5 Impacts of a Rapidly Decentralized Grid

5.1 Introduction and Purpose

As DER, such as distribution generation and electric vehicles penetration levels increase we are seeing a rapid shift from a centralized and simple grid architecture to a more decentralized and complex system that needs to be orchestrated. The decentralized grid will need new technology, talent, and creative solutions to manage while the centralized transmission infrastructure will need to expand to meet the needs of new generation and this load. In regards to the latter item, the ISONE Regional System Plan (RSP) shows that over the next five years we anticipate an increase in asset management and transmission projects in the region further increasing VEC's transmission costs.

We anticipate our 2040 load without electrification to be like our load today with a peak similar to our 2022 peak of around 80MW

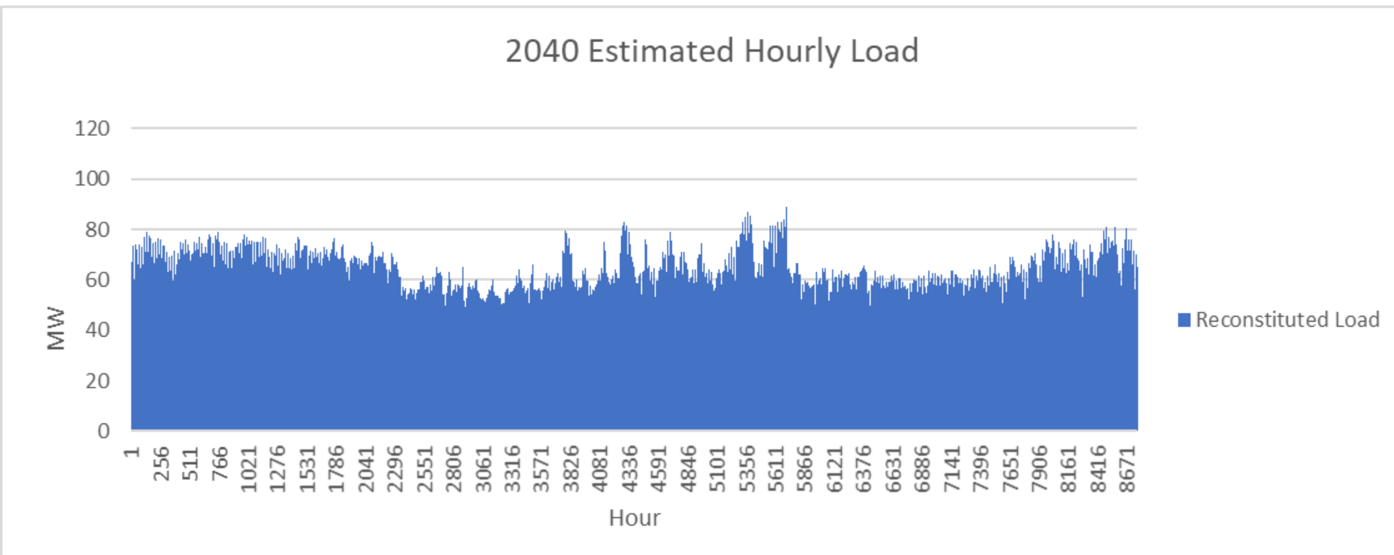


Figure 5.1.1.A 2040 Estimated Hourly load without electrification

However, when we add unmanaged electrification load from CCHPs and EVs the load in certain months can exceed 120 MW which is an almost 50% increase in where the system is designed to today.

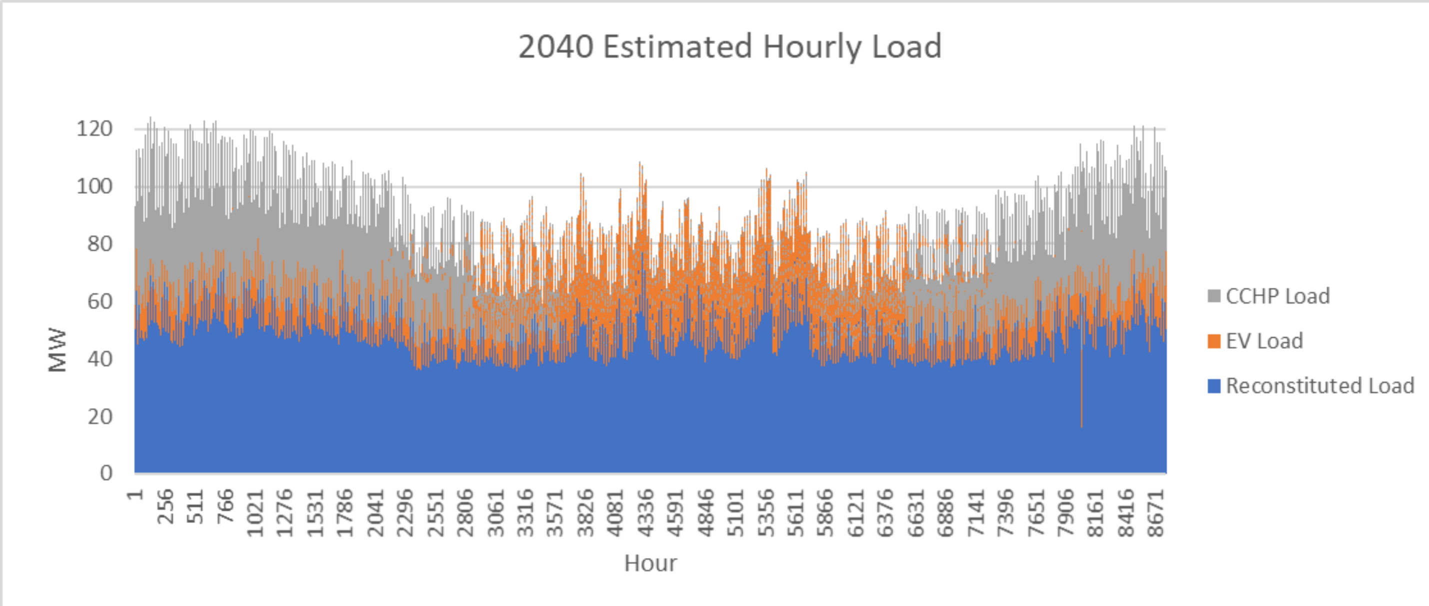


Figure 5.1.1.A 2040 Estimated Hourly load without electrification

This sort of impact would put significant pressures on our electric system infrastructure. VEC anticipates ~30% of its substation transformers would not be able to handle this increase and many single phase and legacy conductor would also be pushed to their design limits. VEC anticipates a continued investment in load management to ensure that this load growth does not occur at times when the grid is already heavily loaded. This will reduce the likelihood of system upgrades attributable to new load.

5.1.1 Section Overview

Electrification Impacts to the Distribution Grid

- Types and Sizes of Load
- Locational
- System

Generation Challenges

- Distributed Generation
- Net Metering
- 100% Renewable

Load Management

- Value to the VEC, Other State Targets/Incentives
- Utility Scale, Commerical and Industrial, and Residential Options
- Rate Opportunities

5.2 Electrification Impacts to the Distribution Grid

As with any type of load growth, quantity and location of electrification can have significant impacts on the electrical grid. VEC is forecasting a 180% increase in sales by 2042 as result of electrification. This creates a host of challenges in prioritizing investment to maintain and improve an extensive and aging infrastructure while balancing cost to the membership. This infrastructure is approaching its end of usual life in many sections of VEC's territory, and in some cases has passed its expected life. Undersized and high loss conductor provide the biggest area of concern. 6A Copperweld, #6 Steel, and 8D Amerductor make up approximately 10 percent (568 conductor miles) of VEC's distribution plant. We plan to remove the #6 Steel, and 8D Amerductor wire by 2030 and to continue replacing the 6A Copperweld.

5.2.1 Types and Timing of Load Growth

When looking at the types and sizes of load growth VEC expects, approximately 94% comes from CCHP and EV's. This forecast uses the CCHP and EV projections from the Climate Action Plan

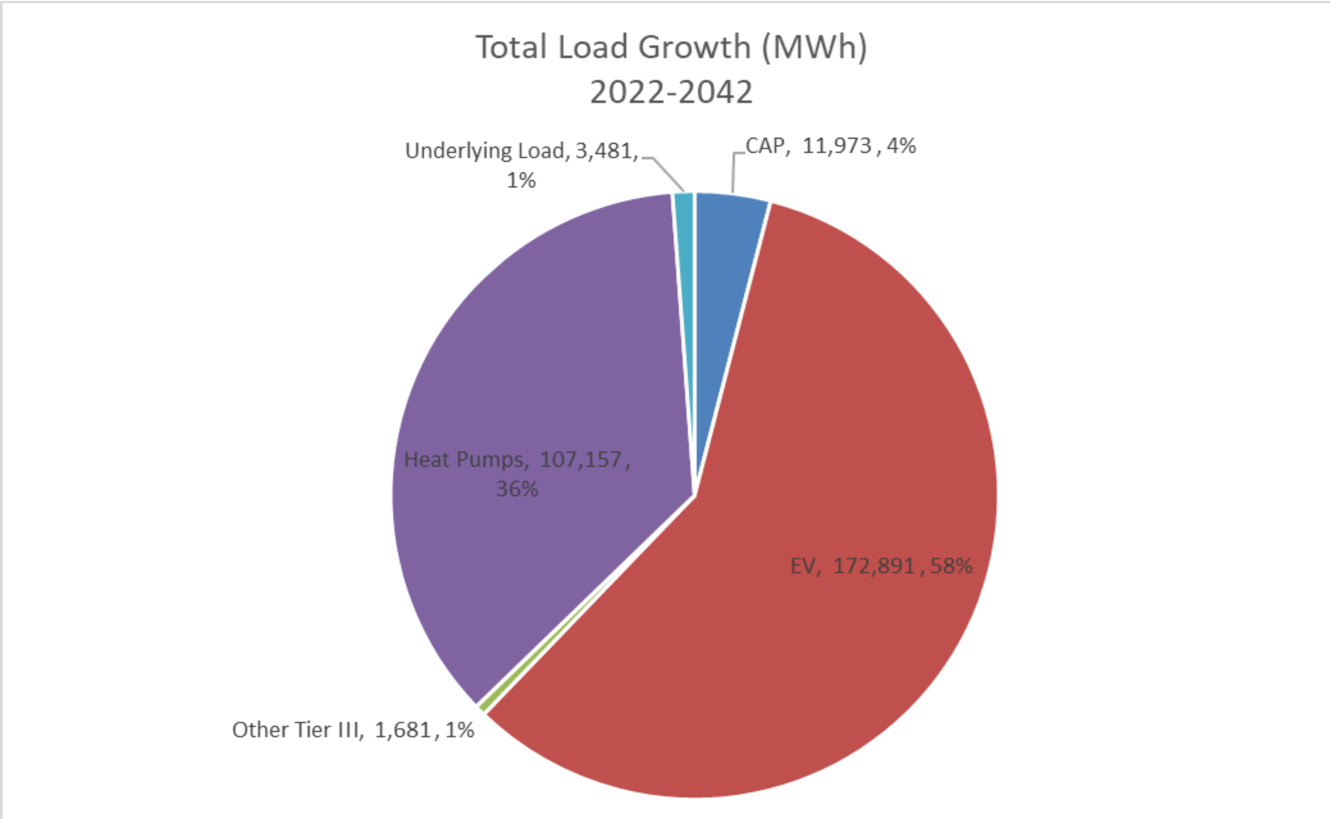


Figure 5.2.1.A Cumulative load growth (MWh) 2022-2042

The charts below show the timing of CCHP and EV estimated load impacts during hours 4pm-8pm in 2040 by month. The data behind these charts unrealistically assumes that 100% of the EVs and CCHPs are unmanaged, it presents a worst case scenario that highlights the need and potential timing for load management into the future. In a later section 5.4.2, these charts and future load management potential are discussed more thoroughly.

