regular system maintenance, and 13% indicated they had trouble finding a qualified technician to service the unit.

Overall satisfaction with the installation was high; but there were several complaints. A number of respondents indicated that their installer was inexperienced, and had difficulties resolving issues when the system didn't operate as expected. Another respondent indicated that the installer was reluctant to come back; while another refused to come back, forcing the homeowner to find another installer to resolve their issue. These comments raise questions regarding the training and qualifications of installers, and the maturity of the local market.

Reason for Installation

Figure 7 indicates that the primary reason customers cited for installing the MSHP was to reduce heating costs.

Figure 7
Reason for Installing MSHP



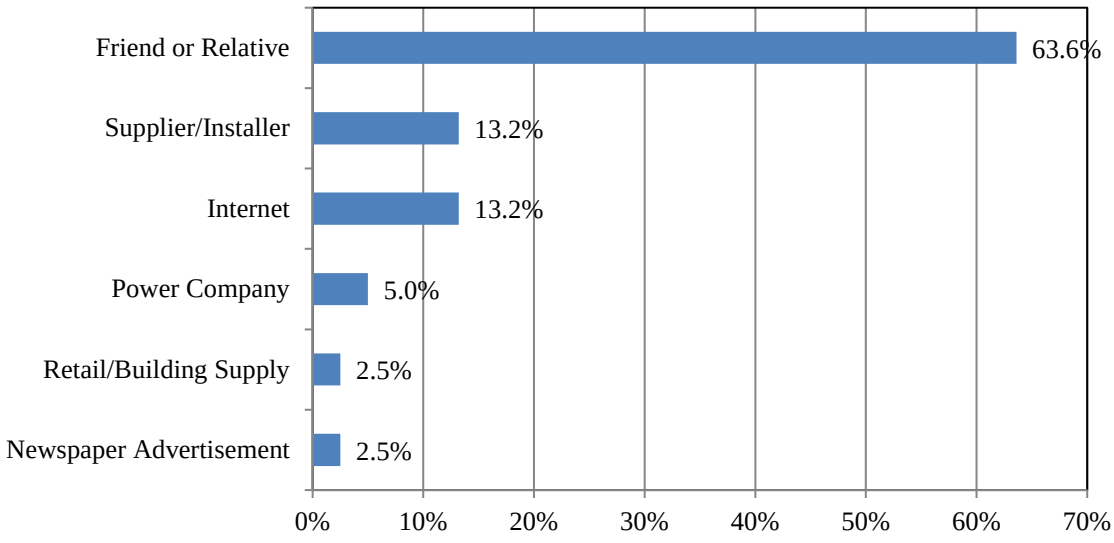
While approximately half of the respondents indicated they installed the MSHP with the goal of energy cost savings, respondents also chose the systems to heat/cool a particular space, increase comfort in the home, or for air-conditioning.

Respondents were also asked about energy cost savings resulting from the installation of the MSHP in their home. Since 44% of the systems were installed in 2013, approximately 30% of respondents were unable to determine the savings, if any, due to lack of operational experience. Of the remaining 70% of respondents, 84% indicated they had reduced their total energy costs as a result of the installation of the MSHP.[42]

[42] Analysis of energy and peak demand impacts is provided in Section 4.0 of this report.

When respondents were asked where they learned about MSHP, 64% indicated from a friend or relative. The results in Figure 8 clearly indicate that word of mouth has been a key driver of the MSHP market.

