ZEF ENERGY

CASE STUDY

THE IMPACTS OF UNMANAGED ELECTRIC VEHICLE CHARGING

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Company

Wright Hennepin Cooperative Electric Assoc.

In partnership with ZEF Energy

Location & Pilot Period

Rockford, Minnesota

November 2018 - October 2019

Focus

A year-long pilot focused on quantifying unmanaged electric vehicle charging loads, measure peak load coincidance and load factor, observe residential charging behavior, and project the impacts of EV load growth.

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> "This study has been pivotal for our team to understand the magnitude of load growth and distribution challenges that lay ahead if we are not prepared. Too many utilities are convinced that they don't have to act or that this won't impact them in significant ways. None of us, even in rural areas, are the exception."
>
> **– Wendy Youngren**
> **COO, Wright Hennepin**

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ABOUT ZEF ENERGY

Headquartered in the heart of the Midwest (Minneapolis, MN), ZEF Energy's mission is to help support a reliable, low emissions transition to electric vehicles. We are a passionate group of software, hardware, development, and policy experts that craft smart transportation electrification solutions. These solutions are simple, nimble, and bring additional social benefit to our customer's communities. We believe in accessible, convenient, and low burden offerings that support the economy as well as the environment.

ZEF Energy specializes in working with cooperative and municipal utilities to deploy a comprehensive EV charging solution that results in beneficial electrification. From hardware to software and support to program guidance, we focus on collaboration and integration that makes program delivery easy for these utilities.

Our Values Include:

» Embedded utility-grade metering in every charger that supports reliable implementation of Time-of-Use rates

» Load management software that integrates with multiple utility billing and meter data management systems

» Driver-facing mobile application to meet the needs of multiple customer use cases

» Whole-solution branding allowing each utility program ownership and a fuller customer value

» U.S. made products and support

PILOT SUMMARY

Wright-Hennepin Electric Cooperative (WH), serving eastern Hennepin and Wright County to the west of Minneapolis, launched a year-long pilot in November 2018. WH had two primary learning objectives:

1. **Quantify unmanaged electric vehicle (EV) charging loads and to measure peak load coincidance and load factor**
2. **Observe and better understand residential charging behavior and project the impacts of EV load growth**

Working with EV charging partner, ZEF Energy, WH walked through data collection and analysis to look at both near term and long-term grid and member cost impacts.

WH partnered with ZEF Energy, an EV hardware and load management solutions company that specializes in electric cooperative collaborations. ZEF brought load management expertise, the metering and software capabilities to integrate with WH's billing system (SEDC), and the firmware needed to deploy future time-of-use pricing. In the process, WH analyzed the near-term and long-term impacts that smart charging would have regarding distribution planning and costs to the co-op and its members. This further analysis compared the financial and operational benefits of multiple EV charging programs, including different rebates, rates, and levels of load management. The engineering, member services, and finance staff partnering on the pilot learned how significant peak loads are, even with conservative assumptions.

The results of this pilot and analysis demonstrated the vital role that managed charging programs and solutions will play in their operations. Starting immediately, these insights are shaping how WH will be investing in technologies and practices that take growing EV loads into consideration

WRIGHT HENNEPIN OVERVIEW

Wright Hennepin is the fourth largest electric cooperative in Minnesota. WH supplies power to 55,000 consumers with a workforce of 150 employees. They are located on the western side of the Twin Cities metro area and service parts of two large suburbs (Plymouth and Maple Grove) with the majority of their service territory coverage in ex-urban and rural areas. WH is served by two wholesale power suppliers -- Great River Energy and Basin Electric. WH serves 13.6 consumers per line mile.

SUMMARY OF FINDINGS

1. Residential EV loads are growing. Most EV drivers live in a household with just one electric vehicle (EV), but that is starting to change. As these loads grow, cooperatives with more than 1 meter per transformer (on average) will see benefits from managing EV charging loads.

