Energy Efficiency is a Non-Wires Solution and Evaluators can help

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ABSTRACT

Reduction in electric load through DSM programs as a Non-Wires Solution (NWS) has the potential to be cost-effective and support electrification. Evaluation teams can add value to the planning, design, and implementation of NWS through experience with load shapes, energy savings curves, and in-depth knowledge of energy efficiency measures (EEMs). The addition of Advanced Metering Infrastructure (AMI) allows for data visualization and finely tuned billing analysis to geotarget meters for specific EEMs based on meter classification, common practices for evaluation teams.

A utility has implemented its first NWS focused on reducing peak load in a rural area of Oklahoma. The area currently experiences its peak load during the coldest winter mornings, partly driven by a high penetration of electric resistance and heat pump space heating. As emphasis is placed on electrification to meet climate goals, this NWS pilot sits center stage on the challenges of decarbonization. The utility and the implementation team strategized cost-effective EEM solutions and set forth on an ambitious goal of using EEMs to meet their peak load reduction challenge. As the evaluator of the utility's energy efficiency portfolio, we have assisted from an early stage to provide analytical support through data visualization of billing data and load shape analysis.

Introduction

Electricity distribution capital expenditures are known to be one of an electric utility's largest capital expenditures. In 2019, electrical distribution systems accounted for 29% of investor-owned utilities capital expenditures [Frick, 2021]. As part of transmission and distribution planning processes, utilities often conduct studies to identify least-cost plans to minimize capital investment. Alternatives which reduce or avoid capital investment can save ratepayers on their bills. An avenue to be considered for distribution systems is known as Non-Wires Solutions (NWS). The concept of an NWS is to determine solutions which defer or replace all or a portion of capital investment required in an electrical distribution system. For this paper, we will refer to potential solutions as Non-Wires Solutions (NWS). An example of NWS is Distributed Energy Resources (DER). The chosen NWS must meet the requirements of various facets of a utility's infrastructure and principles such that reliable electricity is provided to customers.

Proposed NWS often include DER, energy storage (ES), demand response (DR), grid software and controls (such as voltage regulating equipment) and energy efficiency (EE). The decision-making process is known as least-cost planning and is often reliant on a comparison of cost versus benefit. When referring to distribution capacity cost-benefits, or grid reinforcement, a utility is considering the costs and benefits related to a particular distribution line's overload. However, different NWS warrant the inclusion of different types of benefits and costs making comparison difficult. For example, distributed Photovoltaic has an associated interconnection cost that must be considered. [Horowitz, 2018]

With DER a consideration as a NWS, and a commonplace topic lately, the decision-making process may include the levelized cost of energy (LCOE). The LCOE is defined as the average net present cost of electricity generation over its lifetime. While the focus is on generation and not distribution, this can be used as a gauge to encourage low-risk, low-cost environmentally friendly solutions. While caveats remain in the calculation and comparison of LCOE, ACEEE has gathered information from a range of sources to develop a comparison which includes energy efficiency and community solar photovoltaics as shown in Figure 1. [Molina, 2018]

