April 1, 2022

Board of Commissioners
of Public Utilities
P.O. Box 21040
120 Torbay Road
St. John's, NL A1A 5B2

Attention: G. Cheryl Blundon
Director of Corporate Services
and Board Secretary

Dear Ms. Blundon:

In Order No. P.U. 7 (1996-97), the Board ordered, in effect, that Newfoundland Power file annual progress reports on its demand side management activities, including conservation activities. The enclosed *2021 Conservation and Demand Management Report* is filed in compliance with Order No. P.U. 7 (1996-97).

If you have any questions, please contact the undersigned.

Yours very truly,

Dominic Foley
Legal Counsel

Enclosures

ec. Shirley Walsh
Newfoundland and Labrador Hydro

Dennis Browne, QC
Browne Fitzgerald Morgan Avis & Wadden

2021 Conservation and Demand Management Report

April 1, 2022

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1.0 Introduction

In Order No. P.U. 7 (1996-97), the Newfoundland and Labrador Board of Commissioners of Public Utilities (the "Board") ordered, in effect, that Newfoundland Power Inc. ("Newfoundland Power" or the "Company") file annual progress reports on its demand side management activities, including conservation activities.

Since 2009, Newfoundland Power and Newfoundland and Labrador Hydro ("Hydro") (collectively the "Utilities") have offered conservation and demand management ("CDM") programs on a joint and coordinated basis under the takeCHARGE brand. In 2020, the Utilities filed with the Board the *Electrification, Conservation and Demand Management Plan: 2021-2025* (the "2021 Plan"). The 2021 Plan continues longstanding CDM programs and introduces customer electrification programs.[1]

CDM programs were implemented by the Utilities throughout 2021 in a manner consistent with the 2021 Plan. While CDM programs under the takeCHARGE brand are available throughout the province, this report focuses on the results and evaluation of Newfoundland Power's CDM programs.

Planned electrification programs are the subject of an ongoing review by the Board and are therefore not addressed in detail in this report.

2.0 CDM Programs

2.1 Program Delivery

Newfoundland Power's CDM programs provide residential and commercial customers with incentives that result in quantifiable energy and demand savings.

In 2021, Newfoundland Power offered five CDM programs for residential customers. These programs target: (i) insulation; (ii) high performance thermostats; (iii) heat recovery ventilators ("HRVs"); (iv) various small technologies through the Instant Rebates Program; and (v) low-cost behavioural changes through the Benchmarking Program.[2] While these programs focus on reducing electrical energy consumption, they also provide reductions in peak demand.

The Company continued to offer the Business Efficiency Program for commercial customers in 2021. The Business Efficiency Program has three components: (i) prescriptive rebates; (ii) custom energy rebates; and (iii) custom demand rebates. Prescriptive rebates provide money back when customers purchase and install eligible products. Custom energy rebates involve takeCHARGE consulting with the customer on an energy saving project that is customized to their individual circumstances.[3] Custom demand rebates are available to commercial customers

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1 The 2021 Plan was filed with the Board on December 16, 2020.

2 Also referred to as the Home Energy Report program, the Benchmarking Program involves using social norms to encourage friendly competition to reduce electricity consumption by comparing customers' energy usage with homes having similar attributes.

3 Incentives are provided on an individualized basis for projects that are cost-effective from customer and utility perspectives. Rebates are paid on the energy savings the customer achieves in the first year of the project.

who implement individualized demand reduction measures that are economically viable and provide measurable demand reduction during peak times.[4]

The COVID-19 pandemic and related public health measures impacted CDM program delivery throughout 2021. For example, while in-store events returned as part of the Instant Rebates Program, COVID-19 outbreaks caused disruptions throughout the campaign. Similar circumstances interrupted in-person consultations for commercial customers looking to participate in the Business Efficiency Program. Supply chain interruptions also caused uncertainty around product availability and pricing for items such as thermostats and insulation.

2.2 Program Results

Table 1 provides customer participation in Newfoundland Power's CDM programs for 2021, as well as the estimated energy and peak demand savings achieved by new participants.[5]

Table 1:
Newfoundland Power
CDM Program Participation and Savings
(2021)

	Customer Participation[6]	Annual Energy Savings (MWh)	Peak Demand Savings (kW)
Residential Programs			
Insulation Program	1,110	2,890	1,191
Thermostat Program	1,069	527	209
HRV Program	564	320	99
Instant Rebates Program	N/A[7]	6,566	1,178
Benchmarking Program	73,522	16,883	7,479
Commercial Programs			
Business Efficiency Program	209	3,898	579
Total All Programs	**76,474**	**31,084**	**10,735**

[4] Under the Business Efficiency Program, customers can receive incentives for demand reduction based on the amount of demand they are able to reduce during peak times. This one-time incentive is based on project demand savings at $100 per kW per month over the December to March period. Demand savings projects require a minimum savings of 50 kW and must be sustainable over 5 years.

[5] Unless otherwise noted, estimated savings indicated in this report are provided on an annualized basis. Actual savings during the year of participation will be less, since this depends on the actual timing of installation. Due to the nature of customer behavioural changes, Benchmarking Program savings are assumed for one year only.

[6] COVID-19-related restrictions imposed challenges in program delivery in 2021, as product prices increased, product supply and availability decreased, and outreach and community events were impacted. These impacts resulted in lower than normal customer participation in the Insulation Program, Thermostat Program and Business Efficiency Program.

[7] The Instant Rebates Program resulted in 213,268 units purchased in 2021; however, the number of participants is not available as customer information is not captured at the point of purchase.

In 2021, the Company's CDM programs achieved energy savings of 31.1 GWh and peak demand savings of 10.7 MW. The Benchmarking Program resulted in the highest contribution to energy and peak demand savings in 2021, comprising approximately 54% of total energy savings and 70% of total peak demand savings.

In addition to CDM programs, the Company continued to offer the Curtailable Service Option to Rate 2.3 and 2.4 customers in 2021. Twenty-four General Service customers participated in the Curtailable Service Option during the 2020-2021 winter season, providing an average aggregate load reduction of approximately 11.4 MW.[8]

Appendix A of this report provides the detailed results for each CDM program for 2021 and over the life of the programs.

2.3 Program Evaluation

The cost-effectiveness of CDM programs is evaluated using the Total Resource Cost ("TRC") test and Program Administrator Cost ("PAC") test, as approved by the Board in Order No. P.U. 18 (2016). These tests are applied annually to assess the cost-effectiveness of CDM programs. Both tests provide a benefit-to-cost ratio whereby a result of 1.0 or greater indicates that a program is cost-effective.

Table 2 provides the TRC and PAC test results for Newfoundland Power's CDM programs in 2021.[9]

Table 2:
Newfoundland Power
CDM Program Cost-Effectiveness Results
(2021)

Program	**TRC Test**	**PAC Test**
Insulation Program	3.4	4.2
Thermostat Program	1.3	1.8
HRV Program	2.0	2.0
Instant Rebates Program	1.6	2.9
Benchmarking Program	1.6	1.6
Business Efficiency Program	1.5	2.3
Total Portfolio	**2.0**	**2.7**

8 This load reduction is exercised to reduce demand on the electrical system when generation reserves fall below normal operating levels.
9 The TRC and PAC tests were conducted using updated marginal cost information provided by Hydro in the first quarter of 2022.

The TRC and PAC test results indicate that the customer benefits of Newfoundland Power's CDM programs were at least double the cost of implementing those programs in 2021.

In addition to cost-effectiveness testing, Newfoundland Power also evaluates changes in market factors that may impact its program delivery. This can include third-party evaluations of certain programs to evaluate changes in technologies, industry standards or customers behaviour. Third-party evaluations were conducted of the following in 2021:

(i) *Instant Rebates Program*

The Instant Rebates Program promotes a variety of smaller energy-efficient products, including LED bulbs. A third-party evaluation of socket saturation levels of LED bulbs in the residential sector was completed in 2021, including an evaluation of free ridership and spillover rates.[10] The socket saturation survey indicated that there are still at least 2.1 million sockets left to be converted to LED bulbs.[11] The free ridership and spillover evaluation showed that approximately 36% of program participants are considered free riders; however, that is offset by an 18% spillover rate, for a program net-to-gross ratio of 82%.[12] These data points indicate there remains a market opportunity to offer the Instant Rebates Program in 2022.

(ii) *Thermostat Program*

A third-party evaluation of the Thermostat Program was performed by Guidehouse in 2021. The evaluation focused on the energy and demand savings impacts of electronic and programmable thermostats. The study conducted a billing analysis of customers who have participated in the program compared to those who did not. The results indicate that the savings amounts per thermostat had decreased. The amount of energy savings claimed for the Thermostat Program was therefore reduced. However, the program remains cost-effective for customers.

(iii) *Benchmarking Program*

The Benchmarking Program promotes behavioural changes to improve customers' energy efficiency. Benchmarking involves the use of social norms to encourage friendly competition to reduce electricity consumption. The 2021 evaluation showed high levels of participant engagement with the program. Approximately 94% of users reported that they read their Home Energy Reports and found the most value in the

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10 Free ridership refers to an estimate of participants who would have chosen the more efficient product without the program. Spillover refers to an estimate of participants who did not participate in the program, but purchased the more efficient product because of the program's influence. The free ridership and spillover evaluation was completed by Guidehouse, an international company that offers program evaluation services to utilities. Prior to 2021, evaluations were completed by Econoler Inc.

11 The 2021 Socket Saturation Survey was conducted by MQO Research.

12 Gross savings are the energy savings achieved through products rebated in a program. The net-to-gross ratio is the level of program energy savings that can be claimed when accounting for free ridership and spillover. In this instance, the net-to-gross ratio is: 100% - 36% (free ridership) + 18% (spillover) = 82%. Cost-effectiveness tests are performed on the net savings of a program.

comparison to similar homes and the comparison of their own energy use to previous months and years. The evaluation also confirmed the energy and peak demand savings associated with the program.

(iv) Heat Pump Load Study

The results of Newfoundland Power's ductless heat pump ("DHP") load study were analyzed by Econoler Inc. after the 2021 winter season. According to Econoler Inc.:

> *"Through the metering study, energy savings were estimated at 3,147 kWh per household (13.3% of annual electricity consumption). Peak demand savings were estimated at 0.89 kW (14.5% of total peak demand consumption) per household, for weather conditions similar to those experienced during the 16-month study period. Due to the relatively mild weather conditions experienced during the study period, additional data would be required to assess DHP performance and system impacts during colder weather conditions that can occur in Newfoundland."*

As conditions at peak are vital to understanding the impacts of heat pumps on the electricity system, data collection was extended for another winter period in anticipation of monitoring heat pump performance during colder weather conditions.

Appendix B to this report provides the results of the Heat Pump Load Study.

3.0 CDM Education and Awareness

3.1 Media and Advertising

Throughout 2021, broadcast, print, online and social media advertising created awareness for residential and commercial CDM programs.

The 2021 takeCHARGE marketing survey conducted by MQO Research continued to show high levels of takeCHARGE program awareness among customers. In 2021, 87% of households surveyed had heard of the takeCHARGE program, with the largest share of customers (47%) recalling the program from television ads.

In 2021, takeCHARGE launched a new educational campaign. Using the theme *"it feels good to save energy,"* the campaign helps motivate customers by focusing on the positive feelings associated with saving energy and improving customers' comfort. All elements of the campaign reinforce takeCHARGE as a one-stop-shop for customers' energy efficiency information needs.

Eleven takeCHARGE newsletters were included with electricity bills throughout the year. These newsletters included energy-saving tips for homeowners and promoted participation in the rebate programs.

takeCHARGE highlighted local businesses during *Business Efficiency Week 2021*. The Utilities held a contest via social media that promoted participation in the Business Efficiency Program, while encouraging customers to support local businesses.

During its 13th annual *Energy Efficiency Week*, takeCHARGE provided customers with the opportunity to virtually connect with energy experts during two free webinars. The Government of Newfoundland and Labrador, the City of St. John's and the Town of Trinity Bay North signed proclamations for *Energy Efficiency Week*.

Customers continued to visit TakeChargeNL.ca for a range of energy efficiency advice and program details. The website received over 292,000 visits in 2021. The Insulation Program and Thermostat Program pages were visited most frequently. New website content implemented in 2021 included an insulation savings calculator, which allows customers to understand how quickly an investment in insulation in their home will provide them with a positive payback.

3.2 Community Outreach

The takeCHARGE team raises awareness of energy conservation and CDM programs through a variety of community and outreach activities.

Access to LED bulbs was increased for lower-income households through the *Make the Switch* initiative. Research shows that customers with lower incomes are less likely to have LED bulbs in their homes. Among households with annual incomes of less than $40,000, only 54% of sockets have an LED bulb.[13] The *Make the Switch* initiative distributed over 18,000 LED bulbs through community groups and organizations, including via partnerships with the Single Parent Association, Newfoundland and Labrador Housing Corporation, the City of St. John's Not for Profit Housing Association, Habitat for Humanity, the Association for New Canadians and others.

The 2021 *takeCHARGE of Your Town Challenge* received 49 proposals from municipalities for energy-efficient upgrades within their communities, representing the largest volume of applications received in any year to date. The Town of Avondale was awarded $10,000 to upgrade the lighting at their softball field to LED fixtures. The field is home to several community leagues, numerous fundraisers and serves as an outdoor ice rink for the community during the winter.

Newfoundland Power educated students on energy conservation through the *takeCHARGE Kids in Charge (K-I-C) Start* school program. The program offers presentations for Kindergarten to Grade 6 students and contests that promote energy-efficient behaviours for primary, elementary and high school students. In 2021, over 1,800 students in 27 schools received presentations on energy efficiency through 56 virtual presentations.

A province-wide school contest invited students in Kindergarten to Grade 12 to submit projects that showcase energy conservation in creative and effective ways. In 2021, a record number of

[13] Results from 2021 Socket Saturation Survey completed by MQO research.

62 contest entries were received. Participants had a chance to win up to $2,500 worth of technology and other supplies for their class or school.

3.3 Trade Allies and Partners

In 2021, takeCHARGE was the recipient of two ENERGY STAR® Canada Awards. The awards recognized the takeCHARGE Instant Rebates Program as "utility program of the year" and broader takeCHARGE ENERGY STAR awareness efforts as "promotional campaign of the year." This was the second year in a row takeCHARGE was the recipient of both awards.

Professional installers, contractors, electricians and associations provide professional services and knowledge to customers that are interested in energy-efficient products and services. takeCHARGE works with these trade allies to influence purchase decisions and drive participation, especially in the retrofit market. Retail partners are also an integral trade ally.

takeCHARGE continued to support trade allies and partners throughout 2021 by communicating virtually, providing supporting materials and offering webinars. takeCHARGE also attended in-person events in 2021, such as the Municipalities Newfoundland and Labrador Conference, the St. John's Board of Trade business awards, the EcoNext Conference, and Memorial University of Newfoundland and Labrador's Botanical Gardens Merry and Bright Festival.

After a hiatus in 2020 related to the COVID-19 pandemic, the takeCHARGE Luminary Awards returned in 2021. Using a virtual format for the first time, takeCHARGE honoured its partners, trade allies and customers who have helped contribute to the success of energy conservation efforts in Newfoundland and Labrador.[14]

takeCHARGE uses an installer newsletter to stay engaged with its trade allies. The newsletters are used to communicate updates to CDM programs and provide information on what is happening in the energy efficiency sector. In addition to circulating its installer newsletter, takeCHARGE reached out directly to its network of HRV, insulation and heat pump installers to provide information on topics such as the insulation savings calculator and virtual training opportunities. This communication ensures trade allies have the most up-to-date information and tools to best serve customers.

The Government of Canada's *Low Carbon Economy Leadership Fund* aims to reduce greenhouse gas emissions. Through this initiative and provincial funding, takeCHARGE continues to offer its Insulation Program and Thermostat Program to customers with oil heating.

[14] Awards were provided in the categories of "Community Impact Award," "Leadership Award – Individual," "Leadership Award – Organization," "Innovation Award," "Partnership Award," "Retail Partnership Award" and "Electric Vehicle Awareness Award."

4.0 CDM Costs

Table 3 summarizes Newfoundland Power's CDM-related costs from 2017 to 2021.

Table 3:
Newfoundland Power
CDM Costs
($000s)

	2017	2018	2019	2020	2021
General Costs					
Customer Education and Support	516	488	421	429	489
Planning[15]	104	282	1,082	429	262
Total General Costs	***620***	***770***	***1,503***	***858***	***751***
Program Costs					
Insulation Program	1,082	1,152	1,379	1,393	1,176
Thermostat Program	538	412	421	324	294
HRV Program	125	209	145	157	205
Benchmarking Program	837	813	793	770	974
Instant Rebates Program[16]	2,133	1,742	1,448	973	1,020
Low Income Program[17]	-	-	-	-	103
Business Efficiency Program	2,044	1,716	1,687	1,344	1,035[18]
Total Program Costs[19]	***6,759***	***6,044***	***5,873***	***4,961***	***4,807***
Capital Costs[20]					
CDM Capital Expenditures	51	50	21	57	41
Other Costs					
Curtailable Service Option	436	388	375	398	403
Total Costs	**7,866**	**7,252**	**7,772**	**6,274**	**6,002**

15 Planning costs in 2019 reflect completion of the Potential Study, development of the 2021 Plan, and the first year of the heat pump load research study. Costs in 2020 reflect completion of the 2021 Plan.