2. Uncontrolled EV loads naturally align with current peaks and would exacerbate peak power strain on cooperative distribution systems. As such, WH is already changing their distribution planning capacity requirements and continuing further piloting around EV load control.

3. Compared to a "doing nothing" scenario, there is a significant return from managed charging. Cooperative utilities that are similar in size and make-up to WH can likely expect to see a gross margin benefit for managed charging that is three to six (3-6) times better than the gross margin seen under unmanaged charging scenarios.

4. A time-of-use rate design paired with managed charging provided the fastest return on investment, of eight (8.4) years, versus unmanaged charging which had a return on investment of 49 years.

5. WH will launch a Subscription Time-of-Use charging pilot (Fall, 2021) using ZEF Energy's SEDC metering and billing system integration.

ZEF Energy's flagship ZEFNET PRO pedestal charger. Includes multiple features including cable management and 13 SQ FT of branding canvas.

Installed at Dairyland Power's HQ
La Crosse, WI.

PILOT SCOPE & PURPOSE

Starting in November 2018, Wright Hennepin (WH) launched a residential electric vehicle (EV) charging pilot with the intention of measuring consumption patterns and system-wide load, specifically for single-family residential users. In essence, this was a baselining exercise to help inform what future programming and utility planning might be needed to support new electrified transportation demands.

The pilot tracked consumption and usage pattern data from 35 residential members. Eleven (11) of these members were engaged directly through WH and were provided (for free) a smart-enabled ZEF EV charger (7.7kW). WH also provided discounted smart-enabled ZEF EV charger to 24 additional residential members through Great River Energy's (G&T) EV charging pilot.

The pilot ran for 12 months so that a full-year of hourly, revenue-grade metering data could be collected and observed. This allowed the WH engineering team to study how these peaks correlate with existing peaks, particularly winter peaks where building and vehicle loads will be most substantial.

In addition to collecting load data, the Pilot also studied what usage will look like overtime and what the impacts will be for WH. To do this, the team applied assumptions from the recent U.S. EV Sales Forecast (2019-2028) from EV Adoption, Lauren McDonald's Growth Model which projects load growth over the next 20 years. This forecast anticipates that approximately 18% of all vehicles sold in 2030 will be electric. This model provided a national average which does not fully consider WH's member demographics and mix of suburban and rural residents but uses conservative estimates of growth over time. Accordingly, it was used to illustrate one snapshot of local EV load growth over the next 10 years. **Applying this model, WH estimated that 9,000 EVs will be plugged in to their grid by end of 2030.**

In 2018, at the onset of their electric vehicle (EV) charging pilot, Wright-Hennepin was aware of approximately 40 electric vehicles that were plugging into their distribution system. Today that number is estimated to be 208 (March 2021).

FURTHER ANALYSIS

While the Pilot's purpose was to identify EV load patterns, WH used this data and other operational assumptions to conduct additional analysis about distribution system impacts and future program options for customers. This included looking at distribution planning practices that might need updating as well as an economic analysis of financial impacts. The economic analysis focused primarily on what the marginal revenue and return on investment impacts would be under the anticipated load growth. This included member and utility costs under three separate residential program and rate scenarios:

THREE PROGRAM SCENARIOS

Unmanaged EV charging (a "do nothing" scenario)

Overnight rate for EV charging with $1,000 charger rebate

Time-of-Use rate for EV charging with $1,000 charger rebate

This analysis looked at upgrade costs for secondary and primary-level distribution, transformers, feeders and substation equipment to estimate the operational costs of these scenarios. The results of this analysis show that an overnight program would have the lowest upgrade costs per charger added to the system at $1,856. The time-of-use (TOU) program option was a slightly higher upgrade cost at $2,096, but offered members more charging flexibility. Both the TOU and Overnight program scenarios had notably lower costs compared to the "unmanaged EV load" or do nothing (italicized) scenario which resulted in utility distribution costs of $3,229 per unmanaged charger installed. Under the more flexible member option (TOU), WH estimates that they will have to spend $1.67 million per year over the next 10 years on additional distribution costs for the (assume a linear adoption rate of 900 more EVs per year).