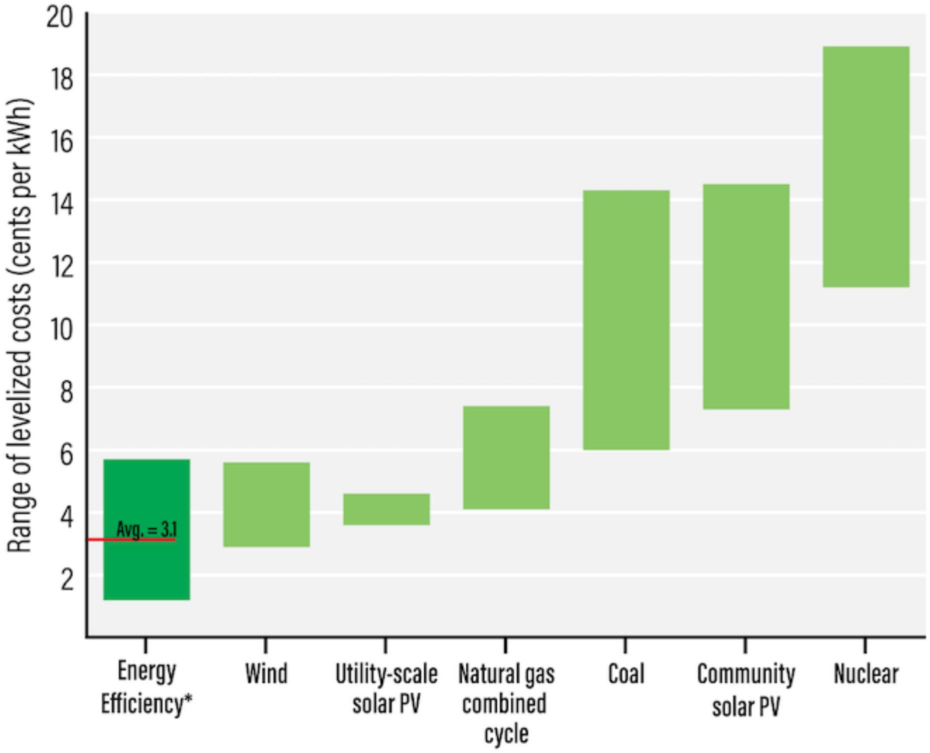

Figure 1. Levelized Cost of Electricity Resources. *Source:* ACEEE 2018.

A radial distribution circuit located in rural Oklahoma servicing twenty-three miles of mainly residential and small commercial customers has a reliability issue caused by persistent tripping of a recloser during cold winter mornings where peak load is highest. This has caused frequent downstream customer outages. In addition, the circuit has power quality issues requiring attention. The electric utility has determined a significant load reduction is necessary to avoid power quality and reliability issues for customers on the circuit. The estimated load reduction needed is roughly 500 kW during winter mornings. The utility has turned to a NWS approach to defer or replace a traditional significant reliability investment.

The utility referred to its Demand-Side Management (DSM) implementation team to perform a feasibility assessment for NWS. The assessment reviewed distributed generation solutions (such as photovoltaics and energy storage), energy efficiency, and demand response. The DSM team worked with transmission and distribution planning teams to weigh the various options. The assessment determined that the load reduction goal could be met through energy efficiency measures alone which provide low-risk solutions to the transmission and distribution teams and distribution infrastructure. Being a rural area, the potential for energy efficiency is high. Therefore, a pilot DSM program was developed around the implementation of geographic and consumption targeted traditional energy efficiency as a first look at load reduction. Based on the maturity of energy efficiency plans and the implementation team in-place, this is a logical first step. In addition, there is an intrinsic benefit to focusing on an underserved rural region that can benefit greatly from energy efficiency measures. In a way, the approach can be illustrated as picking fruit, as shown in Figure 2. Obstacles obstruct the ease of acquiring the fruit higher in the tree even if it is more appealing. The low-hanging fruit represent NWS which can be quickly implemented, have a low technical risk, and are proven techniques.

