2021 Vermont Long- Range Transmission Plan

vermont electric power company

VELCO

January 21, 2021

Operating Committee

Outline

- Study process
  - Criteria
  - Assumptions
  - Forecasts and sensitivities
- Results
  - Load-serving issues
  - Generation issues
  - Operating issues
- Next steps

STUDY PROCESS

CRITERIA

Planning criteria relevant to 2021 plan

- NERC planning standard TPL-001-4
  - No outages (N-0) or Category P0
  - Outage of one element (N-1) or Category P1
  - Outage of two or more elements (N-k, N-1-1) or Categories P2 to P7
- ISO-NE planning standard PP3
  - N-0, N-1, N-k, N-1-1
  - Stressed conditions
    - Extreme weather load (90/10)
    - Probabilistic calculation of generation unavailability
    - Maximize regional power transfers

NERC = North American Electric Reliability Council
ISO-NE = Independent System Operator of the New England electric system
90/10 = 90% chance that the actual load will be at or lower than the forecast, 10% chance that it will exceed the forecast

Transmission outages examined

- Single-element outages
  - Line, transformer, generator, shunts, Ascutney SVC, Essex STATCOM, Highgate HVdc terminal
- Multi-element outages
  - DCT, breaker failure, Sandy Pond HVdc terminal
- First single-element outage, then system adjustment, then tested the entire list of transmission outages
  - Took into account results from prior studies, which showed no criteria violations
    - Tested a subset of elements as the first outage in years 10, 15, and 20

DCT = Double circuit tower outage that disconnects two lines supported by the same poles
Breaker failures = outage that disconnects elements adjacent to a breaker

First transmission outages in N-1-1 analysis

VT Transmission

Line 3320 – Vernon to Newfane 345 kV
Line 3321 – Newfane to Coolidge 345 kV
Line 3340 – VT Yankee to Vernon 345 kV
Line 3381 – VT Yankee to Vernon 345 kV
Line 340 – Coolidge to Vernon 345 kV
Line 350 – Coolidge to West Rutland 345 kV
Line 370 – West Rutland to New Haven 345 kV
Line 379 – Vernon to Fitzwilliam 345 kV
Line 381 – Vernon to Northfield 345 kV
Line F206 – Comerford to Granite 230 kV
Line K21 – Georgia to Essex 115 kV
Line K23 – Essex to Lime Kiln to Tafts Corner 115 kV
Line K24 – Essex to Stowe Tap to Middlesex 115 kV
Line K27 – Tafts Corner to Williston 115 kV
Line K31 – Coolidge to Ascutney 115 kV
Line K33 – Williston to Queen City 115 kV
Line K4 – Bennington to Adams 115 kV
Line K42 – Highgate to Georgia 115 kV
Line K43 – Williston to New Haven 115 kV
Line K51 – Chelsea to Granite115 kV
Line K54 – Granite to Barre 115 kV
Line K60 – Littleton to St Johnsbury 115 kV
Line K64 – New Haven to Vergennes 115 kV
Line K7 – Blissville to Whitehall 115 kV
Line K7 – North Road to Webster 115 kV
Line PV-20 – Sandbar to Plattsburgh 115 kV
Highgate HVdc converter

VT Transmission Transformers

Coolidge 345/115 kV autotransformer
Granite 230/115 kV T1 autotransformer
Granite 230/115 kV T2 autotransformer
Newfane 345/115 kV autotransformer
New Haven 345/115 kV T1 autotransformer
New Haven 345/115 kV T2 autotransformer
Vernon 345/115 kV autotransformer
VT Yankee 345/115 kV autotransformer
West Rutland 345/115 kV T1 autotransformer
West Rutland 345/115 kV T2 autotransformer

External Transmission

Fitzwilliam 345/115 kV autotransformer
Line 3195 – Eagle to Amherst 345 kV
Line 354 – Northfield to Ludlow 345 kV
Line 367 – Amherst to Fitzwilliam 345 kV
Line 380 – Eagle to Scobie Pond 345 kV
Line A152 – Chestnut Hill to Keene 115 kV
Line F132 – Adams to Doreen 115 kV
Line F132 – Weare to Greggs 115 kV
Line I135N – Bellows Falls to Fitzwilliam 115 kV

Sub-transmission outages examined

- Single-element outages
  - VELCO transformer
  - DU line
    - Entire line, breaker to breaker, example 3310_MON_MID
    - Line end open, example END_3310_MON (for information)
    - Radial lines, example RDL_200_HIGH (for information)
    - Pick up radial line, close N.O. switch, example RCN_200_HIGH (for information)