Figure 8
Heard about MSHP

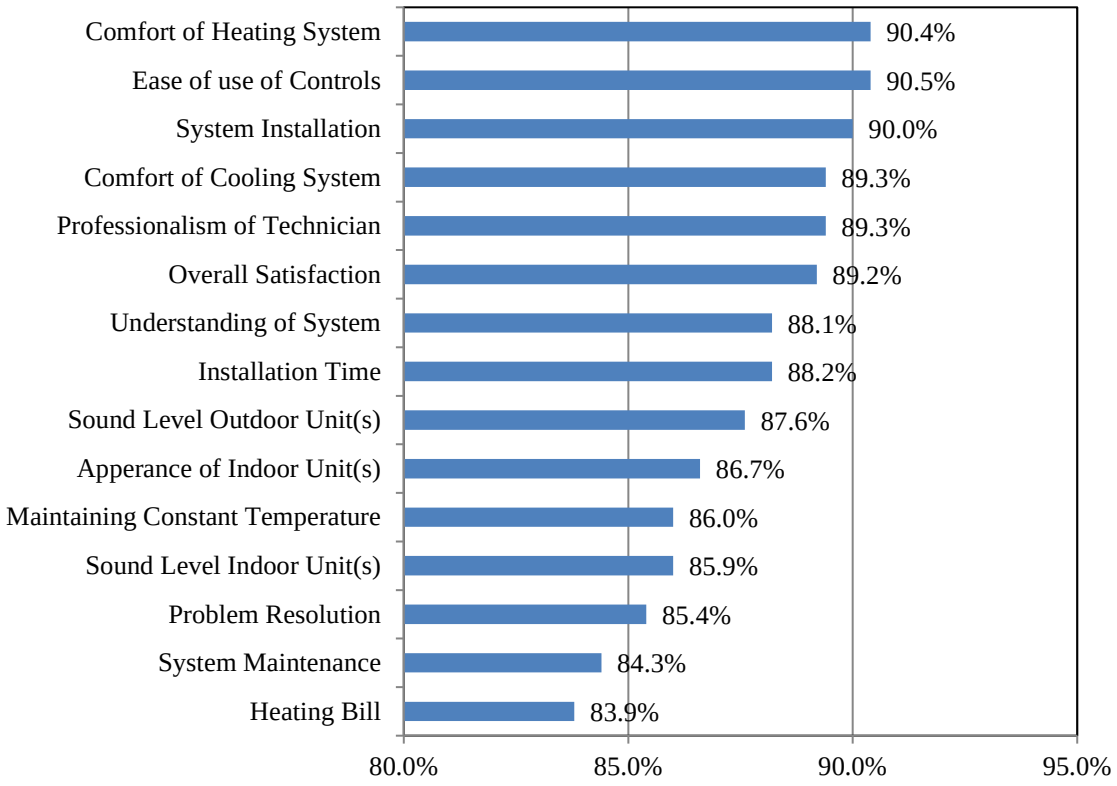


Satisfaction

Customers were asked to rate their satisfaction with various aspects of their experience with the MSHP. Overall, customers are "very satisfied" with the system. The highest rankings were given to comfort of the heating/cooling system, ease of use of controls, the installation of the system and professionalism of the technician. The lowest rankings were given to the heating bill after the system was installed, system maintenance, problem resolution, sound level of indoor unit and the ability of the system to maintain a constant temperature.

Figure 9 summarizes consumer satisfaction with respect to the various aspects of the MSHP.

Figure 9
Satisfaction Ratings



General Comments

Respondents were asked to provide comments with respect to their experience with MSHP. The majority of comments were very positive. However, while some respondents raised concerns regarding poor system performance during colder periods, others were surprised how well the system performed at low temperatures. Similarly, divergent views were expressed with respect to system installation and servicing, and the level of energy savings. These differing experiences may reflect a number of factors, such as the quality of the system, the qualifications and experience of the installer, and consumer understanding of the system and its operation.

Positive experiences prompted a number of respondents to suggest that Newfoundland Power should make information available to customers regarding MSHP and promote the systems as an

alternative method of saving energy. It was also suggested that Newfoundland Power provide rebates to customers as they currently do with some other energy saving products.

Overall, respondents were "very satisfied" with the MSHP installed in their home. In fact, 91% of respondents were "likely" or "very likely" to recommend the system to others. However, there were issues surrounding installation and servicing that must be addressed by the industry.[43]

4.0 ENERGY AND PEAK DEMAND IMPACTS

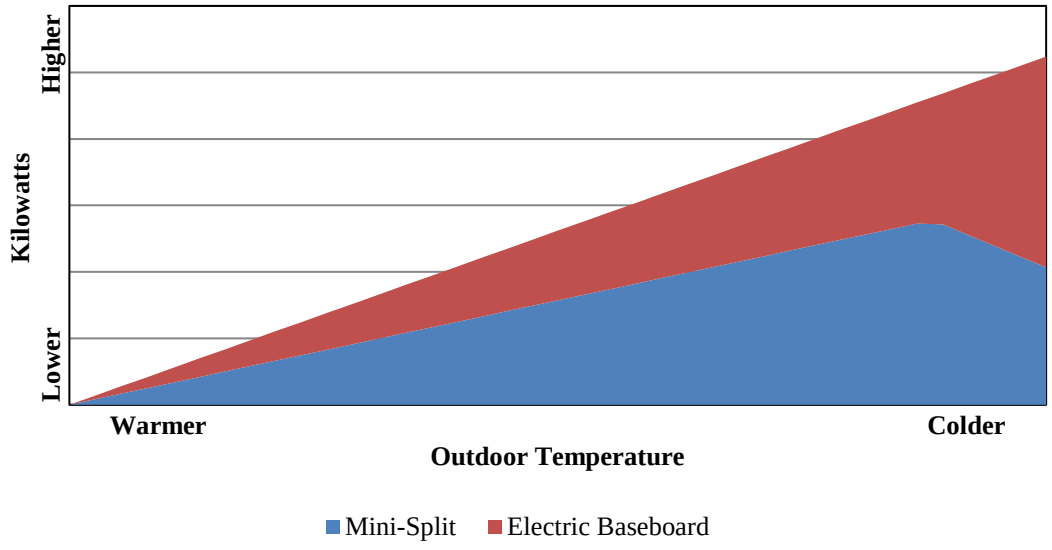
Assessment of the impacts of MSHP on customers' energy usage and electrical system load profile included analysis of historical customer billing data, and load monitoring.

4.1 Impact of MSHP on Energy Usage

General Heating System Dynamics

Figure 10 illustrates the energy ***output*** (total heat output) required to heat a typical home with electric baseboards and with MSHP.[44]

Figure 10
Energy Output



[43] For example, an adequate number of qualified technicians must be available to meet the growing demand in all areas of the province.

[44] Assuming the MSHP does not fulfill space heating needs in all areas of the home. This is typical based on local and U.S. research.

Figure 10 shows the MSHP providing approximately 60% of the heating requirements of the home for most of the outdoor temperature range. As outdoor temperature decreases, the output of the MSHP increases to meet the heating requirements of the home; however when temperature falls below a certain point the system reaches maximum capacity and output of the MSHP declines.

Figure 11 illustrates the energy ***input*** (electricity supply) required to heat a typical home with electric baseboards and with MSHP.