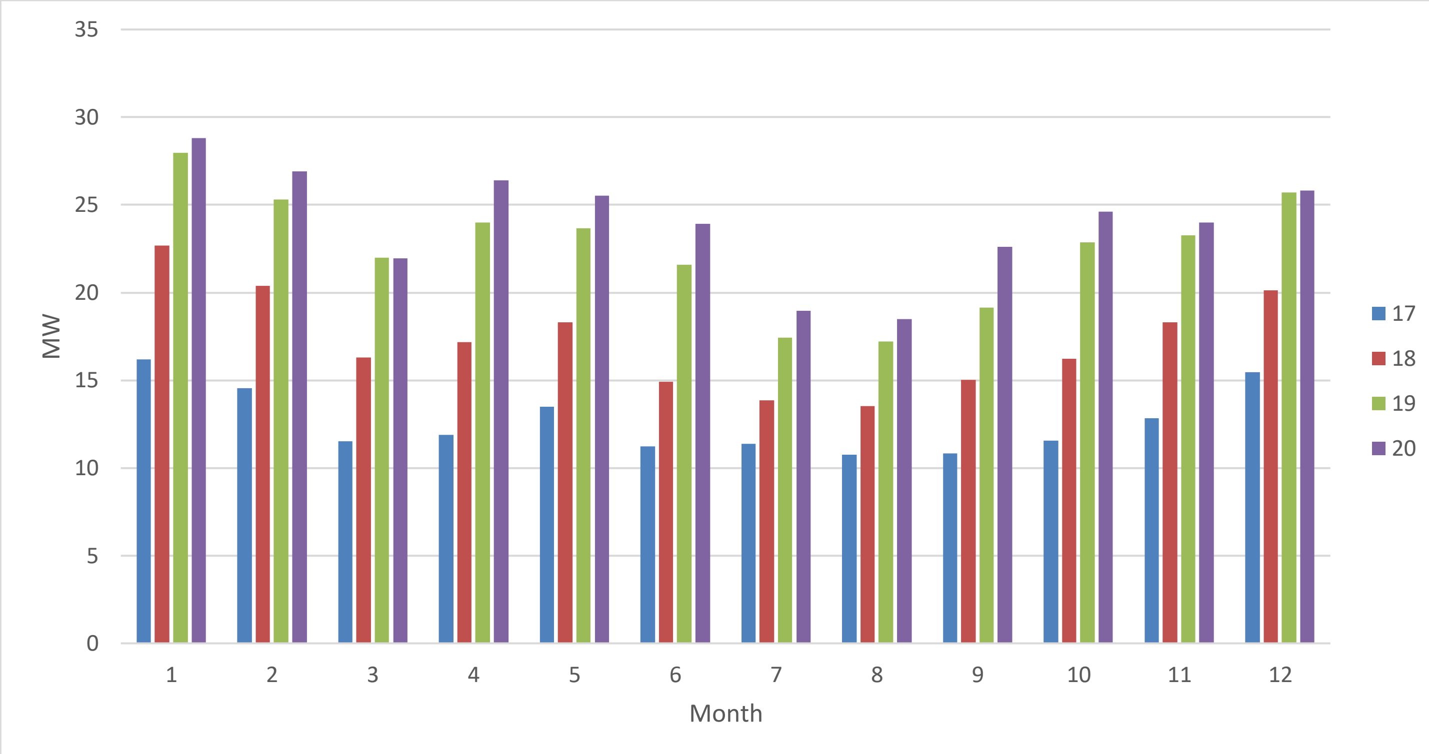


Figure 5.2.1.B – Estimated Unmanaged EV Load 2040 - Hours 17:00 to 20:00

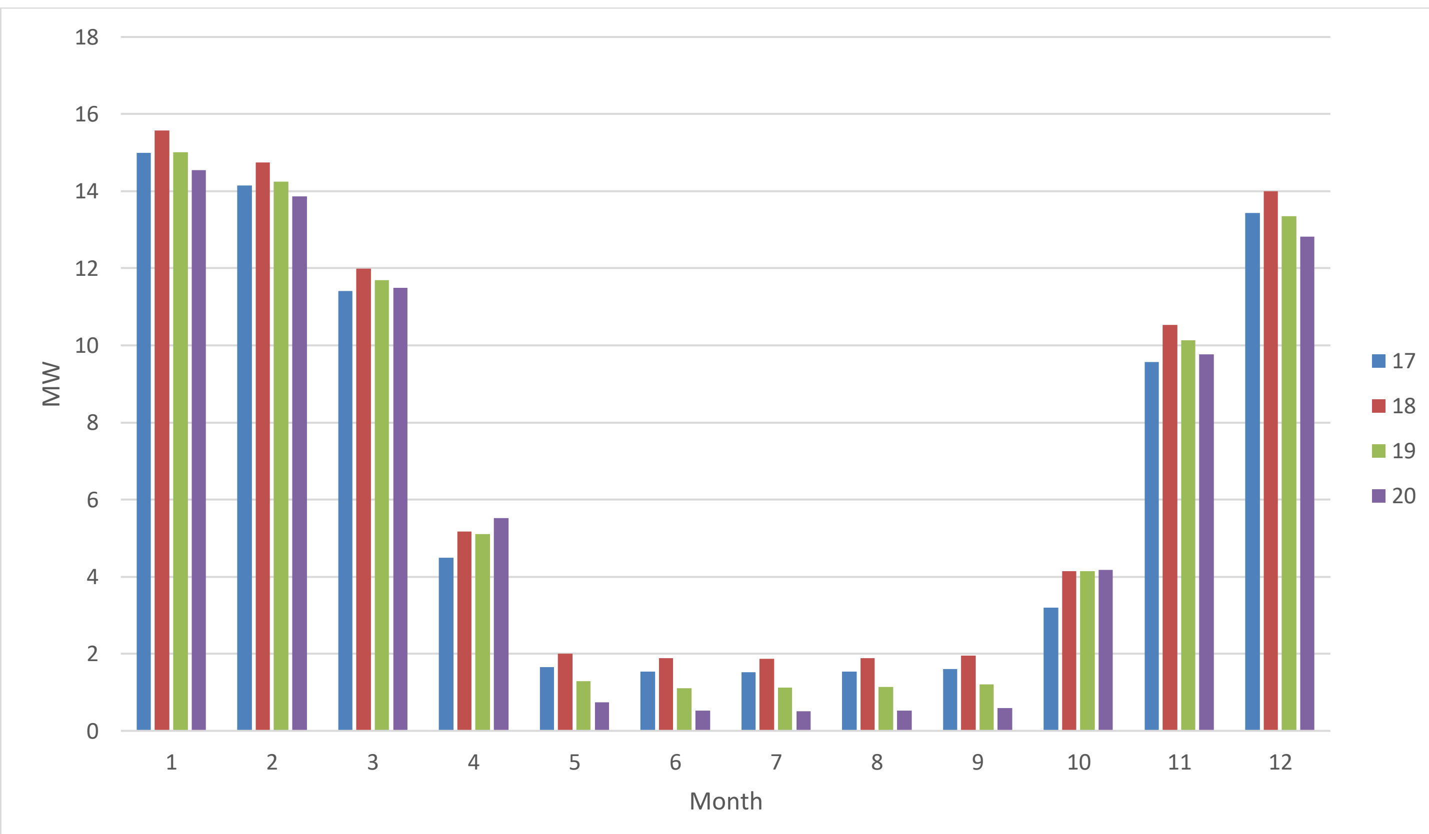
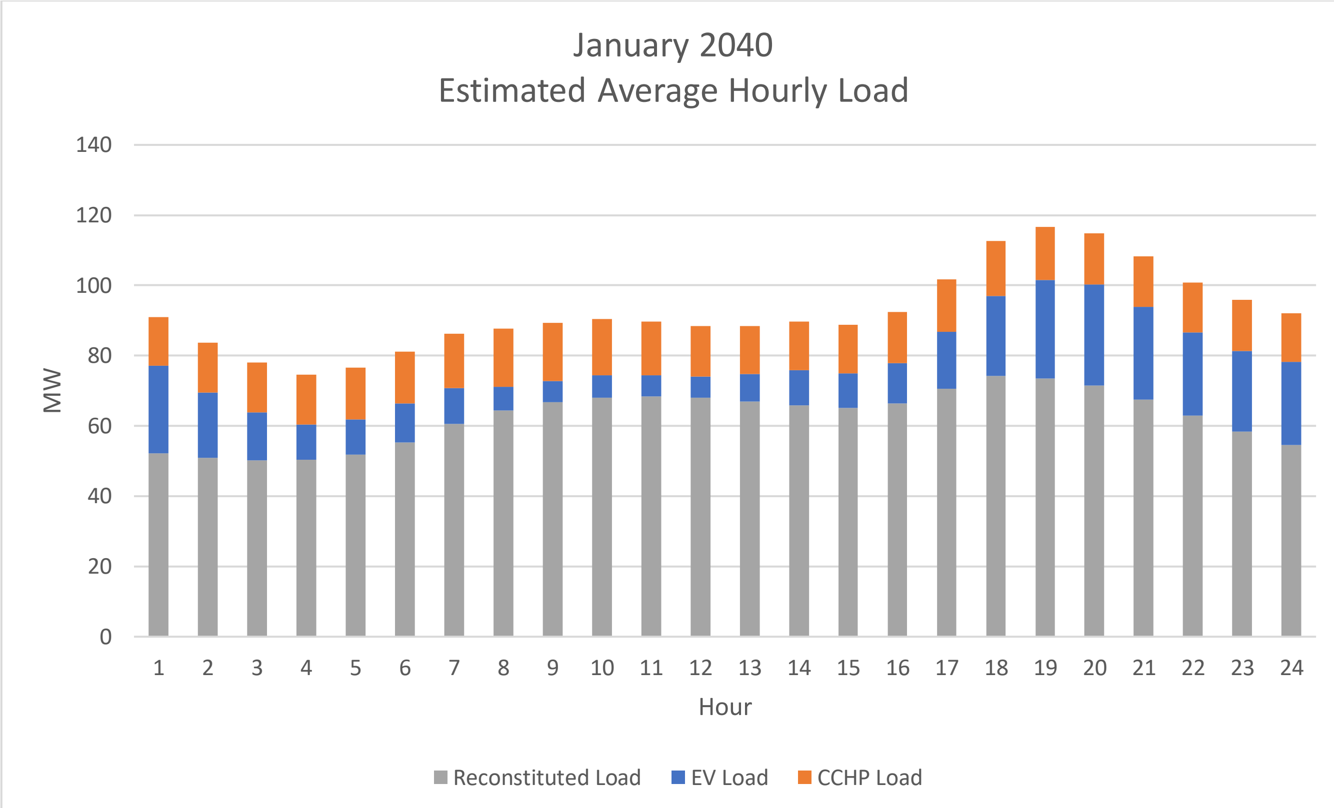
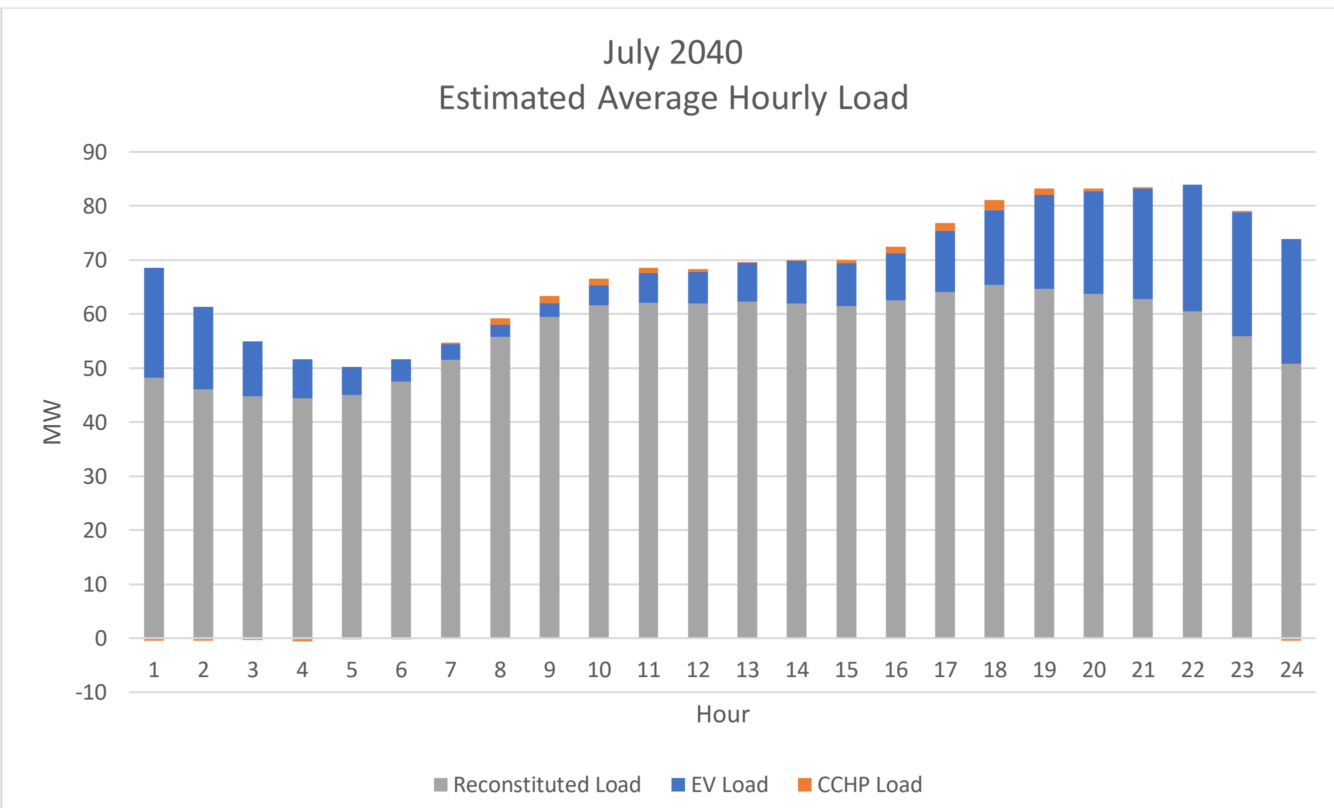
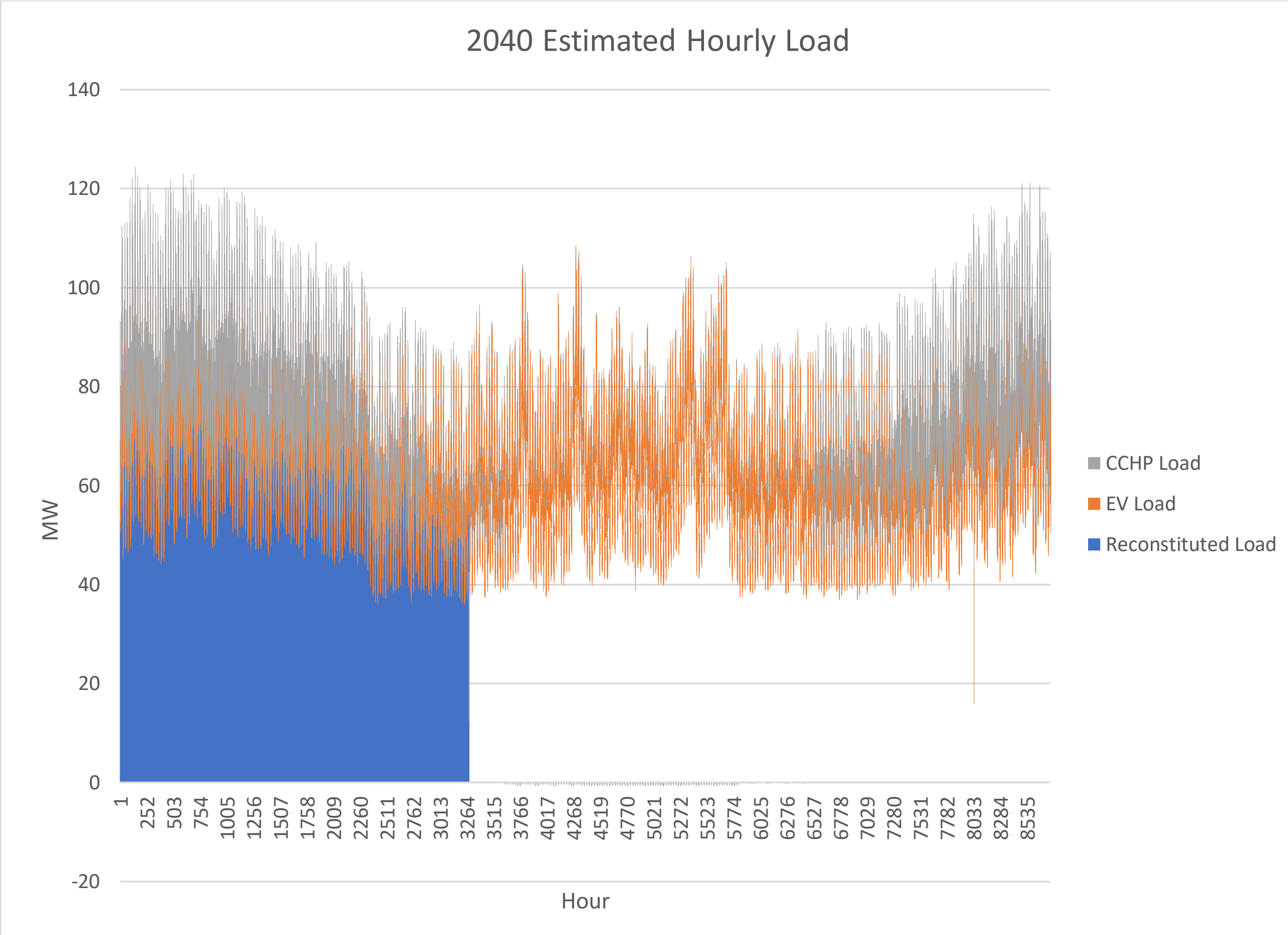


Figure 5.2.1.C – Estimated Unmanaged CCHP Load 2040 - Hours 17:00 to 20:00


January 2040
Estimated Average Hourly Load
140
120
100
80
60
40
20
0
MW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
Reconstituted Load
EV Load
CCHP Load


July 2040
Estimated Average Hourly Load
90
80
70
60
50
40
30
20
10
0
-10
MW
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
Hour
Reconstituted Load
EV Load
CCHP Load



VEC discusses each of the grid impacts of each of these components below

Electric Vehicles

As shown in the charts above EV load represents the largest impact (58% of load growth by 2042) and impacts the grid during our current peak hours.

Based on VEC survey data, 93% of VEC EV drivers currently charge at home, and many trickle charge using a regular outlet (Level 1 charger). Level 2 chargers' range in power level from 3.5 kW to 19.2 kW, while Level 3 chargers can be up to 150kW. The most common level 2 chargers are 7.7kW (32 Amps at 240V on a 40 Amp circuit) and 9.6 kW (40 Amp max draw on a 50 Amp circuit). However, as battery sizes increase, automobile manufacturers are increasing the size of their chargers. For instance, the new Ford F150 Lightning can charge on an 80 Amp circuit, and that 80 Amp is required for the vehicle-to-home technology option.

Vehicle charging profiles vary between vehicles and depend on battery design, battery temperature, and battery state of charge. Most EVs ramp up to full charging power quickly and maintain a constant charge rate to about 75 – 80% state of charge, then the charge rate tapers off as the battery continues to charge. Some vehicles exhibit a more linear charger curve, others are more step-wise.

If the battery is cold or hot, the car's battery management system will adjust the charging rate. Also, some vehicles use a portion of the power supplied to run battery heating and cooling. Finally, most EVs allow the owner to precondition the car while it's plugged in. When you look at charging profiles, you may see that spike in the morning after charging concluded overnight.

There have been several studies completed by IEEE and other journals that analyze the grid impacts of EV charging load.[1] In each study, potential risks are identified related to service transformer overload and service voltage drop. These risks and associated utility infrastructure costs can be mitigated if proper utility planning and notifications occur prior to the purchase and installation of EV charging equipment.

Some studies conclude that 20 percent is a reasonable level of EV penetration that results in no overloading of existing distribution networks. However, other systems can tolerate only 10% of uncoordinated charging load that could be raised to 40% in the case of charging coordination. It appears that every distribution network is a special case, requiring an independent study to explore the issues and limits of EV charging load.

As to EVs driving the need for transformer upgrades, the average residential member will draw around 3 kVA and, in some cases, up to 8 kVA. A 10-kVA transformer is generally used for residential loads, however with ever increasing charging expectations at the home that size transformer may not allow for additional members to be added. In more developed areas where multiple members may be fed off the same transformer, an electric vehicle purchase may cause the need for a transformer upgrade to ensure system reliability and performance.