Transmission performance criteria

	Thermal criteria	Voltage criteria	
System event	For all facilities	For 115 kV facilities	For 230 kV and above
NERC Category P0 (All-lines-in)	At or below normal rating	At or above 0.95 pu and At or below 1.05 pu	At or above 0.98 pu and At or below 1.05 pu
Categories P1 to P7 (single or multi-element outages)	At or below LTE rating	At or above 0.95 pu (post-switching) and At or below 1.05 pu Delta V no greater than 10%	At or above 0.95 pu and At or below 1.05 pu Delta V no greater than 5%

Delta V for shunt switching with all lines in: 2.5% for below 230 kV, 2% for 230 kV and above
Delta V for shunt switching with a line out: 5% for below 230 kV, 4% for 230 kV and above

Thermal = That which is related to current flow
Normal rating = Nearly continuous current capacity of a piece of equipment, such as a line, a transformer
LTE rating = Long-term (4 to 12 hours) emergency current capacity of a piece of equipment
Voltage = That which is needed to allow current to flow. The higher the voltage, the lower the current for the same power level
pu = per unit voltage, which is the ratio of the calculated voltage over the nominal/operating voltage level, such as 115 kV, 46 kV
Delta V = change in voltage before and after an outage

Sub-transmission performance screening approach

System event	Thermal limit	Voltage limit
NERC Category P0 (All-lines-in)	At or below rating	At or above 0.95 pu and At or below 1.05 pu
NERC Category P1 (single-element outages) N-1	At or below rating (LTE rating if applicable)	At or above 0.90 pu and At or below 1.05 pu Delta V no greater than 10%

- Recorded system performance for single loss of:
  - Transmission facility
    - Also with a transmission facility already out of service
  - Step-down transformer (115 kV to a lower voltage)
    - Loss of load for radial transformers will be considered acceptable unless affected DUs state otherwise
  - Sub-transmission facility
    - Breaker to breaker and line-end open scenarios
- DUs will determine whether study results outside the above screening limits need to be resolved

STUDY PROCESS

FORECAST AND SENSITIVITIES

Study approach

- Previous ISO-NE and VELCO TPL-001 analyses not used
  - ISO-NE forecasts understated beneficial electrification
  - Studies overstated solar PV contribution at summer peak hour
- Study results more critical for years 1-10, but also analyzed years 15 and 20
- Analyzed years 11-20 to examine risks and trends due to long-range forecast uncertainties and the inability to forecast public policy initiatives
  - Analyzed 2040 high load scenario – 90% by 2050 electrification
  - Analyzed 2032 Tier II doubled scenario – 1150 MW PV by 2032
- DU input incorporated in analysis
- Plan will be non-CEII public document based on underlying technical analysis, as in previous plans

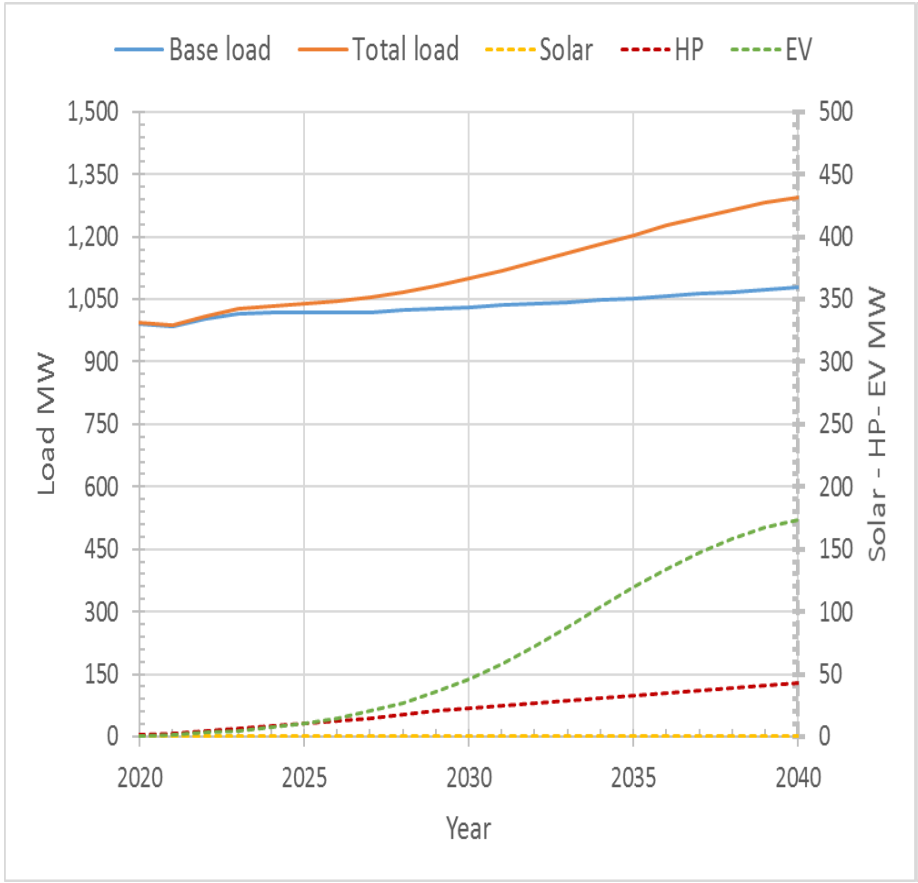
CEII: Critical Energy Infrastructure Information