As an initial analysis based on a baselining pilot, these projections did not consider how EV loads will change over time based on possible faster adoption or the use of heavier or longer-range vehicles, such as light-duty pick-ups or delivery vehicles for businesses, which will take more power to charge. The results of this analysis are discussed throughout this paper and are discussed in detail in a later section.

DATA & IMPACTS

Below is a summary of the key data streams that WH collected under the pilot as well as the primary impacts that they observed during this pilot and through the extended analysis that they completed.

FIGURE 1. SUMMARY OF VARIABLES & IMPACTS STUDIED

Data Points Collected

- System-wide EV loads (peak and non-peak)
- System-wide EV loads (seasonal)
- Aggregated EV loads at the substation and transformer levels

Initial Impacts Uncovered

- Distribution planning standards and assumptions
- Utility ROI for smart EV charging equipment
- Member/end-user program design cost impacts

[1] Loren McDonald, EVAdoption.com. Forecast & Chart. Loren is a prolific EV industry and technology marketing and analyst guru who publishes multiple forecasts and projections annually about EV adoption and growth in EV sales.

KEY OBSERVATIONS

The following observations summarize some of the key issues that were recognized and quantified by WH. Each one is discussed in turn with further analysis details shared in later sections.

1 OBSERVATION 1
UNMANAGED EV LOAD COMPARED TO ALL OTHER LOADS (INDIVIDUAL RESIDENCE)

Results showed that when unmanaged most EV charging loads are coincident with peak power periods. Most of this charging is occurring at night and starts when people arrive home from work between 5:00 and 6:00 pm. During periods of peak charging, these loads are equivalent to the average load of a single-family home (see Figure 2.). However, they observed that there is significant load diversity in charging behavior, as many drivers do not charge every day. On average the study saw peak coincidence loads of 1.8 to 2.0kW on a per day, per charger basis.

UNMANAGED CHARGING LOADS COINCIDE WITH EVENING PEAK & THE LOAD iS COMPARABLE TO THAT OF A SINGLE FAMILY HOME.