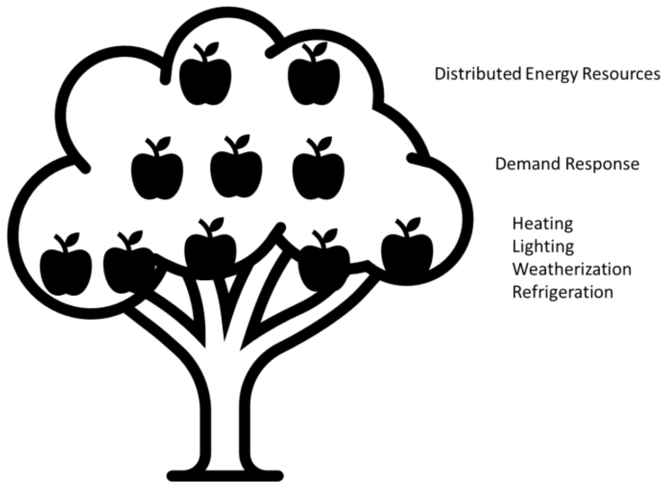

Figure 2. NWS low-hanging fruit

Implementation Strategy

The implementation team performed a billing data analysis using Automated Metering Infrastructure (AMI) billing data. The distribution circuit was identified as supplying electricity to approximately 950 residences, 125 commercial meters, and 20 industrial meters. Review of historical data indicated the circuit peak to be 7-8 AM on non-holiday weekday mornings in the months of December and January. Consumption by sector during this period is approximately 60% residential, 25% commercial and 15% industrial concluding that a residential energy efficiency push has the largest potential. However, all energy efficiency measures would be implemented across all sectors. The target for implementation based on consumption (tree size) and number of customers (apples) is illustrated in Figure 3. The figure demonstrates that while residential consumption is prominent it will also require many more transactions.

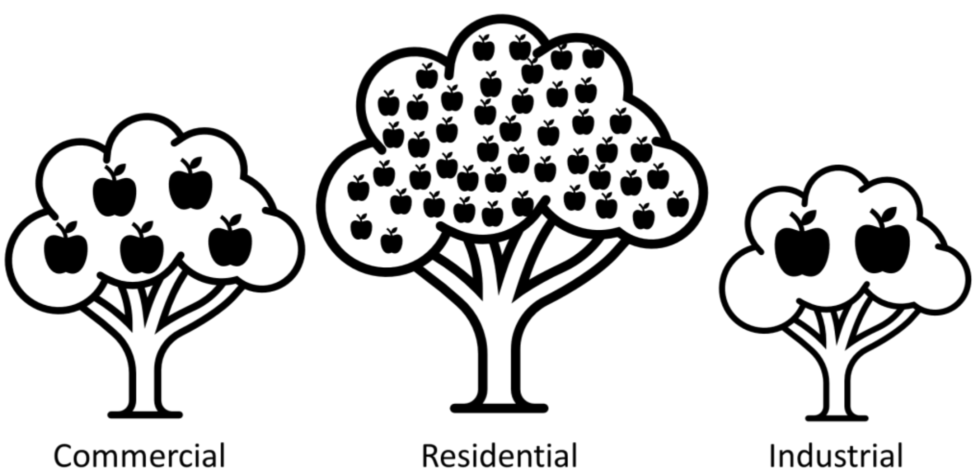

Figure 3. Distribution Circuit Load

Based on the distribution by sector and consumption, the implementation team set forth exploring energy efficiency measures previously configured in the utilities' DSM Energy Efficiency Portfolio to meet the load reduction goal. Measures were considered which target high intensity loads during the winter season.   The implementation team identified a list of energy efficiency measures to consider for the winter peak load period. This includes:

- Residential Weatherization (air sealing, duct sealing, attic insulation, low-flow showerheads, faucet aerators, hot water pipe insulation)
- Residential LED light bulbs
- Residential heat pumps
- Small Business lighting and refrigeration
- Commercial & Industrial lighting
- Commercial & Industrial Energy Coaching
- Residential HVAC Tune-Up

Residential Energy Efficiency

The implementation team set forth to determine a winter peak load reduction through calibrated energy simulation. However, they first classified residences into three daily consumption profile categories to differentiate those whose consumption matched outdoor temperature trends, those who demonstrated the typical morning ramp-up (mostly like a thermostat night setback) and those who maintained relative consistency in consumption throughout the day. Energy simulations were then performed to develop calibrated load shapes and infer load reduction during the winter peak hour.

The implementation team targeted residences through door-to-door canvasing, survey efforts, and promotion at public events. In addition, increased incentives were offered. The distribution circuit serves a region with a low threshold for upfront investment and minimal historical participation in energy efficiency programs. Implementation conducted two waves of marketing. The first wave reached all customers with a marketing strategy of promoting community welfare and outreach. The second wave targeted high-savings potential customers as identified by AMI meter data.