Figure 11
Energy Input

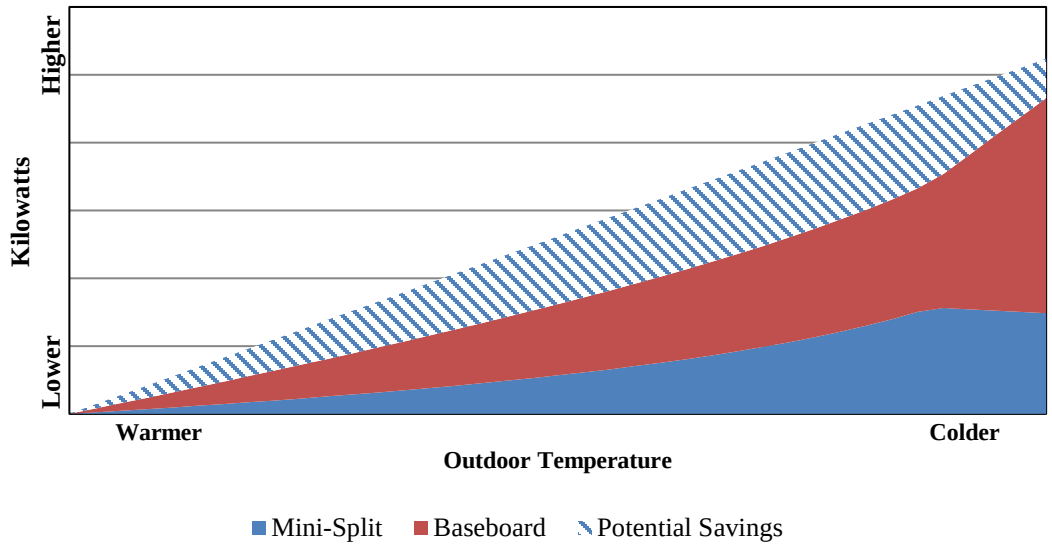


Figure 11 shows that the portion of energy input to the MSHP is about one-third of the total input energy required to heat the home. When the MSHP reaches maximum capacity and its output declines, the electric baseboard system input increases to make up the shortfall. The partially shaded area represents the potential energy savings at various temperature levels for a home using electric baseboards and MSHP to meet the space heating requirements, relative to a home using 100% electric baseboard heating.

MSHP can also be used in homes that are heated by fuels other than electricity. In this configuration, the MSHP would increase the electricity usage and reduce the amount of other fuels used to heat the home.

Newfoundland and Labrador Climate Considerations

Specific climatic conditions are important considerations when assessing the potential for energy and peak savings in Newfoundland and Labrador. The requirement for other space heating equipment to meet the total heating needs of the home will be influenced by the efficiency of the MSHP and the range of winter temperatures experienced.

Figure 12 provides normal outdoor temperature data by hour for various weather stations in the province.[45]

Figure 12
Normal Temperature by Hour

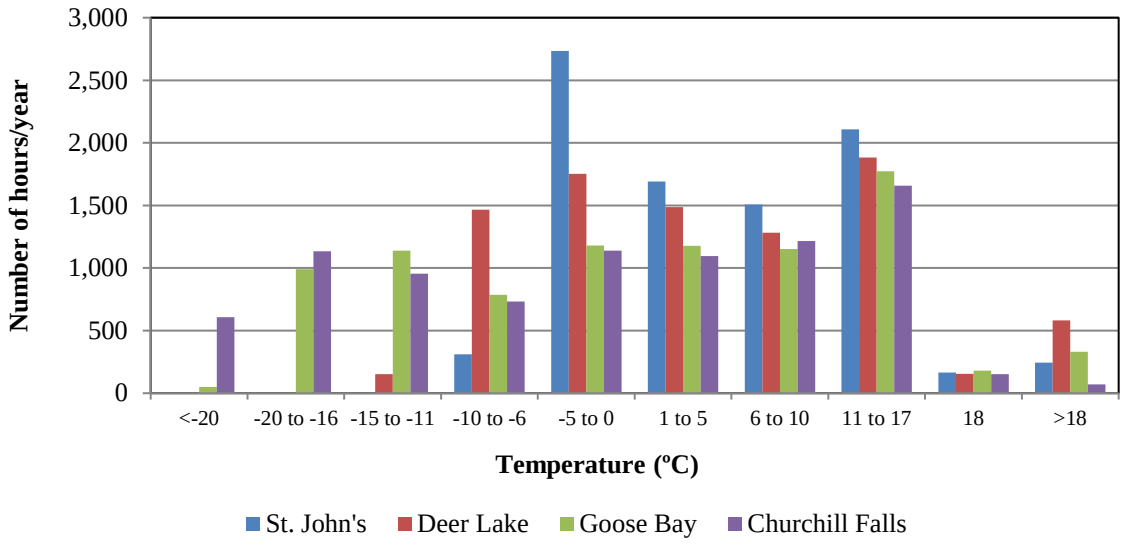


Figure 12 shows the majority of normal outdoor temperatures range from -10°C to 18°C.[46] This data suggests that the climate is favourable to MSHP for heating. The data also shows that under normal conditions the need for air-conditioning is relatively low in the province.

Table 1 summarizes space heating effectiveness of MSHP for homes located in four representative areas of the province under normal and extreme outdoor temperature conditions.[47]

[45] Normal for each weather station is calculated using 30 years of hourly temperature data with the exception of Churchill Falls which is based on 20 years of data.

[46] In Goose Bay and Churchill Falls, from a normal heating perspective, temperatures are colder than -10°C for 25% and 31% of the time, respectively.