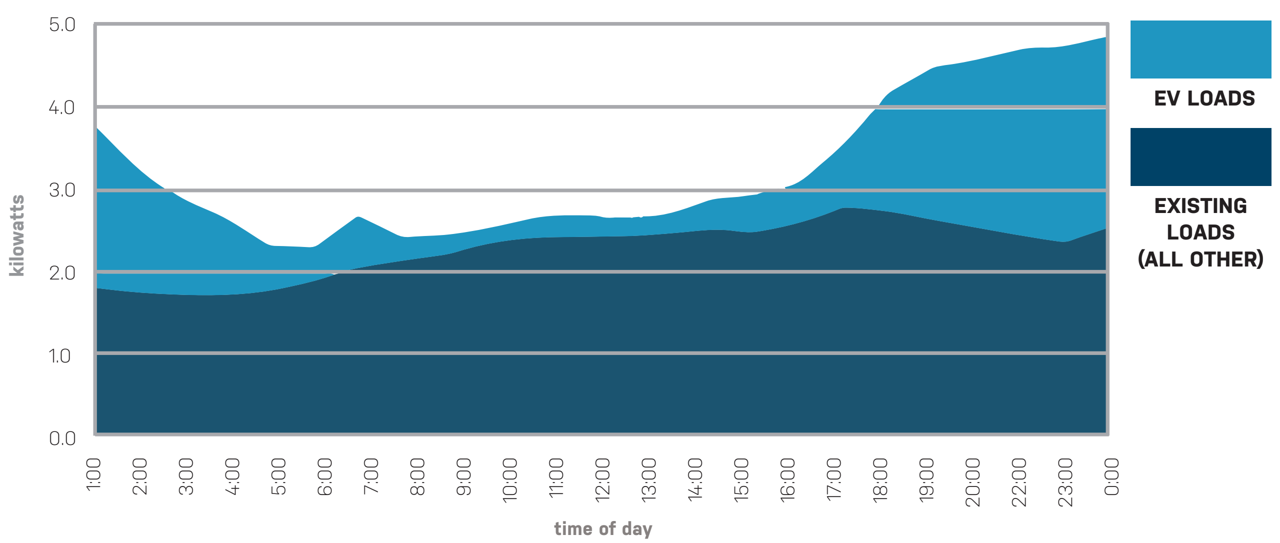
1.8 - 2.0 kW

Average Peak Coincident Load per Day, Per Charger

This peak load is notable because members pay more for electricity during these times. Relative to peak periods, off-peak electricity is very low cost. Under WH's current residential TOU rate members pay $0.06/kWh during off peak hours versus $0.24/kWh during peak hours. Managing loads during peak times has significant benefits to these consumers.

There are a few limiting factors that were inherent in this study and are important to point out. **This pilot study only consisted of households with one electric vehicle and all chargers were 7.7kW chargers.** These trends do not reflect the trends that ZEF and WH continue to see, as more members are choosing higher-powered chargers (e.g. 11.5kW or 15.4kW) to accommodate faster charging and large batteries inherent in new EVs. Also, despite best efforts to remove bias from this analysis (outlier data points were removed), WH noted that these results are likely conservative because of the behaviors of early EV adopters. These drivers might not be representative of the behaviors we can expect looking forward, where individuals will not take the same care to start charging late in the evening, for example.