Commercial & Industrial Energy Efficiency

The implementation team utilized its currently successful program marketing strategies for small business and commercial customers to promote energy efficiency. The team used techniques of drop-in visits and energy audits as well as pulling in contractors to support the promotion of energy efficiency and drive winter peak load reduction. Such services include Energy Coaching to identify and support mechanical system controls and replacement of equipment as needed.

Evaluation Support

As the DSM Energy Efficiency Portfolio Evaluator, ADM Associates Inc. (ADM) was introduced to the pilot study as the implementation team was developing its strategy to market the selected energy efficiency measures. ADM has a deep bench of knowledge regarding load shape development, energy simulations, surveying, and energy savings analysis; all are functions that support the implementation of energy efficiency measures targeted to reduce peak hour load. ADM is also relied upon to develop verified peak hour reductions for the pilot program at the measure level.

Residential Peak Hour Reduction

ADM met with the implementation team simulation experts to review methodologies employed to develop peak hour reduction estimates. Prototypical EnergyPlus calibrated energy simulations were run with expected baseline conditions and energy efficient equipment improvements.[1] Differences between the energy simulations were calculated using hourly results to determine the expected load reduction during the winter peak hour. While the methodology adhered to industry standard practices, the energy simulations would not accurately represent AMI meter consumption during the winter peak hour on the coldest days. While the simulations were within reasonable boundaries on typical winter mornings, the energy simulations were over-predicting consumption on the coldest mornings by up to 125%. This result indicated a few possibilities that need to be considered for validation of results. One likely possibility is that residences' heating systems could not maintain thermostat set points on these coldest mornings. Based on knowledge of the region and vintage of residences there is large presence of heat pumps reaching or beyond their useful life. This is an important consideration when targeting heat pump replacement. A new heat pump may be able to meet the demand but consume additional energy during the winter peak hour.

As the energy simulations met calibration standards on a daily profile but not the winter peak profile ADM decided to develop its own sets of energy savings curves using eQuest energy simulations.[2] Prototypical models were modified for both single family residences and mobile homes[3]. Energy simulations were developed and calibrated using average residential consumption profiles to represent the baseline condition. Energy simulations were modified to be within 10% of AMI hourly consumption across a window of 6-9 AM on non-holiday weekdays from November through February. Load profiles were then generated by running the energy simulations using Typical Meteorological Year (TMY3) weather data.

The difference between the efficient condition energy simulation results and the baseline condition results on an hourly basis was normalized to the annual difference (annual energy savings) to determine an hourly factor (0-1) which can be applied to an applicable annual energy savings that represent a specific measure for a specific residence. Thus, the hourly factor can be applied to an annual energy savings determined through a prescriptive approach to result in an estimate of hourly reduction at any hour during the year. When reviewed as a daily profile for winter weekdays the peak load as well as the potential for load reduction becomes apparent. Figure 4 shows these kW Savings Factors for various residential measures considered. While the impact of the magnitude is difficult to ascertain, comparison among measures indicates those with the largest potential.

[1] EnergyPlus Website: https://energyplus.net/
[2] eQuest Website: https://www.doe2.com/equest/
[3] The implementation team identified during marketing activities that mobile homes may represent up to 50% of the region's residences.

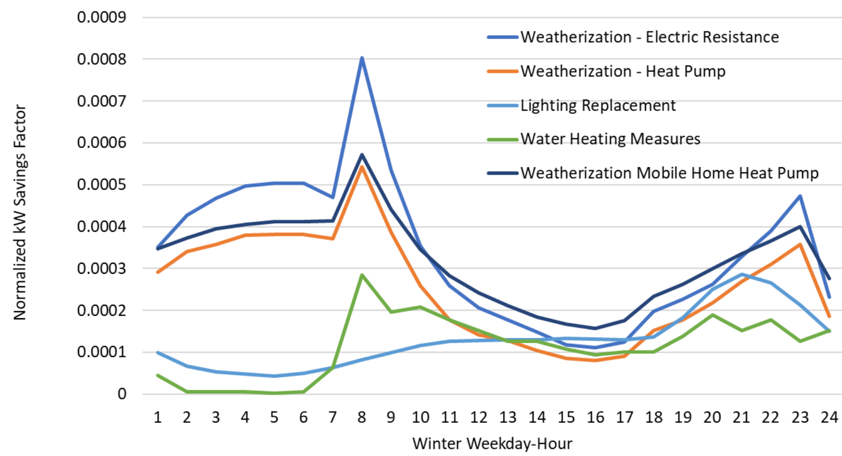

Figure 4. Example Residential kW Factors

The peak hour morning spike in Figure 4 stems from the AMI meter data review and calibration of the energy simulation model. This spike would indicate that heating set point temperatures are raised in the morning hours by residences served by this distribution circuit.

