# Appendix E

# Electric System Impacts of Heat Pumps

# Discussion on Electric System Impacts of Adding Heat Pumps to the Grid

This section is a more in-depth discussion centered on the topic of beneficial electrification and more specifically, heat pumps and their potential impacts on the electric system for customers adding a heat pump to replace or supplement their fossil fuel heating alternative.

This information focuses on air-to-air heat pump systems excluding air-to-water (AWHP) and geothermal heat pump systems. AWHP and geothermal heat pumps will equal to or higher than air-to-air systems as they have additional benefits including thermal storage capabilities or the ability to extract/reject heating from the ground which limits impacts from extreme outdoor temperature conditions.

The Company breaks down this discussion into four different parts. This includes customer types, market size in Otter Tail's service area, size of heating versus cooling load, and impacts to the electric system.

## Customer Types

There are three main customer types that are installing heat pumps on Otter Tail's system as shown in Table 1. The main drivers for each customer type in replacing their system are if they have a current system failure due to equipment age or upgrading to reduce annual operating cost.

**Table 1**

| Customer Type | Current System Type | | Replacement System Type | |
|---|---|---|---|---|
| | Cooling | Heating | Cooling | Heating (Backup) |
| All Electric | A/C | Electric Resistance | Heat Pump | Heat Pump (Electric Resistance) |
| Fossil Fuel (#1) (Natural Gas, Propane, Fuel Oil) | A/C | Gas (Furnace/ Boiler) | Heat Pump | Heat Pump (Electric Resistance) |
| Fossil Fuel (#2) (Natural Gas, Propane, Fuel Oil) | A/C | Gas (Furnace/ Boiler) | Heat Pump | Heat Pump (Gas Furnace/ Boiler) |

**Market Size in the Otter Tail Service Area**

The market size for each customer type was estimated based on census data for South Dakota residential home heating fuel types.[1] The census data was filtered by selecting each of the counties the Company serves in. The data then provides an estimated count of residents for each heating fuel type that was converted to a percentage with each fuel type. The Company then took the census data percentages and applied them to the number of residential customers served in South Dakota in 2023. These results reflecting the estimated number of Otter Tail customers with that heating fuel type are shown in Table 2.

**Table 2**

| Heating Fuel Type | Percentage | | Otter Tail's Estimated Customers |
|---|---|---|---|
| Natural Gas | 38.7% | | |
| Propane | 20.7% | 64.9% | 6,073 |
| Fuel Oil (all others) | 5.6% | | |
| Electricity | 35.1% | | 3,282 |
| Total (Includes Residential and Farm Customers) | | | 9,355 |

The Company currently has approximately 9.47 percent of all South Dakota customers participating in the off-peak Small Dual Fuel rate. This rate is available to customers who have been approved and have agreed to have a portion of their load, primarily electric heating system load, interrupted and switched to a back-up system that is not an electric fuel source. These customers have a dual fuel heating system set-up to optimize cost savings, navigate price changes, and provide increased reliability with a second option should non shared components fail.

Assuming a similar percentage, of the estimated 6,073 South Dakota customers with fossil fuel heating types, would elect to install a new dual system, the Company has approximately 575 potential customers that would be controlled and shifted off critical demand peaks just on the off-peak Small Dual Fuel rate. The Company has a long history of working with customers to develop successful load control initiatives and

[1] 2022 American Community Survey sorted for House Heating Fuel for Hughes, Day, Deuel, Codington, and Marshall Counties on data.census.gov.

programs. Otter Tail will continue to research new technologies and review potential options to maintain or expand the current level of adoption from customers.

## Heating Load vs Cooling Load

Otter Tail utilizes the Minnesota Technical Reference Manual (TRM), Version 4.0 Residential HVAC – Air Source Heat Pump Systems, to better understand the heating and cooling load of heat pumps.[2] Also utilized are the average Effective Full Load Hours (EFLH) for heat pumps that are applied to MN zones 2-3, aligning directly east of the service area Otter Tail serves in South Dakota. The heating EFLH is 78.9 percent and the cooling EFLH is 21.1 percent. These percentages represent the usage of heating or cooling out of the total annual operating hours of a heating and cooling system in a typical year. A system is assumed to be operating 78.9 percent of the time in heating mode and 21.1 percent of the time in cooling mode.