FIGURE 2. EV LOAD COMBINED WITH EXISTING LOADS (2019 DAILY AVERAGE PER CUSTOMER)



[2] These calculations assumed that overnight charging would result in lower upgrade costs at the substation level, requiring only 50% of the cost under the TOU program scenario and 65% of the cost under the Overnight program scenario (compared to the do nothing scenario).

2 OBSERVATION 2
UNMANAGED EV LOADS -- WINTER VERSUS SUMMER LOADS

WH's year-long data was helpful for identifying seasonal differences in load shape. Between midnight and noon consumption was quite similar – winter compared to summer demands. One notable difference, however, was the short spike in demand that came between 6:00 am and 8:00 am as drivers started their cars ahead of driving for the purposes of pre-heating the battery (and likely the internal compartment). In doing this, the chargers would be started to support battery warming or would be turned on to get a final charging boost.

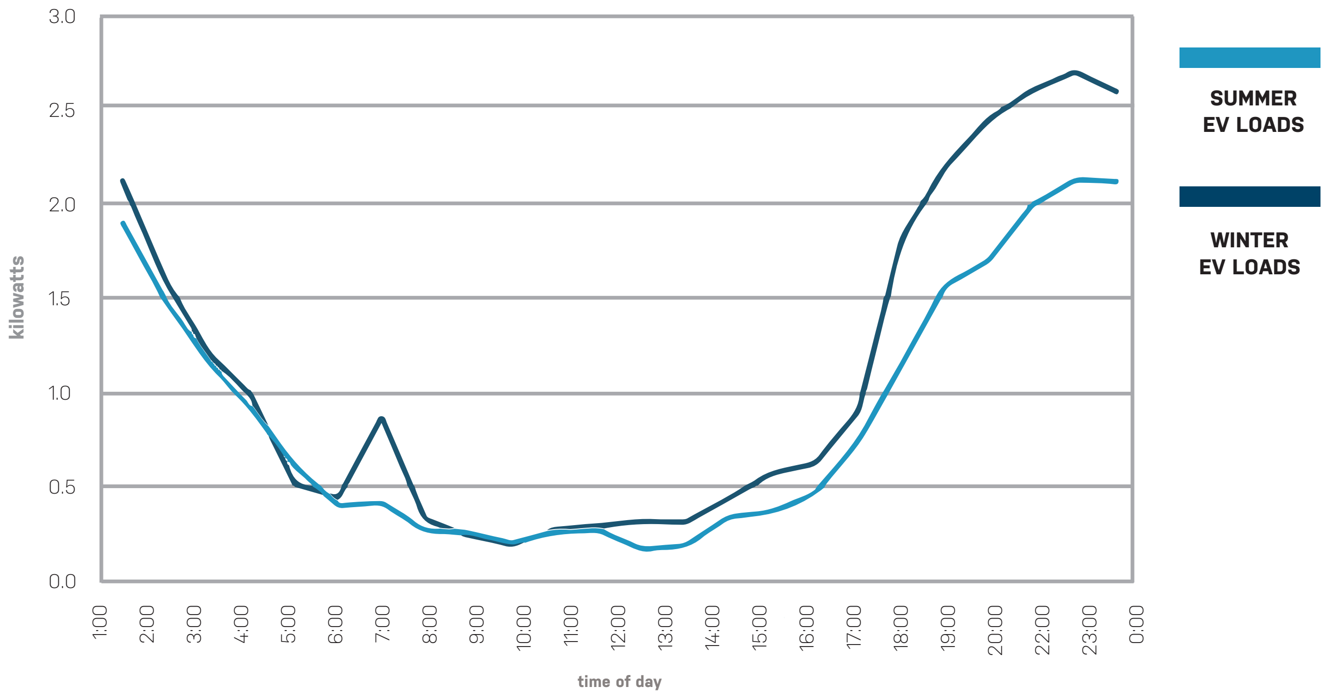
Winter electic vehicle loads produced a short spike in demand between