16 As the saturation of LED bulbs increases, the number of bulbs purchased and the total incentives paid to customers decreases, causing reductions in program costs and energy savings. In 2020 and 2021, other program cost savings were achieved by reducing the number of campaigns from two to one.

17 Low Income Program costs represent program development costs for a January 2022 program launch.

18 Decreases in program participation were driven by COVID-19-related impacts on local businesses.

19 Variations in program costs primarily reflect varying levels of customer participation.

20 Capital expenditures are associated with improvements to the takeCHARGE website and the Company's tracking systems. In 2019, there were limited updates to programs that required website or tracking system upgrades and associated capital expenditure.

5.0 Outlook

CDM programs remain an essential part of managing peak demand while meeting customers' expectations that their utility help them with their energy costs.

CDM programs will be expanded to include new offerings in 2022. An Energy Savers Kit will be introduced for low-income customers. The Insulation Program will be expanded to include duct insulation and air sealing. A direct install pilot program will be implemented to address the primary barriers small businesses face to participating in CDM programs, cost and time.

Community outreach and customer education will remain a focus for Newfoundland Power. In 2022, the Company aims to return to its normal complement of community events and activities.

The planned delivery of customer electrification programs is the subject of an ongoing review by the Board. In 2021, the Board approved capital expenditures to install a network of 10 Direct Current Fast Chargers ("DCFC") and 10 Level 2 chargers by Newfoundland Power.[21] This network will be completed in 2022 and will help establish the minimum geographic coverage necessary to travel across the Island of Newfoundland in an electric vehicle.

If approved, customer electrification programs in 2022 would include electric vehicle and charger rebate programs for residential and commercial customers, and a custom electrification program for commercial customers. Additionally, the Company will receive $200,000 in funding from Natural Resources Canada to increase awareness, knowledge and public confidence in electric vehicles through outreach and education campaigns in the province in 2022. The funding will allow the Utilities to complete electric vehicle demonstration events, while providing drivers with information on electric vehicles such as range, charging infrastructure, and total cost of ownership.

The Island Interconnected System continues to undergo significant change upon commissioning of the Muskrat Falls Project. These changes are expected to impact the marginal cost of electricity supply. Changes in forecast marginal energy costs will reduce the TRC and PAC test results for Newfoundland Power's CDM programs, while improving the business case for electrification programs. Going forward, CDM programs will continue to be monitored for participation levels and cost-effectiveness on an annual basis. Based on the latest information available, all CDM programs are expected to remain cost-effective in 2022.

[21] See Order No. P.U. 30 (2021).

Appendix A
takeCHARGE Program Descriptions and Results

1.0 Introduction

The following tables provide details of customer participation levels, savings results achieved and the levelized utility cost ("LUC") for each CDM program for 2021 and since implementation.[22] The TRC and PAC test results for 2021 are based upon estimated future marginal costs of energy and capacity.[23]

The estimated annual energy and peak demand savings in each year represent the savings resulting from participants in that year. The estimated life to date energy and peak demand savings reflect the energy savings associated with energy-saving technologies that have been installed by all participants in the program. These savings will continue to occur each year for the life of the installed measures.

2.0 Residential Programs

With the exception of the Instant Rebates Program and Benchmarking Program, residential program incentives are processed primarily through customer applications. The programs are promoted in partnership with trade allies in retail, home building and renovation industries.

2.1 Insulation Program

The objective of the Insulation Program is to provide incentives to increase the insulation R-value in residential basements, crawl spaces and attics, thereby increasing the efficiency of the homes' building envelope. Eligibility for the program is limited to electrically heated homes, determined on the basis of annual energy usage. Home retrofit projects are eligible. Customers can receive an incentive of 75% of basement wall or ceiling insulation material costs up to $1,000, and 50% of attic insulation material costs up to $1,000.

Table A-1 shows the customer participation levels, savings results achieved, and the LUC for the Insulation Program for 2021 and since implementation.

Table A-1:
Insulation Program Results

	Customer Participation	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)
2021	1,110	2,890	1,191	4.0
Life to Date[24]	17,110	48,455	17,429	2.8

2021 TRC Result: 3.4
2021 PAC Result: 4.2

[22] The LUC represents the economic cost to the utility (per kWh) to save energy considering only utility program costs (i.e. program development, marketing, incentives and administration costs), not customer costs.
[23] The TRC test accounts for customer costs and benefits, whereas the PAC test accounts for costs and benefits incurred by the utility only.
[24] "Life to Date" represents the program results since the launch of the program.

2.2 Thermostat Program

The Thermostat Program encourages the installation of programmable and electronic thermostats, which provide customers with better control of the temperature in their home and to save energy. High performance programmable thermostats allow customers to set back the temperature during the night or when they are away. Eligibility for the program is limited to electrically heated homes, determined on the basis of annual energy usage. Home retrofit projects and new home developments are eligible. Incentives of $10 per programmable thermostat and $5 per electronic high-performance thermostat are offered.

Table A-2 shows the customer participation levels, savings results achieved, and the LUC for the Thermostat Program for 2021 and since implementation.

Table A-2:
Thermostat Program Results

	Customer Participation	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)
2021	1,069	527	209	3.5
Life to Date	27,057	24,334	3,189	2.0

2021 TRC Result: 1.3
2021 PAC Result: 1.8

2.3 Heat Recovery Ventilator ("HRV") Program

The HRV Program encourages customers to purchase a high efficiency HRV to improve the efficiency of their home. Eligible measures in this program include HRV models that have a Sensible Recovery Efficiency of 70% or more. Customers who purchase a high efficiency HRV can receive a rebate of $175. All customers are eligible for this program regardless of the age of their home or heat source.

Table A-3 shows the customer participation levels, savings results achieved, and the LUC for the HRV Program for 2021 and since implementation.

Table A-3:
HRV Program Results

	Customer Participation	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)
2021	564	320	99	6.9
Life to Date	3,328	1,838	575	7.3

2021 TRC Result: 2.0
2021 PAC Result: 2.0

2.4 Benchmarking Program

The Benchmarking Program encourages customers to adopt energy-efficient behavioural changes. Participants receive home energy reports that provide insight into their home's electricity use. The reports help customers understand changes in their usage over time, as well as how they compare to similar homes. Reports also include practical tips on how to save energy moving forward. The program includes an online portal component that allows customers to engage even further through weekly challenges and personalized savings plans.

Customers were randomly selected as participants in this program. Program participants broadly reflect the composition of Newfoundland Power's customer base in heating type and geographic distribution. No financial incentive is offered for this program.

Table A-4 shows the customer participation levels, savings results achieved, and the LUC for the Benchmarking Program for 2021 and since implementation.

Table A-4:
Benchmarking Program Results

	Customer Participation	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)
2021	73,522	16,883	7,479	5.8
Life to Date[25]	73,522	16,883	7,479	6.2[26]

2021 TRC Result: 1.6
2021 PAC Result: 1.6

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[25] Due to the nature of customer behavioural changes, benchmarking savings are assumed for one year only.
[26] While Benchmarking Program savings are claimed for one year, the LUC for the life of program is derived considering the sum of savings and program costs in all years the program has been offered.

2.5 Instant Rebates Program

The Instant Rebates Program promotes a variety of smaller technologies, such as LED bulbs and high-efficiency showerheads, through rebates available at the cash register of participating retailers. All customers are eligible for this program regardless of the age of their home or heat source.

Table A-5 shows the customer participation levels, savings results achieved, and the LUC for the Instant Rebates Program for 2021 and since implementation.

Table A-5:
Instant Rebates Program Results

	Customer Participation [27]	At-the-Cash Rebates	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)
2021	0	213,268	6,566	1,178	3.0
Life to Date	7,288	3,701,092	75,603	17,423	2.9

2021 TRC Result: 1.6
2021 PAC Result: 2.9

[27] The Instant Rebates Program was previously included as part of a Small Technologies Program, which also included an on-bill rebate component for Appliances and Electronics. The Appliances and Electronics component ended in 2017. The life to date customer participation presented in Table A-5 represents participants in the Appliance and Electronics component prior to its end. Customer participation data is not tracked for the Instant Rebates Program.

3.0 Commercial takeCHARGE Programs

3.1 Business Efficiency Program

The objective of the Business Efficiency program is to improve electrical energy efficiency in a variety of commercial facilities and equipment types. Program components include financial incentives based on energy savings, and other financial and educational supports to enable commercial facility owners to identify and implement energy efficiency and demand reduction projects. This program is available for existing commercial facilities that can save energy or reduce demand by installing more efficient equipment and systems. The program includes custom project incentives and rebates for specific measures on a per unit basis.

Table A-6 shows the customer participation levels, savings results achieved, and the LUC for the Business Efficiency Program for 2021 and since implementation.

Table A-6:
Business Efficiency Program Results

	Customer Participation	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)
2021	209	3,898	579	2.5
Life to Date	2,994	44,857	8,306	2.9

2021 TRC Result: 1.5
2021 PAC Result: 2.3

4.0 Total Results of takeCHARGE Programs

Table A-7 shows the participation levels, savings results achieved, and the LUC for all of the programs for 2021 and since implementation.

Table A-7:
takeCHARGE Programs
Total Results

	Customer Participation	At-the-Cash Rebates	Energy Savings (MWh)	Peak Demand Savings (kW)	LUC (¢/kWh)	Provincial LUC (¢/kWh)[28]
2021	76,474[29]	213,268	31,084	10,735	3.7	4.7
Life to Date	131,299[30]	3,701,092	211,970	54,401	3.2	3.6

Table A-8 shows the TRC and PAC test results for Newfoundland Power's residential and commercial portfolios, along with the provincial portfolio, which includes Hydro's Island Interconnected System costs and energy savings.

Table A-8:
takeCHARGE Programs
TRC and PAC Test Results
(2021)

	TRC Result	PAC Result
Residential Portfolio	2.2	2.8
Commercial Portfolio	1.5	2.3
Provincial Portfolio	2.0	2.7

28 "Provincial LUC" represents the combined cost and energy savings of the Utilities' Island Interconnected CDM program offerings.
29 Figure consists of 73,522 participants in the 2021 Benchmarking Program, and 2,952 participants in on-bill rebate programs.
30 Prior years' participants in the Benchmarking Program are not included in this number.

Appendix B
Heat Pump Load Study – Annual Results

HEAT PUMP LOAD STUDY – ANNUAL RESULTS

NEWFOUNDLAND POWER

Final Report

October 26, 2021

ECONOLER

ANS DE SUCCÈS
YEARS OF SUCCESS

ABBREVIATIONS

CDD	Cooling-degree day
COP	Coefficient of performance
DHP	Ductless heat pump
DHW	Domestic hot water
HDD	Heating-degree day
HSPF	Heating seasonal performance factor
NEEP	Northeast Energy Efficiency Partnership
SEER	Seasonal energy efficiency ratio

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INTRODUCTION

Econoler was commissioned to design and conduct a study to quantify the impacts of ductless heat pumps (DHPs) on Newfoundland Power's grid. The primary objective of the study is to determine the impacts that DHPs have on the electricity system's load shape and particularly peak demand as more and more consumers adopt this technology. The secondary objective of the study is to understand how DHPs operate by focusing on their power demand and energy consumption.

This study was conducted in collaboration with Ecofitt and Simptek. Ecofitt implemented the study homeowner-recruitment strategy and installed the metering equipment. Simptek was responsible for wirelessly collecting metering data and compiling it. The study was implemented according to the Evaluation Plan submitted to Newfoundland Power in the fall of 2019.[1]

This report provides the final results and findings of the study after 16 months of metering (January 2020 through April 2021). It includes a description of the methodology adopted, a review of the quality of data collected, a summary of the characteristics of DHPs included in the study, and a validation of the control and treatment groups. Then, the savings and consumption results are presented, along with a discussion on the validity of those results.

The conclusions of this report supersede those outlined in the preliminary report. As more metering data was collected, different analyses could be conducted, and the explanations proposed in the preliminary report were sometimes found to be incorrect. This report presents the final analysis based on all available data.

[1] Econoler, *Heat Pump Load Study Evaluation Plan*, report prepared for Newfoundland Power, December 19, 2019.

1 OVERALL APPROACH

The Heat Pump Load Study was aimed at assessing the impacts of the growing popularity of residential DHPs on Newfoundland Power's electricity system. The study results will be used to assess the potential impacts of DHPs on system load shapes by focusing on the system peak. The study results will also inform future energy conservation and demand management program designs and customer education initiatives. This study is also aimed at providing insights on how customers use DHPs, such as their DHP usage patterns and control methods.

To accomplish these objectives, metering equipment was installed in 263 Newfoundland homes to monitor electricity consumption in the entire home as well as electricity consumption associated with DHPs. The monitoring period lasted 16 months to include data for two full winters. Approximately half of those participating homes each had a DHP (these are the treatment group);[2] the other half are heated with an electrical-resistance heating system (these are the control group). Ecofitt installed a separate meter dedicated to the DHP in each treatment group home so that DHP electricity consumption could be monitored separately from that of the whole house. The metered electricity consumption data were to be used to obtain the following metrics to fulfill the objectives of the study:

- The average hourly energy savings load shapes[3] correspond to the average difference in whole-house metered electricity consumption between the control group and the treatment group. This result corresponds to the savings achieved by displacing the heat provided by an electric-resistance heating system with that of a DHP. Once a full year of metering is completed, the annual load shapes will reveal the annual energy savings in kWh.
- The average hourly peak demand savings load shapes, which correspond to the average difference in whole-house metered electricity demand between the control group and the treatment group under grid peak conditions.
- The average hourly load shapes of DHP electricity consumption. This result corresponds to the electricity consumption added to the grid if the heat provided by the DHP displaces that of non-electrical heating system.
- The average DHP electricity demand under grid peak conditions. This result corresponds to the demand load added to the grid under peak conditions if a DHP replaces a non-electrical heating system.

These results are to be calculated for two subgroups of the study, namely Climate Zone 1 (which corresponds to the central and western parts of Newfoundland with the coldest climate) and Climate Zone 2 (which corresponds to those areas with more moderate winter temperatures). Table 1 below lists the average weather characteristics of both zones, along with the geographic areas they cover.

[2] All homes in the treatment group had electric baseboards as their main back-up heating system. Homes with a main non-electrical heating system (such as an oil furnace) were not eligible for this study, but some homes had a secondary heating system, including wood stoves or wood or propane fireplaces.

[3] Hourly load shapes express the distribution of energy consumption or savings over a day and over a year. Load shapes might cover multiple days (for example, one load shape could represent all weekdays in a given month), but once all load shapes have been calculated for a year, they represent all the conditions over that year and cover all 8,760 hours.

Table 1: Climate Zones

Climate Zone	Average HDD (18C)	Average Temperature on Coldest Days	Areas Included
1	5,050	-18 °C	Grand Falls
			Gander
			Corner Brook
			Stephenville
2	4,800	-14 °C	Bonavista
			St. John's
			Burin

More details about the sampling and homeowner recruitment methodology as well as the metering equipment installed are provided in Sections 2 and 3 of the Evaluation Plan.

2 DATA COLLECTION

This section summarizes the steps taken to collect and clean metering data. The approach used for whole-house meters is distinct from that used for DHP meters.

2.1 Participant Recruitment

With 263 participants recruited, Ecofitt reached the minimum number of homes required for each sampling category. Furthermore, Econoler verified whether the Grand Falls region represented 30% of the homes recruited in Climate Zone 1 treatment and control groups, thereby sufficiently representing the coldest climate zone under peak conditions. During the recruitment process, Econoler also validated whether the income levels of the treatment and control groups were sufficiently comparable for each climate zone so that adjustments could be made before all participants were recruited.

2.2 Validation of Whole-House Meter Data

Various approaches were used to validate the quality of the whole-house meter data for both the control and treatment groups.

› Simptek compared the February 2020 whole-house metered energy consumption with Newfoundland Power utility bills to remove those participants with large differences (above 3% and not due to missing data), resulting in the removal of 18 participants from the analysis.

› Econoler identified seven participants who had persistent disconnection issues (meaning several months were missing more than 50% of the required data) and removed them entirely from the study.

› Econoler identified outlier consumption data (more than twice the standard deviation from the mean) and further investigated the five-minute interval data for those meters to ensure that the data made sense. The only participant with a meter that was identified as being incorrectly installed was removed due to persistent disconnection issues.