Commercial Peak Hour Reduction

ADM utilized an approach like the residential engineering analysis for the commercial and industrial measures. Energy simulations using eQUEST were developed to represent energy efficient equipment installed. Commercial load shapes are highly dependent on the business type as well as operating schedule of the business. Thus, commercial measures require the application of appropriate business types along with accurate weather data and installed energy efficiency measure. Figure 5 shows normalized kW savings factors on non-holiday weekdays in December and January for various end-uses and facility types.

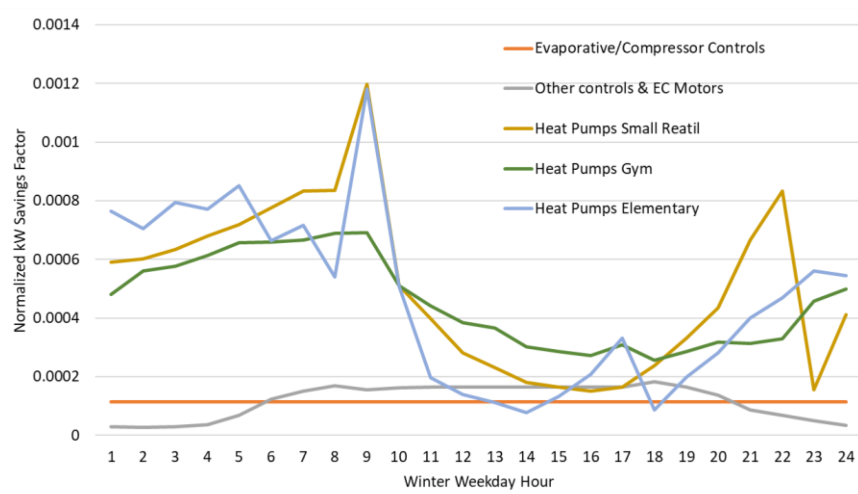

Figure 5. Example Commercial kW Factors

Some of the larger commercial projects consisted of LED lighting retrofits. ADM developed a commercial lighting calculator utilizing a schedule function to allow for the generation of an annual hourly energy savings curve based on the schedule for each participant. Thus, the reduction in connected load through the installation of LEDs would be accounted for during each hourly interval. The average across the winter peak hours is presented as the winter peak load reduction.

Residential Survey Support

ADM was able to support the implementation team in the development of a survey effort to gather information from residences on the potential for energy efficiency measures. The survey effort collected information pertaining to the home type and construction, mechanical system, and appetite for weatherization measures. As the rural area has proven to be underserved by the DSM Energy Efficiency Portfolio, the survey was instrumental in determining necessary incentive levels for various residential measures.

Commercial Consumption Targeting

As the evaluator for the utilities' energy efficiency programs, ADM receives daily AMI data that includes meters on this distribution circuit. ADM utilized this data to provide visual representation of load shapes for industrial, commercial, and residential meters on the circuit. ADM provided visual representation of both individual meters as well as aggregated load shapes across sectors. ADM provided information as requested in support of implementation marketing strategies.

Data visualization supports identification of various facets of energy consumption when available at one hour or less intervals. Visualization allows for a review of heating impacts, cooling impacts, and schedule impacts (daily, weekly, and seasonal). To provide rapid and accessible visualization, a web-based user interfaced was developed using the shiny application in programming language R. This tool allowed the team to immediately visualize patterns of consumption over time (single meters as well as aggregated) and compared to ambient weather. For example, Figure 6 represents a hourly consumption of commercial meter in which consumption is independent of ambient temperature (top illustration) and a commercial meter in which electric consumption is dependent on ambient temperature (bottom illustration).