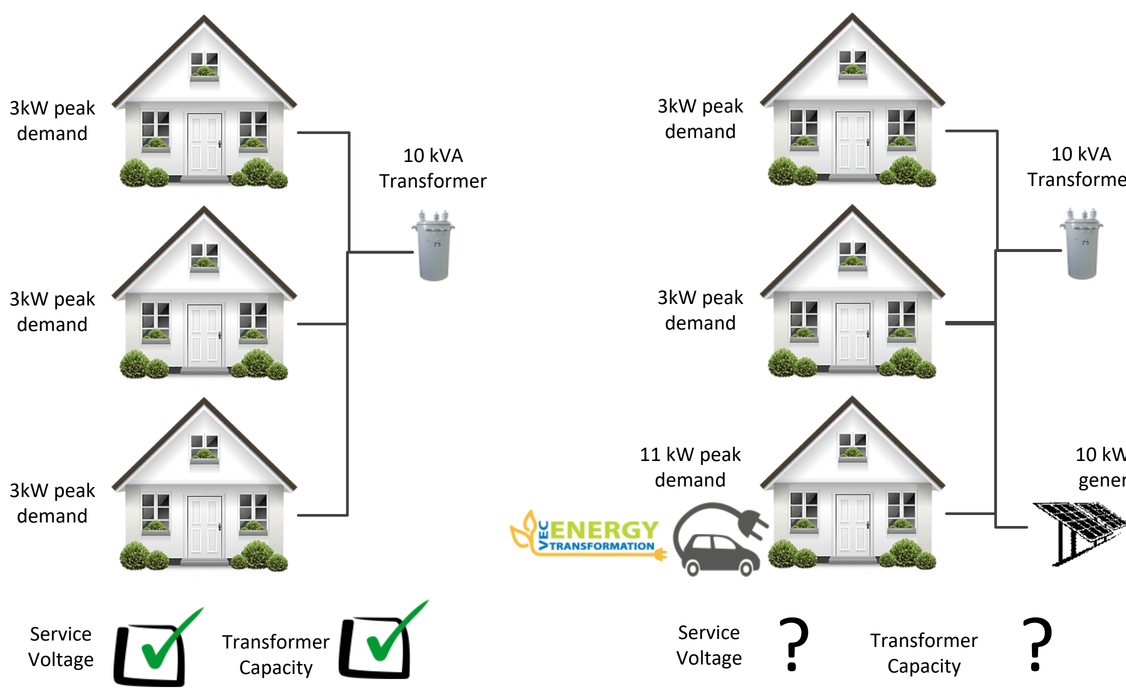


Figure 5.2.1.D Service voltage and transformer capacity review process

Most EV charging occurs at home and can add significant load to an electric service and premises electrical wiring and circuits. Voltage drop could be a concern depending on distance of EV charging stations from the utility's service transformer. Proper member planning with members' electricians can mitigate these risks.

[1] Electric Vehicle Charging on Residential Distribution Systems: Impacts and Mitigations (2015); Impact of EV Charger Load on Distribution Network Capacity: A Case Study in Toronto (2016).

Heating

As shown in the charts above CCHP load represents the second largest impact (36% of load growth by 2042 and impacts the grid more during winter peak hours.

CCHPs follow along the same lines as the EV charging discussion above; however, these resources may be used for longer periods throughout the day and night as compared to EV charging and may also result in additional incremental load if all three resources are used at the same time. The utility and members' electricians should be notified of these additions before purchasing of this equipment to plan for any necessary utility or member-owned electrical upgrades.

Clean Air Program

VEC's Clean Air Program, which was initiated in 2016, offers customized opportunities to members with off-grid or underserved homes or businesses to replace fossil fuel usage with electricity. These opportunities may include service upgrades or line extensions, with the costs shared between the utility and the member through customized agreements.

Each Clean Air Program project requires fuel receipts (in the case of an existing generator) to estimate the additional electric load and resulting carbon savings. In the case of a project that currently does not have a generator (for example a new sugaring operation which is considering a fossil fuel generator), we estimate what the consumption and corresponding carbon use would have been based on the projected power requirements of the operation. Once the projected load is determined, VEC reviews each project for system upgrades, analysis of load profile, increases electric sales, and net present value (NPV) payback period.

Underlying Load Growth

The Underlying Load Growth is the load increase prior to accounting for any impacts from Demand Side Management, Net Metering and Tier III. This includes additional members building or expanding homes in our service territory and new businesses. As shown in the chart the number is small in comparison with CCHP and EV load growth. These loads are assessed at the time VEC receives a new service application or increase in capacity application.

Other Tier 3 Loads

Other Tier 3 loads includes things like electric lawnmowers, pellet stoves, or electric forklifts. The impacts of these loads is also small and VEC does not perform any locational assessment as a result of a member adding these loads.

5.2.2 System Impacts

System impacts include issues associated at the substation and distribution system level such. The section below discusses VEC's analysis of impacts of electrification at the system level and proposed mitigations.

VEC completes a System Load and Voltage Study (SLVS) annually. The study reviews all VEC's 74 distribution circuits via equipment loading, voltage performance, and phase load balancing design criteria. VEC utilizes Supervisory Control and Data Acquisition (SCADA), Automated Metering Infrastructure (AMI) data, and Milsoft WindMil model to identify system constraints and appropriate solutions. VEC completes this system-wide study annually to identify constraints up to five years from the study completion. Given the substantial increase in distributed generation and increased load through beneficial electrification initiatives (e.g., electric vehicles and heat pumps), planning outside the five-year horizon is more uncertain than it ever has been.

This study is discussed further in Section 7 – Assessment of the Transmission and Distribution System. The SLVS study identified the following themes:

Voltage Outside of Tolerance

Load growth causes low voltage on weak sections of the distribution circuit. These weak sections are generally a function of line distance, quantity of phases, voltage rating (2400V versus 7200V), and type/size of conductor. Additional voltage regulation, reconductoring, or voltage conversions may be required.

Line Distance

VEC's service territory is very rural and as a result many of its distribution lines are long. As the distance of a power line increases so does the resistance of the conductor. Voltage levels drop as resistance increases which is further exacerbated by any load growth.

Quantity of Phases

82% of VEC's lines are single phase including many main feeder backbones. VEC aims to reduce the number of large radial single-phase lines to more easily manage the system from a load balancing perspective. Having multiple phases also improves VEC's ability to serve new load by freeing up capacity and improving system voltage through reducing high single-phase line loading. Balancing load between phases improves the efficiency and operability of the distribution circuits. Balancing phase loading helps to keep voltage balanced and creates a better foundation for voltage regulation on long single-phase taps and to three-phase customers. A balanced system also reduces neutral current on three-phase lines, leading to a reduction in losses.

Voltage Rating

VEC continues to operate about 85 miles of 2.4 kV lines, all of which are in the legacy Citizens Utilities system. These lines are more susceptible to load growth problems as the lower voltages mean higher current on the wires.

VEC does not have an explicit timetable for converting its lower voltage circuits to standard 7.2 kV. Voltage conversions are driven by several considerations including, but not limited to, low voltage complaints, opportunities arising from the need to replace deteriorating assets, and capacity constraints. VEC has eliminated all existing 2.4 kV lines where loss savings have justified a capital upgrade. As with all capital upgrades, VEC prioritizes those projects that provide the greatest value to its membership.

Poor condition and high loss conductor

6A Copperweld, #6 Steel, and 8D Amerductor make up approximately 10 percent (568 conductor miles) of VEC's distribution plant. Most of this conductor is located on single phase lines and their corresponding neutral conductors.

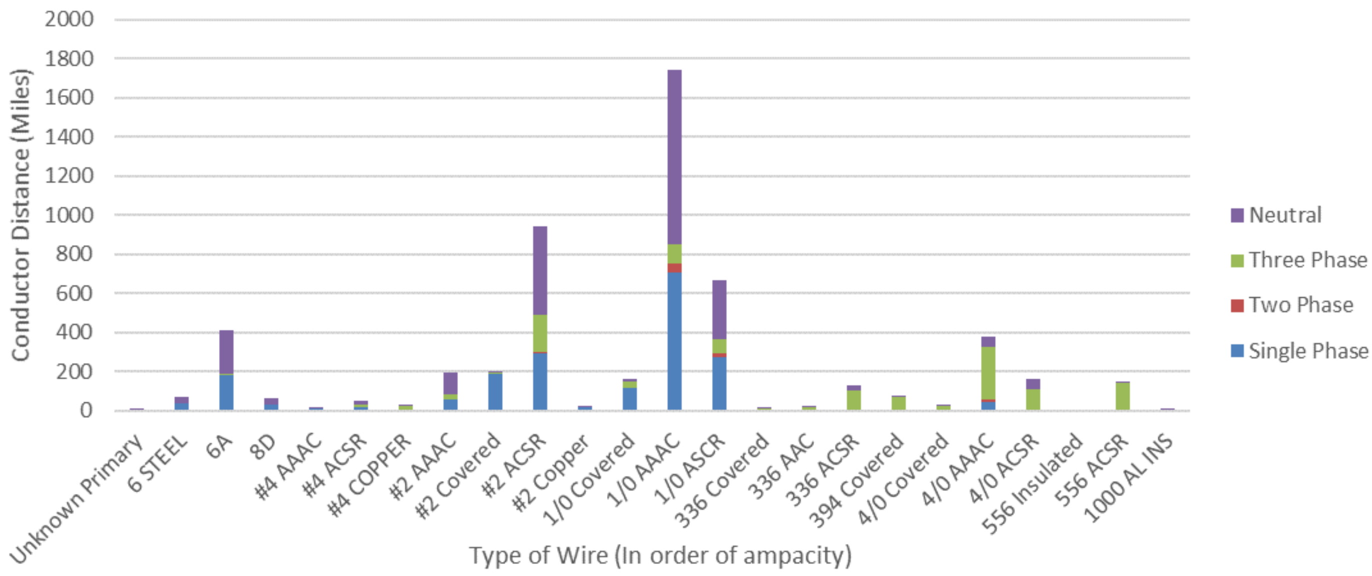


Figure 5.2.2.E Miles of VEC overhead distribution conductor by type

These wire sizes were a common, cost-effective conductor when rural electrification occurred in the early to mid-1900s. But these conductors are now nearing (or at) end-of-life and are not compatible with present materials and construction practices. As steel wire ages, it becomes hard and brittle, which then becomes a safety issue during repairs since the conductor can break while being handled. As a result, VEC performs work on 8D and #6 Steel only after it has been de-energized. The cross-section below is an example of the Amerductor wire mentioned above

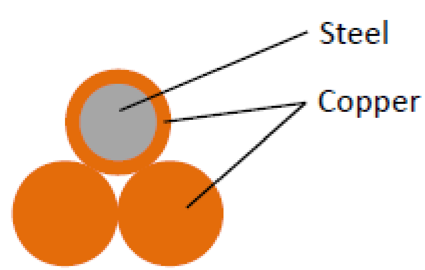


Figure 5.2.2.F Cross-section of Amerductor wire

In addition, resistance increases significantly for small wire which in turn increases line losses leading to higher operating costs. High losses cause voltage to drop more quickly over a length of line, thereby greatly limiting the amount of load that can be served by that line. This becomes even more important as loads such as electric vehicles and heat pumps continue to see growth.

Work on these replacements has been slow but is trending in a more positive direction. The four-year average is 4.4 conductor miles per year, up from the prior IRP average of 2.6 miles per year.

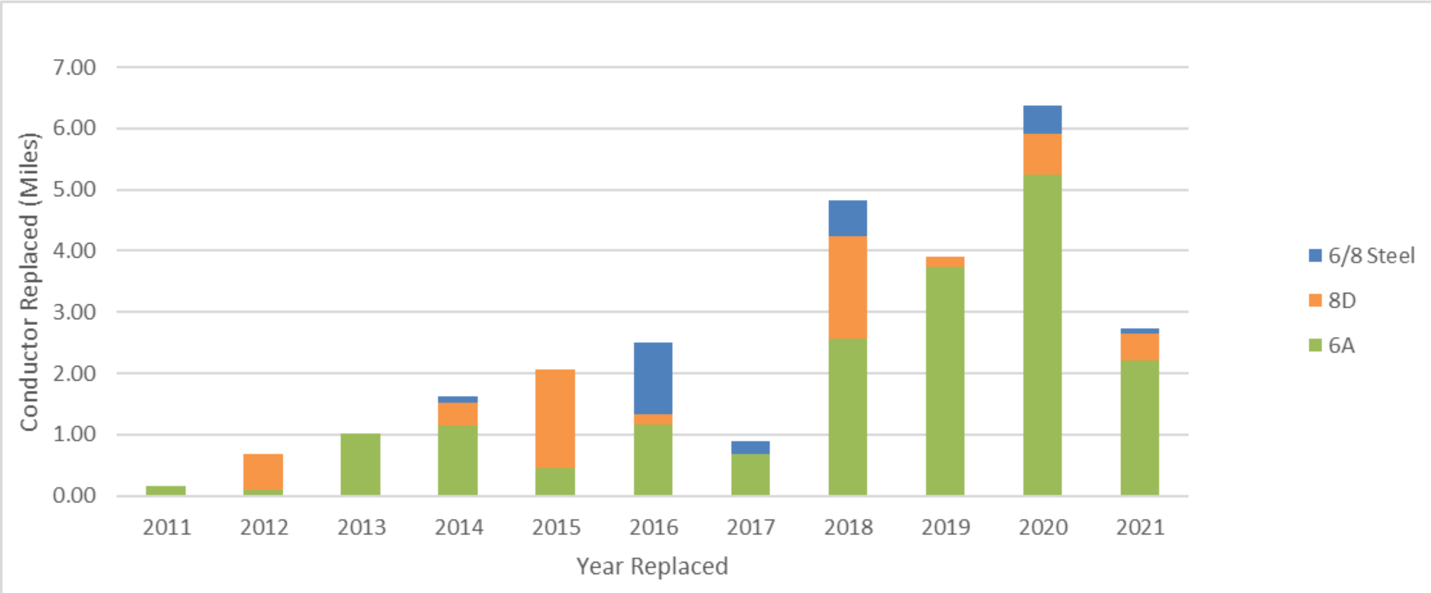


Figure 5.2.2.G Miles of undesirable conductor replaced 2011-2021

Substation Transformers

VEC currently upgrades its substation transformers when our studies indicate that load exceeds 80% of base rating MVA. 10 of VEC's 31 substation transformers (~30%) would not be able to handle the 180% increase in load by 2042 as result of electrification. VEC anticipates a continued investment in load management to ensure that this load growth does not occur at times when the grid is already heavily loaded. This will reduce the likelihood of substation transformer upgrades.

System Protection

Load growth causes the need to upgrade reclosers and fuses to ensure proper sectionalizing of the distribution system. As part of our annual SLVS study, VEC identifies locations where protection may be need to be changed and addresses those through capital upgrades as required.

Limits to Feeder Backup and Contingency Impacts

In the event of transmission outage or maintenance requirement, feeder backup can allow the backup of a circuit or potentially substation from another substation or feeder. VEC has several substations and feeders on its system that have this ability. However, many are limited by the amount of load they can carry during these times. Because of significant increases in load due to electrification these backups can be further limited or eliminated altogether without capital upgrades such as reconductoring to larger wire.

5.2.3 Locational Impacts

Locational Impacts include everything from the service transformer down to the house panel. The electrical power system is designed to perform to certain criteria during peak load. While the additional load proposed presents challenges, VEC is confident that with effective load management and rate design, the constraints identified above will not need to be mitigated with costly grid upgrades. VEC plans to do an annual analysis, using equal and distributed allocation, of the existing and forecasted load to ensure the safe operation and reliability of the grid.

Service Panels

VEC has seen an increase in service panel upgrades due to electrification. VEC's data on service panel sizes on its system is limited given it is not a VEC owned asset. However, around 27% of new services installed between 2017 and 2022 were 100-amp services. In general, if a member is installing a new level 2 charger and a heat pump a 100-amp service will not be adequate. VEC is exploring options to make this process easier and more affordable as it is likely that many members will need to upgrade their panel at a cost of $3,000 to $4,000. These costs can play a very significant role in the financial justification to electrify.

Service Conductor

For overhead conductor, VEC sizes service conductor (from transformer to service panel) based on the load rating of the panel and the distance. For underground conductor, the member owns the conductor and as such we rely on the electrician to size this appropriately. In general, the NEC (National Electric Code) sizes service panels and conductor to far exceed the usage in the house. It is unlikely that the service conductor would need to be upgraded as part of electrification but VEC reviews these when a new incentive is applied for and as part of transformer loading reviews.

Distribution Transformers

In 2020, VEC increased its standard transformer size to the following:

- 2 or fewer meters on a transformer – from 10 kVA to 15 kVA
- 3 or greater meters on a transformer – from 15 kVA to 25 kVA or larger, case by case basis

As VEC mentioned we are continuing to see an increase in electrification and. EV's, especially Level 2 chargers, can have up to 10kW of load. While service transformers can be overloaded for short durations (hours) up to 200%, repeated overloading will decrease the overall asset life. While making this change VEC did consider the 30-year losses of the increased transformer size. This came out to a total of $83.41 ($2.78 annually) which VEC deemed worth the decrease in risk associated with upgrading a transformer in the future.

VEC worked with GMP to analyze transformer sizes on the respective systems.

Size (kVA)	VEC %	GMP %
< 10 kVA	2.26%	8.88%
10	47.84%	44.29%
15	32.41%	25.85%
25	15.97%	12.31%
37.5	0.95%	2.13%
45	0.02%	0.54%
50	3.16%	1.98%

Figure 5.2.3.A Transformer size percentage of total VEC versus GMP

VEC has around 24,000 transformers, approximately half of which are 10kVA transformers. VEC assesses transformer sizing at the time of an energy transformation inventive application. Additionally, VEC has transformer loading software which it describes further in Section 6.

5.3 Generation Challenges and Solutions

Distributed generation includes all generation that is connected to VEC's distribution system and generally located behind the meter and owned by a member or a developer. Distributed generation is often grouped into a larger subset of resources called Distributed Energy Resources (DER) which also includes energy storage and other controllable resources.