The heating mode hours are further broken down based on temperature bin data provided in the TRM Appendix G: Residential ASHP Fuel Switching Calculator. The data provides a breakdown of the percentage of the heating load that could be served by the primary heating source (Heat Pump) vs a backup/supplemental system. The data is based on the set switchover temperature between the systems. Table 3 provides the breakdown provided within Appendix G.

**Table 3**

| Outside Temperature (°F) | Primary % of Heating (EFLH) | Backup % of Heating (EFLH) |
|---|---|---|
| 10 | 77.16% | 22.84% |
| 5 | 83.62% | 16.38% |
| 0 | 89.10% | 10.90% |
| -5 | 93.47% | 6.53% |
| -10 | 96.56% | 3.44% |
| -15 | 98.35% | 1.65% |
| -20 | 99.29% | 0.71% |
| -25 | 99.74% | 0.26% |

[2] https://mn.gov/commerce/energy/conserving-energy/eco/technical-reference-manual/

In the past, heat pump equipment had a higher switchover temperature set by contractors based on performance then current models. These past early model heat pumps, that did not include inverter technology or enhanced vapor injection, had limitations that led to rapidly diminishing heating capacities with some systems only achieving 50 percent of nameplate at temperatures of 5° Fahrenheit. The cold climate models of heat pumps, available in the market today, can achieve 100 percent heating capacity at temperatures of -4°F with the ability to continue operation all the way down to -22°F.

Today, heat pump technology is advancing rapidly with momentum anticipated to continue. This innovation is being driven by the Department of Energy (DOE) Cold Climate Heat Pump Technology Challenge (Challenge).[3] The Challenge began in late 2021 with the goal to advance heat pump performance and capacity capabilities to lower temperatures. The Challenge set a benchmark goal of achieving 1.7 coefficient of performance (COP) at 5°F. The Challenge targeted commercialization of this new product, having it sold in the market, by the end of 2024. Currently, lab testing has been completed and field testing is currently underway. Completed lab testing results have illustrated overachievement of benchmark goals.

Midea, a cold climate heat pump manufacturer, has a 3-ton model achieving 118 percent of rated capacity heating output at -15°F.[4] This means the Midea system can utilize the heat pump for primary heating, therefore reducing the need for a secondary heat source. The Midea system delivered efficiency at -15°F with a COP of 1.92.[5] As highlighted in Table 3, a -15°F switchover would capture 98.35 percent of all heating operating hours in a typical year. Operation could continue at lower temperatures, but with diminished efficiency and capacity.

As indicated in Table 3, the ability to move the switchover temperature from 0°F down to -15°F would increase the number of heating hours captured by the primary system (heat pump) from 89.10 percent up to 98.35 percent. This would leave any backup or supplement heating operating less than 37 hours each year.