6:00 AM
and
8:00 AM

due to pre-heating the battery and likely internal compartment.

Elevated morning charging loads were noted in the winterlikely due to colder weather and an earlier sunset.

FIGURE 3. SEASONAL VARIATION FOR EV LOADS (2019 DAILY AVERAGE PER CUSTOMER)



PEAK EV DEMANDS ACROSS THE SYSTEM WERE

↑25-30%

HIGHER IN THE WINTER

In the second half of the day, demand increases and is shifted earlier, as people may leave work earlier and charge at home earlier due to colder weather and an earlier sunset. In winter, peak EV demands across the system were about 25% to 30% higher (2.65 kW versus 2.2 kW). Notably, **in both summer and winter, the periods of greatest demand coincided with existing periods of peak power.**

3 OBSERVATION 3

DISTRIBUTION SYSTEM IMPACT IF UNMANAGED (IN 2030)

Without programs and flexible load controls

56%

would occur during peak times.

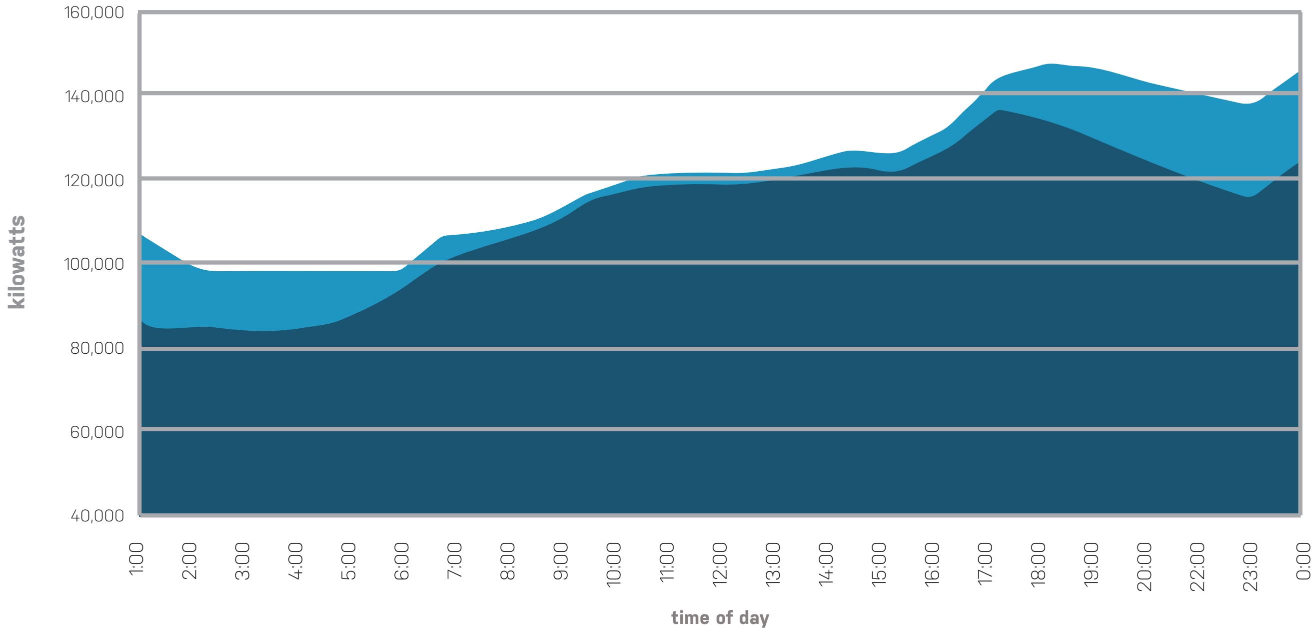
By 2030, WH projects that 9,000 EVs will be plugging in on their system. With this, load growth will be significant and so will the impacts to the distribution system. Without programs and flexible load controls in place, loads will coincide with existing periods of peak power. WH's pilot analysis estimated that 56% of charging would occur during peak times and that peak load would increase by four to six percent (4% to 6%). For context, WH's winter peak is approximately 178MW and 219MW in the summer..

