2018 Vermont Long Range Transmission Plan

January 18th, 2018
OC meeting

Outline

- Study plan
- Criteria and assumptions (load and generation)
- Results by system level
  - Bulk, predominantly bulk, and subsystem
- Results for single contingencies
  - Summer and winter peak loads – base forecast and high load scenario
  - Spring load – base forecast and high solar PV scenario
- Conclusions

Steps in developing 2018 long-range plan

- Extensive collaborative load forecast process (VSPC)
- Presented scope and requested input
- Used ISO-NE and VELCO TPL-001-4 assessments of the bulk system for years 1-10 of the plan
- Supplemented to meet VT planning requirements
  - Analyzed sub-transmission system
  - Analyzed years 11-20 only to examine risks and trends due to long-range forecast uncertainties and the inability to forecast public policy initiatives
    - Analyzed high load scenario – on track to meet state goal of reaching 90% renewable energy by 2050
    - Analyzed high solar PV scenario – 1000 MW by 2025
- Requested ISO-NE input
- Requested DU review of results and draft plan
- Plan will be non-CEII public document

CEII: Critical Energy Infrastructure Information

Plan development timeline

Jan to Jul 2017	Prepare a load/renewable energy forecast
May to Jul 2017	Prepare load flow cases and auxiliary files
Jun 2017	Consultation with distribution utilities
Jul VSPC quarterly meeting	Review high level scope with the VSPC
Jul to Nov 2017	Perform system analysis
Jul to Oct 2017	Identify deficiencies and develop solution options
Aug 2017	Engineering support (modeling data)
Sep and Oct 2017	Construction Controls support (Cost estimates)
Nov and Dec 2017	Prepare the draft report for VSPC review
Jan to Mar 2018	Obtain formal feedback from VSPC
Mar 2018	Incorporate VSPC comments
Apr to May 2018	Conduct public meetings for input to the report
Jun 2018	Incorporate comments from the public
Jun 2018 (by 7/1/18)	Publish plan

We are here

CRITERIA

Planning criteria relevant to 2018 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)
    - Two significant resources unavailable (probabilistic considerations currently under review)
    - Maximize regional power transfers, mainly West-East and NY-NE

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, 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 for information purposes in year 15

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

List of first transmission outages

- Line 379 – Vernon to Fitzwilliam 345 kV
- Line 381 – Vernon to Northfield 345 kV
- Line 3320 – Vernon to Newfane 345 kV
- Line 3321 – Newfane Coolidge 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 F206 – Comerford to Granite 230 kV
- Fitzwilliam 345/115 kV autotransformer
- Vernon 345/115 kV autotransformer
- Newfane 345/115 kV autotransformer
- Coolidge 345/115 kV autotransformer
- West Rutland 345/115 kV autotransformer
- New Haven 345/115 kV autotransformer
- Granite 230/115 kV autotransformer

All 345 kV and 230 kV outages

- Line K60 – Littleton to St Johnsbury 115 kV
- Line K42 – Highgate to Highgate Converter Tap to St Albans Tap to Georgia 115 kV
- Line K21 – Georgia to IBM Tap to Essex 115 kV
- Line K54 – Granite to Barre 115 kV
- Line K64 – New Haven – Vergennes 115 kV
- Line K31 – Coolidge to Ascutney 115 kV
- Line K4 – Bennington to Adams 115 kV

Selected 115 kV outages

DCT = Double circuit tower outage that disconnects two lines supported by the same poles

Breaker failures = outage that disconnects elements adjacent to a breaker

Sub-transmission outages examined

- Single-element outages
  - VELCO transformer
  - DU line
    - Entire line, breaker to breaker, example ASCT_LAF_H20
    - Line end open, example LAF_H20_END
    - Radial lines, example High_200_RDL
    - Pick up radial line, close N.O. switch, example HART_H83_RDLR or STJ-X15_RDL2

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 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
All-lines-in	At or below rating	At or above 0.95 pu and At or below 1.05 pu
(single-element outages) N-1	At or below rating	At or above 0.90 pu and At or below 1.05 pu Delta V no greater than 10%