Table 1
Analysis of MSHP
Space Heating Effectiveness Potential
% of Heating Hours [48]

	Outdoor	St. John's		Deer Lake		Goose Bay		Churchill Falls	
	Temperature	Normal	Extreme	Normal	Extreme	Normal	Extreme	Normal	Extreme
Highest Efficiency MSHP	**≥ -20**	100.0	99.3	100.0	86.5	99.4	70.4	92.9	65.7
	≥ -15	100.0	91.3	100.0	74.7	87.4	62.7	79.6	59.5
	≥ -10	100.0	74.8	98.1	65.1	73.6	56.1	68.4	53.2
Lowest Efficiency MSHP	**≥ -5**	96.3	61.1	79.8	55.8	64.1	48.7	59.8	45.1

In the St. John's area, a high efficiency MSHP is capable of providing energy savings 100% of the time during the heating season under normal temperature conditions, and 99.3% under extreme temperature conditions.[49] By comparison, in the same area, a lower efficiency system can provide savings for 96.3% of the heating season under normal temperatures, but as low as 61.1% under extreme temperatures.

In colder climate areas, such as in Churchill Falls, a high efficiency system is capable of providing energy savings 92.9% of the time during the heating season under normal temperature conditions, but only 65.7% during extreme temperature conditions. A lower efficiency system can provide savings for 59.8% of the heating season under normal temperatures, and as low as 45.1% under extreme temperatures.

The analysis shows that MSHP can provide effective space heating and energy savings for the majority of the heating season in most parts of the province, even under extreme conditions. It

[47] Extreme temperatures are based on the coldest hourly temperatures experienced during the past 30 years.
[48] The heating season is calculated based on the number of hours the temperature is lower than 18°C.
[49] A high efficiency MSHP system is capable of efficient operation at an outdoor temperature of -20°C.

also suggests that the economics of installing a MSHP may be more favourable in the warmer parts of the province.[50]

Analysis of MSHP Electricity Usage

An analysis was completed of the billing history of homes with MSHP to evaluate the impact on customers' electricity usage.[51] The analysis reviewed customer billings before and after the installation of the system.[52]

[50] Economics of installing a MSHP are also impacted by other factors, including the cost and efficiency of the system, and the price of energy. For example, the residential rate for customers on the Labrador Interconnected System is 3.280 ¢/kWh compared to the Island Interconnected System rate of 10.573 ¢/kWh. Higher electricity prices result in greater energy cost savings and shorten the payback period. (Rates as of July 1, 2015).

[51] Actual billing data was adjusted to remove the impact of variations in weather. The adjustments were based on Newfoundland Power's existing weather normalization methodology.

[52] Where available, billing data for two years before, and two years after, the installation was used. Of the 129 customers identified, 40 were excluded from the research sample, primarily due to insufficient historic billing data. Several were excluded because ownership of the home had changed or due to erratic usage patterns (e.g. cottages).

Table 2 summarizes the results of the customer energy usage analysis for the 89 MSHP installations evaluated.[53] For analytical purposes, the sample has been separated into three categories: decrease, increase or minimal change in annual electricity usage. Customers who experienced a decrease in electrical usage all had electric heat as their existing primary heat source.

Table 2
Summary of Customer Energy Usage Analysis

Usage Category	Number of Customers	Annual kWh Before	Annual kWh After	Annual kWh Change	% Change
Decrease	45	27,573	22,228	-5,345	-19.4
Increase	23	18,733	23,450	+4,717	+25.2
Electric Heat	*12*	*22,229*	*26,234*	*+4,005*	*+18.0*
Other Fuels	*11*	*14,919*	*20,413*	*+5,494*	*+36.8*
Minimal Change	21	24,100	24,116	+16	0.0
Total	**89**	**24,469**	**22,989**	**-1,480**	**-6.0**

(i) Customers with Decreased Electricity Usage

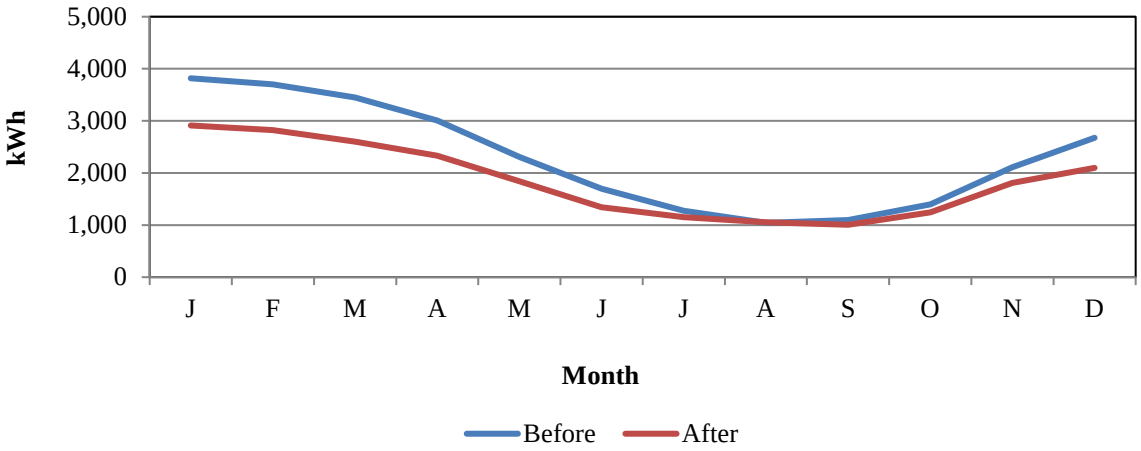
Approximately 50% of the customers in the sample recorded lower electricity usage after the installation of the MSHP. On average, these customers' electricity use declined by 5,345 kWh or 19% per year, with reductions ranging from a low of 7% to a high of 50% energy savings.[54]

[53] Changes in energy use from year to year are also impacted by many factors other than the installation of a MSHP, such as energy efficiency improvements, addition of equipment and appliances, changes in the number of occupants, etc.