VEC continues to see a dramatic rise in distributed generation on its electrical system, largely driven by technology availability and federal and state incentives. Distributed generation projects generally fall into one of three categories formats: net-metering projects, independent projects developed pursuant to Power Purchase Agreements (PPAs) with VEC, and Standard Offer projects. The chart below shows total nameplate (AC) generation of all active projects on VEC's system since 2012:

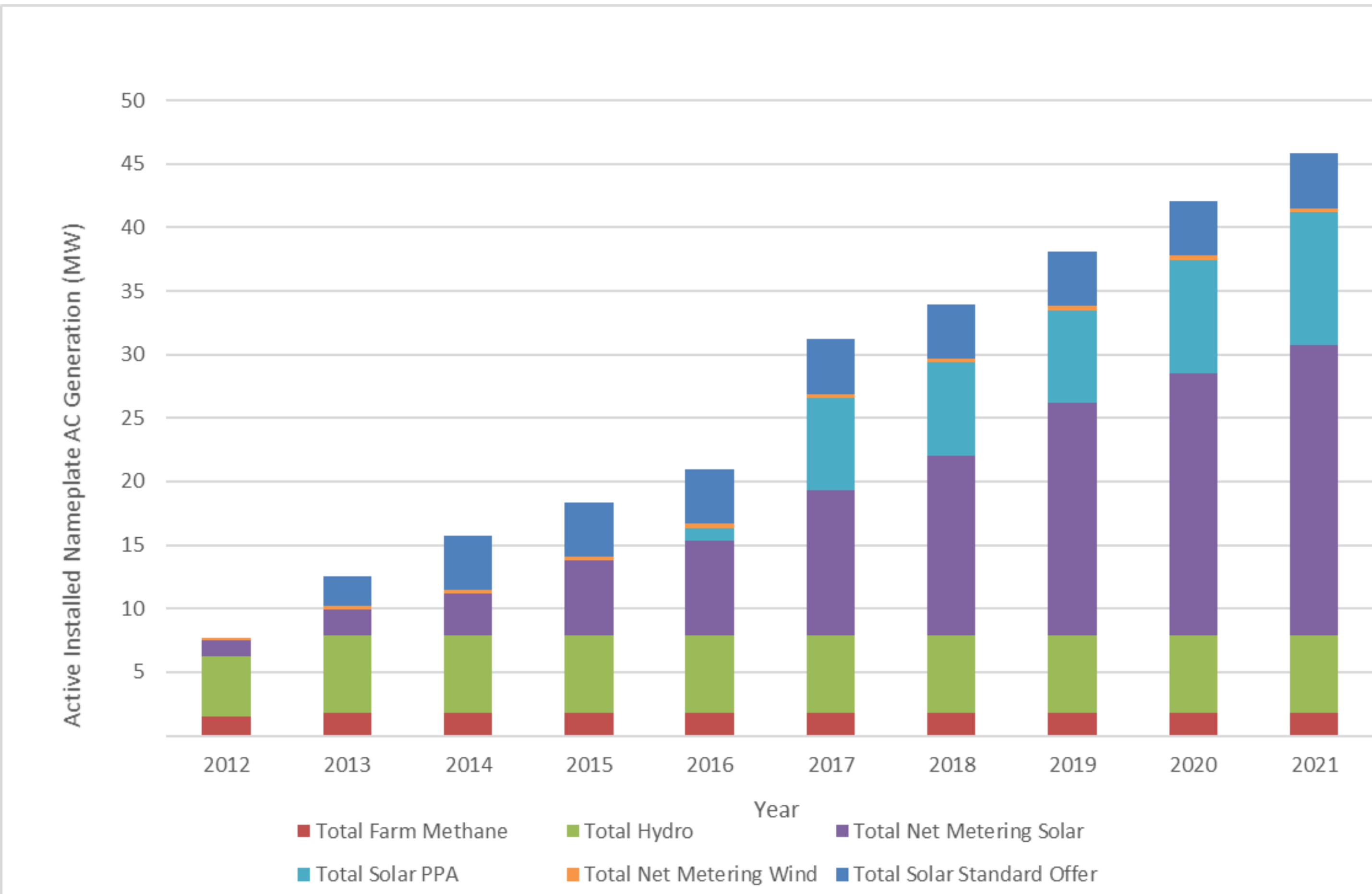


Figure 5.2.3.A Increase in installed distributed generation since 2011 (current as of 01/01/2022)

VEC currently has almost 46 MW of distributed generation installed on its system (22.8 MW of which is net-metering solar).

VEC maintains two internal databases to track net metering and Standard Offer/PPA projects. These databases include a queue for each project application, type of generator, technical application details including inverter type and system capacity, location, and member information. This database is fed into VEC's GIS system and then into its Milsoft WindMil Engineering model.

5.3.1 Net-Metering

VEC has seen a rapid increase of the amount of net-metering solar on its distribution system. Of the 22.8 MW total installed net-metering solar, larger net-metering projects 150kW and above (group-net metered) make up 30% (~6.7MW). Around 3.4 MW of solar is pending installation, with the clear majority (2.6MW) being projects less than 150kW. These larger interconnections generally have a bigger impact to VEC's distribution system and may cause constraints. If VEC identifies a constraint, the generation project developer is responsible to pay for the system upgrade per current PUC rules.

Around 2,600 of our members have net metering at their home (~8% of all homes in our service territory)

While there was a slight drop during the COVID pandemic VEC's quantity and capacity of net metering projects continue to increase. VEC closed its queue to new net-metering projects in early 2015 due to regulatory limits and then reopened its queue in 2017. Since 2017, VEC has seen around 326 applications annually.

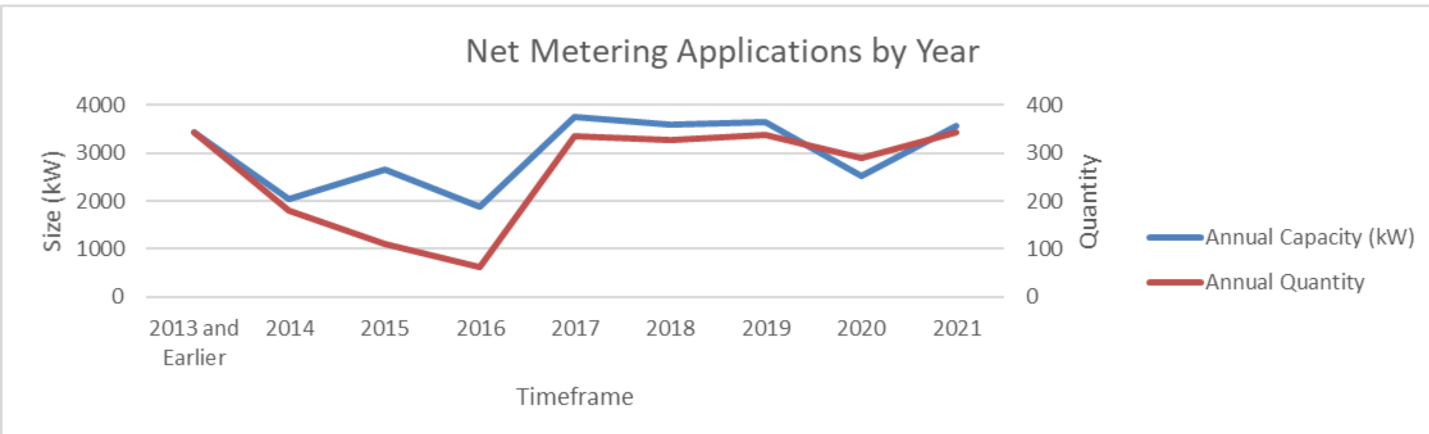


Figure 5.3.1.A Active and pending net-metering by size (current as of 01/01/2022)

Location of Net Metering

Residential projects, which VEC classifies as 15 kW and under, have been primarily located off substations in Grand Isle, Chittenden, and Franklin Counties with the town of Hinesburg representing the largest quantity. The figure below shows these residential projects by substation.

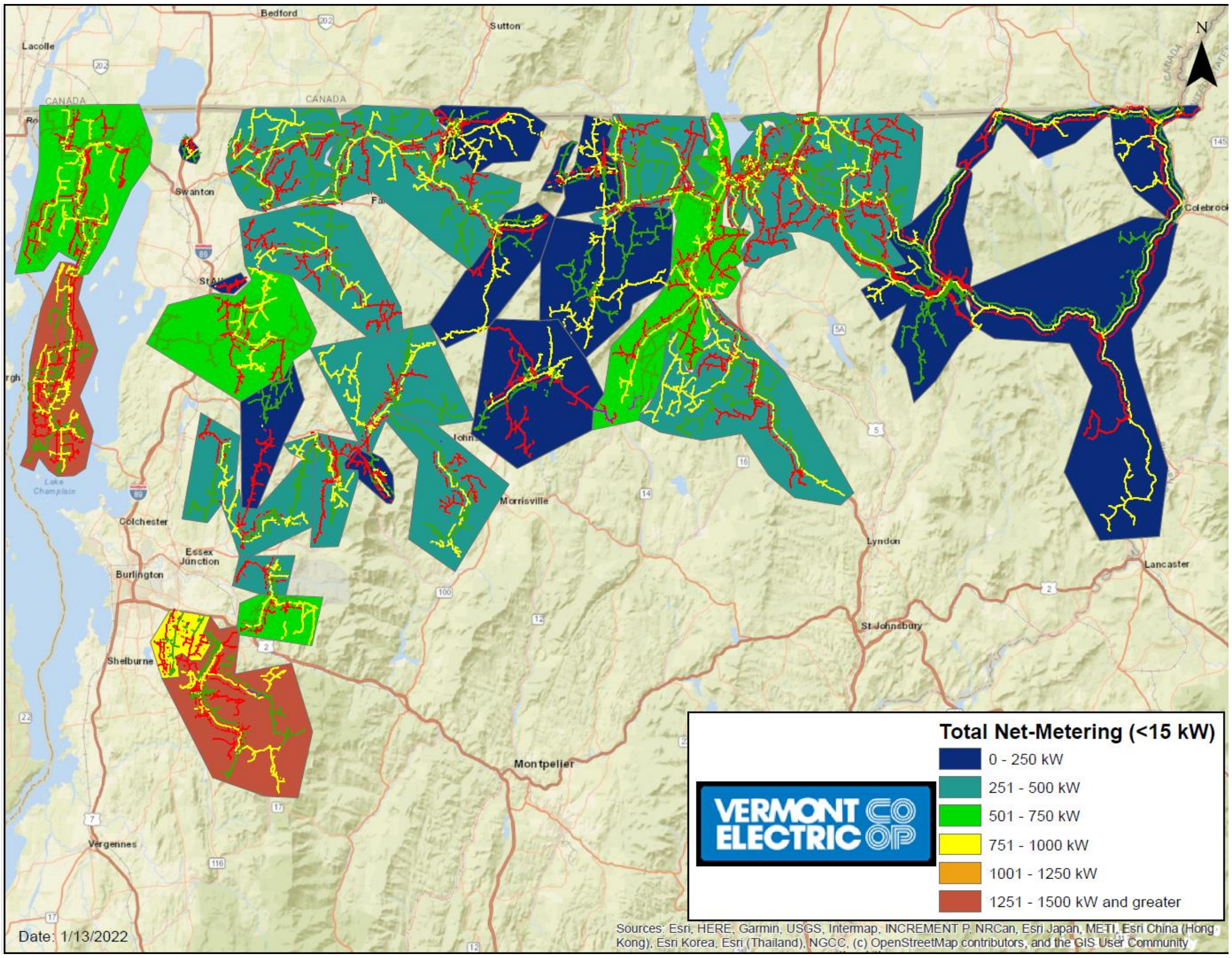


Figure 5.3.1.B Total net-metering (<15kW) by substation

Rate Impacts

In case No. 22-0334-INV, the department stated that: *"Net metering has been, and remains, the most expensive pathway for Vermont to meet its renewable energy goals. In other words, renewable energy can be obtained, and built in State, in a less expensive way … Net-metering also continues to result in a cost shift from participating customers to non-participating ratepayers."*

The chart below shows the $/kWh costs comparisons of the net metering rates and other renewable resource procurements in the state.

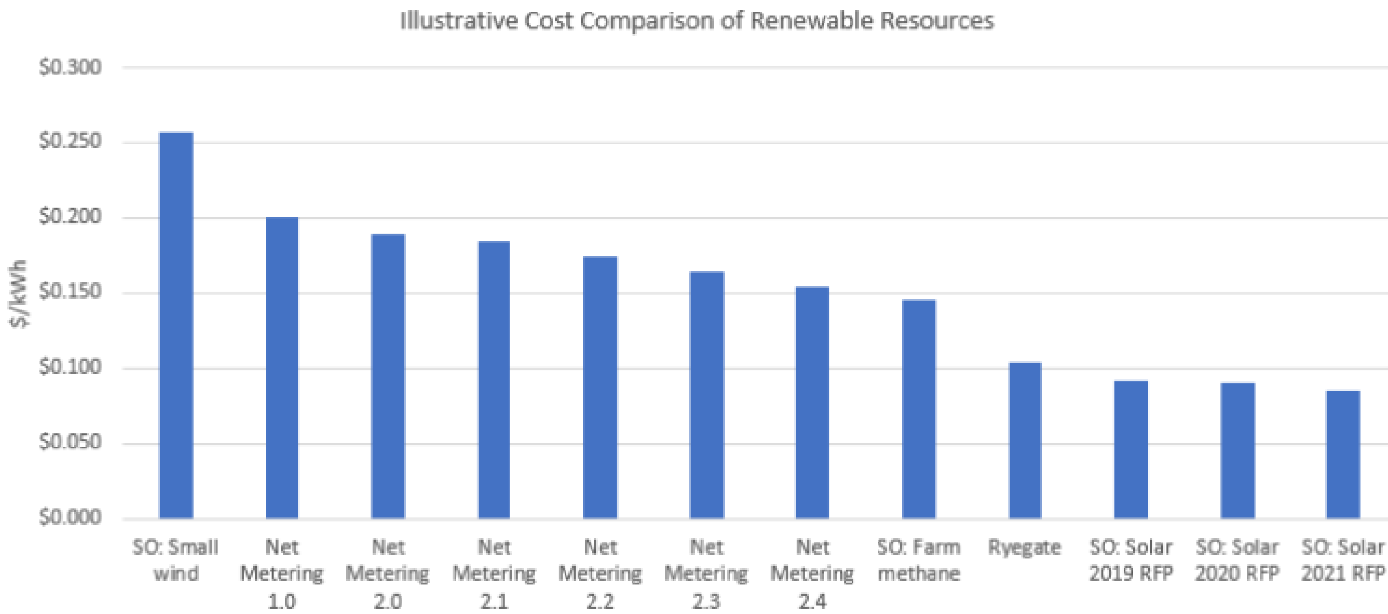


Figure 5.3.1.C Case No. 22-0334-INV Comparison of In-State Vermont Renewable Resources

VEC agrees that net metering is the costliest way to develop renewable resources in Vermont. The same project developed through a power purchase agreement or Standard Offer would cost up to five cents less per kilowatt-hour than the rates required under the net metering program. This is the case even though many large (500kw) net metering projects are directly tied to the grid and do not offset load onsite, belying the term “net metering” (i.e. net of generation and load).

Electric cost has become even more important as the state works to transition heating and transportation to electricity. Lower electric rates encourage more Vermonters to install heat pumps and purchase electric vehicles, considerable investments that can often be paid back within a few years due to the cost savings from the difference in electric versus fossil fuel prices. However, cost pressures, including paying a rate considerably above market for net metering, threaten the competitiveness of this critical tool in reducing carbon emissions. Without a fast and widespread push towards electrification, Vermont’s carbon goals are unachievable.

Oversizing Generation

VEC supports the installation of solar at homes and businesses and believes that net metering projects should be limited to those co-located with and sized appropriately for the load they are intending to serve. VEC has compiled data together with GMP which shows that most residential net metering sites are oversized to the load they are intending to serve. It is likely that, as heat pumps and electric transportation grow, this gap will be mitigated for existing arrays.

According to the EIA in 2020, the average annual electricity consumption for a U.S. residential utility customer was 10,715 kilowatt-hours (kWh) per year or around 3kW peak per hour. With electrification this can increase slightly but in general EV charging and most of the heating happens outside the hours of the day when the sun is shining.