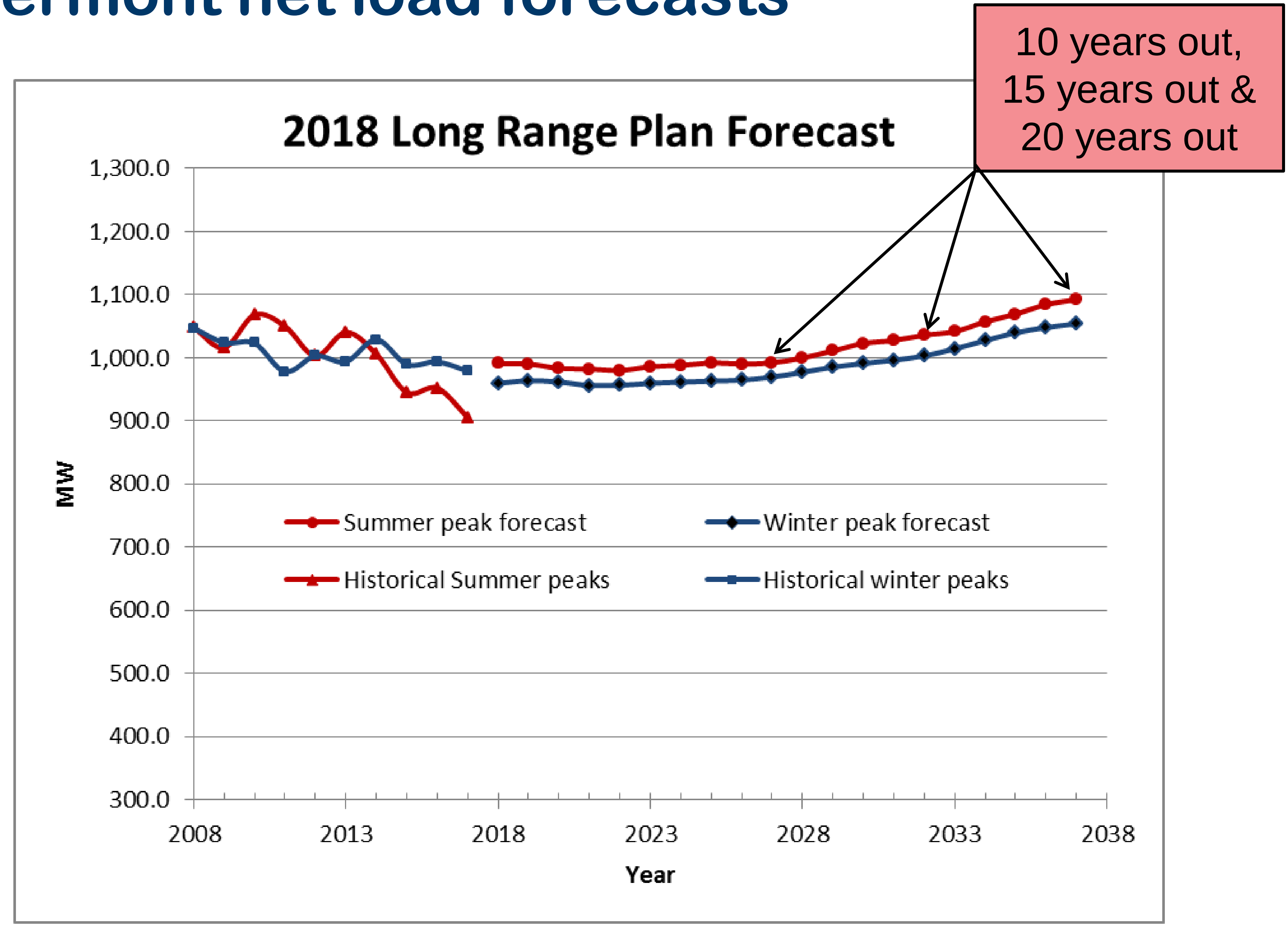
- Will record system performance for single contingency:
  - Transmission facility
    - Also with a transmission facility already out of service
  - Step-down transformer (115 kV to a lower voltage)
    - Loss of load for radial transformers will be considered acceptable unless affected DUs state otherwise
  - 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