[54] Analysis was also conducted regarding customers' estimated payback period for MSHP installation costs. Approximately half of participating customers experienced a material reduction in electricity usage and related costs. Of the customers who experienced savings, 27% could be expected to achieve payback within 5 years and 70% within 10 years. Of all 89 customers included in the analysis of MSHP electricity usage, 11% could be expected to achieve payback within 5 years and 29% within 10 years.

Figure 13 shows the average savings on a monthly basis for customers whose electricity usage decreased. As expected, the figure shows electricity savings in the cold months of the year, and little or no impact during the warmer months when cooling may be required.

Figure 13
Decrease in Annual Electricity Usage

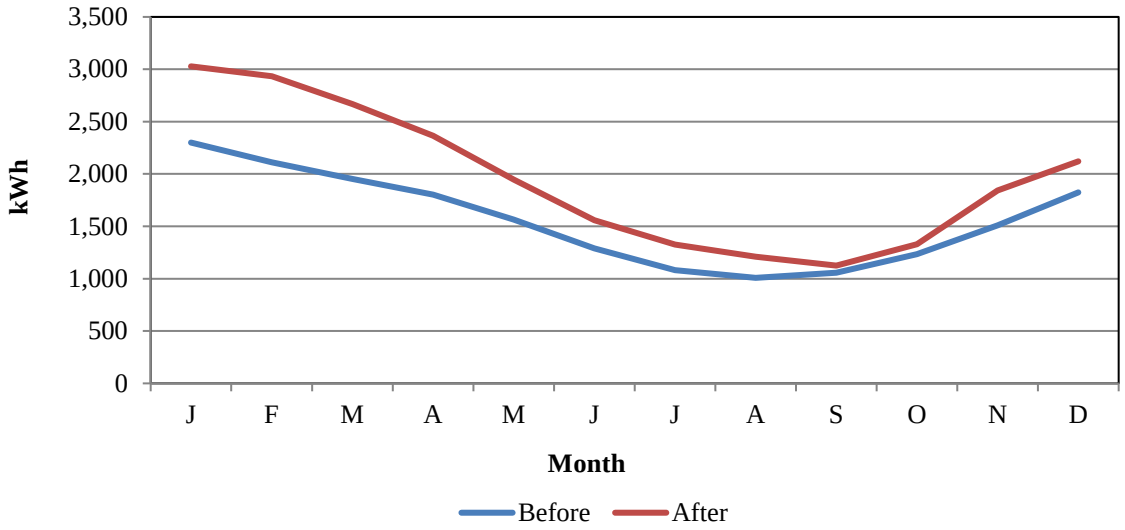


(ii) Customers with Increased Electricity Usage

Approximately 26% of the customers in the sample recorded higher electricity usage, averaging 4,717 kWh, or 25% per year. Within this group, approximately 50% of the homes were originally heated with fuels other than electricity. These customers increased their electricity usage by an average of 5,494 kWh, or 37% per year. The remaining customers, whose homes were electrically heated, increased their electricity usage by an average of 4,005 kWh, or 18% per year. This increase is primarily due to customers heating spaces that were previously unheated or under-heated, such as basements and garages. A number of these electric heat customers also indicated the use of other space heating fuels in the home, which may suggest a reduction in usage of these fuels.

Figure 14 shows the average usage by month for customers whose usage increased following installation of the MSHP. As expected, the figure shows an increase in usage in the cold months of the year, with a smaller increase in the warmer months when cooling would be required.

Figure 14
Increase in Annual Electricity Usage



(iii) Customers with Minimal Change in Electricity Usage

The remaining 24% of customers in the sample recorded little or no change in electricity usage on an annual basis. It was not discernible from the survey responses why the installation of the MSHP had little or no impact on these customers' electricity usage. Possibilities include infrequent use of the system[55], savings from the installation of the system being offset by the addition of other electrical equipment in the home, heating of spaces in the home that were not previously heated or were under-heated[56], operational issues arising from the setting of the thermostats of the baseboard and the MSHP systems[57], or problems with either the installation or system itself.

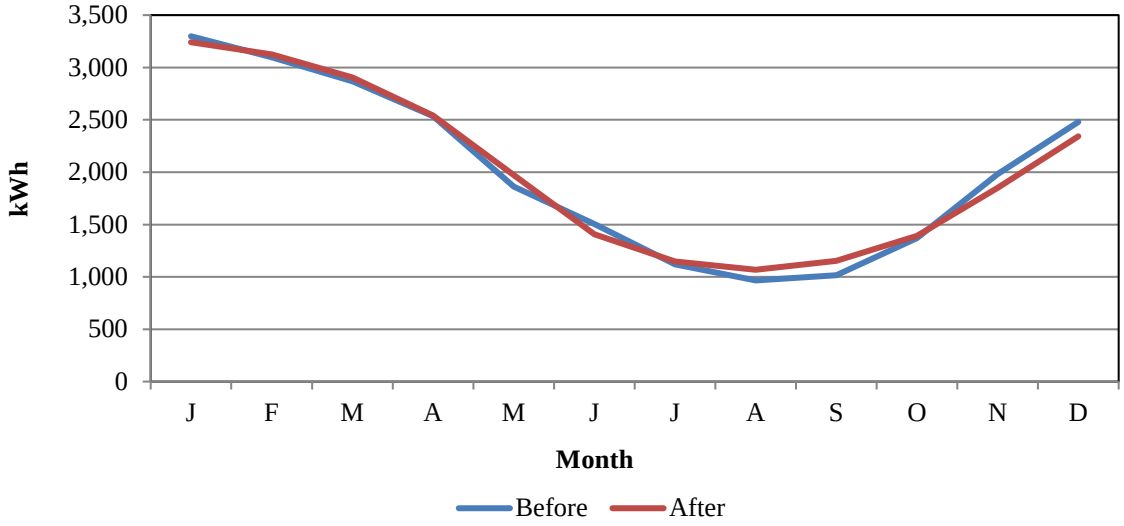
Figure 15 shows the usage by month for this group before and after the installation of the MSHP. The chart shows very little change in monthly usage, with the exception of a slight increase in usage during the warmer months of the year.