› Ecofitt performed a mid-study survey in November and December 2020, which included questions about satisfaction with the metering process as well as questions about changes made to their home (heating system or renovation) or the size of their household. Two participants were removed from the study because they were part of the control group and had installed a heat pump.

Table 2 outlines the impacts of the whole-house meter data validation on the number of participants available for the analysis as of February 2020.

Table 2: Number of Participants at Recruitment and After Whole-house Meter Data Validation

	Climate Zone 1		Climate Zone 2	
	Control Group	Treatment Group	Control Group	Treatment Group
Recruited Participants – Fall 2019	66	65	65	67
Participants with Valid Metering Data	58	61	57	61
% Valid Participants	88%	94%	88%	91%

2.3 Validation of DHP Meter Data

The following steps were taken to ensure the validity of DHP meter data for the treatment group:

› The DHP meters installed in homes wherein the whole-house meters were identified as defective due to a comparison with the billing analysis were also removed from the study, which resulted in the removal of eight DHP meters.[4]

› Persistent disconnection issues mentioned for whole-house meters affected two DHP meters, which were removed from the study.

› Econoler identified outlier consumption data (more than twice the standard deviation from the mean) and further investigated the five-minute interval data for those meters to ensure that the data made sense. As a result, six meters were removed from the study because the consumption patterns indicated that other pieces of equipment were installed on that circuit. Some other DHP meters exhibited suspiciously low energy consumption, but Econoler was able to confirm that those patterns were consistent with how participants used their DHP through follow-up calls and, therefore, those DHP meters were kept in the study.

As a result, 57 and 59 DHP meters were available for further analysis in Climate Zones 1 and 2 respectively. The number of DHP meters is independent from the number of available whole-house meters, meaning that the whole-house meter for a given participant is still included in the study even if the DHP meter was removed.

2.4 Availability of Data Over the Study Period

The metering period for the study is from January 2020 to April 2021 inclusively. The 263 metering equipment units began being installed on November 4, 2019, and the process was completed on January 13, 2020, as detailed below.

› 252 units installed between November 4 and December 31, 2019.

› 11 units installed between January 1 and January 13, 2020.[5]

[4] The other 10 whole-house meters that were defective were found in the control group, so their removal had no impact on DHP meters.

[5] The January 2020 data for meters installed during that month was kept as long as at least 50% of the data points were available, as per the general rule used for all months of the study.

Additionally in the fall of 2020, nine participants were recruited and added to the control group of Climate Zone 1 since the margins of error were higher than targets for that group. Table 3 presents the evolution of the number of valid whole-house meters per sub-group throughout the duration of the study. Valid meters are defined as having passed all steps of the validation process described in Subsection 2.2 and having data for at least 50% of the hours of a given month.[6] New meters added in the fall of 2020 appear as valid meters starting in December 2020.

Table 3: Number of Valid whole-house Meters per Sub-group and per Month

	January 2020	February 2020	August 2020	December 2020	April 2021
Climate Zone 1					
Control Group	56	57	55	61	63
Treatment Group	58	59	60	60	57
Climate Zone 2					
Control Group	55	57	55	53	52
Treatment Group	55	59	58	55	53

[6] While 50% might seem like a low number, it is important to keep in mind that data are averaged to one weekday and one weekend per month to obtain energy load shapes and energy savings, so 50% is sufficient to obtain a good estimate of the consumption in a given month. Requiring a higher percentage of available data would have disqualified a few more participants for each month, which posed a higher threat to the validity of results since it could have impacted the comparability of the control and treatment groups.

3 DHP CHARACTERISTICS

For all recruited participants with a DHP, detailed information on their DHPs was collected as part of this study. This section presents an overview of the DHPs installed in all the recruited homes (including those excluded from the savings analysis due to insufficient data or following efforts to render the treatment and control groups comparable, which are discussed in Section 4).

In total, 75% of the DHPs in the treatment group were installed in the past two years before the beginning of the study, indicating that treatment group DHPs were very recent. The average DHP HSPF was 9.6 for region V and 11 for region IV. As illustrated in Figure 1 below, 88% of DHPs had an HSPF region IV above 10, which corresponds to the minimum HSPF value to meet Northeast Energy Efficiency Partnership (NEEP) standard for cold-climate DHPs.

Figure 1: Proportion of Metered DHPs Meeting NEEP Standard for Cold-climate DHPs (HSPF Region IV Greater than 10)

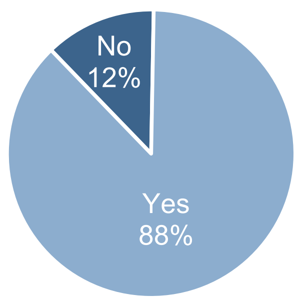


Table 4 provides the heating capacity values of metered DHPs. The average heating capacity in Climate Zone 1 is higher than the average in Climate Zone 2.

Table 4: Average DHP Heating Capacity

	Average Heating Capacity (Btu/h)	Standard Deviation of Heating Capacity (Btu/h)	Maximum Heating Capacity (Btu/h)
Climate Zone 1	24,700	10,600	72,000
Climate Zone 2	20,100	5,600	36,000
Total	**22,400**	**8,700**	**72,000**

4 VALIDATION OF CONTROL AND TREATMENT GROUPS

As previously explained, one of the study objectives was to establish the savings achieved by replacing an electric-resistance heating system with a DHP by comparing the energy consumption patterns of the control group (without DHPs) with the patterns of the treatment group (with DHPs). Therefore, the study was designed to recruit participants who have similar electricity consumption levels. Econoler validated whether this goal was achieved by comparing the characteristics of the control group and treatment group by examining all the following parameters expected to have a significant correlation with electricity consumption:

› The number of occupants per household;
› The year the house was built;
› The house size in square feet;
› The income level;
› The domestic hot water (DHW) fuel source;
› Presence and usage of a secondary heating system;
› Presence of special electric loads (hot tubs, electric vehicles, etc.).

The analysis was performed based on meter data available in February 2020, which was the first complete month after which all meters had been installed. February is also the coldest month of the year and so the most important month to calculate peak demand savings – it was therefore critical that the control and treatment groups be the most comparable at this point.

Econoler first plotted the February energy consumption of each participant as a function of each parameter above to determine the strength of the correlation and therefore the impact of each parameter on energy consumption. The income level and age of the house exhibited weak correlation with energy consumption, while the number of occupants per household and house size were strongly correlated with energy consumption. The domestic hot water fuel source was electricity for all but three participants and, thus, it did not have an impact on the comparability of the control and treatment groups. Since the presence of a secondary heating system or a special electric load are binary parameters, Econoler compared the average energy consumption of participants who had such systems or loads to that of participants who did not, for each climate zone. The consumption difference between the two groups was significant. Econoler therefore ensured the control and treatment groups were similar with respect to the percentage of participants who had secondary heating systems and special electric loads.

To obtain adjusted groups, Econoler removed participants to ensure both groups were as comparable as possible. For each parameter, Econoler aimed to establish groups for which there was at least a 10% chance that the two values were the same. Said differently, this means that two groups are not considered statistically different unless the difference can be demonstrated with a confidence level of 90%. Where possible, the preferred approach was to remove participants from the control group. This served to obtain a control group that is similar to the treatment group (comprised of participants who installed DHPs); making changes to the treatment group would have excluded certain types of DHP owners from the study, which could have skewed results.

Figures 2 to 5 below illustrate how the adjustments to the control and treatment group impacted the composition of each group with respect to the main parameters that influence energy consumption.

In Climate Zone 1, two parameters were significantly different between the control and treatment groups. The average house size was significantly higher for the treatment group (1,674 ft² vs 1,373 ft² respectively). Adjustments made to the groups reduced that gap to 1,505 ft² and 1,354 ft² respectively. This difference fell slightly short of the target, with a 9% probability of the treatment population not having a value higher than the control population, instead of the target of 10%. Econoler could not further improve that variable despite multiple attempts.

Figure 2: Initial Distribution of House Sizes

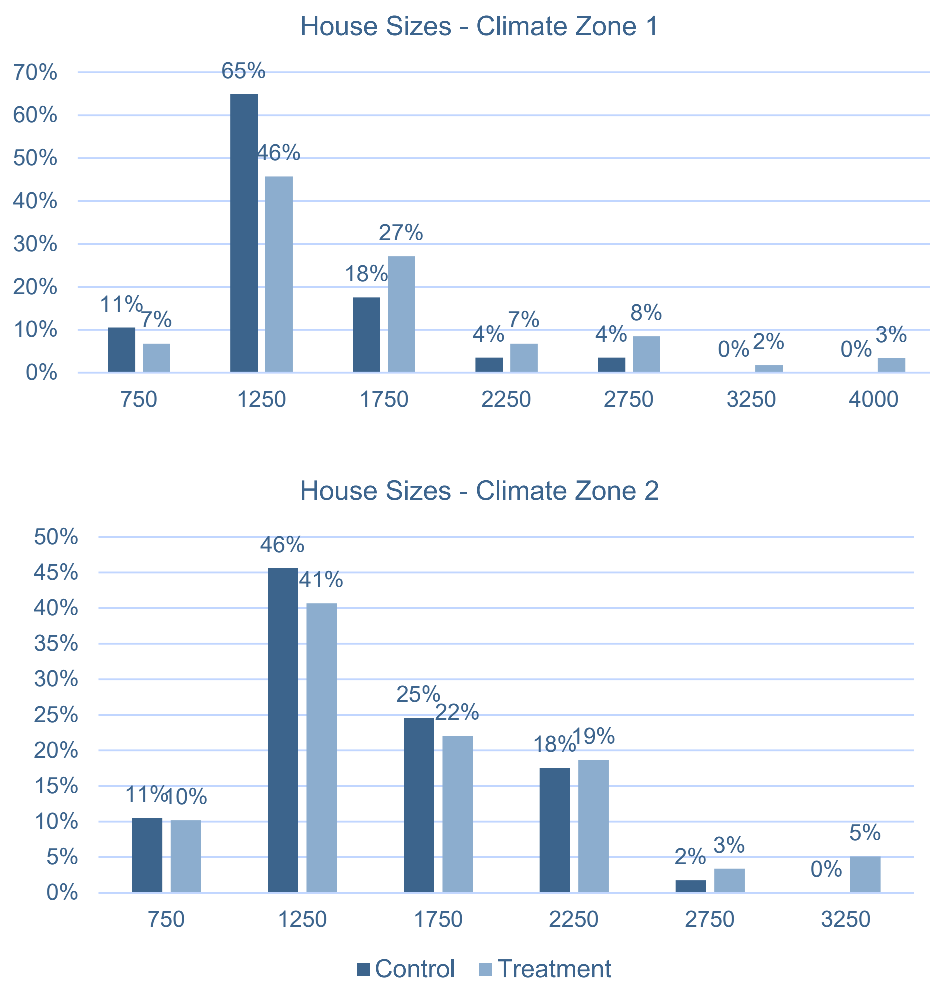
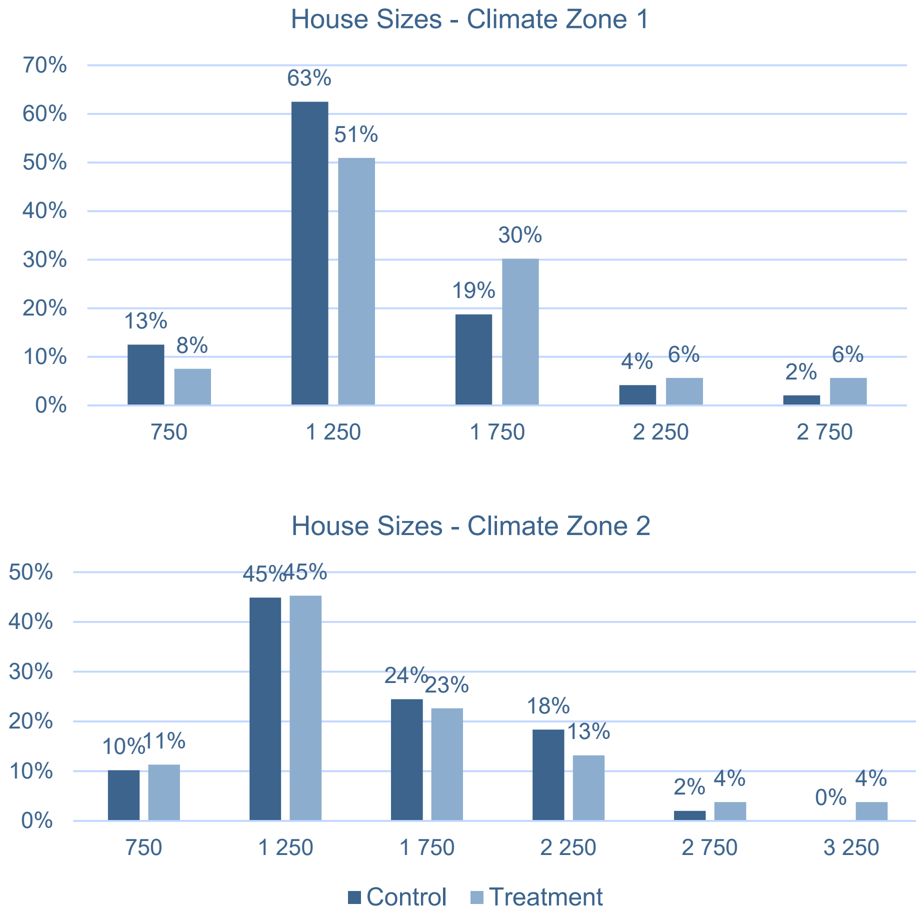


Figure 3: Adjusted Distribution of House Sizes



The second parameter that required adjustments in Climate Zone 1 was the presence of secondary heating systems. Twelve participants regularly used the secondary heating system in the control group, while that was the case for only one participant in the treatment group. Econoler removed all but three participants who regularly used their secondary heating system from the control group and kept the single participant who did so in the treatment group.

In Climate Zone 2, two parameters were problematic: The number of occupants per household and the presence of special electric loads. Initially, the control group had 3.16 occupants per household and the treatment group had 2.58. After adjusting the Climate Zone 2 groups, the difference was reduced with the control group having 2.92 occupants per household and the treatment group having 2.62, which was not statistically significant at a confidence level of 90%.