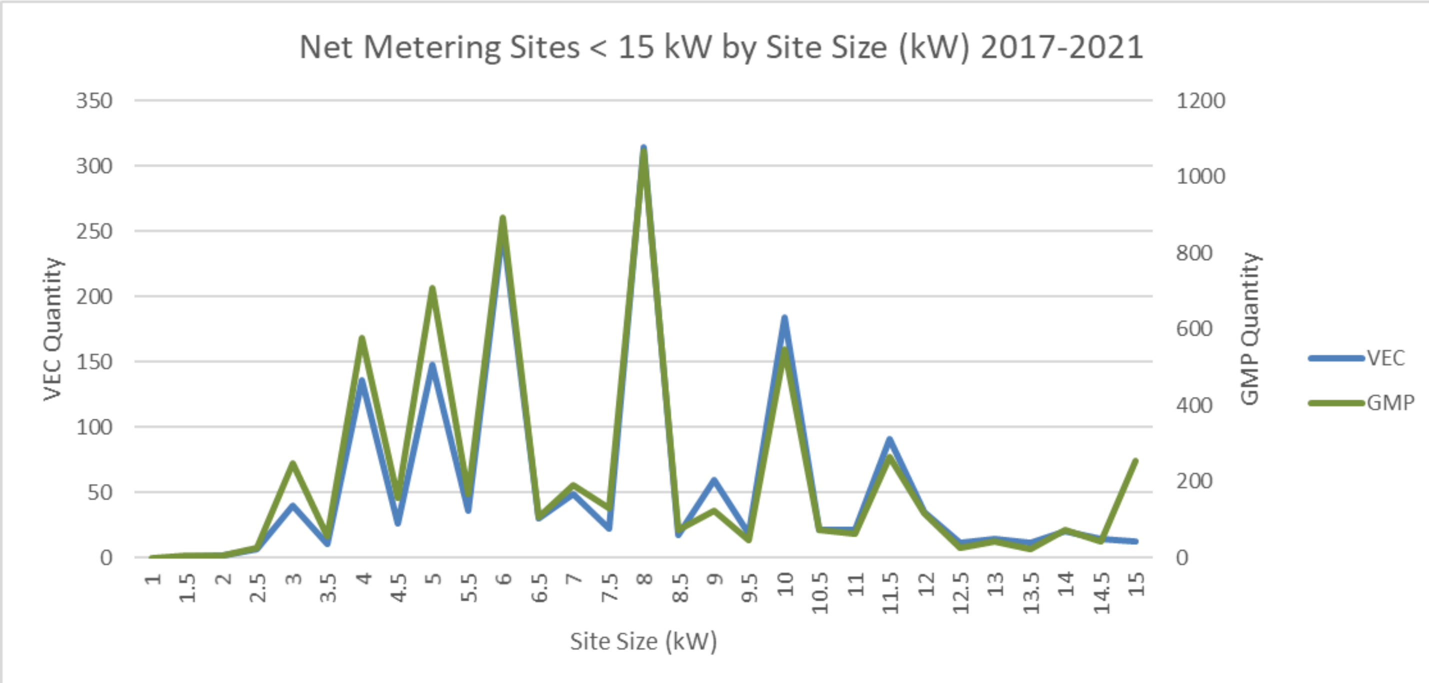


Figure 5.3.1.D Case No. 22-0334-INV Comparison of Renewable Resources

The chart above shows that the average site size is closer to 7.5 kW almost doubling the typical peak load of a member. The challenge with oversizing is that it increases the likelihood of grid constraints such as high voltage on the distribution network and larger transmission constraints.

Alternatives

VEC continues to argue that net metering projects should be limited to those projects co-located with and sized appropriately for the load they are intending to serve. In the long run, VEC would advocate for a transition to an avoided cost rate for the electricity sent back to the grid monthly. The rate currently given mirrors the retail rate, which does not account for the fixed costs of operating the grid and providing service to customers. In VEC's case about half of these costs are recouped through the customer charge and the other half are recouped through energy charges, thereby reducing the amount net metering members pay to support the increasing cost and complexity of managing a reliable grid.

Discussed further in this document is an analysis of which types of generation would be needed to get Vermonters to a 24/7 100% renewable future, if becomes a goal.

5.3.2 Co-op Community Solar

VEC offers members the option of sponsoring panels in our three solar arrays located in Hinesburg, Grand Isle, and Alburgh. Members pay a lump sum up-front and then are guaranteed fixed monthly bill credits on their electric bill. By the end of the term (either 10 or 20 years), the total of the credits exceeds the amount of the original up-front payment. One of the benefits of the program is that renters or homeowners who do not have a suitable site on their property can participate. If participants move out of VEC territory, they can get a refund based on the amount of time they have participated in the program.

Figure 5.3.2.A VEC board member John Ward promotes Community Solar

VEC has three community solar projects

- Alburgh Solar (3,996 panels, 1 MW, 100% sponsored)
- Magee Hill Solar (4,914 panels, 1.3 MW, 50% sponsored)
- Grand Isle Solar (19,490 panels, 4.8 MW)

We continue to see our members participating in our program and have sponsored 23% of the total capacity of the three sites. This equates to over 6,500 panels or about 1.7 MW. We continue to pursue funding to subsidize the enrollment of income-qualified members into VEC's Community Solar program. Participation in the program will provide direct benefits to members through monthly bill credits for a 10-year term, thus reducing their bills. Participation would also engage these members in our energy transformation future.

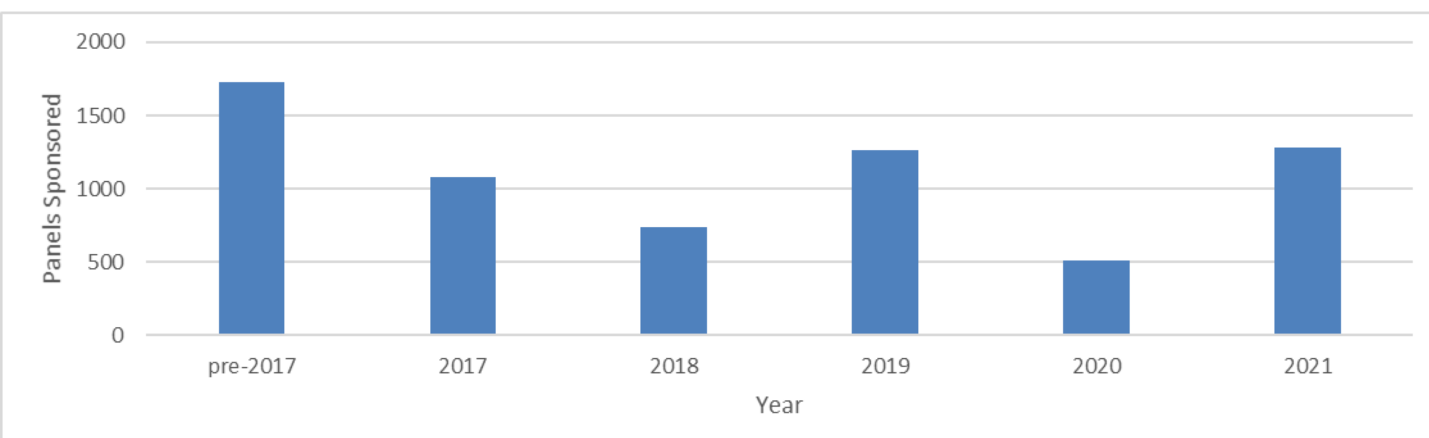


Figure 5.3.2.B Number of VEC Community Solar Panels sponsored by year

5.3.3 Generation Grid Impacts

All generation projects are required to obtain a Certificate of Public Good (CPG) from the Public Utility Commission (PUC) in order to interconnect to VEC's system. VEC reviews every generation interconnection and, when required by PUC Rule 5.500, performs a Fast Track Screening and/or System Impact Study to ensure that generators are interconnected to the system safely and reliably. VEC's Interconnection Guidelines can be found online on VEC's website. They provide developers with information on the interconnection process, equipment requirements, application instructions, screening criteria, and service extensions.

While the increased penetration of distributed generation onto the system presents challenges to planning and operation of the system, there are potential solutions for each of these challenges. The challenges and solutions are identified below:

- <u>Impacts to Feeder Backup:</u> If the feeder with a large generator is being tied to and sourced from a feeder further from the source, the voltage rise can exceed the top of the acceptable voltage range. *This issue is identified in VEC's Fast Track Screening of the project and a typical solution is to install larger line conductors to reduce source impedance or to add strategically placed line voltage regulators to buck the high voltage. However due to the cost implications of both of those solutions, VEC will typically request the generator go off-line while the feeders are tied.*

- <u>Islanding:</u> Islanding occurs when the grid is disconnected and a distributed generator continues to provide power and backfeeds into the grid. *This unintentional islanding is not permitted per IEEE 1547 (Standard for Interconnecting Distributed Resources with Electric Power Systems) and can have negative impacts from a safety and reliability perspective. All inverters utilized for photovoltaic generation are also governed by UL 1741, which requires anti-islanding protection.*

- <u>Voltage:</u> Most members on VEC's system are fed from long radial lines with small conductor; as such, distributed generation that exceeds load will typically result in a voltage rise at the point of interconnection. *To mitigate this there may be requirements for Volt/VAr compensation or system upgrades such as additional voltage regulation or reconductoring.*

- <u>Fault Current Contributions:</u> Protection schemes on radial feeders are designed with the assumption that current flows in a single direction and into a fault through the upstream protective devices. Distributed generators can provide fault current from alternate directions resulting in the desensitizing of existing protection. Desensitizing means that less fault current may flow through the upstream protective device than would have otherwise existed if the downstream-distributed generators were not present.

  Since faults are detected and sectionalized utilizing over-current protection schemes and an over-current relay's speed is inversely proportional to current magnitude (more current equals faster operation), the distributed generation contribution may slow the speed of operation. In some cases, it may keep the upstream protective device from reaching its pick-up current value until the distributed generators sense the fault and trip off line. In addition, given the low quantities of fault current on some parts of the system, distributed generation can further exacerbate protection margins.

  IEEE 1547 requires all distribution generators to go off line during sustained fault conditions. Once the generation goes off-line, the upstream protective devices are no longer desensitized and should function normally. It should be noted that VEC does not foresee significant delays in its protective devices normal *operation (through desensitizing) since most distribution generators contribute very little fault current to the system and go off-line very quickly during fault conditions as compared to traditional utility protection operation.*

- Voltage and Frequency Ride Through: As the penetration of behind the meter distributed generation has increased there exists increased potential for grid instability. *To mitigate these instabilities, inverters are required to ride through voltage and frequency irregularities per UL 1741-SA and ISO-NE Source Requirements document. These requirements are listed in PUC Rule 5.500.*

- Transmission Ground Fault Over-Voltages: High voltages can occur during ground faults in circumstances in which a proposed generator is not effectively grounded or bonded to the system neutral and there is a relatively large generation-to-load ratio in the area. These can occur on the transmission side of the delta-wye substation transformers as well. *The least-cost solution to this problem is a direct transfer trip scheme between the transmission line breakers and distribution substation circuit reclosers, assuming fiber optic communications between the two breakers is available.*

- Substation Capacity: As large group net-metering projects that far exceed the load they serve are built, the likelihood of substation capacity constraints also increases. *While VEC does not have any locations where this has occurred, it would be up to the next project in line (developer) to pay for any substation upgrades to allow for their project to be constructed.*

- Visibility and Control: There is a concern on behalf of transmission and grid operating entities such as VELCO, ISO-NE, and the North American Electric Reliability Corporation (NERC) that in a post-blackout restoration effort intermittent distributed generation may interfere with progressive restoration of load. *VEC currently adds SCADA to provide visibility and control to all generator interconnections with a capacity of greater than 150 kW (17 solar facilities, ~6.7MW, ~30 percent of total net-metering). The remaining 2,000 locations (~16MW) are without any VEC visibility or control.*

  Creating a dedicated communications pathway to add visibility and/or control to each of these locations is not financially feasible for the VEC membership. However, there are other solutions to this problem. California, a state that has a high distributed generation penetration, is working to implement coordination between California ISO (CAISO), utilities, and distributed generation developers. In this model, the distributed generation developers aggregate their resources together and have communications pathways with each of the developers. California's Rule 21 Interconnection sets out standards for communications to and from these DG aggregators. For more information, see the Coordination of Transmission and Distribution Operations in a High Distributed Energy Resource Electric Grid report put together by CAISO.

  Another model that may work would be for VEC to integrate different inverter types through a DERMS platform like what it currently does with Tesla Powerwall batteries and ChargePoint EV chargers. Over 80% of the inverters on VEC's system are either SMA, Solar Edge, or Enphase. An integration with each of these would be feasible and could grant VEC visibility and potential control of almost 19 additional MW of solar generation.

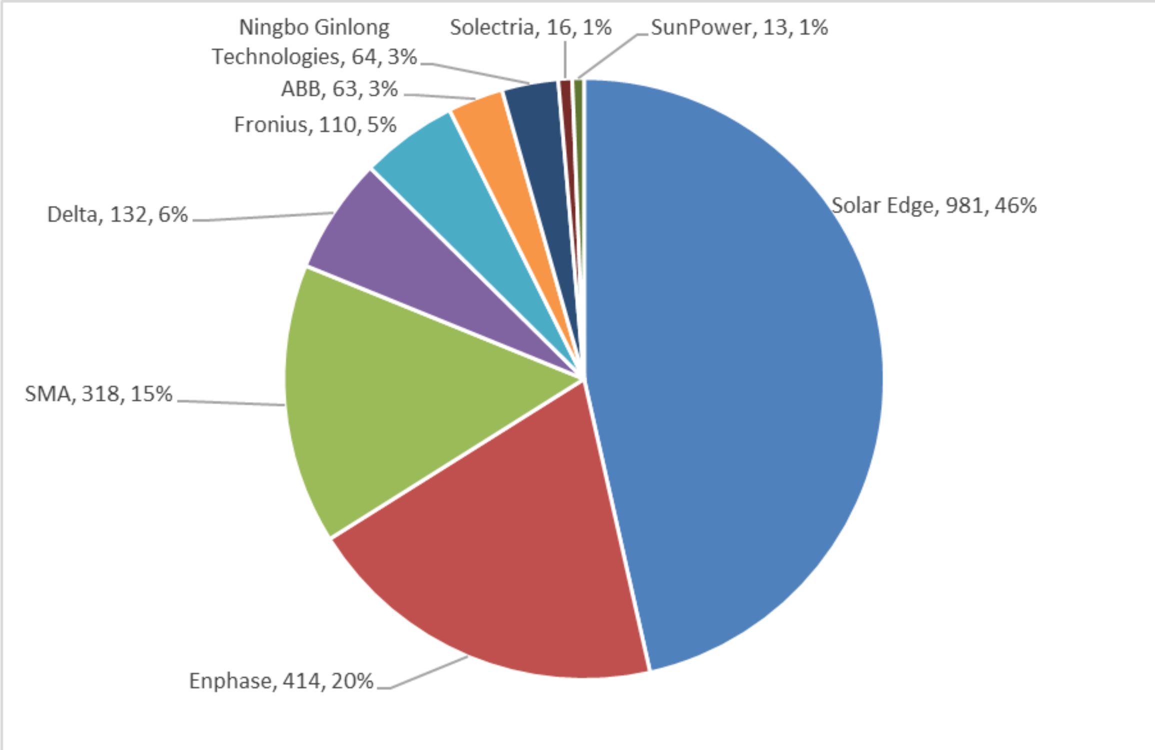


Figure 5.3.3.A VEC Solar Inverters by manufacturer

5.3.4 Safety Impacts

VEC takes safety very seriously, especially when it comes to managing ever increasing grid complexity due in large part to distributed generation. Some of the activities VEC is engaged in to bring safety awareness and ongoing training to employees and members include:

- All VEC construction, including the interconnection of Distributed Energy Resource (DER) projects, is conducted in compliance with all applicable and required standards such as:
    - NESC – The National Electrical Safety Code (e.g., utilities)
    - NEC – The National Electric Code (e.g., electricians, members, interconnects with utilities, etc.)
    - OSHA 1910.269
    - IEEE1547 – Standard for Interconnecting Distributed Resources with Electric Power Systems
    - UL1741 - The Standard for Inverters, Converters and Controllers for use in Independent Power Systems
- VEC verifies anti-islanding requirements prior to placing generation into service.
- VEC conducts task briefings on the possibility of back feed from residential/commercial solar installation or other large generators (e.g., whole house battery systems, wind, etc.). We require a visual open, testing for de-energized line, and proper grounding techniques. This is the same process we go through after a restoration of power or re-connecting to the grid.
- VEC periodically audits electrical services to identify and correct any potential safety concerns.
- VEC regularly communicates to its members the dangers of standby generators.
- VEC's Safety Committee meets regularly and discusses any known or potential safety concerns, including the hazards of reverse power flow associated with certain DER's. The Manager of Safety and Security takes these reviews and shares them with a large audience of field workers due monthly district safety meetings.

- VEC is collaborating with ISO-NE, VELCO, and other Distribution Utilities to develop plans to avoid system-wide blackouts caused by energy emergencies.

5.3.5 Generation Constraint Areas

VEC provides developers and its members a map of generation constrained areas on its website https://vermontelectric.coop/electric-system/distributed-generation. The map is updated as new constraints are identified. As part of an effort to make this information more useful and increase transparency VEC is working to make this map available through its ArcGIS online portal. This effort is discussed further in Section 6 – Data and Technology.