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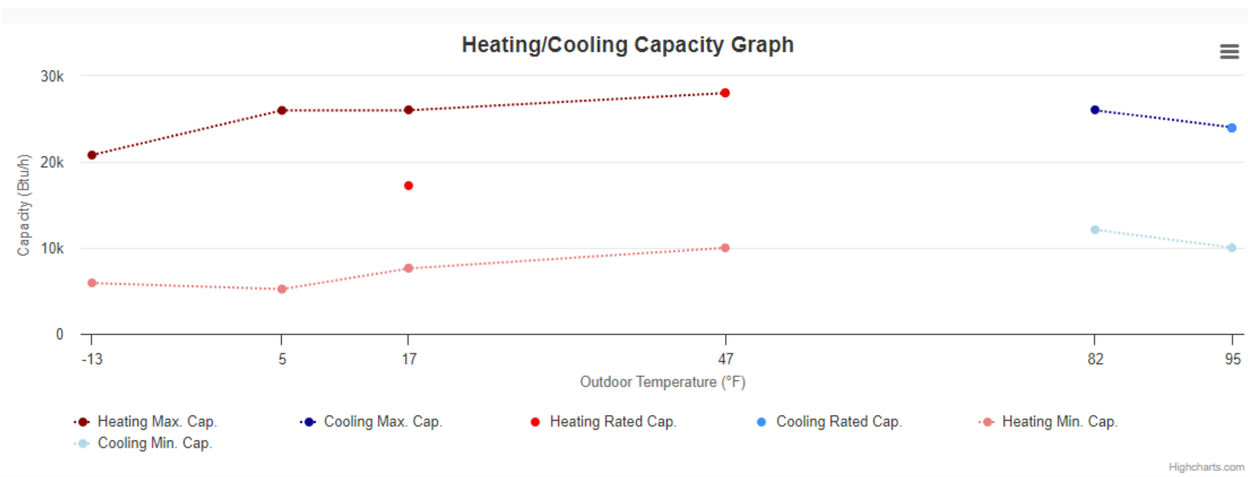
[3] Residential Cold-Climate Heat Pump Technology Challenge (energy.gov)
[4] Midea HVAC-Residential Heating & Cooling Solutions | Midea HVAC (mideaevox.com)
[5] Midea Exceeds Performance Benchmarks in Department of Energy's Cold Climate Heat Pump Technology Challenge (prnewswire.com)

The remaining 37 hours does not consider that the heat pump can still provide heating at lower temperatures, just with reduced heating capacity and efficiency, further reducing any operating hours needed of the supplemental heating system.

A good visual of a heat pump's continued operation with reduced heating capacity (derating) is demonstrated in test data graphs published on the Northeast Energy Efficiency Partnership heat pump product list website, as seen in Figure 1.[6] These test data graphs are provided for each heat pump listed on the website and is a reference resource for contractors designing a system. The upper *Heating Max Cap* line shows the max capacity output at lowering outdoor temperatures with the capacity derating as the temperature shifts from 5°F down to -13°F. The lower *Heating Min Cap* shows the lowest capacity output able to be achieved for this variable speed compressor unit to remain running. The unit can ramp up or down between these max and min lines to achieve the required needs of the home.

Heat pumps included in the DOE Challenge and the Media example previously discussed would have a max heating capacity line that would remain flat all the way to -15°F before beginning a derating slope that would extend down to the minimum operating temperature.

**Figure 1**




[6] https://ashp.neep.org/#!/product/34513/7/25000/95/7500/0///0

**Impacts to the Otter Tail System**

When a customer installs a heat pump the impacts are dependent upon the type of energy a customer is reliant on. The general impacts on demand and energy usage are grouped by the energy customer type as summarized in Table 4.

**Table 4**

| Customer Type | Peak Electric Demand Impacts (kW) | | Energy Usage (kWh) |
|---|---|---|---|
| | Summer | Winter | |
| All Electric | Decrease | *Decrease** | Decrease *(13,328 kWh)* |
| Fossil Fuel (#1) (Natural Gas, Propane, Fuel Oil) | Decrease | *Increase** | Increase *(9,699 kWh)* |
| Fossil Fuel (#2) (Natural Gas, Propane, Fuel Oil) | Decrease | Neutral | Increase *(9,699 kWh)* |