Study approach (continued)

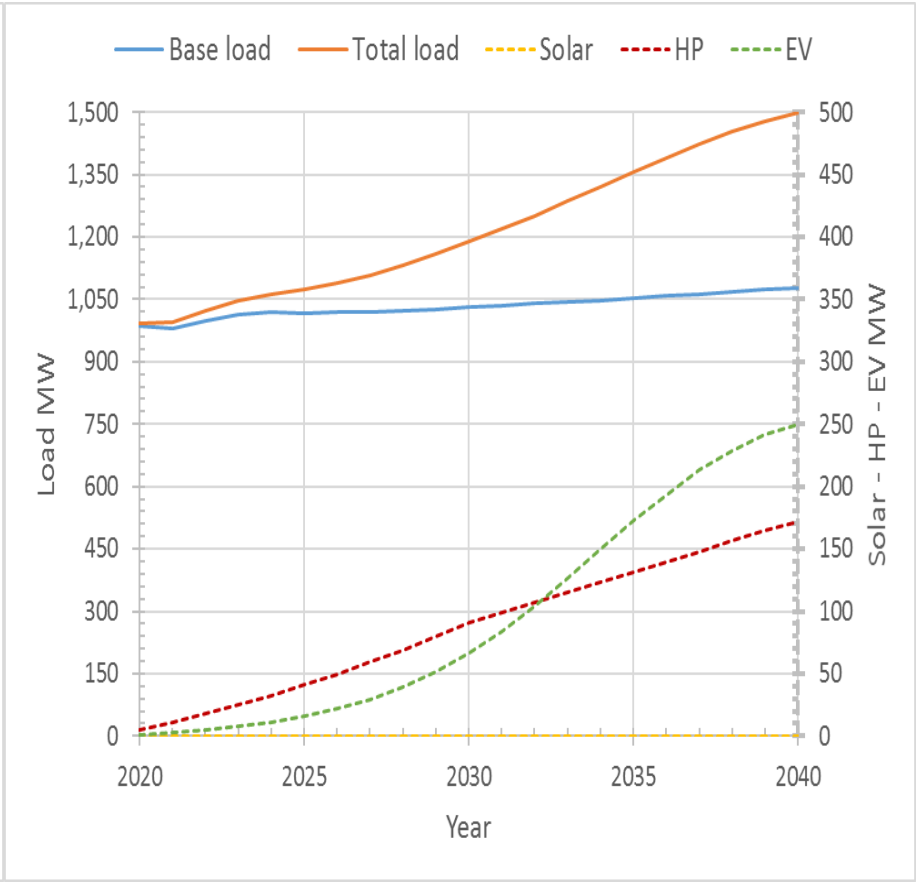
- Generation dispatch and system stresses similar to those used in 2018 analysis, but
  - Utilized the new ISO-NE generation outage approach
- Load forecast created by ITRON with VSPC forecast subcommittee
  - The forecast is quite uncertain due to the 20-year horizon and unpredictable public policies
- Steps taken to mitigate risk
  - Examine multiple scenarios in long-range plan
  - Evaluate how the grid may be negatively affected by a large amount of DG during lower load levels
  - Continue to use the geographical targeting subcommittee to identify areas where DG and EE can help mitigate issues