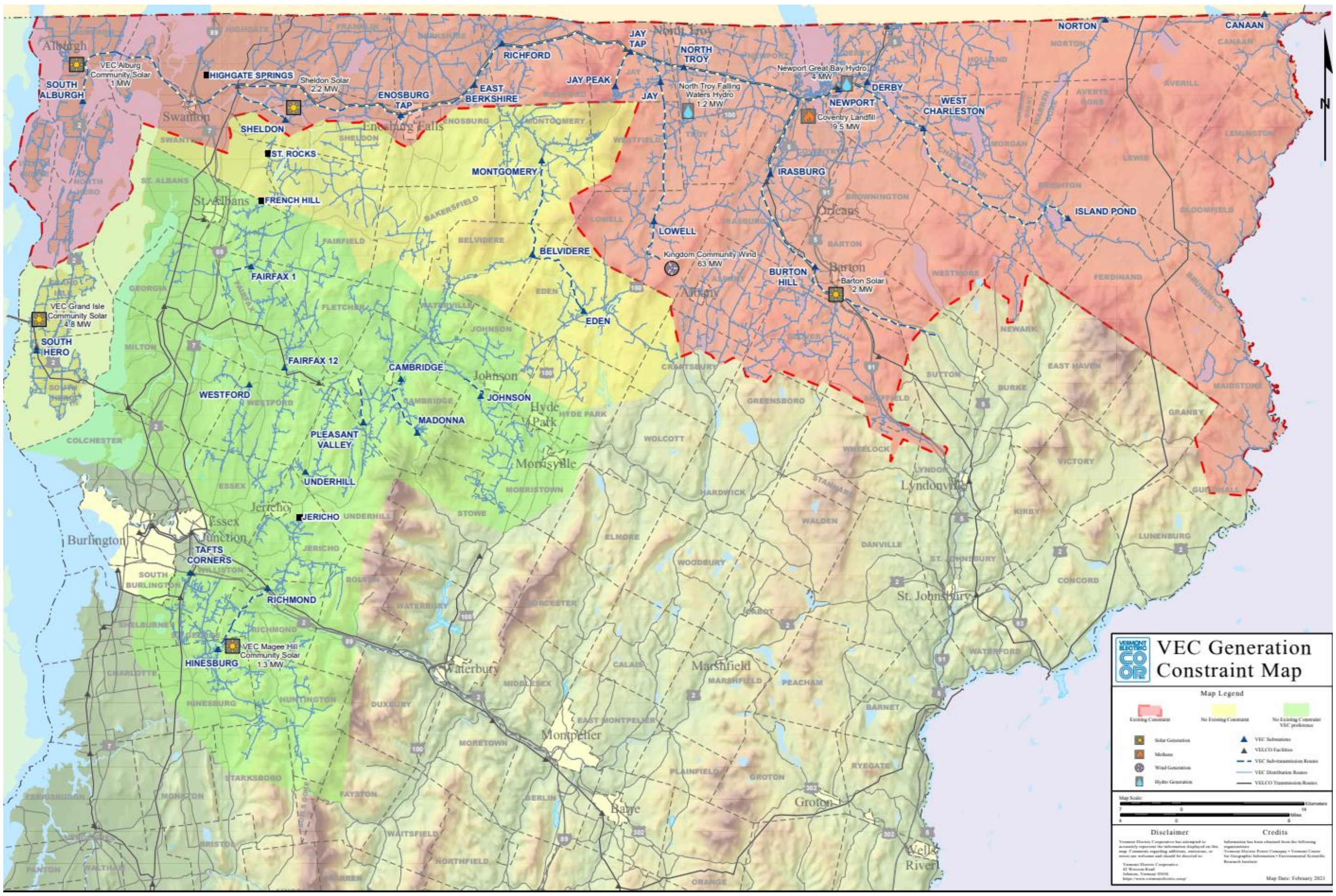


Figure 5.3.5.A VEC Generation Constraint Map

SHEI (Sheffield Highgate Export Interface)

The SHEI an ISO-NE defined transmission region in northern Vermont. A VELCO-owned 115kV transmission line from Sheffield to Highgate to St. Albans and a GMP owned 34.5kV subtransmission line from VELCO East Fairfax to Lowell make up the region. Around 21,500 VEC members are fed from these transmission lines via 16 substations, and the area has significantly less load than generation.

The average load in the region is around 35MW, and the total generating capacity is around 450 MW. This generating capacity includes imports from Hydro-Quebec on the Highgate Converter (225 MW), Kingdom Community Wind (63 MW), Sheffield Wind (40 MW), Sheldon Springs Hydro (~26 MW), Coventry Landfill (8 MW), and several other net-metering and small generation projects (~80 MW).

Since the load in the region is often low (spring and fall) when generation from wind and hydro tend to be high, there is excess generation that needs to flow out on the transmission system. The capacity of this transmission system (originally designed to meet the load) limits its ability to export the power to the rest of Vermont and New England and as a result projects are curtailed (shut down or limited generation output). A map of the area is provided below along with a more detailed version which is available on our website.

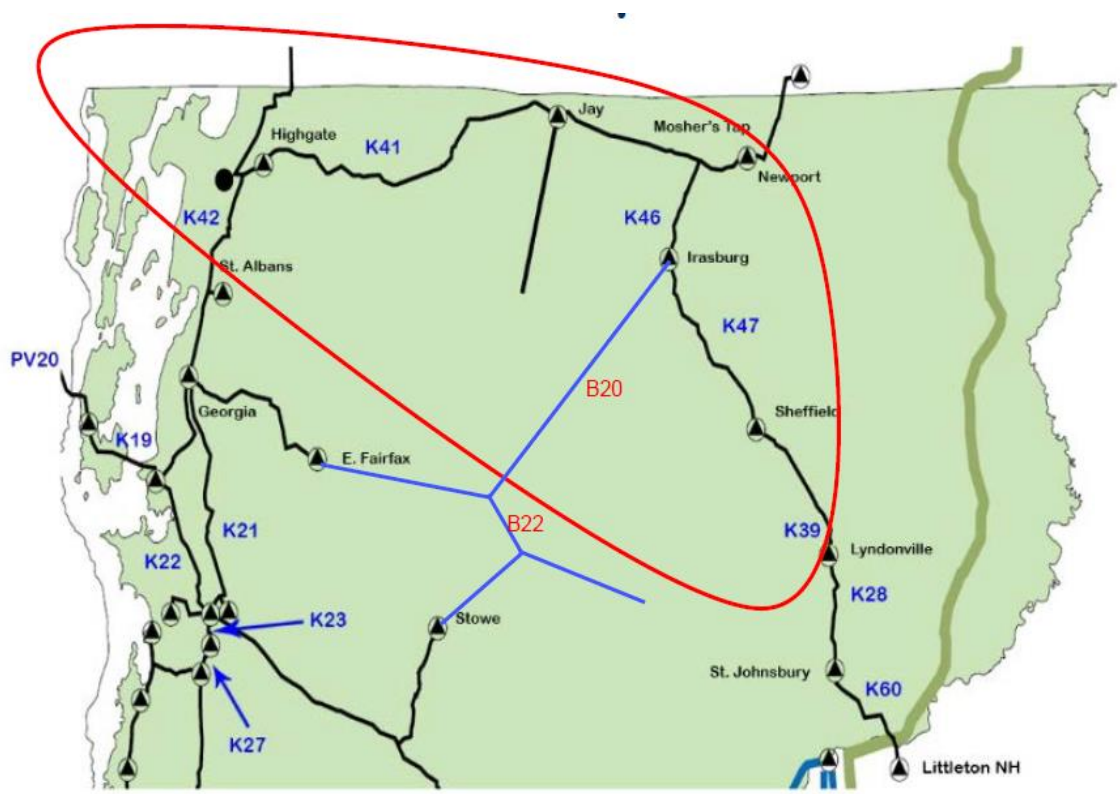


Figure 5.3.5.B Simplified visual of the SHEI

While VEC has been able to slow down the growth of larger solar facilities in the SHEI, over 6MW of smaller Net Metering has been installed since the DNE rule became effective in 2016,

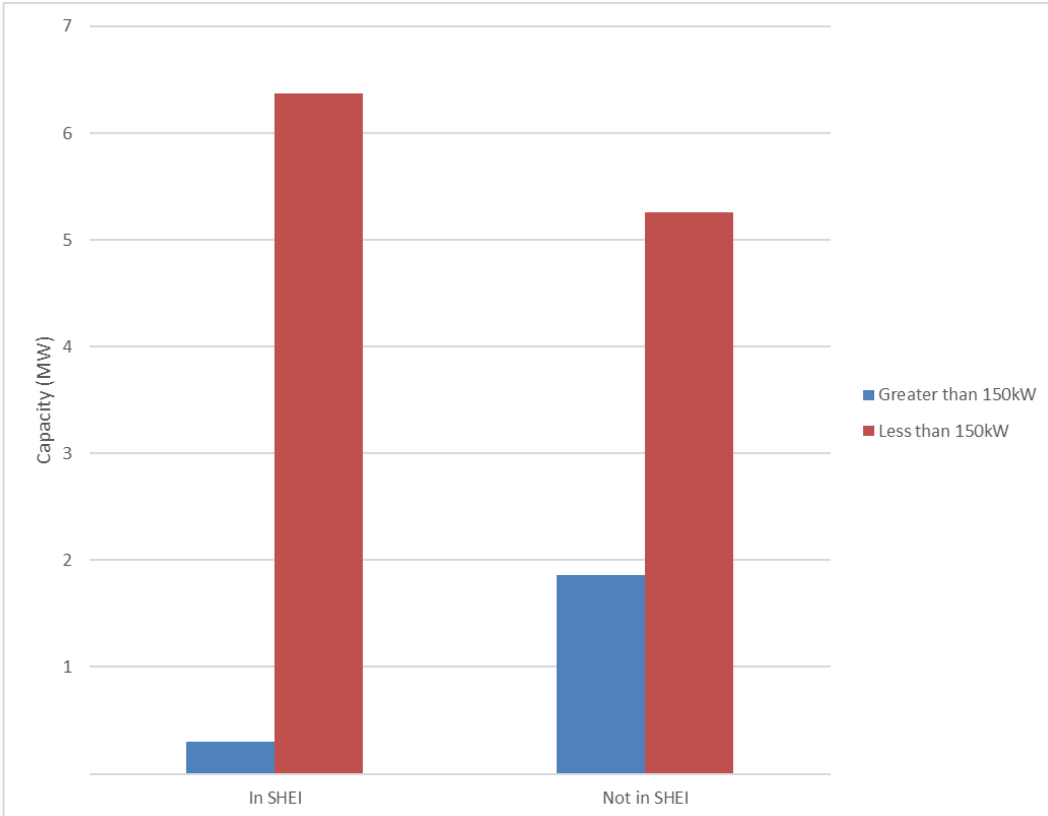


Figure 5.3.5.C Net Metering installed in and out of SHEI since DNE rule became effective as of 01/01/2022

VELCO has discussed the potential expansion of this transmission constraint in its 2021 [Long Range Transmission Plan](#).

Solutions for Grid Constrained Areas

Since the issue first began affecting VEC and other Vermont ratepayers VEC has intervened in any new generation over 150kW and encouraged developers to locate any larger generation outside of the SHEI. To resolve this constraint, several initiatives are underway at the distribution and transmission level (owned by GMP and VELCO).

Load Growth

Load building within the SHEI may also provide relief to SHEI constraints, and VEC's Tier III Energy Transformation Program, discussed elsewhere in this Plan, may help with that, although we do not see enough load-building solutions that will allow us to "grow our way out" of the SHEI constraint.

Subtransmission Upgrades

Upgrades to the Lowell Substation and some 18.1 miles of the B20 transmission line from Johnson to Lowell, as well as upgrades to 1.5 miles of the B22 line in the towns of Eden, Johnson, Lowell and Morrisville are almost complete. The projects would reduce curtailments by around 80%. The B20 and Lowell Sub projects are complete and the B22 project will be completed by the end of 2022.

Transmission Upgrades

The Highgate-St Albans-Georgia K42 115 kV line is a 1958 vintage line located in the Northwest corner of Vermont near the Canadian and New York Borders. The Highgate 225 MW HVDC converter, which connects Vermont to Hydro

Québec, taps the K42 line near the Highgate ring substation. The K42 line is one of two 115 kV lines that cross the Sheffield Highgate export interface (SHEI), which is limited by voltage and stability concerns. The K42 line is the primary path for power to flow out of the interface.

VELCO's assessment of the K42 line's condition showed that 146 out of 212 structures need to be replaced. VELCO is in the early stages of pursuing approval of a line rebuild project anticipated to address the asset condition concerns. To avoid line outages, reduce line losses and provide additional regional benefits the proposed construction will use steel poles alongside the existing line and the reconductor will provide additional capacity. The positive impact on the SHEI constraints is yet to be determined but is expected to be significant.

5.3.5**Battery Storage**

VEC is currently working on joint utility scale battery storage with GMP located at its North Troy substation. The project is primarily driven by peak shaving benefits but is also looking at how both utilities can use the battery to mitigate local generation constraints. There are lots of variables at play including peak times, congestion times, and the regulation market. Ensuring that the battery is available for use during all these times is the challenge we are trying to explore.

Mitigation Fees

There have been discussions in several PUC matters about imposing a "grid adjuster" on new generation, such that they compensate Vermont electric customers for economic harms caused by grid constraints. While VEC supports the idea of a grid adjuster, we also note that it serves a limited purpose. The grid adjuster fee as originally designed by the Department of Public Service in Case No. 20-3304, and subsequently used as the basis for several settlements, was intended to mitigate the cost to Vermont utilities of curtailments of other renewable resources caused by grid constraints; it was not intended to pay for the (costly) grid upgrades that would be necessary to eliminate the constraints. Accordingly, whether implemented by tariff or PUC rule, a grid adjuster based on the DPS methodology will make ratepayers whole for power supply impacts of building in the SHEI, but will not address the grid constraints.

On the contrary, the adjuster may exacerbate the problem, by allowing new generation within constrained areas with the payment of a relatively modest fee. Planned transmission projects could alleviate the constraints for a time, at a cost borne by ratepayers, leading to the possibility of constrained areas being "opened" and then "closed" as generation is added to "fill up" the newly-created capacity. Moreover, VEC is also beginning to experience constraints on distribution circuits in times of high solar production and low loads, and the cost to solve these constraints are borne by VEC members. VEC believes that policy-makers and stakeholders should be pro-active in anticipating and responding to these issues to avoid unnecessary costs for rate payers and unanticipated consequences such as those experienced when the net metering caps resulted in net-metering programs being closed and then reopened.

In sum, VEC supports the grid adjuster concept to limit impacts on customers, and looks forward to engaging with stakeholders on the larger question of whether and how to upgrade the grid in a cost-effective way to address grid constraints.

Future challenges

While the SHEI is isolated to a specific location in Vermont, it is indicative of a greater issue that can arise when high penetrations of distributed generation occur in areas without adequate electric load. The VELCO Long Range Plan goes into greater detail with respect to how much more generation can fit in various zones of Vermont before creating the next export interface limitations. As we look ahead, we must continue to deploy in-state, distributed renewable generation while also working to locate these systems as optimally as possible to avoid, or at least defer, the need for bulk transmission upgrades like the work in the SHEI area. We will continue to work closely with VELCO to optimize the deployment of these resources.

5.4 Load Management

In addition to investing in infrastructure, VEC considers load management to be a key component in meeting our electrification targets. The grid is designed to support peak load, and the ability to shift or manage the load from these new electric devices is critical to maintaining reliability and keeping rates affordable. With additional transmission investment due to condition and new generation, VEC's transmission costs are expected to rise. To combat this VEC intends to continue investing in load management for peak shaving and working with VELCO to reduce costs.

5.4.1 Load Management Strategy

Over the past several years, VEC has been working to expand its residential, commercial, and utility scale load management programs. In the residential space, VEC currently offers an EV Charger program and a battery storage program. In the commercial space, VEC has begun working with EVT and Dynamic Organics to explore commercial load management. Additionally, VEC currently has one utility-scale battery on its system and is currently working towards two more. As of March 2022, VEC has over 1,200 kW of load management installed on its system, and the chart below shows the cumulative capacity between our various programs. We expect to see further growth in the coming years as technological advances occur and prices drop. Finally, these programs are described in further detail below.