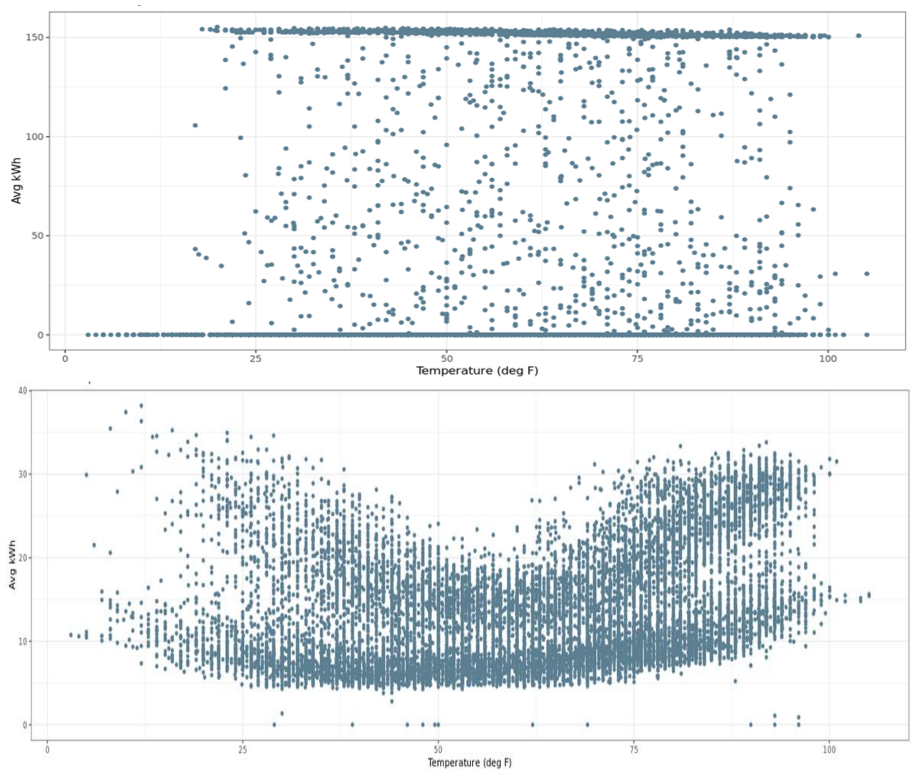

Figure 6. Data visualization of consumption dependence on ambient temperature

As seen in Figure 6, there remains a wide range of hourly consumption. To visualize potential causes, heat maps can be utilized to identify trends based on weekdays and seasons. Heat maps provide a visual representation as to the magnitude of consumption based on the color scale. Consumption increases as the color becomes darker. The heat map shown in Figure 7 is such representation of hourly consumption data for a commercial circuit in question. With some additional knowledge of the facility type, it is possible to identify the potential for a consumption reduction at any given time of year.