Summer and Winter Medium Peak Load Forecast Components

Summer Peak Load Forecast



Winter Peak Load Forecast



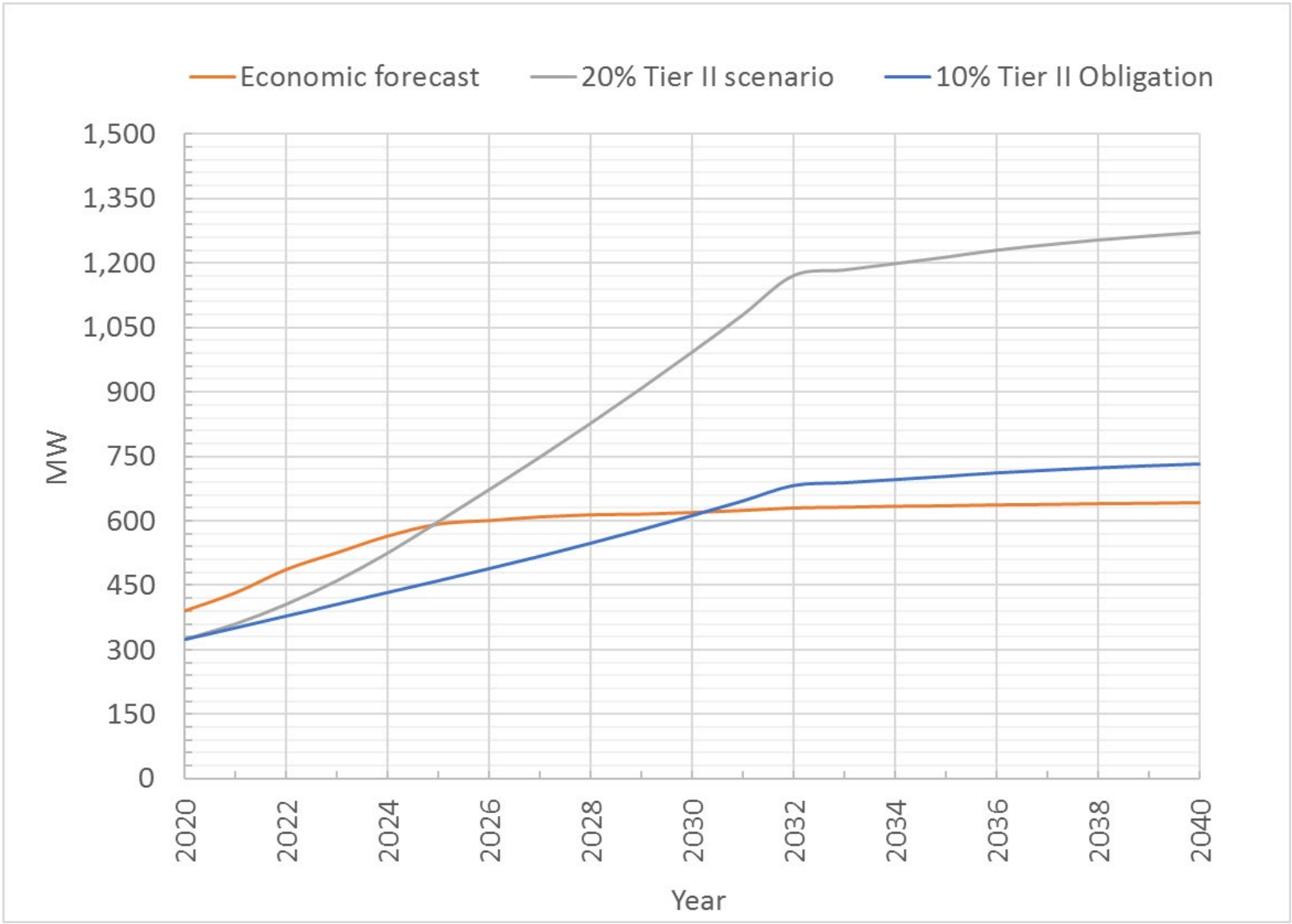
Generation dispatch

Generation	Pmax	Summer	Winter
Hydro	153	14	76
Wind	150	8	38
Solar PV over 5 MW	20	0	0
Methane	11	8	8
GTs & Diesels	145	102	127
McNeil	58	0	0
Ryegate	21	21	21
Total	562	153	270
Sheffield wind	40	2	10
KCW	65	3.2	16
Deerfield wind	30	1.5	7.5
Swanton GT	40	20	20
Berlin GT	59	42	58
Burlington GT	25	20	25
Coolidge Solar	20	0	0
AES Granite Ridge	775	0	0