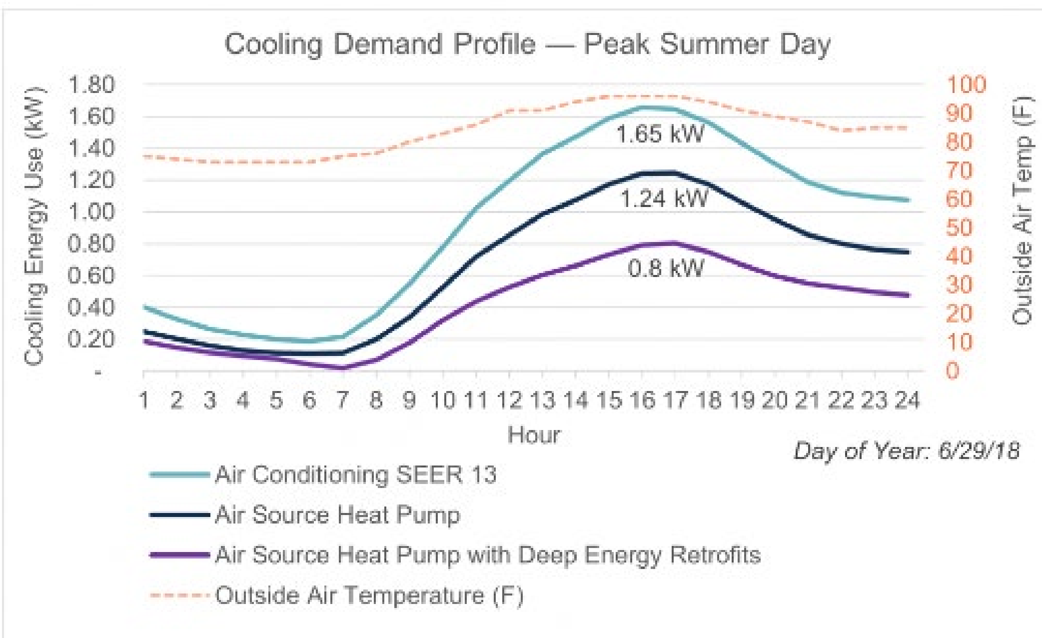
**As highlighted by the CEE study below and with the advancements in heat pump technology. For every all-electric home that installs a heat pump over their current system could result in the ability to convert two fossil fuel homes over to a heat pump with no net effect on peak winter demand.*

A customer replacing their current system with new equipment will improve their efficiency due to advancements in the technology and increases in federal minimums standards over previous standards at the time of the last equipment installation. Generally, this replacement occurs every 15-25 years for a residential customer. It is important to remember that heat pumps hold multiple advantages and lead to summer season benefits as well. Every instance where an old air conditioning unit is replaced with a heat pump, the summer peak kW demand draw will see a decrease, driven from the improvement in equipment efficiency. This results in a reduction of summer peak demand needs for each of the customer types in Table 4. The winter peak demand decreases for an all-electric customer as the heat pump offsets less efficient electric resistance. The winter peak increases for a fossil fuel customer electing to go all electric for a replacement and is discussed further below in the CEE study. The winter peak remains neutral for a fossil fuel customer electing to install a dual fuel system and participate in Otter Tail's off-peak control rates as these systems will be controlled during peak times and their loads will be removed from the grid. The energy usage increase and decrease estimates are based on the MN TRM Appendix G with an assumed 3-ton ducted heat pump with operation switchover set down to -15°F vs baseline equipment. Although electricity usage increases for fossil fuel customers the switch to a heat pump result in source energy decreasing resulting in a net reduction of 64.3 MMBTU being saved.

One thing to note, Otter Tail has already made the investment in system infrastructure capacity to serve this summer peak demand related to cooling of homes. Heat pumps will simply allow this capacity to be utilized for more hours of the year increasing annual load factor and allowing for infrastructure investment cost to be spread out across more sales.