Figure 4: Initial Distribution of Number of Occupants per Household

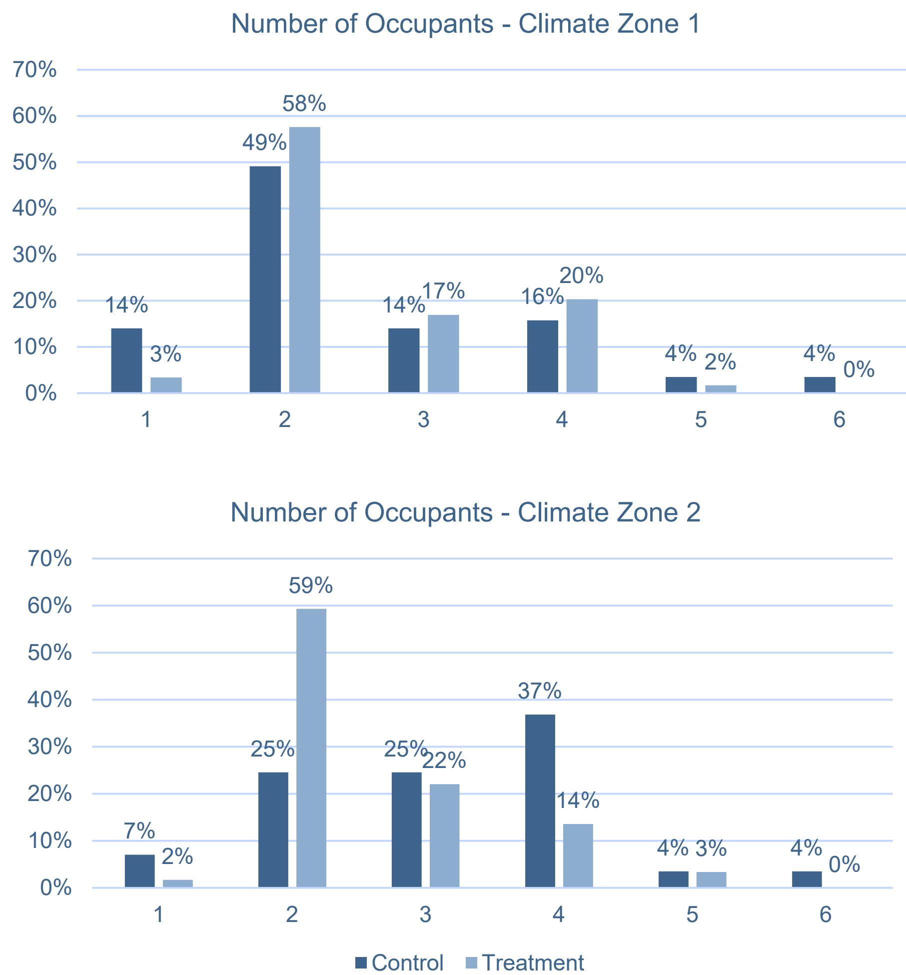
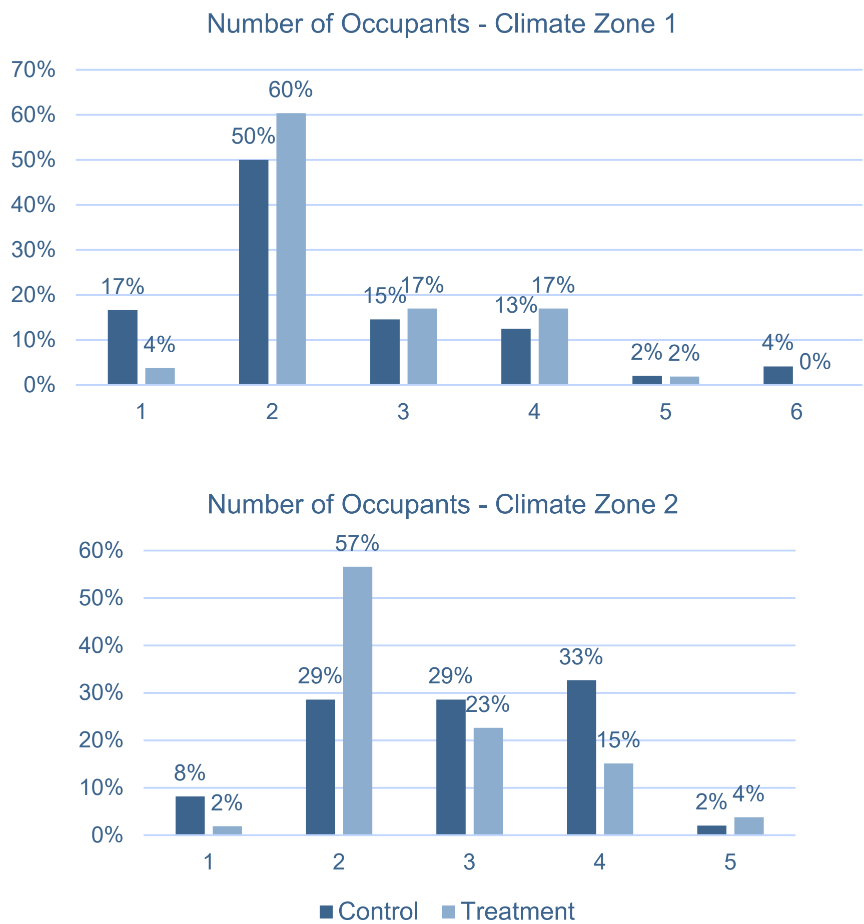


Figure 5: Adjusted Distribution of Number of Occupants per Household



As for special electric loads, eight participants had them in the treatment group compared to four in the control group. Econoler adjusted the treatment group so that only five participants still had special electric loads.

Table 5 summarizes the number of participants for which data were available when first comparing the control and treatment groups and after adjustments to those groups were made.

Table 5: Available Participants for Control and Treatment Group Validation

	Climate Zone 1		Climate Zone 2	
	Control Group	Treatment Group	Control Group	Treatment Group
Participants with available data prior to control/treatment group validations	57	59	57	59
Remaining participants after control/treatment group validations – February 2020	48	53	49	53

4.1 Evolution of Control and Treatment Groups Over Time

As mentioned previously, the control and treatment group validations were performed for February 2020. However, since the list of valid meters varies from one month to another, Econoler ensured that small changes to each sub-group did not have a significant impact on the comparability of the control and treatment groups in each climate zone. The average values for the number of occupants per household and house size and the number of participants who use secondary heating systems were computed for the control and treatment groups in each climate zone for each month of the study. No significant variation was found, which indicated that the control and treatment groups remained as comparable as they were as of February 2020. While the number of available meters decreased by a few units by the end of the study (with no fewer than 43 meters each month for each sub-group), Econoler does not expect that this variation had a significant impact on the reliability of results.

4.2 Impact of Remaining Differences

Although the differences between the control and treatment groups were not statistically significant in each climate zone, those small differences still had an impact on the average energy consumption of each sub-group. Since expected energy savings are a few percent of total electricity consumption, a relatively small difference between the total energy consumption of control and treatment groups can have a large impact on observed energy savings. Econoler therefore sought to quantify the impact of the remaining differences between the control and treatment groups. In Climate Zone 1, the impacts of differences on the size of houses and the number of households regularly using their secondary heating system were analyzed. In Climate Zone 2, the difference in the number of occupants per household was identified as the main discrepancy. Additionally, Econoler looked at the impact of occupancy patterns – a variable that is more qualitative and was not included in the control and treatment group validations but that appeared to have a sizable impact upon further analysis. The detailed calculations used to estimate the impacts on energy savings are presented in Appendix II.

Overall Impacts of Differences Between Control and Treatment Groups

As explained in Appendix II, each of the estimated impacts of individual differences between the control and treatment groups carry significant uncertainty. Therefore, it is not possible to apply those percentages to the energy savings calculated in the following sections to correct results for those differences. Despite this, there is value in listing the identified impacts to provide an order of magnitude for the overall impact on savings. Table 6 summarizes the impacts of energy savings in February.

Table 6: Estimated Impacts of Differences Between Control and Treatment Groups

Parameters that Are Different	Estimated Impact on Energy Savings in February*	
	Climate Zone 1	Climate Zone 2
House size	2.3%	-
Number of occupants per household	-	-1.5%
Secondary heating system usage	1.0%	-
Proportion of participants leaving their homes during winter	-0.3%	-2.6%
Proportion of participants leaving their homes during weekends	-1.3%	-0.3%
Overall Impact	**1.7%**	**-4.4%**
*Negative values indicate that savings are overestimated.		

4.3 Conclusions

Econoler draws two main conclusions from the comparison of the control and treatment groups and the analysis of the remaining differences.

- Overall, savings in Climate Zone 2 tend to be overestimated, and the composition of the control and treatment groups favour greater savings in Climate Zone 2 than in Climate Zone 1.
- Given that DHP energy savings are expected to be of the order of 10% to 20%, the control and treatment group approaches may not yield very precise savings results. The small variations in the composition of the control and treatment groups have a sizable impact on energy savings, especially if most differences influence savings in the same direction (i.e. both upward or downward). In addition, there could be other parameters that significantly influence energy consumption and that were not captured in the already extensive questionnaire used during the installation process. Finally, some household habits and characteristics are naturally different between the group of participants who have a DHP compared to those who do not; for instance, data shows that households that have a DHP consist of fewer people, and those people are more likely to leave the house for a sustained amount of time, thus impacting the energy consumption profile. For all those reasons, it is difficult to obtain perfectly matched control and treatment groups.

5 SAVINGS RESULTS

This section presents savings results, i.e. results that were obtained through a comparison of metered data from the control and treatment groups. It includes the annual energy savings as well as the peak demand savings, followed by additional analyses that were performed to provide additional insights into certain inconsistencies in the savings results, which are outlined in Subsections 5.1 and 5.2.

5.1 Energy Savings

Table 7 below summarizes the energy savings calculations per month. Monthly DHP energy consumption is also presented for comparison purposes. Then, Table 8 further below presents margins of error for the energy consumption and energy savings of each climate zone for the main heating season month (February) and the main cooling season month (August) to provide some perspective as to the accuracy of those values. All margins of error are presented at a 90% confidence level.

Table 7: Normalized Monthly Energy Consumption and Savings

Month	Whole-house Energy Consumption (kWh)				Energy Savings		Energy Savings in %		Energy Consumption of DHPs	
	Control Group		Treatment Group							
	Climate Zone 1	Climate Zone 2	Climate Zone 1	Climate Zone 2	Climate Zone 1	Climate Zone 2	Climate Zone 1	Climate Zone 2	Climate Zone 1	Climate Zone 2
January 2020	3,215	3,094	2,939	2,720	276	374	8.6%	12.1%	859	661
February 2020	2,890	2,921	2,641	2,458	249	463	8.6%	15.9%	724	632
March 2020	2,700	2,858	2,483	2,426	217	433	8.0%	15.1%	651	579
April 2020	2,041	2,281	1,952	1,917	89	363	4.4%	15.9%	406	394
May 2020	1,613	1,824	1,623	1,552	-10	271	-0.6%	14.9%	270	275
June 2020	1,152	1,314	1,279	1,221	-127	93	-11.0%	7.1%	305	176
July 2020	747	891	929	866	-182	24	-24.3%	2.7%	79	59
August 2020	773	887	947	865	-174	22	-22.5%	2.5%	82	57
September 2020	931	970	1,010	908	-78	63	-8.4%	6.5%	91	59
October 2020	1,519	1,541	1,403	1,354	115	187	7.6%	12.1%	250	224
November 2020	2,187	2,099	1,924	1,719	263	380	12.0%	18.1%	437	361
December 2020	2,740	2,916	2,645	2,442	95	474	3.5%	16.3%	631	553
TOTAL 2020	**22,508**	**23,595**	**21,774**	**20,448**	**733**	**3,147**	**3.3%**	**13.3%**	**4,786**	**4,030**
January 2021	3,125	3,215	2,901	2,710	224	505	7.2%	15.7%	750	679
February 2021	2,826	2,918	2,649	2,511	177	406	6.3%	13.9%	707	628
March 2021	2,638	2,789	2,495	2,410	143	379	5.4%	13.6%	631	589
April 2021	2,039	2,290	1,938	1,955	102	335	5.0%	14.6%	421	424

Table 8: Margins of Error for Energy Savings

Months	Control Group Consumption		Treatment Group Consumption		Savings	
	Absolute (kWh)	Relative	Absolute (kWh)	Relative	Absolute (kWh)	Relative
Climate Zone 1						
February	205	7.1%	183	6.3%	317	127%
August	81	10.5%	78	8.3%	120	69%
Climate Zone 2						
February	161	5.5%	195	7.9%	267	58%
August	65	7.3%	81	9.4%	109	494%

Although the margins of error on monthly electricity consumption are quite low (between 5% and 9%), the margins of error for savings appear to be very high. The margin of error for Climate Zone 1 February 2020 savings is higher than the savings value. However, looking only at the margin of error can be misleading. The margin of error of 317 kWh established at a confidence level of 90% means that we can be 90% confident that the true savings value is between -68 kWh and 566 kWh and that there is a 5% chance that the savings are below that interval and there is a 5% chance that savings are above that interval. To determine whether the savings are statistically significant, we need to be quite confident that the savings are actually not nil. So, Econoler calculated the probability of savings being below zero, which is 9%. Typically, a statistical significance level of 5% or lower is the convention among experimental scientists, although it is not uncommon for a metering study of this type to encounter a probability of nil savings between 5% or 10%.[7] In conclusion for Climate Zone 1, February savings are statistically significant but toward the upper limit of what is acceptable.

Winter savings in Climate Zone 2 are clearly statistically significant. Although the margins of error on the electricity consumption of the treatment group and the control group are similar to those of Climate Zone 1, the savings calculated for Climate Zone 2 are much higher than those of Climate Zone 1. Savings during the shoulder seasons and the summer are not statistically significant given the low level of savings observed. The relative margin of error of 494% for August savings appears extremely high, but it is driven by the close to nil energy savings rather than high variability in the data.

[7] For instance, measured savings as part of one of the most detailed metering studies conducted on DHPs, which were used to evaluate the residential programs of Electric and Gas Program Administrators of Massachusetts and Rhode Island, also present margins of error of the same magnitude as the savings themselves. See The Cadmus Group, Inc., *Ductless Mini-Split Heat Pump Impact Evaluation*, report prepared for The Electric and Gas Program Administrators of Massachusetts and Rhode Island, 2016, Table 12, p. 67.

However, statistical indicators are not the only or the most important indicators of the validity of the study. Upon analyzing those monthly results for both zones, Econoler makes the following observations and identifies certain issues:

- The monthly energy savings in Climate Zone 2 are consistent with what was expected; savings are fairly high and consistent throughout the heating season (winter) and lowest during the cooling season (summer).
- **Issue #1**: Savings in Climate Zone 1 are significantly lower than in Climate Zone 2. In addition, the negative savings in the summer in Climate Zone 1 are approximately twice the value of DHP consumption.
- **Issue #2**: Savings in Climate Zone 1 do not follow the expected patterns. It was assumed that lower savings might occur during the winter in Climate Zone 1 because lower temperatures negatively impact the performance of DHPs; however, once temperatures rise in the spring and become closer to DHP optimal operating temperatures, energy savings decrease quickly instead of increasing.

5.2 Peak Demand Savings

To determine which days and hours should be considered as meeting the peak conditions, Econoler used the grid-level hourly demand data provided by Newfoundland Power for the period of January 2020 through April 2021.[8] By adding the 2021 data to the analysis conducted, the results of which are included in the Preliminary Report in 2020, it was hoped that more extreme peak conditions would be observed. In fact, that was not the case and, since the 2021 winter was significantly milder than 2020 and the grid peak demand was generally lower, Econoler only used 2020 data to establish peak demand periods.

Econoler considered two definitions for the peak period: The top 20 and the top 10 highest-demand hours of the 2020 winter. Using only the 10 highest demand hours yields results that are closest to the absolute peak conditions sustained by the grid but allowed fewer data points. The 20 hours and their corresponding maximum grid demand and weather conditions in the two main cities for Climate Zones 1 and 2 are presented in Table 9.

[8] The grid-level demand data correspond to the total of Newfoundland Power's production and purchases from Newfoundland and Labrador Hydro.

Table 9: Top 20 Hours of Grid Peak Demand

Date/Time	Time	Maximum Grid Demand (MW)	St. John's		Gander	
			Temperature (°C)	Wind Chill (°C)	Temperature (°C)	Wind Chill (°C)
Feb 21, 2020	7:00 AM	1,373.65	-12.4	-24.20	-16.40	-26.16
Feb 21, 2020	8:00 AM	1,358.88	-11.60	-24.05	-14.70	-25.65
Mar 10, 2020	7:00 AM	1,358.16	-12.90	-23.15	-16.30	-26.46
Mar 10, 2020	8:00 AM	1,357.86	-11.90	-20.85	-15.30	-25.38
Jan 15, 2020	8:00 AM	1,350.39	-12.70	-19.19	-16.80	-23.78
Jan 15, 2020	7:00 AM	1,350.07	-11.90	-18.82	-15.90	-24.57
Feb 14, 2020	6:00 PM	1,338.15	-13.70	-27.01	-16.20	-29.18
Feb 14, 2020	7:00 PM	1,337.25	-13.70	-27.39	-18.50	-32.89
Jan 10, 2020	8:00 AM	1,337.09	-13.00	-22.96	-15.80	-27.40
Jan 10, 2020	7:00 AM	1,334.76	-13.20	-25.39	-15.90	-25.53
Feb 14, 2020	5:00 PM	1,330.70	-13.20	-25.39	-15.90	-27.38
Jan 15, 2020	9:00 AM	1,330.14	-12.00	-16.83	-14.10	-21.51
Feb 21, 2020	6:00 AM	1,322.69	-12.60	-25.01	-17.10	-26.82
Feb 14, 2020	8:00 PM	1,322.58	-14.00	-28.25	-19.70	-30.58
Feb 15, 2020	8:00 AM	1,313.97	-14.30	-25.72	-16.60	-28.61
Jan 22, 2020*	8:00 AM	1,312.43	-13.30	-18.80	-14.70	-20.46
Feb 15, 2020	7:00 AM	1,308.86	-15.00	-27.57	-17.50	-30.38
Feb 14, 2020	9:00 PM	1,307.58	-14.00	-27.12	-20.00	-32.20
Jan 22, 2020*	7:00 AM	1,306.78	-16.20	-22.24	-14.60	-22.69
Jan 10, 2020	9:00 AM	1,295.24	-12.30	-22.67	-15.00	-24.80

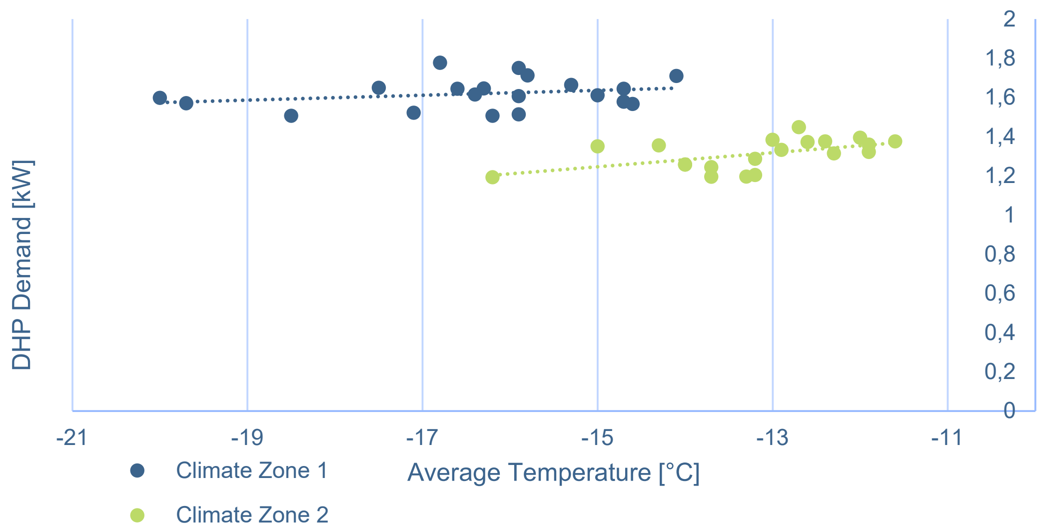
Table 10 summarizes the average demand consumption and savings by climate zone for the 20 hours during which grid demand was the highest for the 2020 winter. The results are presented alongside their margin of error at a confidence level of 90%. The demand consumption for these calculations was not weather-normalized. Econoler also calculated the same values for the top 10 hours, but results were only marginally different, so the top-20 peak hours definition was used.