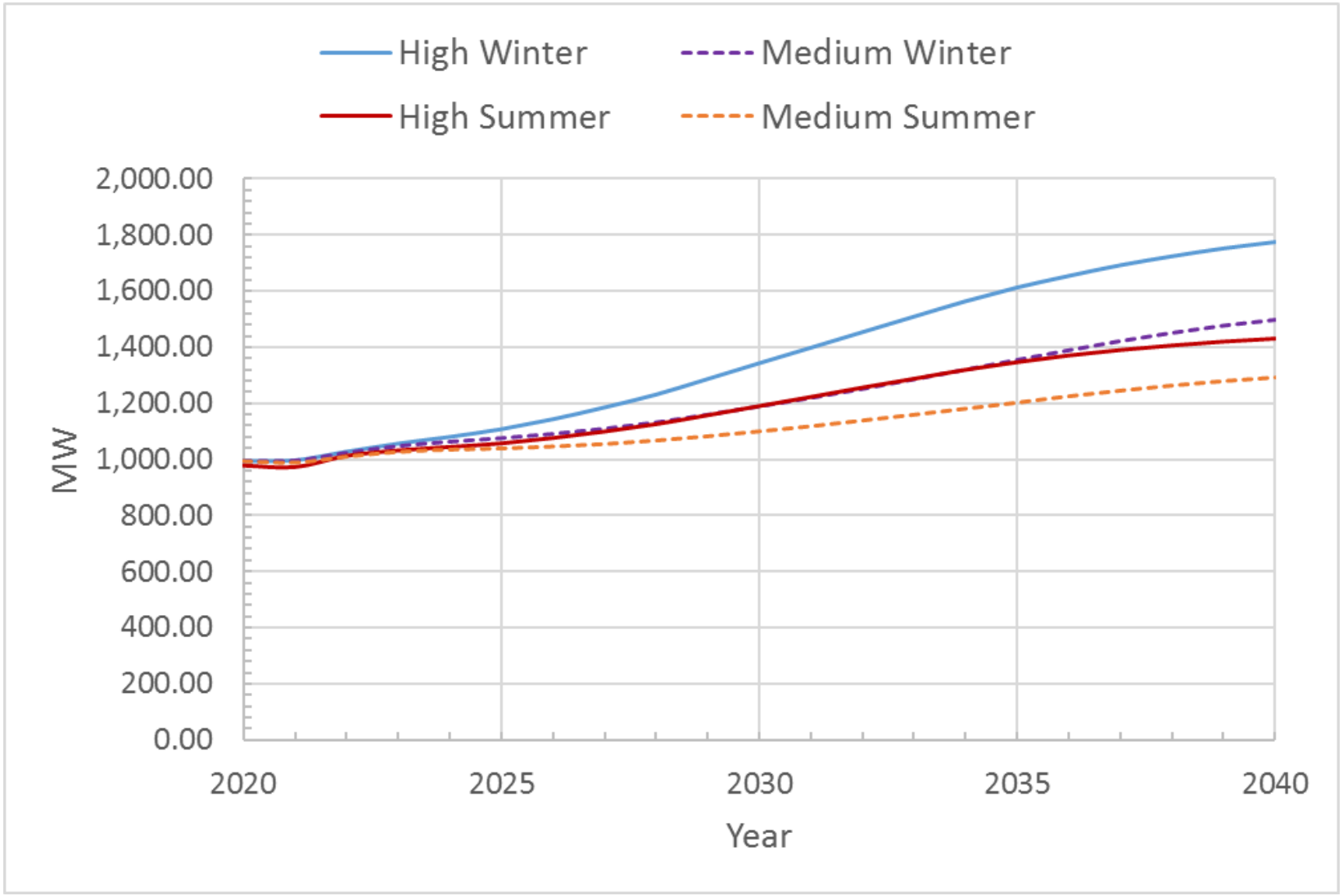
Sensitivity analyses

- High in-state distributed generation
  - Doubling of Tier II
  - Low daytime spring loads
  - Refine 2018 Optimized Distribution
    - Use more realistic assumptions
    - Consider distribution transformer limits
- High electrification load
  - Significant growth in EVs and heat pumps
  - Account for EV load management measures

Tier II Doubled solar PV forecast



Load forecast comparison



RESULTS

LOAD-SERVING ISSUES

Transmission and transformer results

- No transmission issues within 10 years
  - Phase shifter adjustments eliminate overloads
- St Albans transformer overload
  - Contingency: loss of the Georgia transformer
  - Critical state load level: 1090 MW
  - Timing: 2030
  - Assumes 34.5 kV bus rating is sufficiently high
  - Lead Utility: GMP
  - Affected Utility: VEC
- Other transformer overloads addressed with sectionalizing and load shedding less than 300 MW