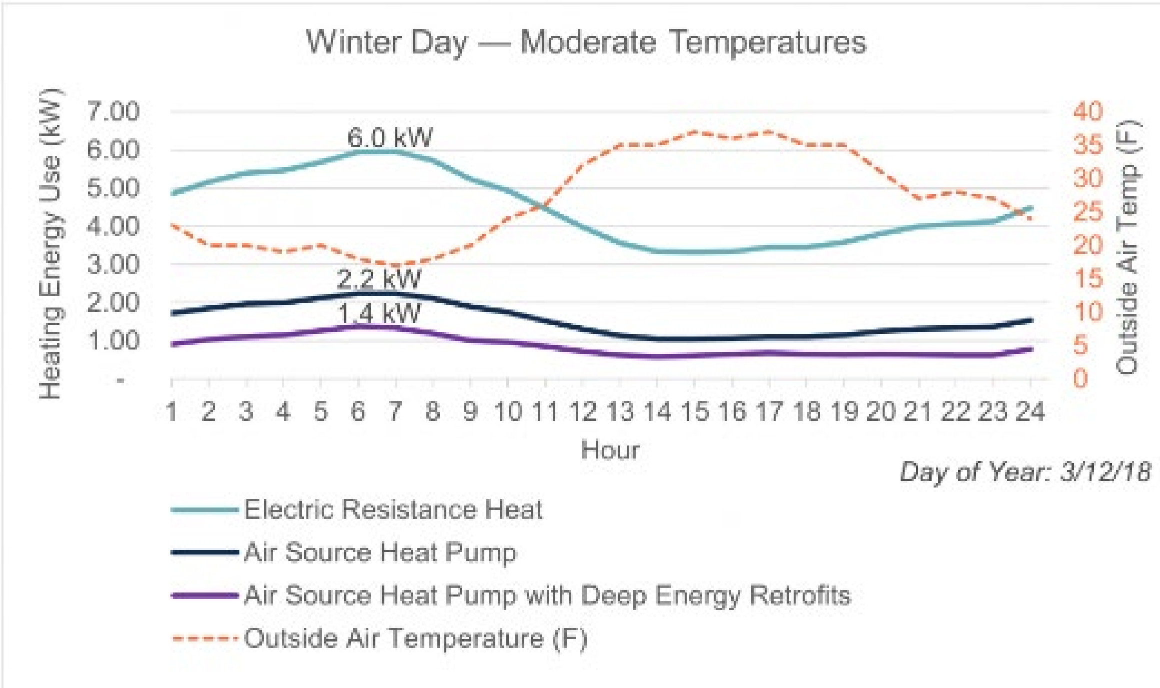
In 2018, a study conducted by Center for Energy and Environment (CEE) began to review the demand impact of heat pumps.[7] This study showed heat pumps produce a reduction in demand during peak summer days of 10 percent (0.41 kW) at 95°F and a reduction in demand in winter days of over 60 percent (3.8 kW) at 15°F for customers with A/C and electric resistance.

**Figure 2**




[7] Electrification, Energy Efficiency, and Peak Demand | Center for Energy and Environment (mncee.org)

**Figure 3**




The advancement in the heat pump technology, especially in cold temperatures, has resulted in winter demand reductions shifting and occurring at even lower temperatures with equipment maintaining 100 percent heating capacity (-4°F with current equipment and -15°F with equipment coming to market end of 2024). The CEE study goes on to conclude that for approximately every heat pump installed in a current all electric home, two fossil fuel homes can convert to a heat pump with no net effect on peak demand. This is the result of the significant demand savings achieved by the all-electric home allowing for the additional demand from the fossil fuel customers.

At this point in time, the Company does not anticipate capacity being impacted by the addition of heat pumps as the net effect of demand savings from all-electric customers will allow the addition of fossil fuel customers to switch to electric heat pumps. Another item to note is Otter Tails participation in the MISO system that remains summer peaking. Recent clearing prices ($/MW-day) from the Planning Resource Auction for 2024-2025, that closed April 25, 2024, resulted in the following price breakdown for the four seasons Summer $30.00, Fall $15.00, Winter $0.75, Spring $34.10. Although these prices will fluctuate year to year, one common theme is that winter capacity remains the lowest cost season being bid into the market. The distribution system will not be impacted as the current infrastructure is currently built to handle the current air conditioning load for customers and heat pumps are the same technology concept as traditional air conditioning load but with the additional ability to reverse flow and provide heat. The advancement of heat pump technology provides a bright future for continued demand and energy savings for customers lowering their annual heating and cooling costs.