Table 10: Demand and Demand Savings During Top-20 Peak Hours

	Whole-house Average Consumption (kW)		Savings (kW)	Savings (%)	DHP Consumption (kW)
	Control Group	Treatment Group			
Climate Zone 1	5.67 ± 0.42	5.56 ± 0.42	0.11± 0.59	1.9%	1.62
Climate Zone 2	6.04 ± 0.37	5.16± 0.47	0.89 ± 0.59	14.5%	1.31

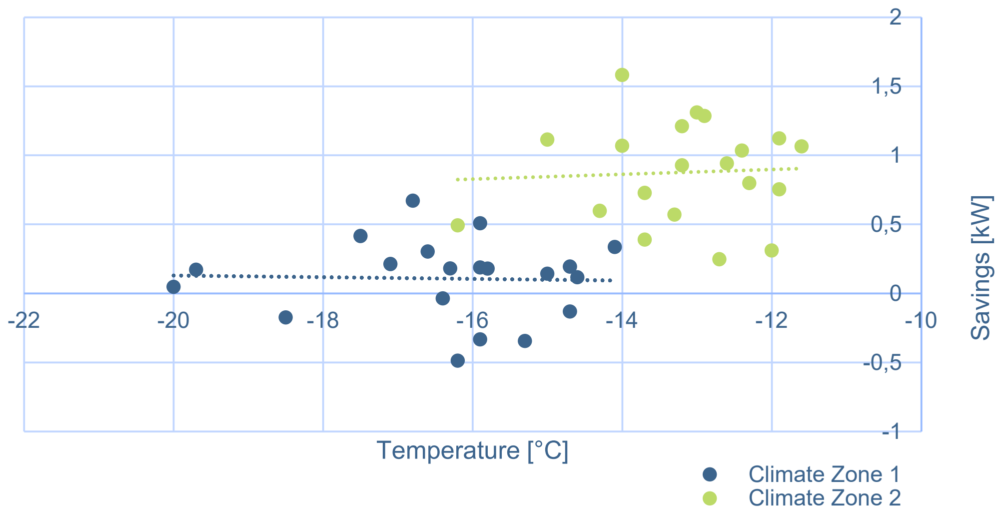
In Climate Zone 1, peak demand savings were not statistically significant, and they were much lower than in Climate Zone 2. However, the average demand of DHPs during those peak hours are higher in Climate Zone 1. This is further illustrated in Figure 6 below; it illustrates how demand varies as a function of outside air temperature in both zones.

Figure 6: DHP Demand as a Function of Outside Temperature During Top-20 Peak Hours



While DHPs tend to consume less as temperature decreases, the above figure also indicates that Climate Zone 1 DHPs consume more than those in Climate Zone 2. This is probably because DHPs in Climate Zone 1 have an average capacity that is 25% higher than DHPs in Climate Zone 2. Since the observed power consumption in cold temperatures remains high in Climate Zone 1, Econoler is confident that the low peak demand savings in Climate Zone 1 are not due to the heating load being met by other electric resistance heating while DHPs are turned off. DHP energy consumption patterns are further discussed in Section 6.1 below. Figure 7 illustrates energy savings as a function of outside temperature for those same top-20 hours.

Figure 7: Demand Savings as a Function of Outside Temperature During Top-20 Peak Hours



Demand savings are much more dispersed and do not correlate with outside temperature as clearly. Based on the two previous graphs, demand and savings results are not expected to be significantly different if the outside temperature was lower by a few degrees during future peak hours.

This analysis, however, identifies a third issue with the results of the control and treatment group comparison:

› **Issue #3**: Despite evidence that the DHPs in Climate Zone 1 operate during peak hours, the comparison of the control and treatment groups yields very low peak demand savings. To the contrary in Climate Zone 2, the savings level for peak demand savings is high and of a similar value, in percentage, to that of energy savings in the winter months.

5.3 Additional Analyses

To identify the root causes of the three aforementioned issues, Econoler applied various analysis techniques including:

› A comparison of weather data to understand differences between zones;
› An analysis of individual DHP and whole-house meter interval data to find patterns that vary between zones;
› A regression analysis performed on the control and treatment groups within each zone to disaggregate heating, cooling, and base loads.

The details of these analyses and the corresponding findings are presented in Appendix III.

These analyses demonstrated that there are indeed differences between the control and treatment groups, which are not captured in the validation of the groups, especially in Climate Zone 1. Given the differences are not linked to any of the documented parameters of the metering study participants, their exact nature cannot be known.

5.3.1 Pre-post Billing Analysis

Since the control and treatment group compositions induce some bias in the results and Climate Zone 1 results are inconsistent, Econoler used an alternative approach to provide a point of comparison and validation. A pre-post billing analysis was performed and consisted of comparing the electricity consumption of households before and after the installation of their DHPs. The methodology used is described in Appendix IV.

Table 11 presents the savings obtained using the above methodology along with average characteristics of the group of participants included in the analysis.

Table 11: Pre-post Billing Analysis Results

Climate Zone	Valid Participants	Average DHP Heating Capacity (Btu/h)	Average DHP HSPF (W/Btu/h)	Average Installation Date	Average Energy Savings (kWh)	Average Pre-installation Electricity Consumption (kWh)	Average Energy Savings (%)
1	44	23,207	9.36	December 2017	4,480	26,451	16.9%
2	37	21,350	9.54	January 2018	4,349	26,117	16.7%

The average characteristics of participants in both climate zones are quite similar. Heating capacity is slightly higher in Climate Zone 1, and efficiency is slightly higher in Climate Zone 2, but overall those differences are minor. Energy savings, both in percentage and kWh, are also extremely similar.

The margin of error on these results is relatively large, due to the limited number of participants sampled in each climate zone. For instance, the margin of error at a confidence level of 90% is of 2,787 kWh, for savings of 4,480 kWh in Climate Zone 1 (savings of 16.9% carry a margin of error of ± 10.5%). However, those savings are also clearly statistically significant, with the probability of them being nil below 0.5%. These results also demonstrate that savings are likely to be fairly high; there is a 69% chance that annual savings are above 3,000 kWh.

One drawback of this methodology is that it also captures some savings that could be due to something other than the DHP installation that occurred between the pre and post-installation periods. For example, participants could have changed some of their lighting to LEDs or replaced an old refrigerator with a new more efficient unit. To obtain a more reliable value, a control group would have to be analyzed over the same period covered by the pre-post billing analysis to establish a savings value based on general energy efficiency improvements other than the installation of a DHP. It should, however, be noted that the pre and post-installation periods are only 14 months apart, so this should not have a major impact on savings, at most of a few percent.

Despite this, the billing analysis allows drawing one important conclusion: Energy savings in both climate zones should be similar. The confidence interval excludes the annual savings value of 3.3% that was obtained with the control and treatment group approach in Climate Zone 1, while the value for Climate Zone 2 (13.3%) is well within that confidence interval. The billing analysis cannot be used to calculate peak demand savings but, knowing that the control and treatment group approach seems to be valid in Climate Zone 2, it is reasonable to assume that the peak demand savings values obtained in Climate Zone 2 are close to real savings.

An analysis of the load factor obtained for each subgroup, as presented in Table 12, supports the use of Climate Zone 2 peak demand savings for Climate Zone 1. The load factor is calculated by dividing the average power consumption (in kW) over the entire year by power consumption under peak conditions.

Table 12: Load Factor Calculations

	Control Group	Treatment Group
Climate Zone 1	45.2%	44.6%
Climate Zone 2	44.5%	45.1%

Load factors are similar between the control and treatment groups as well as between climate zones. The fact that load factors do not vary between the two groups demonstrates that energy savings and peak demand savings are of the same magnitude, as it was already established by the peak demand savings percentages calculated in Table 10 above. Now, if it is accepted that energy savings in Climate Zone 1 are indeed similar to those of Climate Zone 2 (of a magnitude of around 15% as demonstrated by the control and treatment group comparison for Climate Zone 2 and by the pre-post billing analysis for both climate zones), then a similar load factor for both treatment groups means that, if there are peak demand savings in Climate Zone 2, similar peak demand savings are also found in Climate Zone 1. Indeed, the absence of peak demand savings and presence of energy savings in Climate Zone 1 would result in a significantly lower load factor, which is not the case. Consequently, Econoler considers that the measured peak demand savings for Climate Zone 2 can be used as a reasonable estimate of savings in Climate Zone 1. This conclusion is consistent with the fact that the measurement of DHPs during peak demand hours shows that DHPs in Climate Zone 1 do operate at a level similar to those of Climate Zone 2.

6 CONSUMPTION RESULTS

This section details the energy consumption of DHPs throughout the year. The energy consumption level is expected to be added to the grid load if DHPs replace non-electrical heating sources; it should, however, be noted that all participants selected for this study had fully electrically heated homes, so the DHP consumption value might not be representative of DHP consumption if a non-electrical heating system (such as an oil furnace) is used in conjunction with a DHP. The consumption results for DHPs are based solely on the DHP meters installed for the treatment group. As such, these results are not affected by any bias or issue that was identified in the control and treatment group validation.

Table 13 summarizes the monthly energy consumption of DHPs, adjusted for normal temperatures. The results are averaged for the months that were metered in both 2020 and 2021.

Table 13: Normalized Monthly Energy Consumption of DHPs

Month	Energy Consumption (kWh)	
	Climate Zone 1	Climate Zone 2
January	804	670
February	715	630
March	641	584
April	413	409
May	270	275
June	305	176
July	79	59
August	82	57
September	91	59
October	250	224
November	437	361
December	631	553
TOTAL	**4,720**	**4,057**

The margin of error both for the February and annual values is about 12% in both climate zones.

The figures below present the daily load shapes of DHPs for both zones for a sample of months. The curves are not adjusted for normal weather since the figure is aimed at presenting the shape of daily consumption rather than exact consumption values.