ASSUMPTIONS

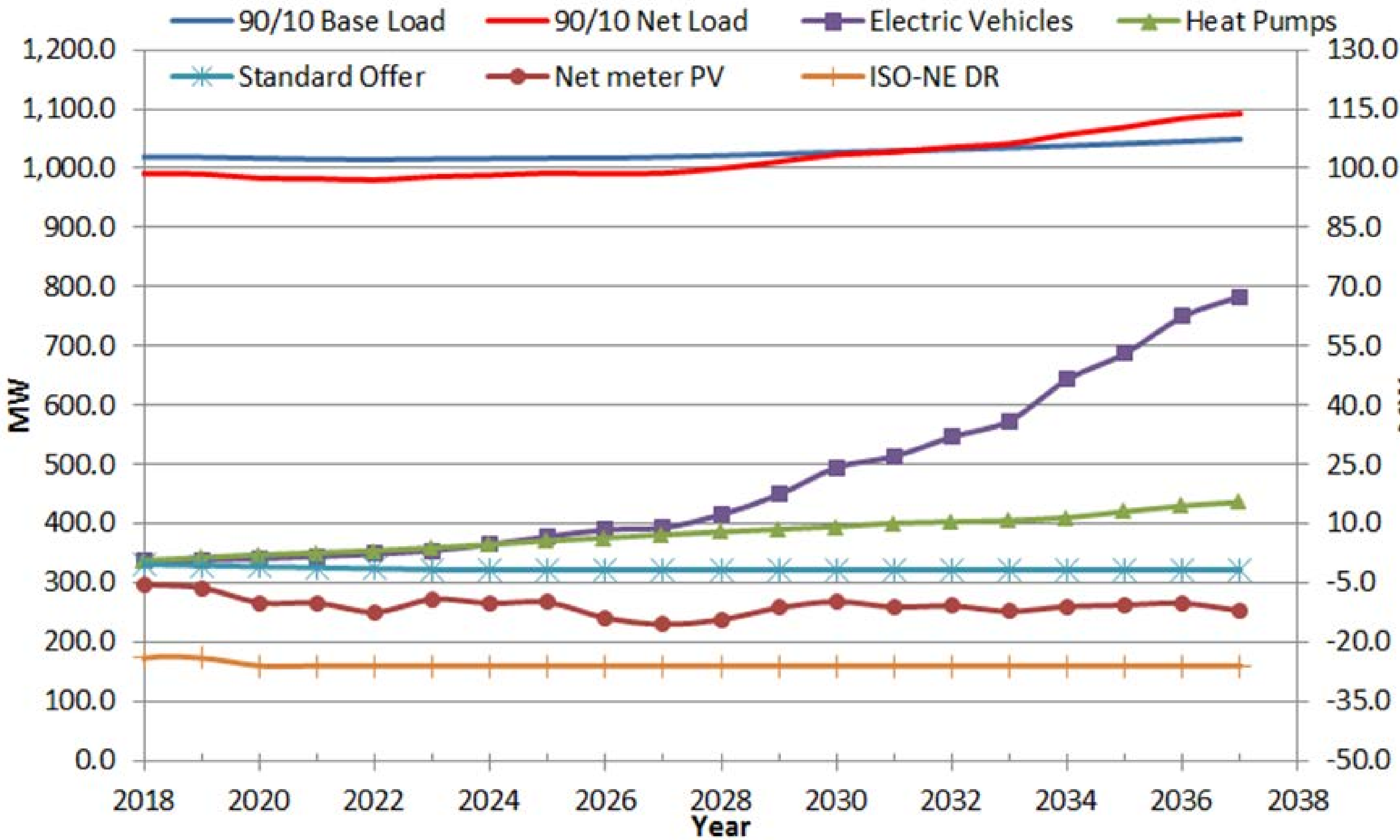
Resources

- Highgate HVDC converter at 225 MW capacity (227 MW at the border)
- McNeil out of service as the significant resource
  - Also tested in service for local impact
- 70% of fast start generation in service
- Intermittent resources at expected seasonal output
  - Summer: Solar 2.5%, Wind 5%, Hydro 10%
  - Winter: Solar 0%, Wind and Hydro 25%
- New generation projects in service
  - Deerfield wind (30 MW capacity)
  - Coolidge Solar PV (20 MW capacity)
- Controlled tie settings
  - Sand Bar and Blissville at 0 MW, Granite at 100 MW
- HVDC elective transmission upgrades modeled out of service