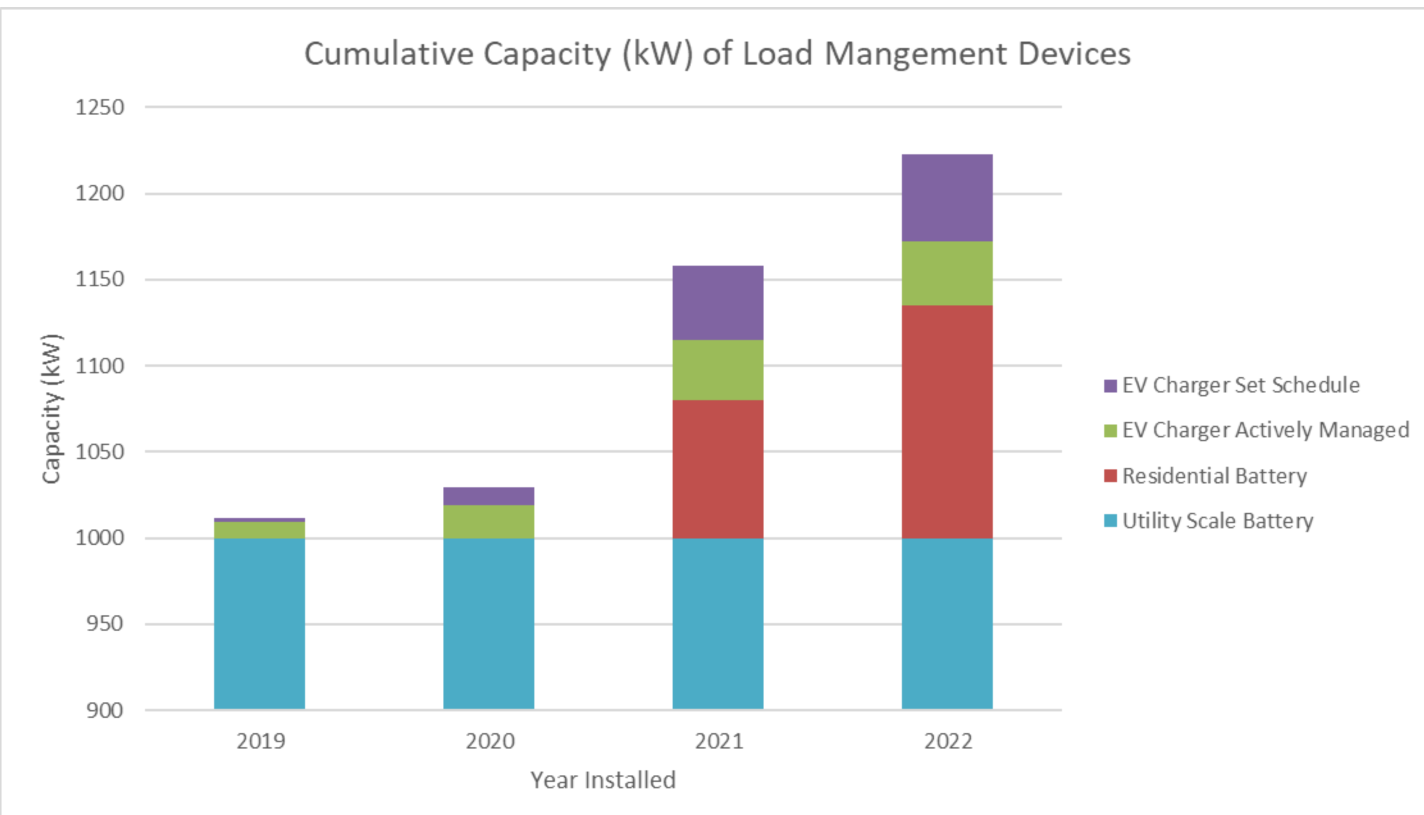


Figure 5.4.1.A Cumulative installed and forecasted storage (kW) 2019-March 2022

5.4.2 Potential Future Load Management

VEC conducted an analysis of what loads may look like at 5-year snap shots throughout the 20-year IRP forecast period. We started by taking VEC hourly load data from 2021 and adding back in any load reducing resources, e.g. net metering, to get to an hourly reconstituted load. VEC then added in any forecasted load from EVs and CCHPs using unmanaged load shapes. We did not attempt to forecast other sources of load growth for two reasons: 1) EVs and CCHPs are by far the largest sources of projected load growth throughout the forecast period and 2) finding hourly load profiles for other load growth like Clean Air Projects or electric forklifts is difficult. Once we arrived at an hourly load profile for each of the years, 2025, 2030, 2035, and 2040 we were then able to forecast our resources to compare those against our load. This analysis serves two functions. It allows us to get a sense of the magnitude of the impact to peak times from EVS and CCHPs as well as look at what it might take, from a resource perspective, to go 100% renewable on an hourly basis into the future. It is important to note that this analysis will be used to get a directional and rough magnitude of changes, rather than predict exact loads on any given day.

The two charts below present estimated load impacts, and conversely the potential for load management, during hours 4pm-8pm in 2040 by month. The data behind these charts assumes that 100% of the EVs and CCHPs are unmanaged. While this is unrealistic as VEC is already actively engaged in EV load management, it presents a worst case scenario that highlights the need for load management into the future. As can be seen in the EV chart, load impacts are estimated to be between approximately 12 MW and 28 MW, generally are higher in the winter months and increase as the day progresses from 4pm to 8pm. As can be seen from the CCHP chart, estimated loads range from less than 1 MW to over 15 MW. For CCHPs the loads are expected to be much higher during the winter months (November to March) than the shoulder & summer months (April through October). While VEC has yet to experiment with managing CCHP loads, this chart suggests that there may be sufficient potential load in the future to warrant management. However, as CCHPs load is much higher during the heating season this presents several challenges including that you cannot shut off a members heat and, at least currently, systems that cooridnate and optimize backup heating systems and CCHP systems are still nascent. Regardless, this is an area that VEC will keep an eye on as CCHPs continue to be deplyed within our service territory.

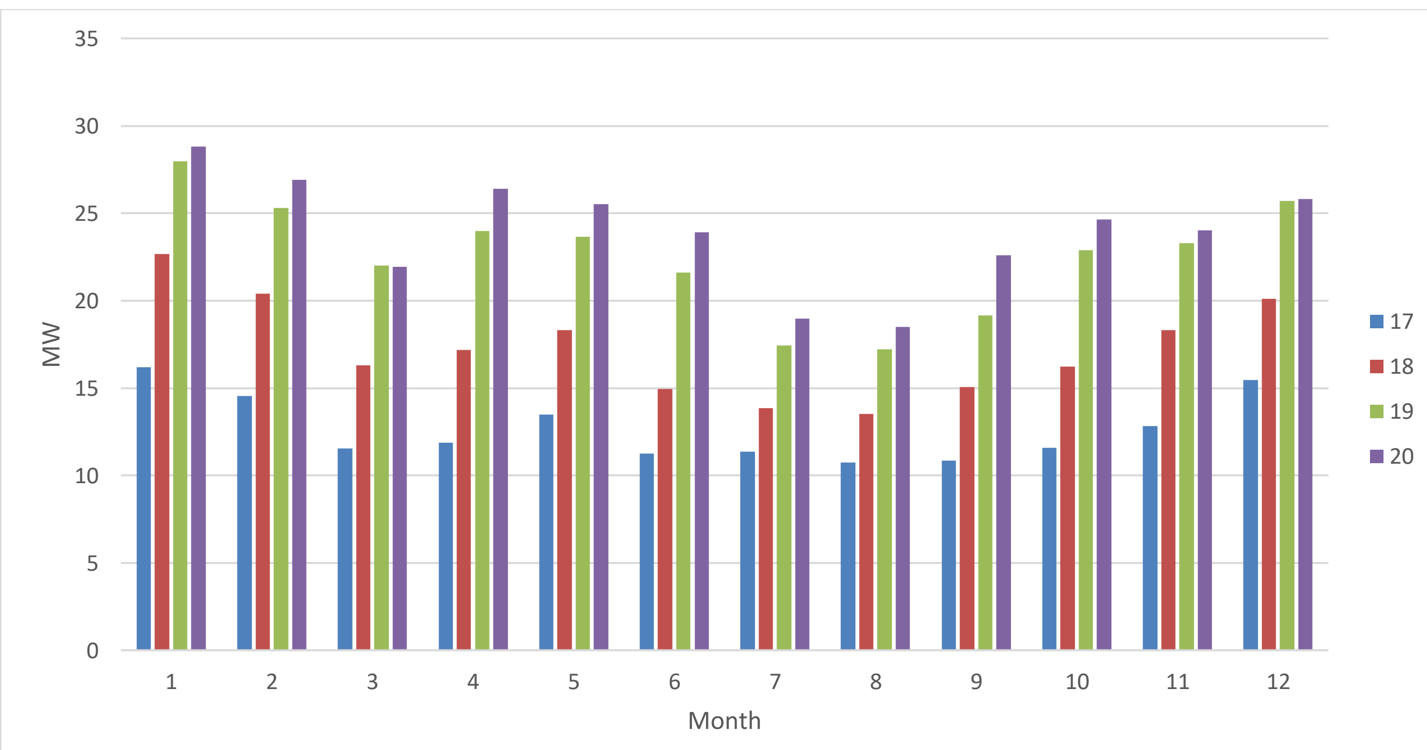


Figure 5.4.2.A – Estimated Unmanaged EV Load 2040 - Hours 17:00 to 20:00

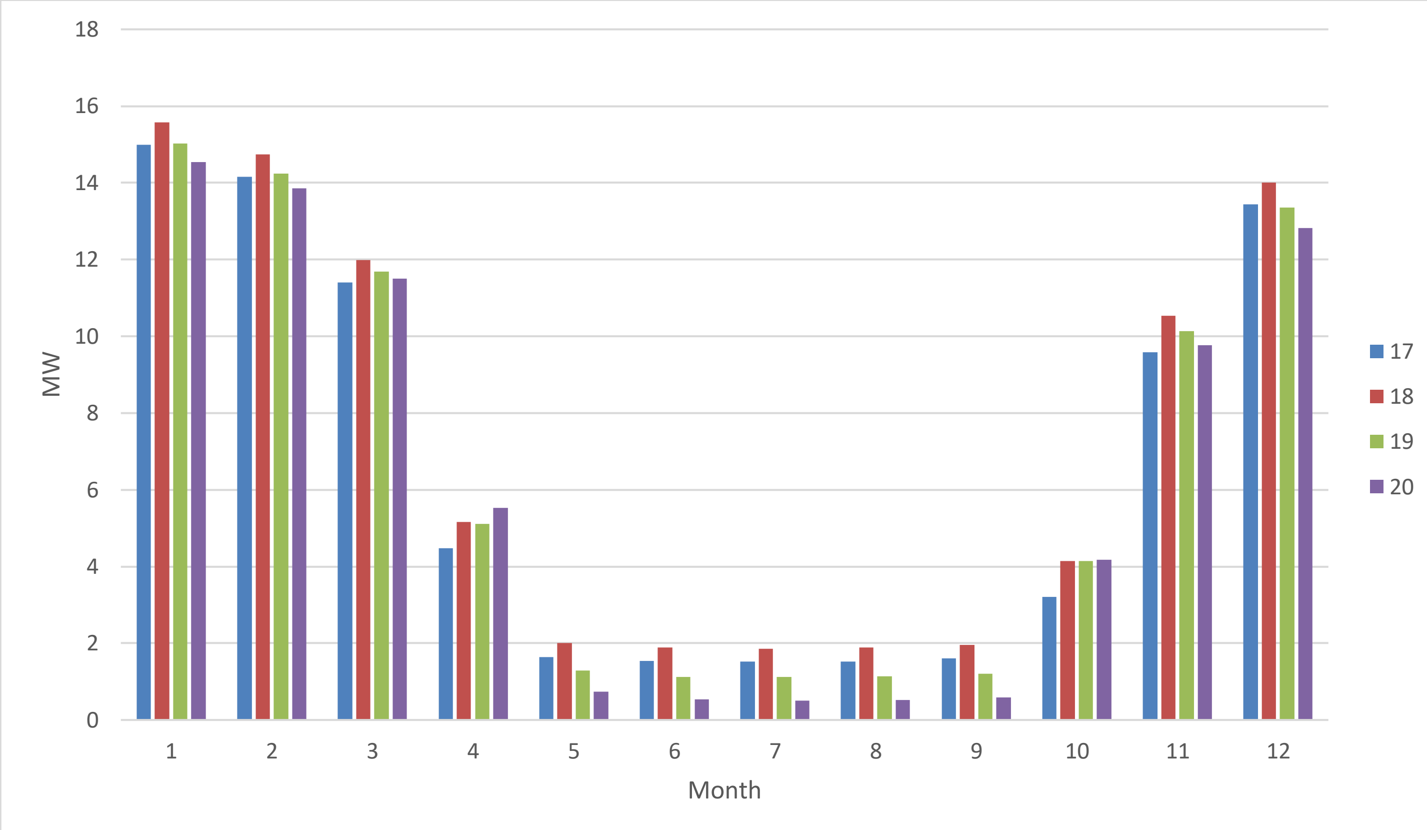


Figure 5.4.2.B – Estimated Unmanaged CCHP Load 2040 - Hours 17:00 to 20:00

5.4.3 Value of Load Management

Load management, when cost-effective, has many practical uses, especially as the generation profile shifts from baseload fossil-fuel to intermittent renewable generation. These benefits include (in order of importance):

1. Reliability of the power system as electrification increases
2. NEPOOL Transmission Cost Reduction
3. ISO-NE Capacity Market Cost Reduction
4. Frequency Regulation/Spinning Reserve
5. Energy arbitrage
6. T&D investment deferral/T&D support
7. Member resiliency

VEC's NEPOOL Transmission costs are a function of its load in the one-hour Vermont peaks each month. Current NEPOOL rates for transmission are approximately $12.00/kw-month. Thus, VEC can reduce its NEPOOL transmission $12,000 in each month it reduces its load by 1.0 MW in the one-hour Vermont peaks for the month, or up to $144,000 in the year if it was able to reduce its load by 1 MW in each of Vermont's 12 monthly peaks. For planning purposes VEC assumes 3% escalation in NEPOOL transmission rates through the planning period.

	Number of Peaks	Approximate Hours to Hit Peak	Approximate Dollars Saved per MW
VT Monthly	12	340	$144,000
ISONE Yearly	1	60	$80,000
Total	13	400	$224,000

Figure 5.4.3.A VEC estimated hours needed to hit peaks and estimated dollars saved

Beating the ISO-NE peak is getting less valuable as prices in the Capacity Market go down. Peak value is increasing, but not at the same rate as the capacity value is going down.

VEC's costs for each capacity commitment period (June – May) for the ISO-NE Capacity market are a function of its load in the one-hour New England peaked in the previous calendar year. Because of the reserve requirement built into the amount of capacity ISO-NE procures through the Forward Capacity Market auctions, if VEC can reduce its load in the one-hour New England peaks in a calendar year, it can reduce its capacity requirement by approximately 1.200 MW – 1.500 MW in each month of the subsequent commitment period. At VEC's Base planning assumption of $5.000/kw-month, it can save approximately $80,000 per year. The actual cost-effectiveness will be a function of VEC's ability to predict the one-hour New England peaks each year, which will get more difficult over time as more market participants invest in storage for the same peak-shaving purposes.

When batteries are not being used for peak load reduction or energy arbitrage, they can be used in the ISO-NE Regulation market to produce more value. However, participation in this market is time consuming and requires dedicated resources and expertise that VEC has not found to be cost-effective. VEC believes that, as more batteries are installed in New England, potential profits in the Regulation market could deteriorate, as occurred in the PJM Regulation market. Because of this, VEC does not assign any meaningful value to Regulation for batteries; therefore, it is not a major factor in a decision of whether to invest in battery storage technology.

The ability to extract value from batteries through energy arbitrage is a function of the difference between the energy prices at the time of discharge (which results in revenue) and re-charge (which results in a cost) as well as the round-trip losses in the system. For example, if a battery has round-trip losses of 10%, the utility will need to incur a charge for 1.1 MW of energy to re-charge the battery for every 1.0 MW of energy it discharges to generate revenue. Although there is potentially some money to be gained there, VEC believes that, under current market conditions (and even more so as utility load shapes flatten out over time as expected) the amount of profit to be made is quite small compared to the potential cost reduction savings from peak load reduction. Because of this, VEC does not assign any meaningful value to energy arbitrage for batteries; therefore, it is not a major factor in a decision of whether to invest in battery storage technology.

VEC currently has few, if any, locations on its system in need of significant upgrades that can be deferred or eliminated cost-effectively using batteries, so this, by itself, is not a major factor in a decision of whether to invest in battery storage. However, as there are points on the system that can make better use of batteries than others, location will be a consideration when we decide to deploy a battery.

Customer reliability is one major benefit of batteries. Batteries placed at substations or other VEC-owned property can also be used as backup power to improve reliability for several customers on connected circuits, while smaller batteries located behind an individual customer's meter can be used to supply that customer in the event of an outage on the circuit serving that customer. Although it can be difficult to assign a value to that improved reliability, aside from sales being higher than they may have otherwise been with the outage, VEC recognizes the value is there and is investigating the feasibility of Commercial/Industrial and Residential Class battery storage programs.

As part of the approval of its 2019 IRP, VEC entered a Memorandum of Understanding (MOU) with the Department of Public Service.