Figure 8: DHP Average Electricity Consumption in February

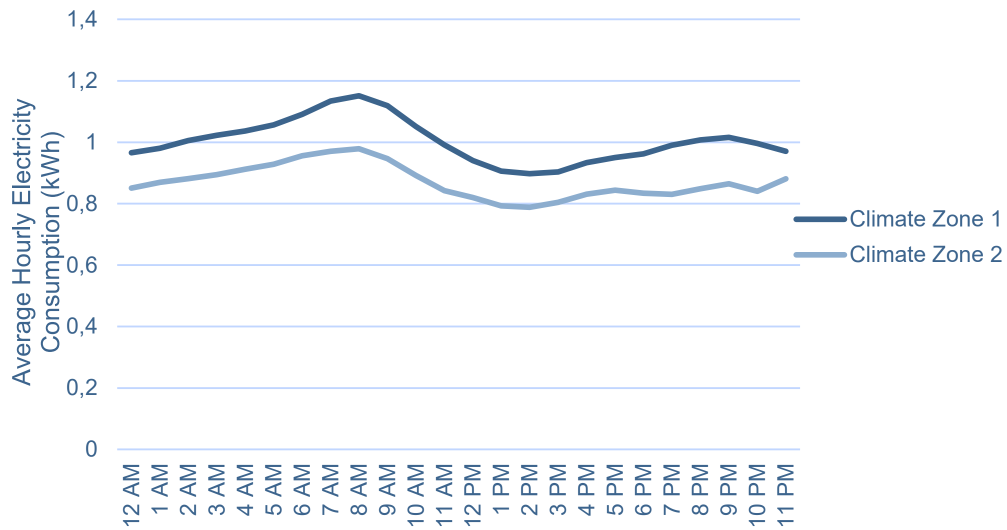


Figure 9: DHP Average Electricity Consumption in April

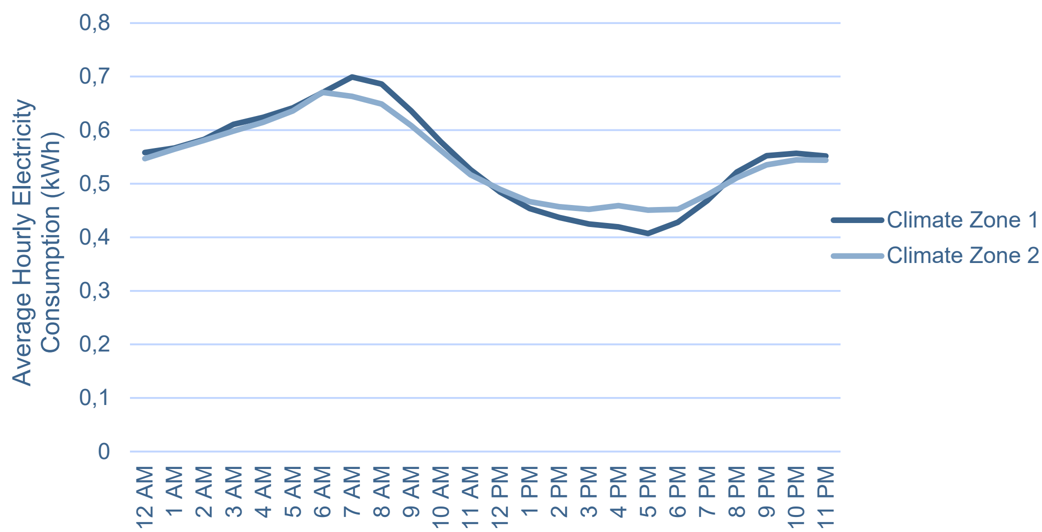


Figure 10: DHP Average Electricity Consumption in June

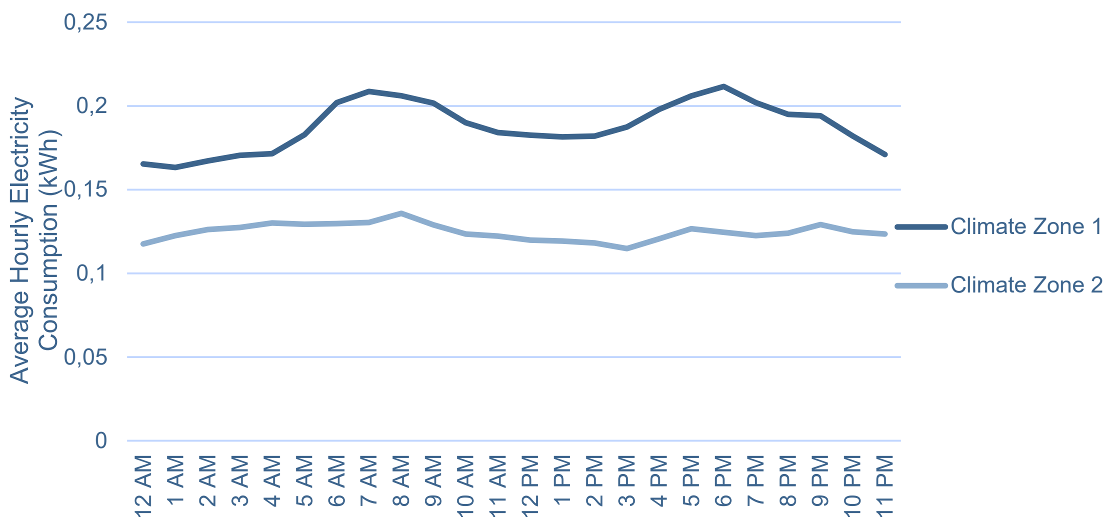


Figure 11: DHP Average Electricity Consumption in August

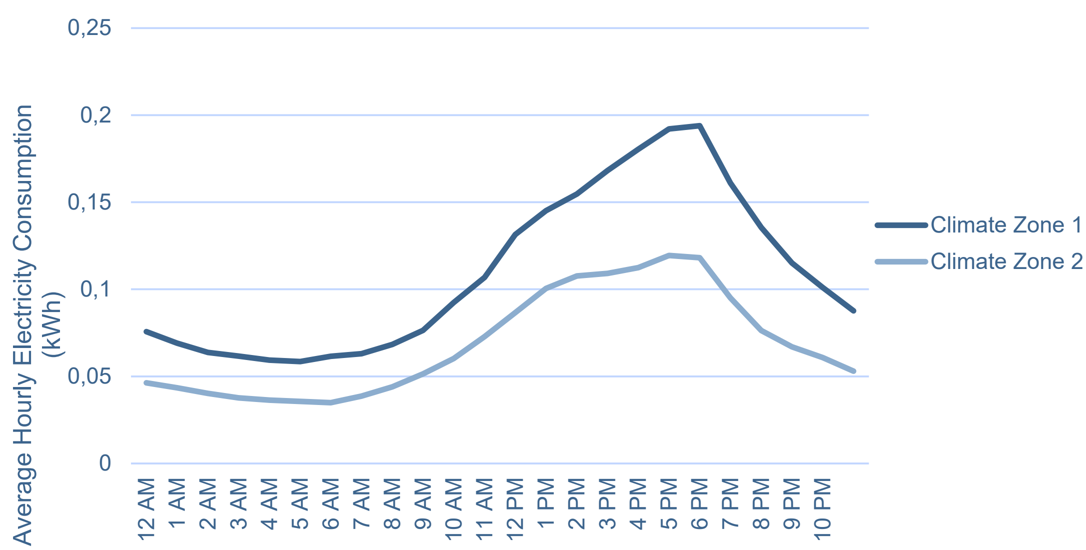


Figure 12: DHP Average Electricity Consumption in October

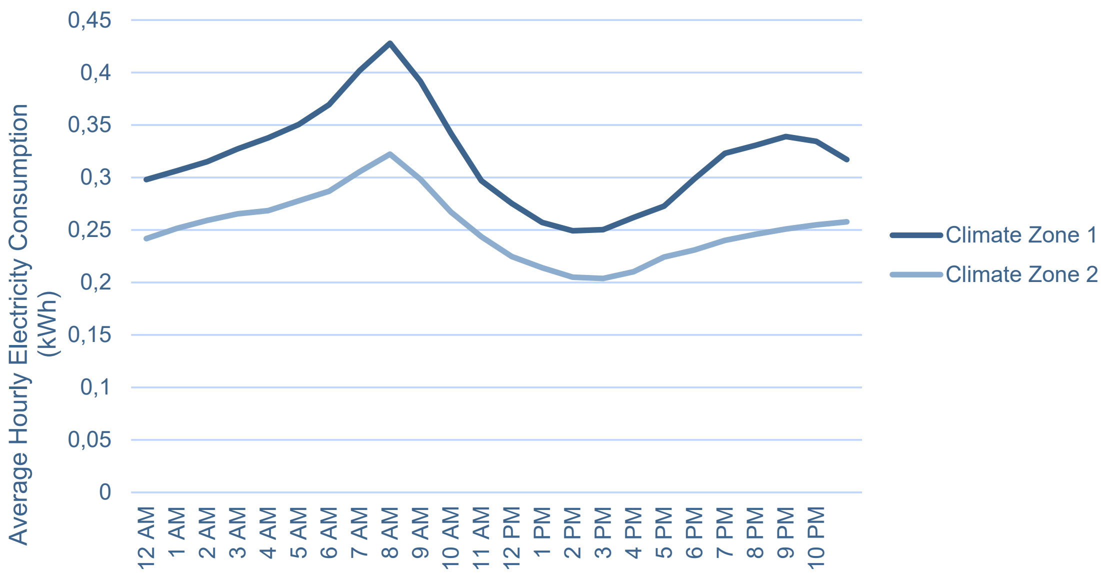
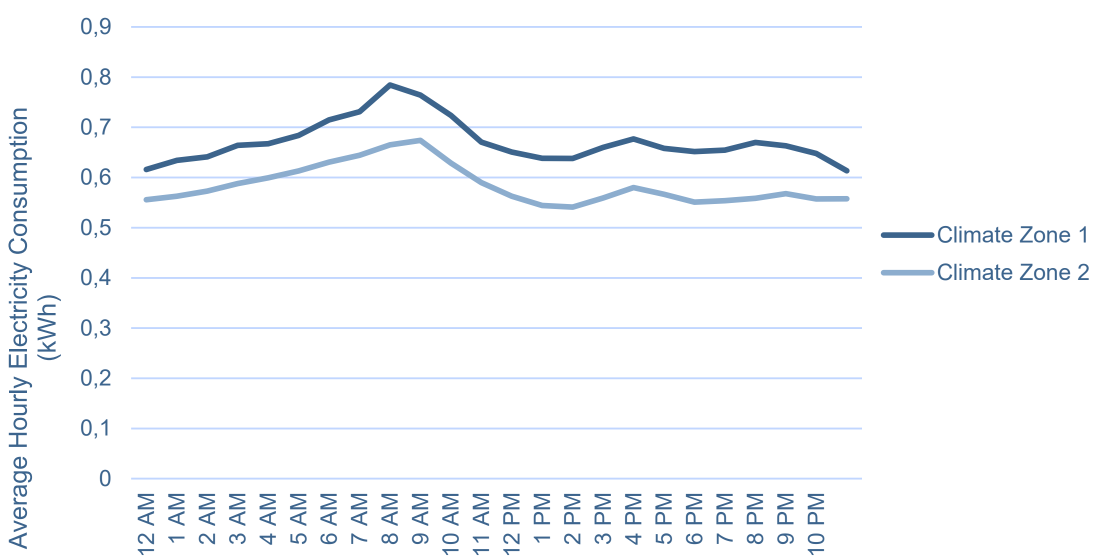


Figure 13: DHP Average Electricity Consumption in December



Throughout the year, DHPs in Climate Zone 1 consume more electricity than in Climate Zone 2. During the heating season, two peaks are generally observed, one in the morning and one in late afternoon. During the cooling season, the main peak becomes the afternoon peak.

Average Power Draw During Peak Hours

Table 14 below lists the average power draw during peak hours, thus providing insights on how DHPs consume energy during peak hours.

Table 14: DHP Average Demand During Peak Hours

	Climate Zone 1	Climate Zone 2
Average kW	1.62	1.31
Margin of error	**±0.18**	**±0.15**
Margin of error (%)	**10.9%**	**11.6%**

The average power draw in both zones may seem low given that the average heating capacity for Climate Zone 1 is 20,000 Btu/h (5.9 kW) and for Climate Zone 2 is 25,000 Btu/h (7.3 kW). However, the heating capacity was obtained at the rated condition of 8.8 °C; this capacity lowers as the ambient temperature decreases. For instance, for the DHP models listed on the Air-Conditioning, Heating, and Refrigeration Institute website that have an HSPF of 10 or higher and a rated output between 9,000 and 36,000 Btu/h, the average ratio of heating capacity at -8.8 °C to the heating capacity at 8.8 °C is 63%. Under the peak conditions (between -10 °C and -20 °C), that capacity is likely to further decrease. If a DHP has a rated heating capacity of 5.9 kW, a capacity of about half this value at -15 °C, and a coefficient of performance (COP) of 2, it consumes about 1.5 kW at -15 °C if it operates at full load. This value of 1.5 kW is close to the average power draw observed during peak hours, thus indicating that most DHPs do operate most of the time in peak conditions.

6.1 DHP Consumption Patterns

Although metering data were aggregated at the hourly level for most of the calculations in this study, Econoler used the five-minute interval data collected by the meters to analyze the consumption patterns of DHPs. The objective of that analysis was to find evidence of differences in the way DHPs operate in Climate Zone 1 and Climate Zone 2 that could explain the lower savings in Climate Zone 1. More specifically, Econoler was looking for signs that DHPs were operating less often, or that issues such as frequent defrosting occurred more in one zone than the other.

Econoler selected a total of 30 DHPs, divided equally between the two climate zones. In each climate zone, the 15 DHPs were organized in groups of five: Five that consumed the most electricity in February, five that consumed about an average amount in February, and five that consumed the least in February. The consumption levels then were normalized, meaning the electricity consumption was divided by the heating capacity, to avoid identifying smaller DHPs as lower consumers.

First, Econoler identified the four main operation patterns that were observed among the 30 DHPs, which are presented in Figure 14 to Figure 17. In those figures, the yellow line is the consumption of the whole-house meter and the purple line, the consumption of the DHP meter.

Figure 14: Example DHP that Cycles to Zero

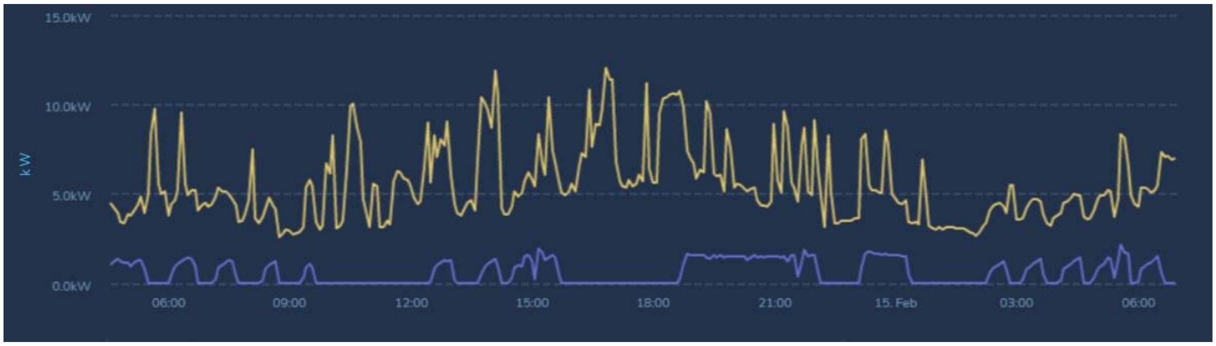


Figure 15: Example DHP that Cycles Between Plateaus

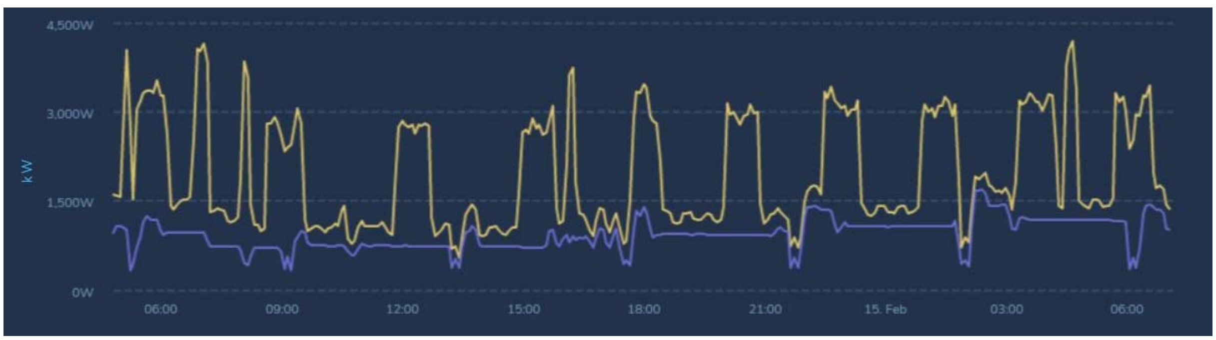


Figure 16: Example DHP that Operates Steadily with Short Dips

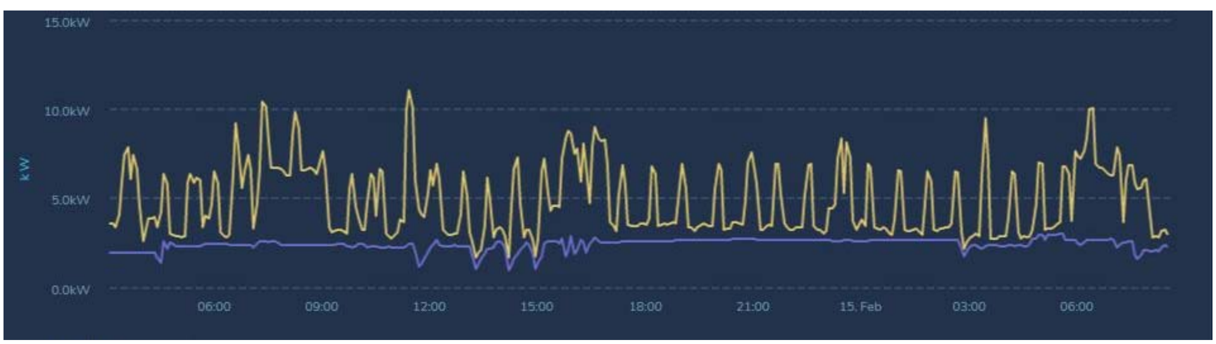
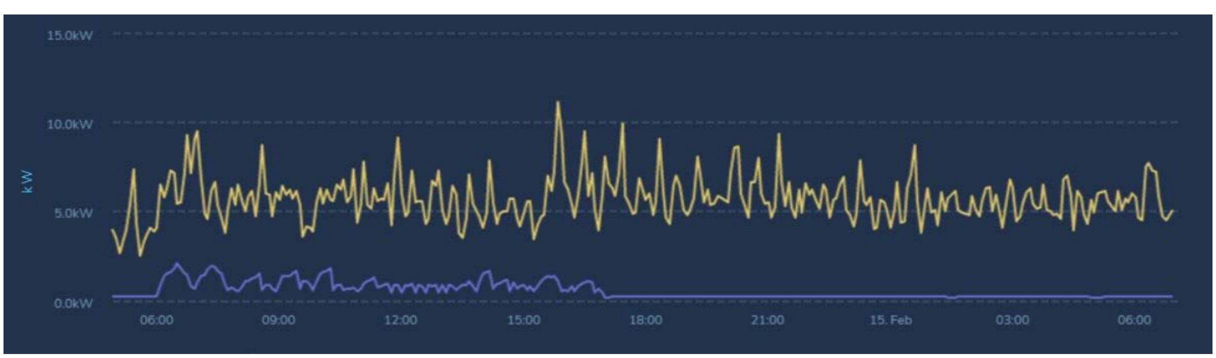


Figure 17: Example DHP with Rapid Oscillations



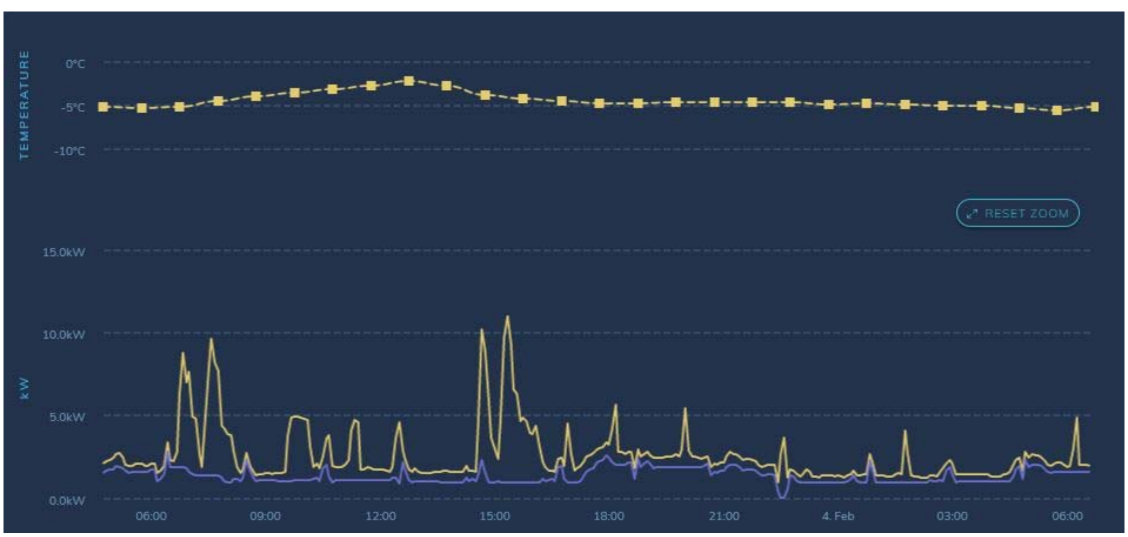
Econoler found that each pattern was present and that their relative frequencies were the same in both climate zones. As expected, DHPs that cycle to zero are more common among low consuming DHPs. However, DHPs that consume less also have lower maximum power inputs, as outlined in Table 15 below.