Subtransmission results grouped by location

Location	Year Needed*	90/10 Load Forecast for Year (MW)	Contingency	Reliability Concern	N-1 Criteria Violation	Affected DUs	Lead DU
Ascutney	2020	< 987	Subtransmission	Thermal Low Voltage	Maple Ave – River Rd – Charlestown	GMP / PSNH	GMP
Ascutney	2020	< 945	Subtransmission	Thermal	Lafayette – Bridge St. – Bellows Falls	GMP / PSNH	GMP
Ascutney	2020	974	Subtransmission open end	Thermal	Windsor – Windsor V4	GMP	GMP
Ascutney	2021	992	Transformer Subtransmission	Low Voltage	Lafayette – Bridge St. – Bellows Falls	GMP / PSNH	GMP
Ascutney	2021	992	Transformer Subtransmission	Thermal	Highbridge – Ascutney	GMP / PSNH	GMP
Blissville	2020	< 945	Transformer	Thermal	West Rutland – Castleton	GMP	GMP
Blissville	2021	992	Transformer	Low Voltage	Blissville area	GMP	GMP
Burlington	2020	< 948	Subtransmission open end	Voltage	Richmond area	GMP / VEC	GMP

*(Projects needed in past listed as 2020 in this table)

Subtransmission results grouped by location

Location	Year Needed *	90/10 Load Forecast for Year (MW)	Contingency	Reliability Concern	N-1 Criteria Violation	Affected DUs	Lead DU
Montpelier	2020	< 970 Winter	Subtransmission open end	Low Voltage	Moretown – Irasville – Madbush (winter)	GMP / WEC	GMP
Montpelier	2020	< 945	Transformer Subtransmission	Thermal	Berlin – Montpelier	GMP	GMP
Montpelier	2021	1000	Subtransmission	Thermal	Barre – South End	GMP	GMP
Montpelier	2027	1116	Subtransmission	Thermal Voltage	South Barre – Websterville	GMP	GMP
Rutland	2020	< 970 Winter	Subtransmission open end	Low voltage	Snowshed (winter)	GMP	GMP
Rutland	2020	< 948 Winter	Subtransmission open end	Low voltage	Brandon – Mendon	GMP	GMP
Southern	2023	1050 winter	Subtransmission & open end	Thermal	Manchester – East Arlington	GMP	GMP
Southern	2028	1157 winter	Subtransmission open end	Thermal	Newfane – Jamaica	GMP	GMP
St. Albans	2025	992	Transformer Transmission	Low voltage	Sheldon	GMP / VEC	GMP
St. Albans	2020	981	Transmission Transformer	Thermal	Georgia – Ballard Road	GMP / VEC	GMP

Low voltage for double circuit loss of K24 and 3312 not a reliability concern

*(Projects needed in past listed as 2020 in this table)

High load scenario

- No additional transmission issues and minimal additional subtransmission issues
- 75% EV load reduction assumed
  - Without EV load reduction:
    - 1789 MW VT winter peak load
    - 425 MW EV winter peak load
  - With EV load reduction:
    - 1471 MW VT winter peak load
    - 106 MW EV winter peak load
- Load levels above 1471 MW would worsen violations
  - Load reduction events forecasted to occur on 40 days in 2040
    - 39 days in January and February
    - One day in December
  - Events begin at 5 or 6 pm, can last until midnight
    - Average duration of 3.5 hours
    - Maximum duration of 7 hours

RESULTS

GENERATION ISSUES

General Observations

- DER hosting capability decreases nearly 1 to 1 with increase in PV20 flows and increase to SHEI generation
  - North-South Transmission elements impacted by these key elements
- F206 flows have similar impacts but less than 1 to 1
- Queue Projects may alter the limiting elements and shift around an optimized solution, limiting DER locally