One final point we should address in this discussion of load management is a term agreed to in our last IRP MOU. It required that "VEC will perform a quantitative analysis of strategies for peak shaving, including but not limited to, opportunities to base demand charges on coincident peaks, as appropriate, for inclusion in its 2022 IRP."

VEC has developed a spreadsheet tool that compares the cost of various peak shaving programs to the expected savings from reduced capacity, transmission, energy and ancillary services charges from ISO-NE. The tool allows the user to enter (1) savings rates for each of the ISO-NE charges, (2) expected kW peak reduction savings for the program, (3) expected success rates of dispatching the peak shaving program at the time of the New England annual peak (for capacity charges) and the monthly Vermont Peak (for transmission charges), (4) the cost of the program and (5) the term of the program.

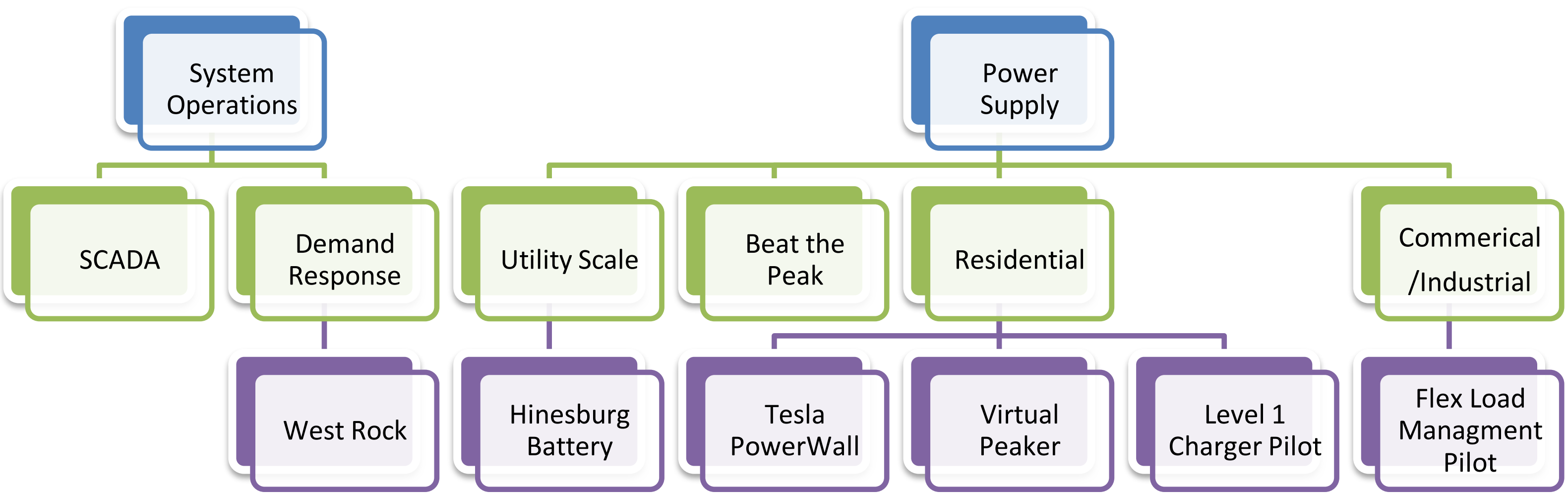
The tool has proven valuable in evaluating the cost-effectiveness of utility-scale battery proposals, and smaller devices such as VEC's Bring-Your-Own-Battery program for residential members.

To date, VEC has not yet analyzed opportunities for basing demand charges on coincident peaks and will continue to consider this as we look at ways to optimize rate designs in the future.

5.4.4 Load Management Platforms and Integration Costs

Platforms and Programs

VEC has many platforms and programs that enable us to manage load for either reliability or peak shaving.



Integration Costs

One of the biggest challenges of implementing load management programs are the various integration costs. These costs range from device-to-device integration to aggregation programs. All of these play a key role in whether a program is economic for the VEC membership.

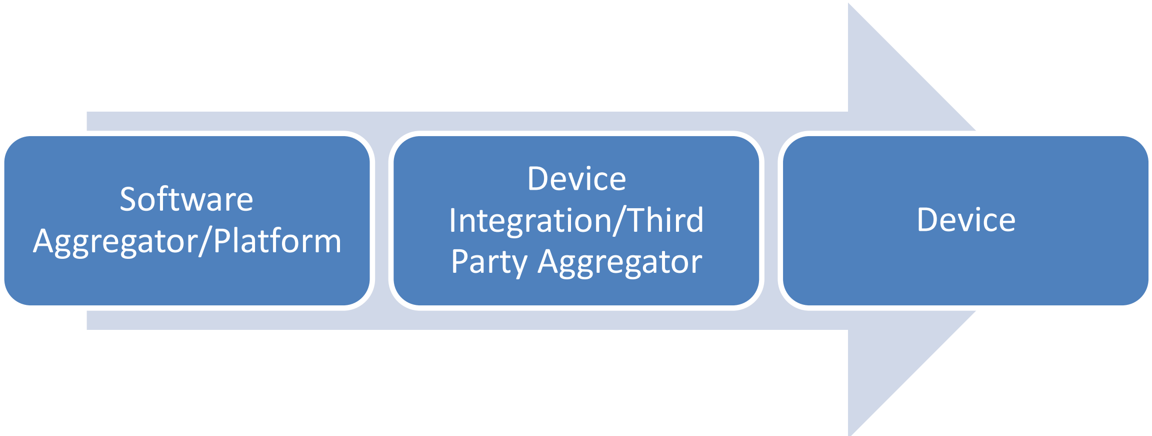


Figure 5.4.4.A Cost components to implement load management solutions

We can use VEC's ChargePoint program as an example. The member will purchase a ChargePoint charger and apply for the VEC Level 2 EV charging incentive. ChargePoint and VEC have an existing partnership with an annual fee that enables VEC to gain access to the device. VEC partners with Virtual Peaker, also at a cost, to aggregate these devices into a common platform along with other vendors and manage the dispatching in response to anticipate peak demand. This same cost structure is potentially replicated for each type of device and each manufacturer of various device types. As smart managed devices proliferate, these costs can at times outweigh the value gained through the device peak management program.

We discuss our plan for expanding our aggregation and device technology in Section 6 – Data and Technology.

5.4.5 Utility Scale Load Management Programs

There is no industry specific definition of utility-scale storage. VEC uses the term to mean any storage that is not located at a specific customer site; we anticipate such projects to typically be 150 kW or larger. VEC believes it can provide value to members by employing cost-effective utility scale storage throughout its system both to optimize the use of distributed generation on its system and to improve reliability. VEC discusses its existing and planned utility scale projects in the following section.

Existing Projects

Hinesburg Battery Project

VEC commissioned its first utility scale battery project at is Hinesburg substation in late 2019. The project is a collaborative effort between VEC, Viridity Energy Solutions, Inc. (Viridity), and WEG Electric Corp (WEG). Through an Energy Storage Services Agreement (ESSA) with Viridity, VEC has the right to call on a 1MW-4MWh battery for 400 hours per year (no more than 4 hours per day) for peak shaving purposes. VEC does not own the battery, but instead pays Viridity a fixed monthly fee for the right to use the battery. When VEC is not using battery, Viridity has the right to use the battery in other ISO-NE markets to enhance their revenue stream.

Planned Projects

North Troy

This utility-scale battery project is a collaborative effort between Green Mountain Power and VEC. VEC and GMP secured a Department of Energy grant to study how a battery could be used to "soak up" otherwise curtailed renewable energy. VEC and GMP, joint owners of the KCW Wind facility, are uniquely positioned in order to take on a project of this type. The plan is to install a 3 MW/ 12 MWH battery in North Troy which will be used for storing curtailed energy from KCW, for peak shaving, and for Frequency Regulation.

South Hero

VEC is also examining the potential to locate a battery at its substation in South Hero. VEC published a Request for Proposals for a 3 MW/12 MWh battery at this location and received 5 responses. VEC selected WEG Electric Corporation as their response was the most competitive. However, as the project progressed, the price of lithium rose significantly challenging the economic basis for the project. As of spring of 2022, the project has been placed on hold until the economics of the project improve. WEG has already received a Certificate of Public Good for the project, and WEG and VEC remain in touch to monitor factors that will significantly impact the price of the battery, including the price of lithium and a potential stand-alone battery tax credit at the federal level.

VELCO Radio Backup Sites

VEC is working with VELCO towards the construction of two 250 kW/1200 kWh batteries at two VEC substations where VELCO has a co-located radio in Montgomery and Richford. The battery will provide backup for the radio's power and VEC will contract with VELCO for shared access to the batteries to use for peak shaving.

Storage Plan

VEC performed an analysis of locations suitable for a battery near or at VEC substations based on locational impacts, and system constraints. Through this process we identified a potential of an additional 31 MW of utility scale storage that it could site. However, given the cost constraints identified throughout this section, it is unlikely we will be able to site batteries at all these locations.

5.4.6 Commercial/Industrial Load Management Programs

Again, there is no industry-standard definition for commercial/industrial size load management. VEC uses the term to describe any battery at a specific commercial/industrial member's site for the purposes of providing back-up power or reducing demand charges.

Since September 2017, VEC has had a 2.5-5.0 kW/30 kWh battery located at a specific commercial member's site. The purpose of the project is to test whether VEC can manage the battery to both reduce the member's demand charges as well as VEC's ISO-NE and NEPOOL transmission charges.

VEC recognizes the potential for third parties to provide storage services to members served through rates with demand charges for the purposes of reducing those demand charges and it will be important for VEC to monitor these services to avoid negative impacts on our members. For example, under current rate schedules, the member and/or third party could be focused only on reducing that member's peak loads, and not concerned with when the battery is recharged. If the battery is recharged at the time of Vermont's monthly peak or the New England annual peak, VEC's power costs could increase.

By managing the battery or through proper rate design, VEC could incentivize the battery to avoid charging during Vermont and New England peak hours thus minimizing costs to VEC and its other members. In addition, if VEC can manage the battery, or incentivize the battery to be discharged in the right hours, VEC's costs could actually decrease.

Efficiency Vermont Commercial and Industrial Load Management Pilot

VEC is working with Efficiency Vermont to examine the possibility of establishing a Commercial and Industrial Load Management Pilot to target C&I members that have a building management system or other process driven loads that can be managed during peak times. VEC would develop a pilot rate that would compensate participants for the management of their load. Some of the challenges that VEC will need to overcome include:

- Setting up an easy to understand and easy to administer rate
- Monitoring and verifying performance during peak events
- How to address increases in load and demand resulting from peak events

5.4.7 Residential Scale Load Management Programs

As of March 2022, VEC has approximately 275 kW and 743 kWh of residential load management installed on its system.

Flexible Load – Home Battery Program

In the fall of 2021 VEC launched its Flexible Load – Home Battery Program. This program offers members an incentive if they share their battery with VEC for peak management purposes. VEC utilizes Virtual Peaker and Tesla PowerHub to communicate with eligible device types, which currently include Tesla Powerwalls, Generac PWRCells, and Sonnen batteries. VEC is manufacturer agnostic and will accept any battery type if we can arrange for an economic way to communicate with and dispatch any battery type. Enrolled members can choose 100% of the incentive as a monthly bill credit or they can elect to take the net-present value of 50% of the monthly bill credit as an upfront payment with the remaining 50% as a monthly bill credit. For a single, 5 kW Tesla Powerwall this works out to a $32 per month bill credit or a $1,340 upfront payment and a $16 monthly payment.

VEC will monitor the performance of this program and work to enroll additional batteries into the program. This program presents an opportunity to share value with all members by reducing peak related costs and add resilient DERs to the system. VEC currently has not found it cost-effective to offer a leasing program like what GMP offers currently.

VEC has 67 members with batteries on its system, 21 of which are enrolled in our home battery program. Out of the original 67, all but eight also have net metering at their residence.

Residential Water Heater Management – Packetized Energy

VEC had an active water-heater-control program with Packetized Energy utilizing their Mello smart controller hardware and their "Nimble" management platform. However, Packetized Energy was recently bought out by Energy Hub. Unfortunately, Energy Hub is not interested in supporting programs on the scale of this program and VEC will no longer have visibility or control over the devices installed under this program. Packetized and Energy Hub were able to provide a set peak schedule that the enrolled devices will follow moving forward. VEC anticipates that the number of active devices will decline over time as Wi-Fi passwords change, houses are sold, or devices break down.

This experience highlights the importance of remaining flexible and managing member expectations when engaging in pilot projects that utilize new technology. It is also worth noting that despite the waning of this specific program, the lessons from this early pilot have informed subsequent pilots and provide ongoing value in that way.

Flexible Load - Level 2 EV Charger Program

VEC currently offers members who have purchased and installed specific Level 2 EV Chargers the option of enrolling in an active management program. VEC is utilizing Virtual Peaker software to communicate with and manage

ChargePoint and Flo Level 2 EV chargers which are the most prevalent on our system. In exchange for allowing VEC to send a signal to their EV charger during peak times to curtail charging, VEC provides an $8 per month bill credit. If the member opts out of the peak event for any given month or their device is disconnected (e.g. they changed their Wi-Fi password and haven't yet reconnected their EV charger), they simply do not receive the credit the following month. Members receive an e-mail notification at least 4-hours ahead of a peak event which includes the option to opt out of peak events.

Flexible Load - Level 1 EV Charger Pilot Program

VEC, in partnership with BED and WEC, will be implementing a Flexible Load – Level 1 EV Charger Pilot Program during 2022. VEC, BED, and WEC all submitted similar proposals for a Level 1 EV Charger program to the PSD's Rate Design Initiative for grant funding. The three organizations agreed to work together towards this project. Our annual EV drivers survey shows that 38% of VEC electric vehicle drivers do not use Level 2 charging at home, mostly due to the cost of installing Level 2 chargers.

This project will utilize smart plugs to manage the Level 1 EV load. Questions that VEC hopes will be answered as part of the pilot project include:

- The level of interest in Level 1 EV charging management from VEC members through survey question results.
- The level of demand reduction possible with a Level 1 EV charger
- How often will participants opt out?
- If management becomes a hassle, do participants simply unplug the smart charger
- What type and amount of incentive is appropriate to entice enrollment

Residential storage systems (residential batteries, EV chargers, water heaters, and dispatchable generators) can act as load or as a load reducer and should be modeled accordingly. VEC reviews each new application for storage to ensure that the member's service can handle the potential new load without the need for a service upgrade. VEC also assesses these systems for distribution grid impacts that could be caused by the increase in load.

NRECA Cold-Climate Air-Source Heat Pump (ASHP) Control Pilot

VEC is currently working with other electric cooperatives, mainly in the midwestern part of the country, to develop a pilot program to determine if controlling Cold Climate Heat Pumps can be used to reduce heating and cooling load during projected peak hours.

The purposes of the pilot are to:

- Estimate mini-split ASHP load reduction impact for both utilities and end-users
- Study ASHP load profiles and how they are affected by DR events
- Learn how different DR control strategies affect occupant comfort and system performance
- Create a repeatable control option for mini-split ASHPs

The pilot is still under development and is targeted for the fall of 2022.

5.4.8 Beat the Peak

"Beat-the-Peak" – For several years now VEC has issued an alert 2-4 times per summer encouraging members to reduce electricity consumption for a specified window of hours with a reasonably high likelihood of being the ISO-NE annual peak hour. This is an optional program with no direct incentive to participating members, beyond the personal satisfaction of their small contribution to reduce costs and high-carbon peak sources of generation.

VEC maintains a list of members who want to do their part to curb use during peak-demand periods. VEC members can sign up to receive alerts by e-mail, text, or phone. As of early 2022, about 750 members had signed up to get Beat the Peak alerts.

5.4.9 Rate Structures Incentivizing Load Management

As discussed above in each of the program specific sections, VEC offers members with eligible EV chargers or home backup batteries a monthly bill credit in exchange for shared access to their device. VEC manages enrolled devices for peak shaving purposes.

In addition to monthly bill credit programs, a whole-house, time-of-use rate is offered to all Tier III Energy Transformation program participants. Members who sign up for this rate cannot enroll in the flexible load program that offered a bill credit in exchange for management of a battery or EV charger. As of April of 2022, there are 42 members that have signed up for the time-of-use rate.

Finally, VEC continues to explore the potential for an EV specific time-of-use rate. However, several challenges remain, including how to sub-meter these loads, access to sub-metered load data, etc.

5.4.10 Future Opportunities and Risks

As we look to the future we see the following potential value streams from load management programs.

1. ISO-NE Capacity Market Cost Reduction
2. Frequency Regulation/Spinning Reserve
3. Energy Arbitrage
4. T&D investment deferral/T&D support
5. Member Resiliency

As VEC considers any potential load management program we must consider several factors. They include the list below:

1. Potential impact to the member from a program failure, e.g. with the Packetized water heater program, it was imperative to ensure that no members experienced a cold shower.

2. Whether the program screens economically.
3. Impact to staff from program management activities such as enrollment, troubleshooting, and calling peak events.