Table 15: DHP Maximum Power per Climate Zone and Consumption Level

Consumption Level	Average Temperature on Cold Days		Normalized Average Maximum Power on Cold Days (W/(kBtu/h))	
	Climate Zone 1	Climate Zone 2	Climate Zone 1	Climate Zone 2
High	-18 °C	-14 °C	147	146
Medium			87	107
Low			70	54

Interestingly, Econoler found three DHPs that were entirely shut off at night (one in Climate Zone 1 and two in Climate Zone 2), as illustrated in Figure 17 above. However, no DHPs were found to shut off due to cold temperatures. Econoler also looked for patterns that suggested that the defrost cycle of DHPs was activated. There were only a few cases in which defrosting was visible; in most cases, the defrost cycle only lasted 30 seconds to a few minutes, so it might not be visible with five-minute interval data. Furthermore, since DHPs typically defrost by reversing their compressors, the energy consumption during that interval might not be significantly different from the normal heating mode. There were a few DHPs for which regular short peaks of demand were visible, which could indicate a power surge as compressors were stopped and reversed, as illustrated by Figure 18.

Figure 18: Example DHP with Potential Defrost Mode Power Surges



While the data collected do not demonstrate frequent defrost mode operation, they also do not allow to conclude on the frequency and importance of defrost mode operation. Econoler, however, notes that if defrost was an issue that led to underperformance of heat pumps, it would most likely have an impact in Climate Zone 2, which has more days around the freezing point, where frost accumulation generally occurs.

CONCLUSIONS

Through the metering study, energy savings were estimated at 3,147 kWh per household (13.3% of annual electricity consumption). Peak demand savings were estimated at 0.89 kW (14.5% of total peak demand consumption) per household, for weather conditions similar to those experienced during the 16-month study period. Due to the relatively mild weather conditions experienced during the study period, additional data would be required to assess DHP performance and system impacts during colder weather conditions that can occur in Newfoundland.

These results were obtained for Climate Zone 2 specifically but are considered a good estimate of savings in Climate Zone 1 as well. Savings in Climate Zone 1 presented a number of issues, including unusual patterns in the spring and summer, and an absence of savings in grid peak conditions despite clear evidence that DHPs are operating in those conditions. While the electrical consumption data and participant information collected as part of this study did not serve to answer all questions concerning the issues with savings, Econoler could provide some potentially reasonable explanations for those issues and concluded that the comparison of the control and treatment groups in Climate Zone 1 could not be used to reliably estimate energy or peak demand savings.

Econoler used other approaches to validate the results of the control and treatment group analysis. A billing analysis comparing energy consumption in the year prior to and following the installation of DHPs demonstrated that annual energy savings should be similar in both climate zones and were much closer to the results obtained in Climate Zone 2.

The billing analysis, however, does not provide an estimate of peak demand savings; only the hourly metering data can provide that information. Econoler believes the peak demand savings for Climate Zone 2 are reasonably estimated since the comparison of the control and treatment groups for that climate zone was consistent with the results of the additional analyses performed, including the billing analysis. The analysis of the load factor of the various subgroups also provided strong evidence that peak demand savings were also present in Climate Zone 1.

Consequently, Econoler considers that the energy and peak demand savings results obtained for Climate Zone 2 through the control and treatment group approach are a good estimate of the savings that can be obtained for DHPs in Newfoundland as a whole. This metering study was a first attempt at using a control and treatment group to obtain time-sensitive savings and consumption results. Using a control and treatment group approach presented challenges. It is difficult to perfectly match the multiple parameters that impact energy consumption between the control and treatment groups, and failing to do so induces a bias in results. It is also possible that some energy-impacting parameters are not identified or cannot be documented. Furthermore, there tends to be inherent differences in the habits of households that purchase DHPs compared to those that do not. Recruiting a control group that fully resembles the treatment group is therefore a challenge, and this explains why results in Climate Zone 1 were not conclusive.

APPENDIX I
CALCULATIONS OF LOAD SHAPES

Energy Savings Load Shapes

To obtain the energy savings load shapes for heating, data from whole-house circuit meters of both the treatment group and control group were used.

The following calculation steps were carried out by using the data for each participant in both the treatment and control groups. These steps performed on the whole-house circuit meter data are essentially the same as those performed for the DHP electricity consumption load shapes.

1 The five-minute interval data points for each hour were added up, resulting in one value in kWh for each of the 8,760 hours in a year.

2 The five-minute interval data points for each day were also added up, resulting in one value in kWh for each day in a year.

3 Each daily data point (from Step 2) was associated with outdoor temperature at a given location and on a given day by cross-referencing a historical weather database from Environment Canada (and NASA model data, where necessary, to fill in gaps).

4 A regression of all the daily data points as a function of outdoor temperature was developed for each participant (based on the data points obtained from Steps 2 and 3) and for three separate seasons. Those seasons were the winter 2020 (January 1 to June 20), summer 2020 (June 21 to October 10), and winter 2020-2021 (October 11, 2020 to April 30, 2021). These seasons were identified based on an analysis of the inflexion points for the daily energy consumption of all participants

   Each regression was established using the following equation: $kWh = \alpha + \beta \cdot T$, where T is the outdoor temperature in degrees Celsius. For each season and each sub-group (control and treatment, Climate Zones 1 and 2), an average α and β value was obtained.

5 Each hourly data point was normalized to be compatible with electricity consumption during a typical weather year using the following equation:

$$kWh_{norm_i} = kWh_i \times \left(\frac{\alpha + \beta \cdot T_{norm\,j}}{\alpha + \beta \cdot T_j} \right)$$

Where:

- i represents each hour of a year;
- j represents each month of a year;
- α and β are drawn from the average regression obtained for each season and each sub-group;
- kWh_i is the recorded electricity consumption for each hour at the whole-house circuit meter;
- T_{norm_j} is the normal average temperature for the month (based on a weighted average of the locations included in each sub-group);
- T_j is the average temperature for the month (based on a weighted average of the locations included in each sub-group).

6 To obtain whole-house energy savings load shapes, the following calculation steps were performed to aggregate the individual results of all subcategories in both the control group and the treatment group samples. Normalized data were aggregated at the monthly level and for each climate zone. Energy savings load shapes were obtained by subtracting the treatment group consumption from the control group consumption.

DHP Electricity Consumption Load Shapes for Heating

To obtain the annual load shapes of DHP electricity consumption, the metered DHP electricity consumption data of all participants in the treatment group were used. The following calculation steps were performed on the data for each participant:

1 The five-minute interval data points for each hour were added up, resulting in one value in kWh for each of the 8,760 hours in a year to limit the peaks and valleys caused by equipment being turned on and off.

2 The five-minute interval data points for each day were added up, resulting in one value in kWh for each of the days in a year.

3 Each daily data point (from Step 2) was associated with outdoor temperature at a given location on a given day by cross-referencing a historical weather database from Environment Canada (and NASA model data, where necessary, to fill in gaps).

4 A regression of all the daily data points as a function of outdoor temperature was developed for each participant (based on the data points obtained from Steps 2 and 3) and for three separate seasons. Those seasons were the winter 2020 (January 1 to June 20), summer 2020 (June 21 to October 10), and winter 2020-2021 (October 11, 2020 to April 30, 2021). These seasons were identified based on an analysis of the inflexion points for the daily energy consumption of all participants.

Each regression was established using the following equation: $kWh = \alpha + \beta \cdot T$, where T is the outdoor temperature in degrees Celsius. For each season and each sub-group (control and treatment, Climate Zones 1 and 2), an average α and β value was obtained.

5 Each hourly data point was normalized to be compatible with the electricity consumption during a typical weather year using the following equation:

$$kWh_{norm_i} = kWh_i \times \left(\frac{\alpha + \beta \cdot T_{norm\,j}}{\alpha + \beta \cdot T_j}\right)$$

To obtain the annual load shapes of DHP electricity consumption, the following calculation steps were performed to aggregate the individual results of all the subcategories in the treatment group sample.

6 Normalized data points were aggregated at the monthly level and for each climate zone.

APPENDIX II
IMPACT OF REMAINING DIFFERENCES

House Size and Number of Occupants

The correlations between the quantitative variables and the energy consumption for the month of February 2020 were established in the early stage of the control and treatment group validations. Econoler used these correlations to quantify the impacts of differences in house sizes and in the number of occupants.

Table 16 below details how the impacts of house size differences were calculated for Climate Zone 1.

Table 16: Impacts of House Size Differences on Energy Consumption – Climate Zone 1

	Control	Treatment
Average house size (ft²)	1,356	1,505
Equation to calculate daily energy consumption, February 2020 (kWh)	142.4+0.0276*size	
Adjustment to daily energy consumption due to difference (kWh/day)	4.11	
February daily energy consumption according to above equation, before adjustment (kWh/day)	180	
Relative adjustment to daily energy consumption due to difference	2.3%	

This indicates that, for Climate Zone 1, the remaining difference in house size between the control and treatment groups (after the adjustments described in Section 4 above) results in underestimated savings of 2.3% for the month of February 2020. This value should be used with care since it contains a significant margin of error; indeed, the coefficient of 0.0276 has a p-value of 0.19, meaning there is a 19% chance that this parameter has no impact on energy consumption. Despite this statistical interpretation, knowing that the laws of physics support higher energy consumption based on house size (more heat losses through building envelope), Econoler considers that it's worth to factor in house size to estimate the impacts of the discrepancies between the two sub-groups.

A similar approach was used to quantify the impacts of the difference in the number of occupants per household in Climate Zone 2

Table 17: Impacts of Number of Occupant Differences on Energy Consumption – Climate Zone 2

	Control	Treatment
Average number of occupants per household	2.92	2.62
Equation to calculate daily energy consumption (February 2020)	161.2+9.875*nb occ.	
Adjustment to daily energy consumption due to difference (kWh/day)	-3.0	
February daily energy consumption according to above equation, before adjustment (kWh/day)	190	
Relative adjustment to daily energy consumption due to difference	-1.5%	

This indicates that the discrepancy in the number of occupants per household leads to an overestimation of savings of approximately 1.5%. Again, there is a certain margin of error on the correlation coefficient (which has a p-value of 12%), but the order of magnitude is reliable.

Usage of Secondary Heating Systems

As aforementioned, there are still four participants who use their woodstove regularly in Climate Zone 1, with three of them being in the control group. Logic dictates that homes heated with wood might consume less electricity in the winter, so this difference could underestimate both the energy consumption of the control group and electricity savings. Econoler calculated the average electricity consumption of participants who regularly use their woodstoves and found that they reduced the February energy consumption of the entire control group by 1.0%. This value should be interpreted with extreme caution; electricity consumption varied greatly among those three participants and, so, the 1% value might not be representative of the impact of using a wood stove in general.

Occupancy Patterns

During the installation of meters, Ecofitt collected qualitative information on the occupancy patterns of participants. Participants indicated whether:

› They stay at home during the day on weekdays;
› They leave the house on weekends;
› They leave for at least one month during winter;
› They leave for at least one month during summer.

Noteworthy differences were identified in both climate zones:

1 In Climate Zone 1, four participants leave for at least one month during summer and three of them are in the treatment group, while six participants leave for a least one month during winter and four of them are in the treatment group. Also, four participants leave on weekends and all of them are in the control group.
2 In Climate Zone 2, four participants leave for at least one month during winter and three participants leave for at least one month during summer and all of them are in the treatment group. On weekends, eight treatment group participants leave their home, while only three control group participants do.

Similarly to the usage of secondary heating systems, occupancy pattern impacts on energy consumption cannot be calculated with precision and accuracy because of the very small number of participants that leave their house either during summer or winter; given the small sample size, the margin of error on their average energy consumption is very high. Notwithstanding, Econoler estimated the impact of each of those differences and included results in the summary table presented below.

Table 18: Estimated Impacts of Differences Between Control and Treatment Groups

Parameters that Are Different	Estimated Impact on Energy Savings in February*	
	Climate Zone 1	Climate Zone 2
House size	2.3%	-
Number of occupants per household	-	-1.5%
Secondary heating system usage	1.0%	-
Proportion of participants leaving their homes during winter	-0.3%	-2.6%
Proportion of participants leaving their homes during weekends	-1.3%	-0.3%
Overall Impact	**1.7%**	**-4.4%**
*Negative values indicate that savings are overestimated.		

APPENDIX III
DETAILED ANALYSIS OF SAVINGS ISSUES

The following subsections summarize how those analyses at least partially explain each of the issues identified.

Issue #1: Lower savings in Climate Zone 1, especially during summer

The lower savings observed in Climate Zone 1 are consistent with the expected impact of the remaining differences between the control and treatment groups, as described in Subsection 4.2. The fact that negative savings in the summer are of a higher magnitude than DHP consumption indicates that the difference between the control and treatment groups is due to something other than the added air-conditioning load.

Issue #2: Inconsistent savings patterns in Climate Zone 1

This issue is more complex and required multiple layers of analysis to identify the root causes of observed discrepancies.

The first assumption for the causes of this issue was that something in the control or treatment groups had changed over time and led to different savings starting in the spring. This assumption was invalidated by the analyses results presented in Subsection 4.1.

Econoler also looked at 15 individual DHP meters in Climate Zone 1 during the month of June to determine if energy consumption patterns indicated that heating and cooling occurred during the same day. June was selected because this is when maximum temperatures above 20 °C start occurring. Typically, each home either used their DHP mostly in the morning (when it is still cool) or only in the afternoon (for cooling); very few examples of days were identified during which a DHP was used for both cooling and heating on the same day. However, there were times when some DHPs provided cooling while others still provided heating, so this could appear in the load shapes that average all DHPs.

Econoler then analyzed how the monthly load shapes of the control and treatment groups varied over the year. The three graphs below present the results for February weekdays: the comparison of the control and treatment group whole-house meter consumption for an average weekday in Climate Zone 1 and Climate Zone 2 as well as the DHP consumption over an average weekday in both climate zones. All these graphs present non-normalized data.

Figure 19: Whole-house Electricity Consumption in February in Climate Zone 1

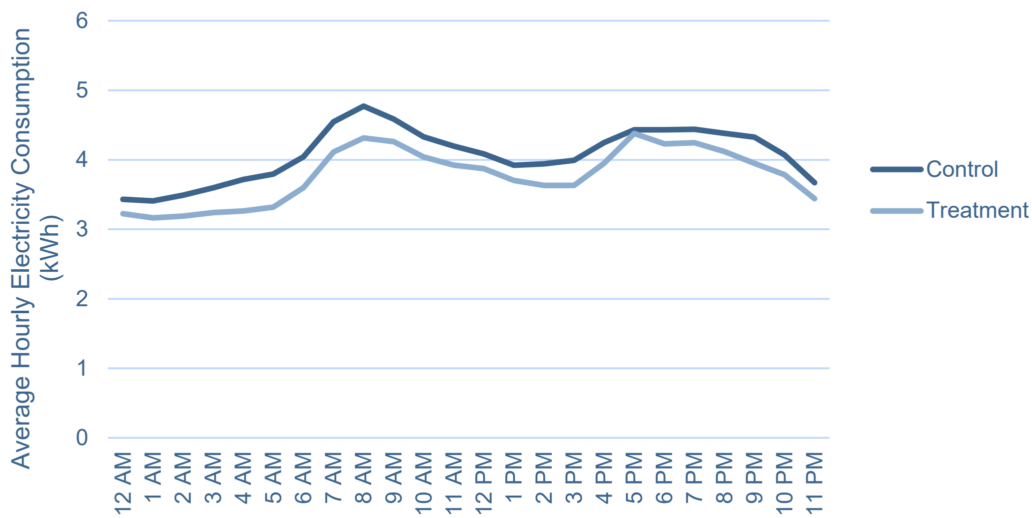


Figure 20: Whole-house Electricity Consumption in February in Climate Zone 2

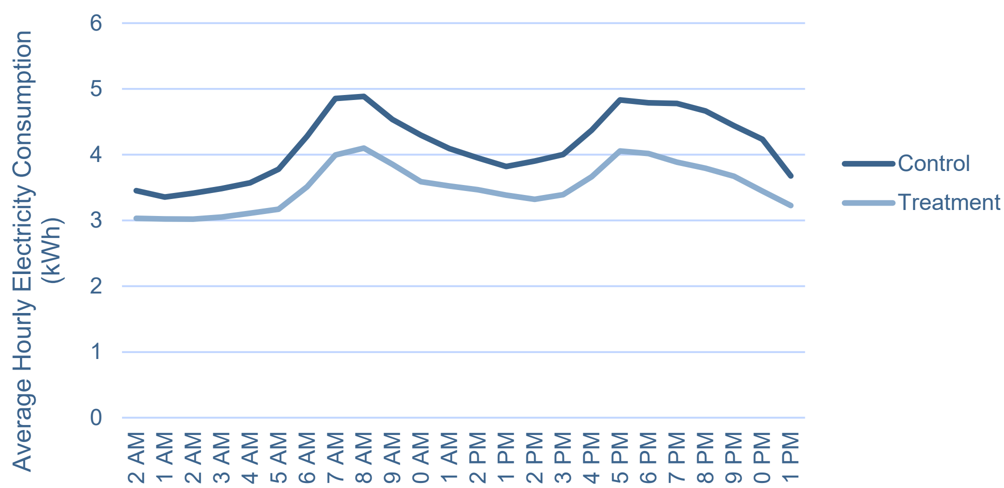
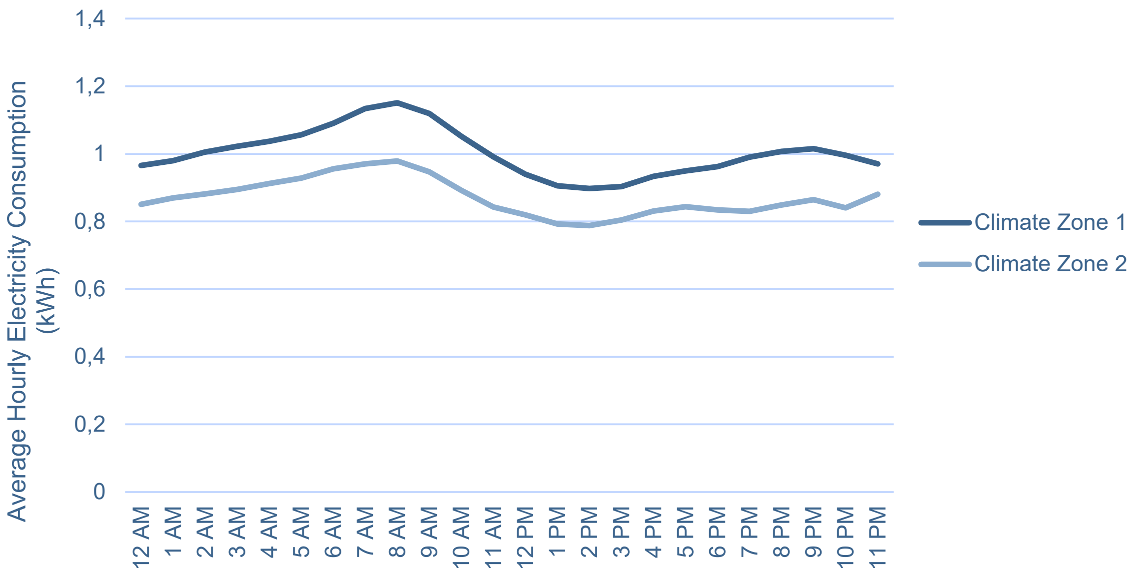