[55] The customer may have installed the system for a particular reason such as cooling or heating a space that is only heated occasionally.

[56] If the customer installed the MSHP at the same time as finishing the basement, the savings from the MSHP could be offset by the increase in the total requirement for space heating.

[57] If both the electric baseboard system and the MSHP were set on the same temperature it would impact both the length of time the MSHP would operate, as well as the efficiency of the system due to short cycling.

Figure 15
Minimal Change in Annual Electricity Usage



Summary

The analysis shows that, depending on the situation, the installation of a MSHP can result in a decrease, increase or minimal change in annual electricity use. Customers with electric space heating can reduce energy consumption by approximately 5,300 kWh per year which is consistent with other research conducted in North America. Not all installations of MSHP will result in electrical energy savings, particularly in homes heated by fuels other than electricity or electrically heated homes where the system is installed in previously unheated or under-heated spaces.

The analysis also indicates that MSHP are primarily installed for heating purposes, rather than air conditioning. The data showed very little load related to cooling during the summer months. Given Newfoundland and Labrador's climate and the high efficiency of the MSHP, these results are not surprising.

4.2 Impact of MSHP on System Peak

System peak on the Island Interconnected System occurs in the winter months (December to March) during the coldest and windiest weather conditions. This reflects the high penetration of

electric heat. System peak typically occurs between 7 a.m. and 11 a.m., or 5 p.m. to 8 p.m., on a weekday.

The impact of MSHP systems on electrical demand at time of system peak is influenced by a number of factors, including the previous heating fuel, the outside temperature, MSHP system efficiency and operational factors such as the impact of the defrost cycle. For homes heated with fuels other than electricity, the addition of a MSHP will contribute to a higher electrical system demand.

MSHP Operational Considerations

MSHP system operation includes a defrost cycle, which operates periodically to remove the buildup of frost on the outside coil. In the defrost cycle, the system switches from heating to cooling mode, and heat from inside the home is used to melt the frost on the outside coil. During the defrost cycle, the input energy required by the home may be greater than if the home was heated by electric baseboards alone.[58]

From a system perspective, a high efficiency MSHP installed in an electrically heated home in warmer areas of the province could possibly provide demand savings depending on the diversity of the defrost cycles among all installations. However, higher system peaks could be expected from the installation of MSHP in colder areas of the province and from less efficient systems, particularly if the systems continue to operate when energy input exceeds energy output. Higher system peaks could also be expected from the installation of MSHP in homes previously heated with non-electric sources.

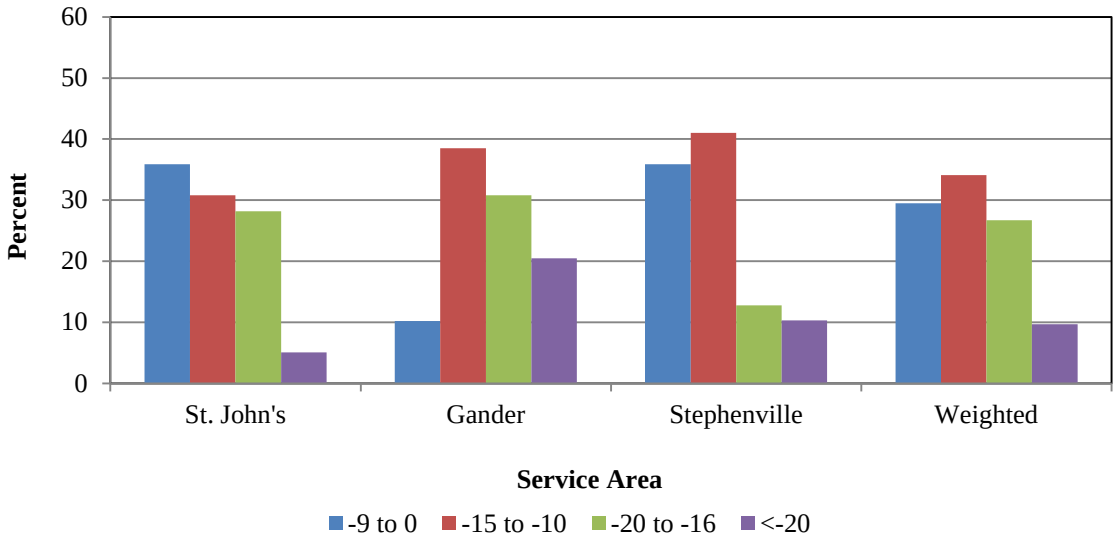
Climate Considerations

Figure 16 summarizes temperature data at time of system peak in 3 representative areas of Newfoundland Power's service terrritory.[59]

[58] During the defrost cycle the MSHP system will use electricity to operate. In addition, the electric baseboard heaters may be required to replace the heat lost and to meet the normal heating requirements of the home.

[59] The data presented in Figure 16 is based on Newfoundland Power's system peaks from 1976 to 2014.