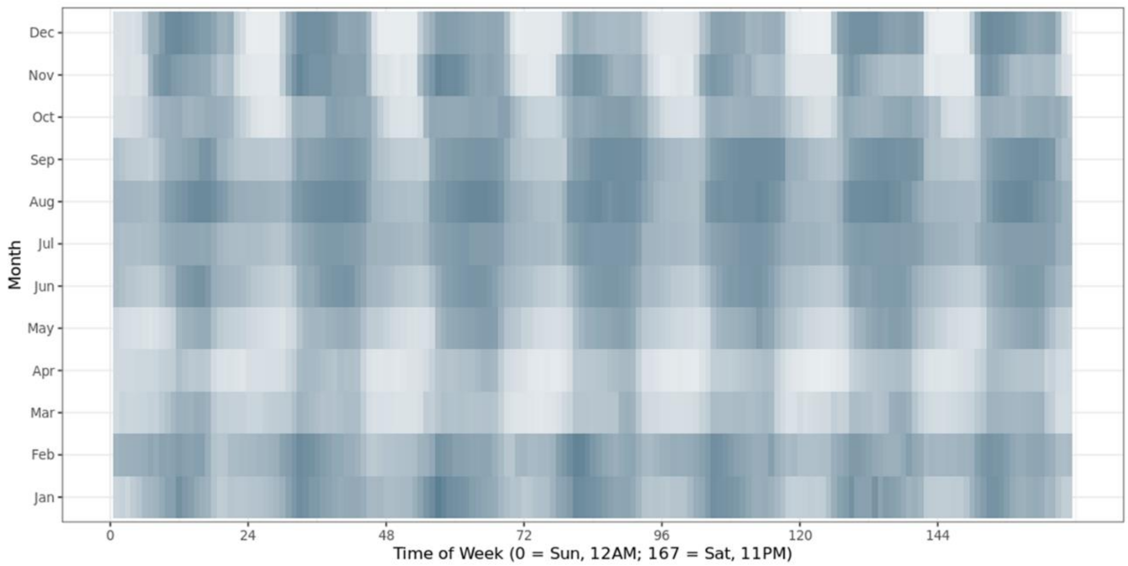

Figure 7. Data visualization using time of week heat maps

The identified winter peak period is on non-holiday weekdays; therefore, it is also important to easily identify consumption based on the day of the week across a select period. The developed data visualization tool allows for a line graph to be immediately generated based a specific date range. Figure 8 represents hourly consumption for a commercial meter in December and January for each day of the week.

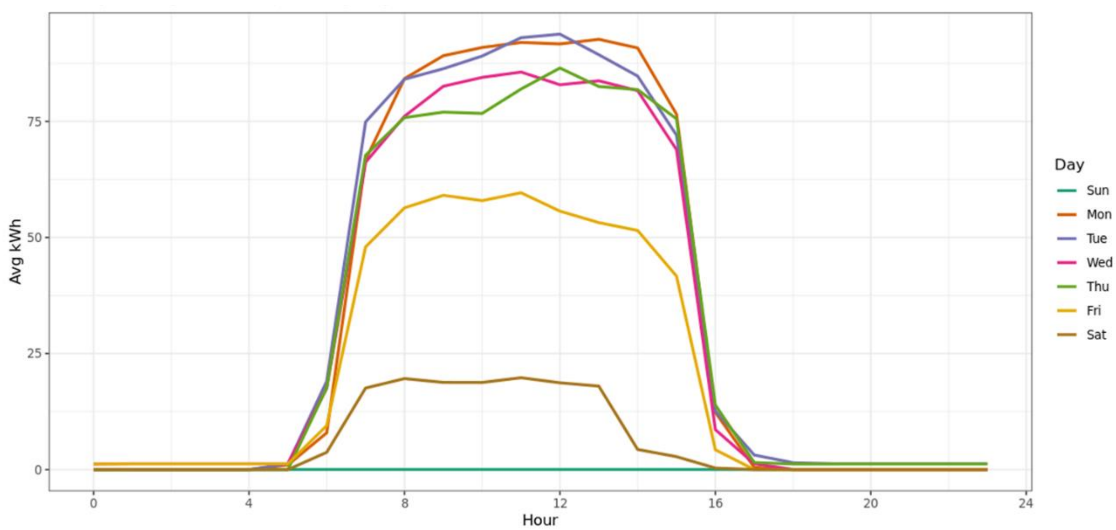

Figure 8. Data visualization of hourly average consumption by day of the week for the winter period

Using AMI data, ADM was able to identify meters with both the largest magnitude of usage during the winter peak period as well as the largest impact on the identified winter peak morning ramp-up. Each C&I meter on the circuit was assessed to identify the top uses by the following four criteria:

- Average consumption between 6-11 AM on Weekdays in December and January
- Average consumption between 6-9 AM on Weekdays in December and January
- Average consumption between 7-8 AM on Weekdays in December and January

• Consumption variance between 6am and 8am (time stamps 6am and 8am) on weekdays in December and January

Of the 145 commercial and industrial meters on the circuit, twelve facilities stood out when reviewing the above mentioned criteria. One industrial user's consumption was magnitudes higher than the rest, as shown in Figure 9.