DER Sensitivity Load model details – SLL

Zones		Tier II doubled Spring 2032		Optimized Distribution Spring 2030 (Queued projects Off)		Optimized Distribution Spring 2030 (Queued projects On)	
Numbers	Names	Net loads	Modeled DER Capacity	Net loads	Modeled DER Capacity	Net loads	Modeled DER Capacity
715	StJohnsbury	-19	35.6	-13.4	30	-13.4	30
725	Newport	-1.3	17.2	10.5	5.4 *	10.5	5.4 *
735	Highgate	-32.2	57.9	3.4	19.8	3.4	19.8
745	Johnson	-9.9	12.2	-17.7	20	-17.7	20
755	Burlington	-168	247.8	-46.4	126.2	-0.2	80
765	BED	14.2	23.7	30.4	7.5	30.4	7.5
775	Montpelier	-36.9	90.3	-23.4	76.8	-22.9	76.3
785	Morrisville	-21.8	39.9	-6.9	25	-6.9	25
795, 798	Middlebury	-74	91	-33	50	-42.7	59.7
805	Rutland	-85.3	134.6	-102.6	151.9	-99.4	148.7
815	Ascutney	-21.4	59.8	-34.6	73	-29.9	68.3
825	Southern	-88	148.6	-190.9	251.5	-133.7	194.3
835, 838	StAlbans	-51.6	95.9	6.8	40	6.8	40
845	Central	-87.5	126.9	-59.3	98.7	-33.6	73
855, 858	Florence	21.8	0.6	2.4	20	2	20.4
878	IBM	45	0	45	0	45	0
Zonal Totals		-615.9	1182	-429.7	995.8	-302.3	868.4
Total Zonal Load / Losses		561 / 110		561 / 59		561 / 59	

* Does not include the block system normally connected to Canada

High DER Results

Upgrade	DER at 1st violation	Number of violations	Category	Length (Miles)	Estimated Cost	Affected DUs	Lead DU
Rebuild 115 kV line between Highgate and Georgia	450 MW	4	Bulk	17	$61M	All Vermont DUs	GMP
Rebuild 115 kV line between Sand Bar and Essex	450 MW	1	Bulk	11.2	$34M	All Vermont DUs	GMP
Rebuild Gorge - McNeil-35 kV line	450 MW	1	Subsystem	2.3	$0.9M	GMP	GMP
Rebuild Brandon - Mendon Tap 46 kV line	450 MW	(No outage) 487	Subsystem	14.6	$5.8M	GMP	GMP
Rebuild Windsor-Highbridge 46 kV line	450 MW	(No outage) 485	Subsystem	6.2	$2.5M	GMP	GMP
Rebuild Newfane-G Pacific 46 kV line	450 MW	1	Subsystem	11.9	$4.8M	GMP	GMP
Rebuild Websterville-South End 35kV line	450 MW	(No outage) 487	Subsystem	2.9	$1.2M	GMP	GMP
Rebuild 115 kV line between Williston and New Haven substations	500 MW	(No outage) 45	Bulk	20.8	$56M	All Vermont DUs	GMP
Rebuild 115 kV line between Middlebury and West Rutland	600 MW	1	Bulk	28	$104M	All Vermont DUs	GMP
Rebuild Taftsville–Windsor 46kV line	600 MW	470	Subsystem	10.6	$4.2M	GMP	GMP
Rebuild 115 kV line between Essex and Williston substations	650 MW	(No outage) 478	Bulk	8.3	$27M	All Vermont DUs	GMP
Replace Vernon Road transformer	650 MW	1	Predominantly Bulk	N/A	$3.8M	All Vermont DUs	GMP
Rebuild E Barnard-Woodstock 46 kV	650 MW	484	Subsystem	10.2	$4.1M	GMP	GMP
Rebuild 115 kV line between New Haven and Vergennes	700 MW	3	Bulk	6.7	$35M	All Vermont DUs	GMP
Rebuild Smead Rd - Brandon 46 kV	700 MW	1	Subsystem	8.4	$3.4M	GMP	GMP