Wright Hennepin estimates they will serve 65,000 consumers with 9,000 EVs on their grid by 2030.

LOAD GROWTH PROJECTION

WH used the Loren/McDonald load growth projection as a basis for their analysis. This projection estimates that **18% of all vehicles on the road will be electric by 2028,** after multiple models of sedans, cross-over vehicles, and SUVs are expected to reach cost-parity. More recent projections from the PJM region show an increase in system load from 200 MW in 2020 to 1,500 MW by 2035, which each EV consuming 4,500 kWh annually.

FIGURE 4. EV LOADS COMBINED WITH EXISTING SYSTEM LOADS)



[3] Lutsey, Nic and Michael Nicholas. Update on Electric Vehicle Costs in the United States Through 2030. ICCT. Published April 2019. Accessed January 21, 2021. https://theicct.org/sites/default/files/publications/EV_cost_2020_2030_20190401.pdf

[4] PJM Releases 2020 Long-Term Load Forecast Report. January 2020. Accessed January 26, 2021. https://insidelines.pjm.com/pjm-releases-2020-long-term-load-forecast-report/

ECONOMIC ANALYSIS & KEY TAKEAWAYS

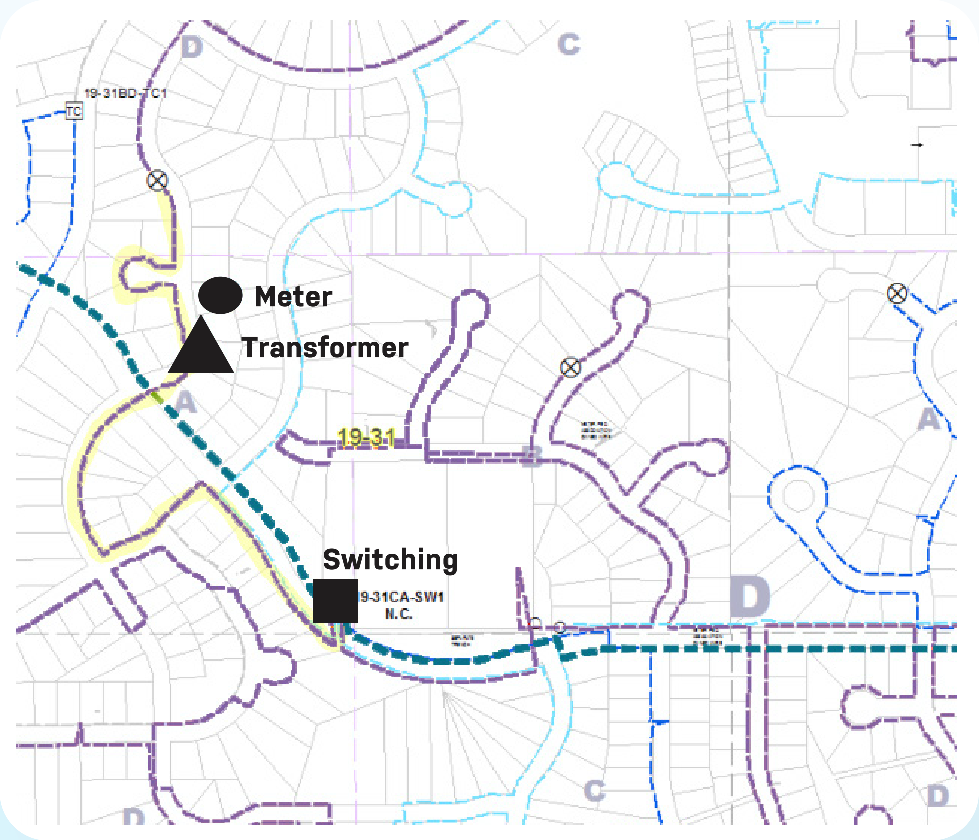
Because of this pilot, WH is looking to take action and update their distribution planning standards for new development. Prior to these updates, WH had been using the same distribution planning assumptions for over 30 years. These planning standards assumed that residential peak loads would range from 4kW (urban areas) to 8kW (rural areas) for the average single family home, including winter heating loads in Minnesota's cold climate. However, with one EV plugged in, even during shoulder peak times, the current distribution and substation capacity will not support these demands. **Without changing their standards, WH anticipates that they could have had significant power quality issues** that may result in individual members or even whole neighborhoods experiencing voltage sag on a regular basis (relative to EV adoption).

As of today, WH's has focused on the how these findings should impact distribution design in residential areas, however they also plan to study the impacts in commercial and multifamily areas as more data becomes available.

"What was most important about this early pilot and analysis was learning how vital it is that we update our distribution planning criteria. Transformer sizing and service wiring is already changing to reflect initial levels of EV adoption. We are alos applying new planning criteria and rate incentives where load curtailing is required, and this will change as EV penetration increases."

- Engineering Team, Wright Hennepin

FIGURE 5. CHANGING DISTRIBUTION PLANNING ASSUMPTIONS & IMPACTS



Meter
Feeds approximately 1 meter
<u>With EV Load:</u> Now seeing 10kW to 15kW per home (expect this to go up as charger capacities increase)

Transformer
Sized at 37.5 or 50kVA
<u>Traditional:</u>
Feeds approximately 6 meters (25kVA total)
<u>With EV Load:</u>
1+ EVs per transformer can cause for upgrade to 50kVA

Switching
Wright Hennepin is not yet seeing overloading at the feeder level, however they are monitoring. They estimate that they will not need upgrades at this junction until >33% of homes have 1 or more EV charging (or lower penetration as charger sizes increase).

FINANCIAL ANALYSIS OF PROGRAM OPTIONS

Through their financial analysis, WH determined that the highest return on investment came from the TOU program scenario, for which they estimated a payback of about eight and a half (8.4) years. By comparison, an Overnight charging program was estimated to result in a 14 year payback. The impacts of offering no program (the *do-nothing* scenario) estimated a much riskier return on investment of 49 years.

While the distribution costs for the Overnight rate option were estimated to be lower than a TOU option, **WH estimated that the TOU program option would have the greatest return on investment and result in the greatest annual margin.** This is due to the fact that under an Overnight charging program, members would not be allowed to charge beyond predetermined off-peak hours. Under the TOU scenario members would have more flexibility and could charge whenever they like. However, the cost of this flexibility is higher volumetric rates (kWh) during peak hours. For some members this might be the preferred option, for others, they might prefer a program that promises the lowest bill possible.