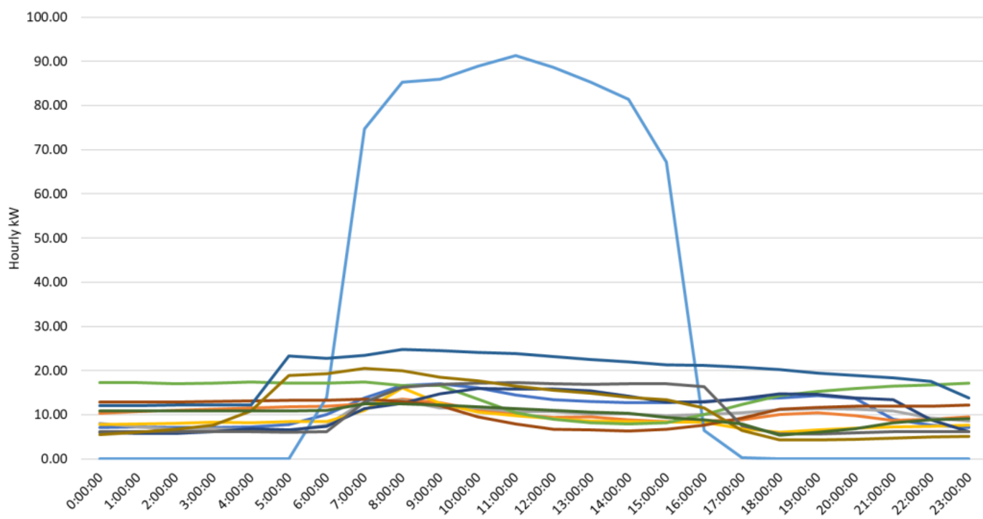

Figure 9. Consumption profile of top consuming commercial facilities

The implementation team performed energy audits and shared information with vendors on the potential for load reduction at these twelve facilities. The facilities were targeted for all commercial measures that might support winter peak load reduction including Energy Coaching.

Results

Over the span of a few months (September through December of 2020) the implementation team was successful in implementing residential measures at 93 residences and commercial measures at 29 businesses.[4] Residential measures consisted of air infiltration, attic insulation, duct sealing, faucet aerators, low-flow showerheads, lighting, water heater pipe insulation, and air source heat pumps. Commercial measures implemented include lighting, refrigeration door heater controls, evaporator and compressor controls, ECM motors, and mechanical system upgrades and building automation systems (through Energy Coaching). Estimated impacts of these measures results in reaching over 50% of the goal winter peak load reduction at 25% of the cost of capital expenditures. Money spent on these measures went directly into the residences and facilities on the distribution circuit and provided additional benefits in avoided costs, emissions reductions, and knowledge.

For measures installed before the end of 2020 energy savings were calculated using several methodologies. As additional measures were installed and commissioned for commercial projects during the early months of 2021, energy savings will be reassessed with winter consumption data in 2022. The continuation of pandemic conditions as well as a historical winter event (leading to below normal temperatures over an extended period) made for difficult assessment through statistical modeling of consumption data. Upon collection of a full winter's post-installation interval data ADM will revisit the

[4] Multiple commercial measures were implemented but continued commissioning periods through the winter of 2021.

residential difference in difference analysis (treatment vs. control), sector level linear regression analyses, and engineering analyses (calibrated energy simulations).

The targeted energy efficiency approach as a NWS was a logical and successful first step to avoiding a large capital investment. These NWS's provided direct improvement to residences and facilities in a rural underserved area as well as assisting in emissions and water reductions. The marketing approaches have resulted in an increase in knowledge on energy efficiency and the environmental impacts with the potential for high rates of spillover. In addition, the availability of AMI data to perform analysis allows for an accurate representation of the impact during peak capacity periods. The utility and implementation team are commended for their targeted energy efficiency strategy which turned a problem into a non-wires solution.

References

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