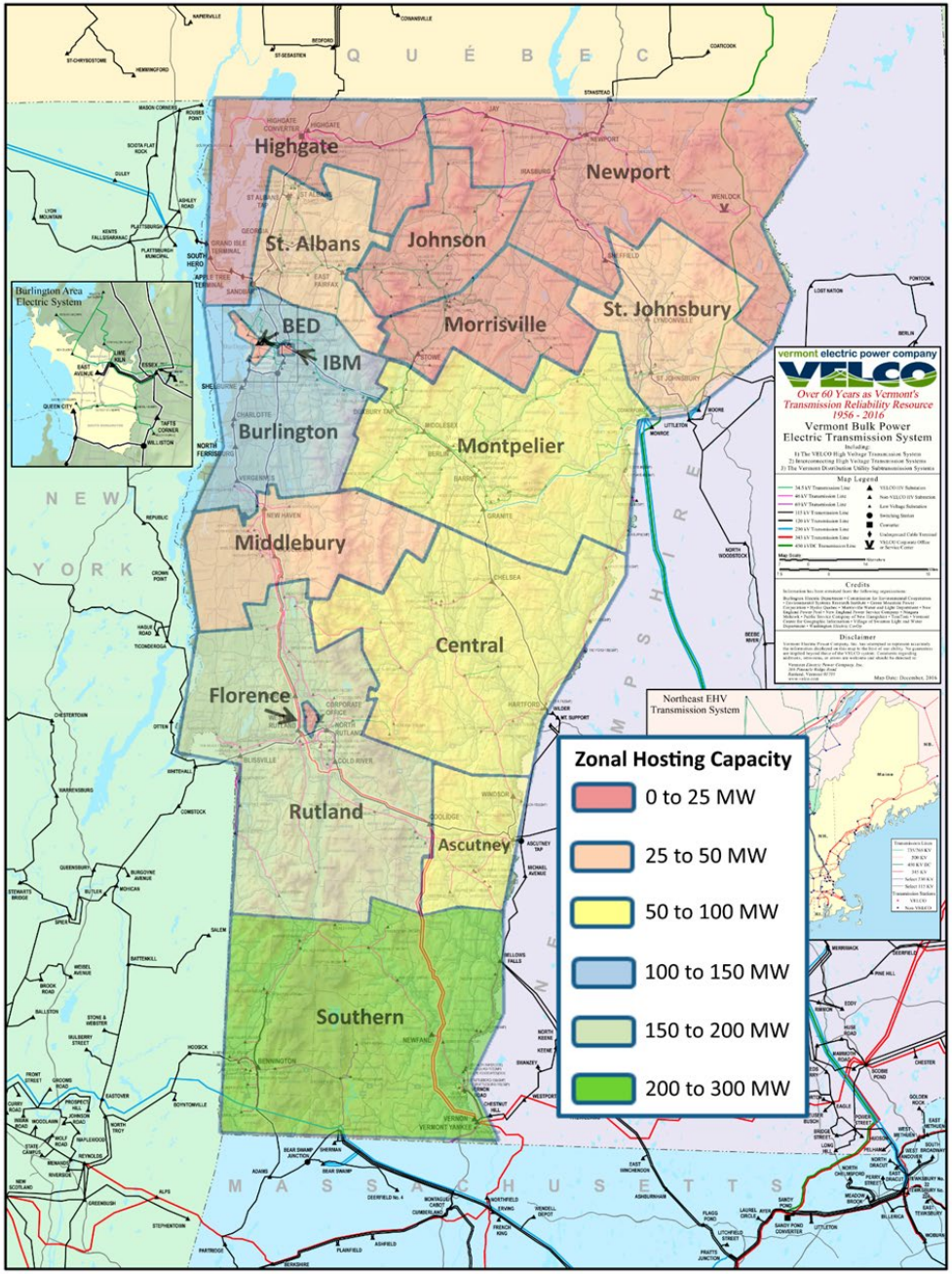
High DER Results

Upgrade	DER at 1st violation	Number of violations	Category	Length (Miles)	Estimated Cost	Affected DUs	Lead DU
Replace Irasburg transformer	800 MW	2	Predominantly Bulk	N/A	$3.9M	All Vermont DUs	GMP
Rebuild Windsor V4 - Windsor 46 kV line	800 MW	2	Subsystem	1.5	$0.6M	GMP	GMP
Rebuild 115 kV line between Georgia and Global Foundries	850 MW	1	Bulk	17.7	$45M	All Vermont DUs	GMP
Rebuild 115 kV line between New Haven and Middlebury	900 MW	1	Bulk	7.5	$21M	All Vermont DUs	GMP
Rebuild 115 kV line between North Rutland and Coolidge	900 MW	1	Bulk	23.8	$70M	All Vermont DUs	GMP
Replace Middlebury equipment	900 MW	19	Predominantly Bulk	N/A	$0.1M	All Vermont DUs	GMP
Rebuild Little River – Duxbury 35 kV line	900 MW	2	Subsystem	3.3	$1.3M	GMP	GMP
Replace Windsor transformer	950 MW	6	Predominantly Bulk	N/A	$4.9M	All Vermont DUs	GMP
Replace Vergennes transformer	950 MW	1	Predominantly Bulk	N/A	$4.5M	All Vermont DUs	GMP
Rebuild 115 kV lines between West Rutland & North Rutland	1000 MW	1	Bulk	5.1	$14M	All Vermont DUs	GMP
Rebuild Ballard Rd –Clark Falls 35 kV line	1000 MW	4	Subsystem	4.3	$1.7M	GMP	GMP

Increased DER/SHEI aggravates overloads outside of VT

Transmission overloads

Optimized DER distribution



Next steps

- Send draft report to VSPC
- Incorporate VSPC comments
- Publish report
- Present plan at public meetings