Figure 16
Temperature at Time of System Peak



Analysis of the data indicates that 10% of the time system peak occurs at temperatures less than -20°C. High efficiency MHSP are capable of efficient space heating at temperatures at or above -20°C . At temperatures below -20°C, it is unlikely that MSHP would reduce system peak.[60] The data also shows that system peak primarily occurs at temperatures between -20°C and -10°C (61% of the time). In this temperature range, a high efficiency MSHP system may have a positive impact on system peak, while less efficient systems could positively impact peak less than 30% of the time. Should the MSHP be in defrost cycle at time of system peak, however, the unit would contribute to a higher peak, regardless of efficiency.

Analysis of MSHP Load Profile

To gain an understanding of the effect a MSHP may have on demand at cold temperatures, load recording meters were installed on 26 homes. The meters recorded data from December 12, 2014 until March 31, 2015. The 18 homes included in the analysis used the MSHP as their primary heating source, with electric baseboard, oil or wood as the backup source. [61]

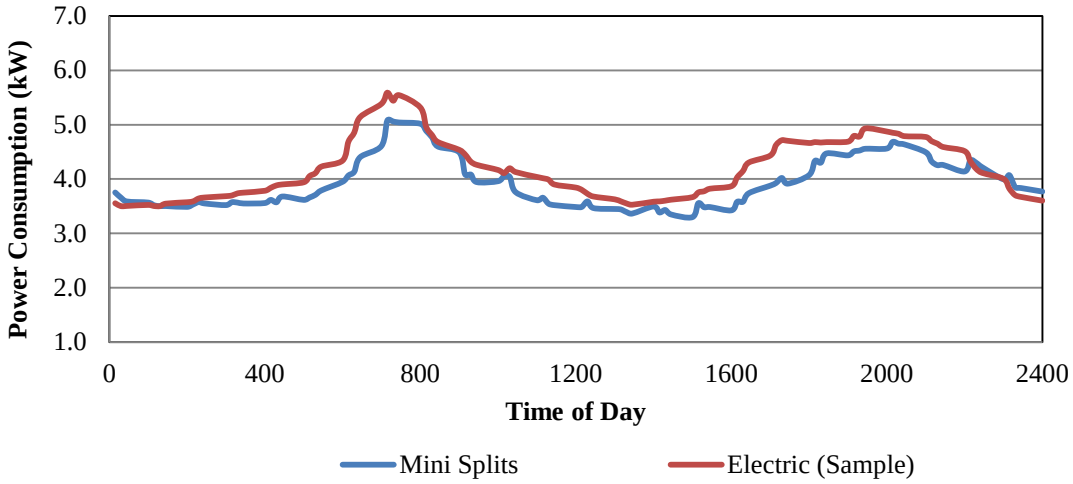
[60] While this study did not analyze system peaks in Labrador, it is unlikely that MSHP would have a positive impact on system peak given the extreme temperatures in the region.

[61] Eight homes were excluded from the data analysis for various reasons, including location of the unit(s) in garages and cottages.

The data collected from the residences with a MSHP was compared to data collected from the "SmartPeak" hot water tank direct load control pilot.[62] In that study, 466 electrically-heated homes were retrofitted with a whole house meter to collect 5-minute interval data. This data was used to compare the MSHP heat load against average electric baseboard heat load.[63]

Figure 17 illustrates the average power consumption for all monitored MSHP homes during the full study period. It also shows the average consumption for typical electrically heated homes, based on the Smart Peak pilot data.

Figure 17
Combined Load Profile



Based on this data, there appears to be a slight decrease in the load requirements of the MSHP homes when compared to the electrical resistance heating profile. The average power consumption during the study for the electric baseboard-heated homes is 4.19kW, compared to 3.94kW for the MSHP-heated homes. This 0.25kW decrease represents approximately a 6% decrease in required load overall.

62 Used because the data was both recently acquired and readily available.

63 The Smart Peak pilot did not discern the type of electrical heat in a specific residence. For the purposes of this study, the heating source is assumed to be electric baseboard, as the penetration rate of heat pump technology is only approximately 1-2%.

However, because the Island Interconnected system is demand-constrained, the impact of the MSHP during peak load conditions is of particular importance. During the study period, the days which yielded the highest native peak and for which sufficient MSHP data was recorded were selected for detailed analysis. This corresponded mainly with the coldest weekdays of the winter season.

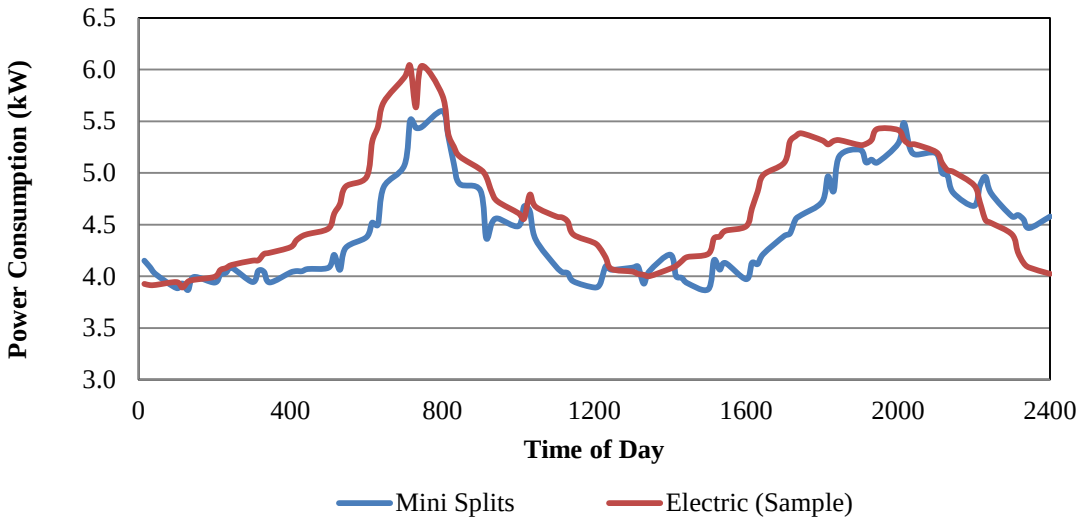
Table 3 lists the dates for the cold days that were analyzed.