Figure 21: DHP Average Electricity Consumption in February



These three graphs indicate that, during winter, the load shapes in Climate Zone 1 and Climate Zones 2 are very similar; in both cases, the control and treatment groups follow approximately the same trajectory throughout the day. The main difference is that the distance between the two curves in Climate Zone 2 is larger, which is consistent with the fact that higher savings are observed in that climate zone. The appearance of the DHP electricity consumption load shape is very similar for both climate zones with DHPs in Climate Zone 1 consuming more electricity throughout the day.

The same three figures, when produced for the month of April, provide a different picture.

Figure 22: Whole-house Electricity Consumption in April in Climate Zone 1

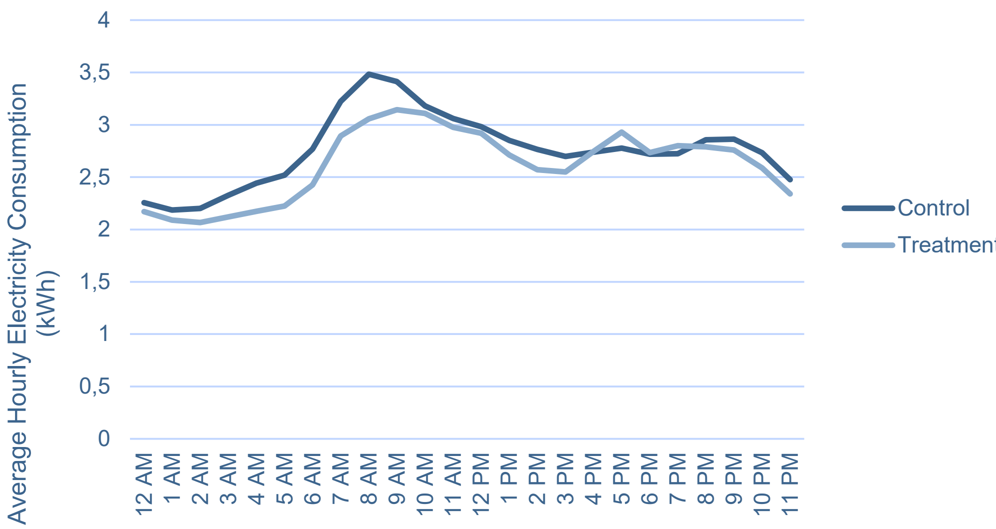


Figure 23: Whole-house Electricity Consumption in April in Climate Zone 2

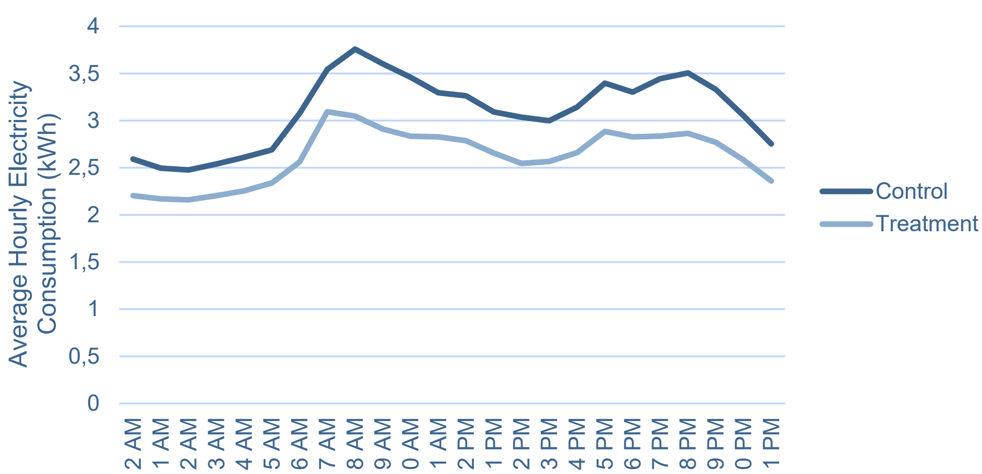
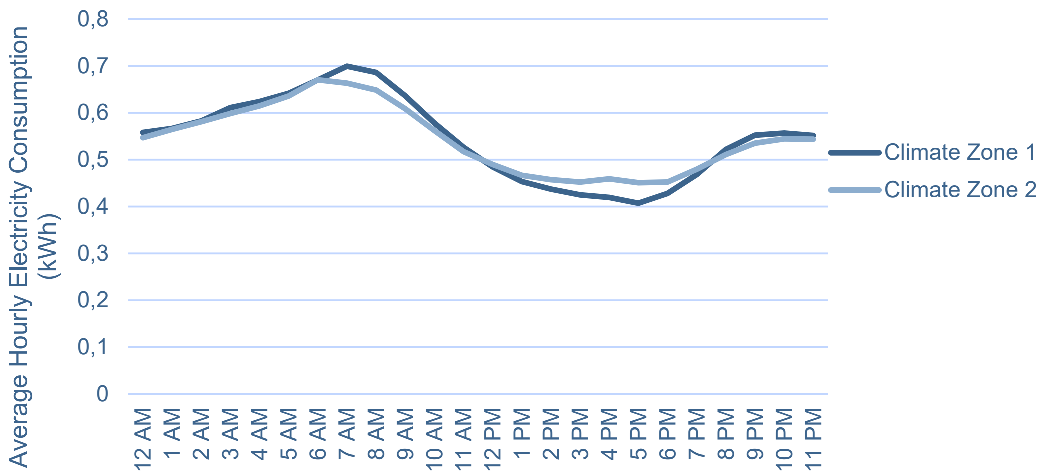


Figure 24: DHP Average Electricity Consumption in April



While the whole-house electricity consumption patterns in Climate Zone 2 remain very similar in April (with both the control and treatment groups exhibiting the same curve and constant savings throughout the day), the savings in Climate Zone 1 start to erode in April. Indeed, the Climate Zone 1 treatment group starts to consume more electricity than the control group in the afternoon; the control group load shape is different than all three others as it exhibits no afternoon peak. The lack of afternoon peak could be due to higher solar gains in Climate Zone 1: The average number of annual days with precipitation in Gander (Climate Zone 1) is 159 compared to 211 in St John's, so there are likely more solar gains in Climate Zone 1. However, that does not explain everything since those solar gains would also flatten the energy consumption of the treatment group, which does not occur.

Around the same time of day, the DHPs in Climate Zone 1 consume less electricity than those in Climate Zone 2 despite the fact that average maximum temperatures in April are lower in Climate Zone 1 than in Climate Zone 2 and the DHPs have a higher capacity in Climate Zone 1. It is possible that solar gains explain the absence of an afternoon peak for the control group and the lower consumption of DHPs; if that is the case, we could conclude that there is a difference in the composition of the treatment group of Climate Zone 1 that explains why this group exhibits an afternoon peak that does not appear in the control group and is not due to high DHP consumption.

Another explanation could be that the absence of an afternoon peak for the control group of Climate Zone 1 is due to an inconsistency in the composition of this group. In that case, the fact that there is an afternoon peak in energy consumption for the treatment group while the DHPs in Climate Zone 1 consume less than those in Climate Zone 2 could indicate that DHPs are not running to their full capacity while there is a heating demand that is unmet.

The first assumption appears to be a better explanation of the patterns that are seen in the two following months. In May and June, the flattening of the control group consumption starts progressively earlier during the day, which is consistent with solar gains. In addition, the DHPs in Climate Zone 1 consume more than those in Climate Zone 2 for those months; the lower DHP consumption in Climate Zone 1 in April was only an exception. Based on an analysis of individual DHP consumption patterns, we suspect that some DHPs start operating in cooling mode during those months.

Therefore, the lower DHP consumption in April could be due to solar heat gains that reduced the heating demand to a point where DHPs in Climate Zone 1 consumed less energy than in Climate Zone 2. In May and June, as those solar gains become unnecessary to meet the heating load, DHPs in Climate Zone 1 consume more to provide some cooling. The only discordant factor to that analysis is the fact that maximum average temperatures remain relatively low in Climate Zone 1: they are of only 12°C in Gander in May, which appear to be low to justify air conditioning usage. For this reason, Econoler believes the second assumption should also be considered.

In summary, the trends observed in the daily energy consumption and low energy savings could be due to one of the following underlying issues:

A. The composition of the treatment group in Climate Zone 1 is incorrect and overestimates the consumption of that group. The energy consumption of the control group and of the DHPs is consistent with higher solar gains and proper operation of the DHPs.

B. The composition of the control group in Climate Zone 1 is incorrect and that is why it does not show an afternoon peak and underestimates savings. The lower energy consumption of DHPs would be due to suboptimal controls that result in them sometimes not operating although there is heating demand.

To further investigate those underlying issues, Econoler used a regression analysis tool embedded in Simptek's Building 360 platform. This tool serves to determine the heating and cooling balance temperature (the temperatures at which a house starts requiring heating or cooling); once that temperature is known, energy consumption can be expressed as a linear regression that includes steady daily consumption (the baseload), a term that varies as a function of heating degree-days (HDDs) and another term that varies as a function of cooling degree-days (CDDs). The following table presents the average baseload, heating and cooling energy consumption levels that were obtained for each sub-group.

Table 19: Estimated Annual Baseload, Heating and Cooling Energy Consumption per Climate Zone and per Control and Treatment Groups

	Climate Zone 1		Climate Zone 2	
	Control	Treatment	Control	Treatment
Base load energy consumption (kWh)	7,880	10,694	8,942	9,289
Heating energy consumption (kWh)	12,272	10,442	13,174	8,970
Cooling energy consumption (kWh)	37	108	67	57

In Table 19 above, the results for Climate Zone 2 are as expected; the treatment group baseload energy consumption is similar to that of the control group, the heating energy consumption of the treatment group is significantly lower due to the presence of DHPs, and cooling energy consumption is very low since the climate is cool. The baseload energy consumption is slightly higher in the treatment group, but that is typically the case for houses that are heated with heat pumps. Since energy consumption in Climate Zone 2 is not perfectly linearly correlated with temperature, a portion of the heating energy consumption is captured by the baseload. In Climate Zone 1, the situation is completely different. The baseload energy consumption is much higher in the treatment group than in the control group. This discrepancy cancels out the savings observed for the heating load.

Econoler also notes that the control group heating energy consumption in Climate Zone 1 is lower than that of Climate Zone 2 despite the HDDs being approximately 5% higher in Climate Zone 1. However, the fact that houses are smaller in Climate Zone 1 can explain this difference.

Again, two analysis assumptions could explain the discrepancies in base load energy consumption:

› In Climate Zone 1, the treatment group is too dissimilar from the control group, perhaps because of parameters that were not documented in the study. This would explain why the baseloads are so different, and this is consistent with the assumption A presented above.

› The way heating is controlled in Climate Zone 1 control group makes heating not directly correlated with HDDs. If heating is not directly correlated with HDDs, a portion of the heating energy consumption is captured in the baseload (the portion of the energy consumption that does not correlate with HDDs or CDDs). This would result in the base load being higher for the treatment group. This could be due to participants manually turning off their DHPs or reducing their setpoint significantly at times when the heating load is high, although the information collected from participants does not allow to determine if that is the case. This would be consistent with assumption B presented above.

Both options are possible, and the different analytical tools used do not allow establishing the exact cause of the low savings with certainty. Econoler however notes that both assumptions imply that there is an incorrect match between the control and treatment groups in Climate Zone 1. One assumption is that the usage of wood heating is more prevalent in Control Zone 1 (as it is more rural) beyond the declarations made by participants. Econoler knows that this type of information can be difficult to collect with certainty, and it is possible that some respondents misrepresented their usage of wood heating. Wood usage can also vary during the heating season, and such subtleties can be difficult to document without overburdening participants

Issue #3: Very low peak demand savings in Climate Zone 1 despite DHPs being in operation

Econoler believes that two main elements can explain the low peak demand savings in Climate Zone 1:

- The differences between the control and treatment groups, as discussed in the previous sections, could be more impactful during peak conditions.
- The way DHPs and their back-up heating systems are controlled in Climate Zone 1 could prevent DHPs from generating significant savings in peak conditions. As aforementioned, manually turning off DHPs could explain some of the findings from the regression analysis. If DHPs are manually turned off during or just before a peak period, peak demand savings will likely be lower.

There could be some installation issues that result in some DHPs consuming a significant amount of electricity without providing much heat, for instance mounds of snow obstruction to the outdoor unit or an insufficient amount of refrigerant in the compressor loop, etc. It is, however, unlikely that a significant proportion of sampled DHPs experience those issues in Climate Zone 1 and not in Climate Zone 2.

APPENDIX IV
PRE-POST BILLING ANALYSIS

Since the control and treatment group compositions induce some bias in the results and Climate Zone 1 results are inconsistent, Econoler used an alternative approach to provide a point of comparison and validation. Econoler performed a pre-post billing analysis that consisted of comparing the electricity consumption of households before and after the installation of their DHPs. The following steps were carried out to perform the analysis:

1 Econoler requested historical billing data for all treatment group participants for whom the installation date was known. For the pre-installation period, Econoler used approximately one year of data up until one month prior to the installation date provided by the participant (to safeguard against potential inaccuracies in dates). For the post-installation period, Econoler used approximately one year starting one month after the installation date.

2 Econoler validated the accuracy of the date by plotting monthly electricity consumption over time. Econoler excluded data where multiple bills were nil or very low as well as when electricity consumption in the pre-installation period seemed too low or non-weather sensitive, which indicated that the participant previously heated their home with a non-electric energy source. This resulted in the removal of 17 participants.

3 To be included in the analysis, each participant had to have a minimum of six bills and 240 days (eight months) covered in both the pre and the post-installation period. A total of 81 participants met all conditions and were included in the pre-post analysis.

4 For each participant and each pre and post-installation period, a regression of electricity consumption as a function of heating and/or cooling degree-days was established to normalize consumption for normal temperatures. Each bill was matched to the historical daily average temperatures over the period it covered, and then the optimal regression was selected among various heating and cooling degree-day base temperatures. The selection of the optimal regression follows the principles outlined in the Uniform Methods Project.[9]

5 The difference between the normalized annual electricity consumption for the pre and post-installation periods yielded the estimated energy savings.

[9] Agnew, K.; Goldberg, M. (2017). *Chapter 8: Whole-Building Retrofit with Consumption Data Analysis Evaluation Protocol, The Uniform Methods Project: Methods for Determining Energy-Efficiency Savings for Specific Measures*. Golden, CO; National Renewable Energy Laboratory. NREL/SR-7A40-68564. http://www.nrel.gov/docs/fy17osti/68564.pdf.

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