From the perspective of Coop operations, a TOU program would offer members flexibility and would likely result in additional annual revenues. Other hybrid programs were not studied by WH, but could also be considered. In 2021, WH launched its residential TOU pilot program to test the assumptions highlighted from this financial analysis. Additional findings from this analysis are shown in Figure 6.

FIGURE 6. FINANCIAL ANALYSIS FINDINGS SUMMARY TABLE

Overnight Charging Program	Time-of-Use Charging Program	No Program Scenario
The Offering Included: • Metered by separate off-peak meter • Requires separate receiver & remote current transformer • Charging allowed 11:00 pm to 7:00 am • Charging rate -- $0.06 per kWh • Rebate for up to $1,000 for member to "bring their own charger"	***The Offering Included:** • ZEFNET smart charger (embedded meter) • Noon to 10:00 pm -- $0.206 per kWh • Other hours -- $0.0605 per kWh • Rebate for up to $1,000 for member to "bring their own charger"	**The Offering Included:** • No rebate to subsidize EV charger installation • No EV load metering • No special rate options • Uncontrolled charging
Evaluation Findings: • Utility ROI = 14 years • Estimated distribution upgrade expense: $1,856 per charger • Utility annual margin of $204 • Average member spends $453 annually on EV charging	**Evaluation Findings:** • Utility ROI = 8.4 years • Estimated distribution upgrade expense: $2,096 per charger • Utility annual margin of $369 • Average member spends $795 annually on EV charging	**Evaluation Findings:** • Utility ROI = 49 years • Estimated distribution upgrade expense: $3,229 per charger • Annual margin of $65.62 • Average member spends $903 annually on EV charging

*These findings are based on the rates that were used during the 2018-2019 study. In 2021, WH launched a TOU rate and those rates vary from what is shown in this table.

HARDWARE FLEXIBILITY ADDS VALUE

Load control would be imperative for both the Overnight and the TOU programs. However, under a TOU program, more granular load sculpting would have significant value to the utility and their members. Further, the utility would have the option to curtail charging at the charger or group level (i.e. feeder, substation, or a customized group). If the utility helped members to manage their charging to use least-cost power, but still allowed for a driver to "override" the utility's control, ZEF Energy smart charging equipment enabled these program options.

These capabilities allow the utility to have very localized control over load to achieve local load balancing as well as sophisticated control for demand response programs and synchronization with renewables. WH and ZEF Energy see that this is a benefit for the whole system while also helping keep member bills lower.

ZEF Energy's solution also provides benefits for G&T operators. G&Ts can collaborate with their distribution members to coordinate around generation resource peaks as well as transmission system constraints. This type of coordination will be a learning process in the near-term, but as seen by this analysis, the benefits for this type of load management, control, and coordination are already here.

ZEFNET SUPPORTS METERING SYSTEM INTEGRATIONS

The ZEFNET platform is designed to connect ZEF's embedded revenue grade metering hardware with the billing software systems used by utilities (e.g. NISC Web Services, SEDC data exports)

The Value of Smart Metering

Through this pilot WH learned about equipment and tools that manage electric vehicle charging, or "smart EV charging". "ZEF Energy worked with us to educate us about the capabilities of smart EV chargers for our members," said Lance Hovland, VP of Energy Distribution. "They really taught us about the benefits of managing these loads and helped us see that this was an important investment for member services as well as operation." Collaborative learning and planning between the engineering team and ZEF Energy was instrumental for WH and this pilot program. For them, there are multiple value streams, but a primary benefit is how ZEF's hardware and software are easy to install at a home and how remote diagnostics will mitigate field calls and truck rolls. Their smart chargers come with embedded load controllers, a revenue grade meter, and the proper enclosures all in one. One product, one install, one integration.

Beneficial Electric Vehicle Load Growth Done *Right.*

ZEF Energy's full array of commercial and residential programs are designed specifically for utility deployment and grid benefit.

ZEF ENERGY

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