Table 3
Cold Day
Dates and Temperatures

Date	Average St. John's Temperature (°C)
January 9, 2015	-8.2
January 14, 2015	-10.2
February 9, 2015	-10.8
March 4, 2015	-6.4
March 6, 2015	-11.4
March 10, 2015	-9.8
March 13, 2015	-13.3
Average	**-10.0**

Figure 18 illustrates the average cold day load profile of the MSHP homes compared to the average cold day load profile of the electric baseboard heated homes.

Figure 18
Load Profile at 'Cold' Temperatures



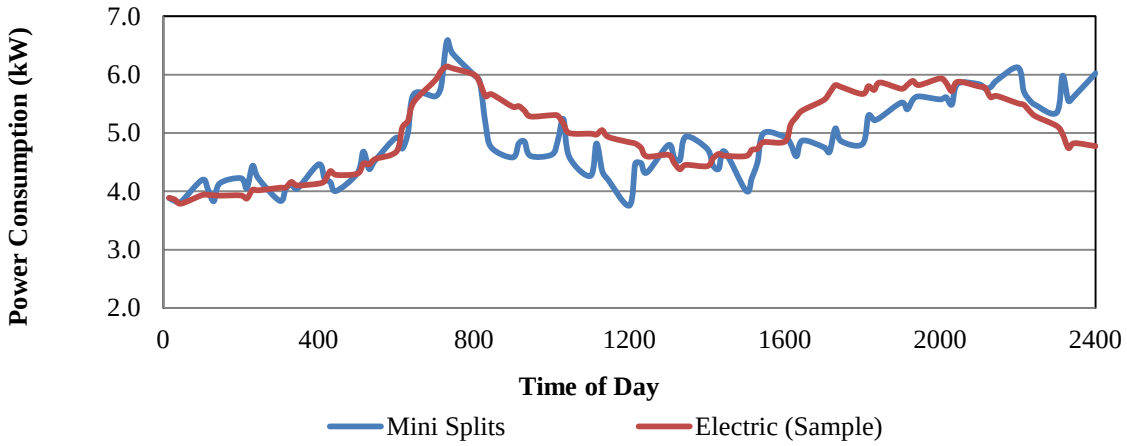
While load for MSHP homes was lower than that for the electrical baseboard homes in the morning peak period, it was equal or higher at times in the evening peak period.[64] As expected, the morning peak for each type of heating system occurs between 6:00 and 8:00. The evening peak starts around 17:00 for electric resistance heat, but not until 18:00 for the MSHP. The electric baseboard peak decreases at 22:00, but continues to be high for the MSHP until 24:00.

The load profile for the coldest day in the study period is shown in Figure 19. This occurred on March 13, 2015. With an average temperature of -13.3°C, this day also exhibited the coldest wind-chill at -24°C.[65]

[64] On colder days, the average power consumption for the electric baseboard home is 4.69kW, whereas the average power consumption for the MSHP heated home is 4.46kW. This 0.22kW decrease represents approximately a 4.8% decrease in required load.

[65] Temperatures were generally milder than average during the 2014-2015 winter season. The temperature on March 13 of -13.3°C was within the range of temperatures at which system peak typically occurs on the Island Interconnected System (approximately 61% occur between -20°C and -10°C.)

Figure 19
Load Profile March 13, 2015



In this case, the average load for the MSHP homes was higher than that for the electric baseboard homes at times during the morning and evening peak periods, and there was little difference in load profile during the rest of the day.

Summary

Based on data from monitoring of homes with MSHP over the 2014-2015 winter season, there appears to be a slight increase in load at colder temperatures (-10°C) as compared to homes heated with electric baseboard systems. This can be expected to contribute to higher overall system peak demand, given the nature and timing of the winter peak on the Island Interconnected System. A slight decrease in the average MSHP homes' load was observed during mild winter temperatures.

Installation of MSHP in homes previously heated using other, non-electric, sources would also contribute to higher electrical system peak demand.

5.0 CONCLUSIONS AND RECOMMENDATIONS

The main conclusions from this evaluation are as follows:

- MSHP are a feasible heating technology for the climate in most areas of Newfoundland and Labrador. With a back-up heating source for extreme temperatures, MSHP can deliver much of the required heating load for residential customers in the province.
- The MSHP market in the St. John's area is more mature, whereas the market is still developing in rural areas. Supply issues, particularly regarding qualifications of installers, exist in all areas.
- Overall, customer satisfaction with MSHP is relatively high. Customer knowledge regarding strategic use of their MSHP is key to maximizing energy and cost savings.
- Use of MSHP can result in electrical energy savings, provided the system is installed by qualified personnel and operated correctly.
- Use of MSHP is likely to result in increased electrical demand at time of system peak.

The following are the key recommendations arising from this report:

- Increase customer awareness of MSHP technology.
- Provide customers with information resources, including the importance of choosing a quality system and qualified installer, so they can make informed decisions.
- Identify qualifications for certified installers and make a list of these individuals and companies available for customers.
- Work with industry stakeholders to improve installer coverage in rural areas and encourage ongoing training for installers.