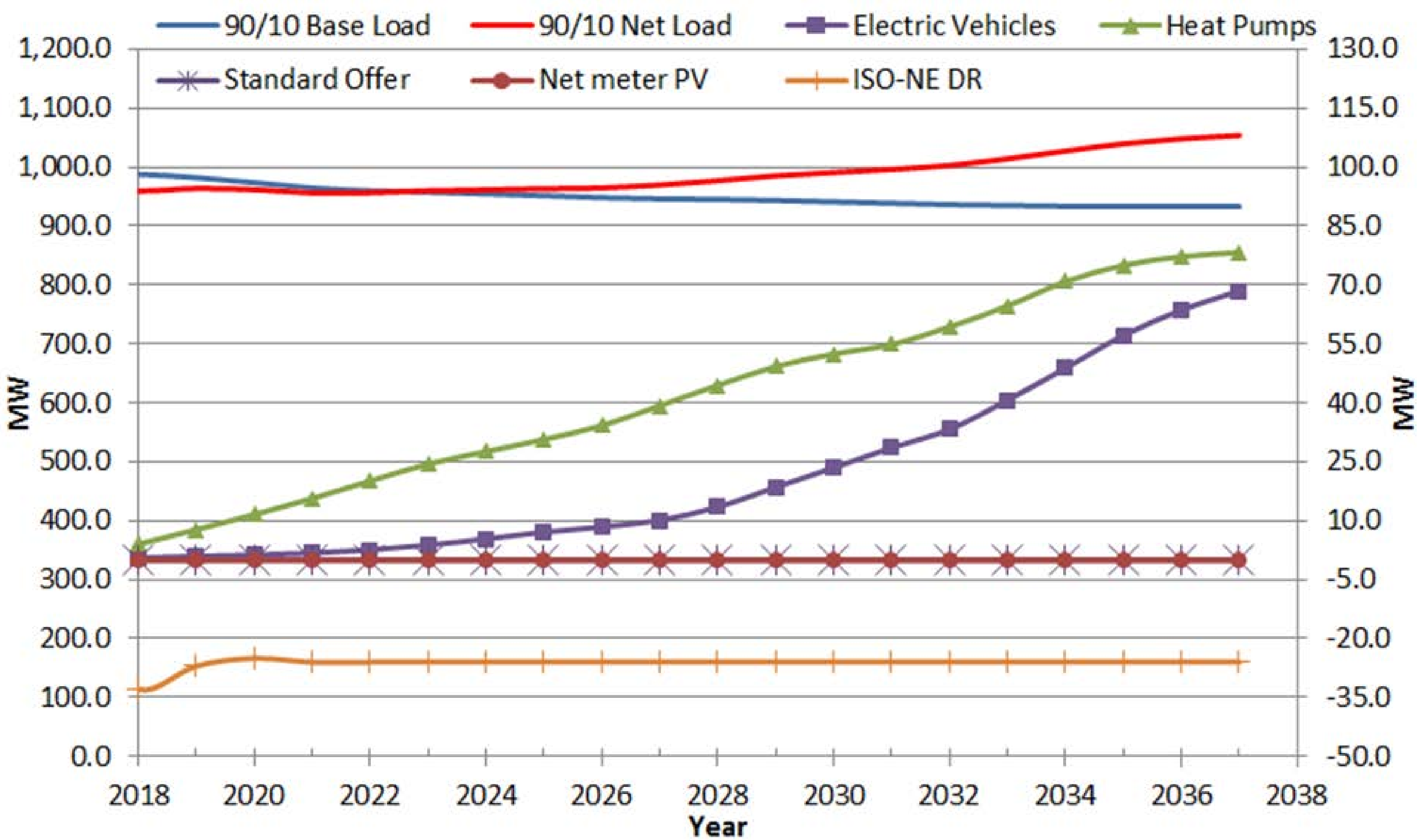
Vermont net load forecasts



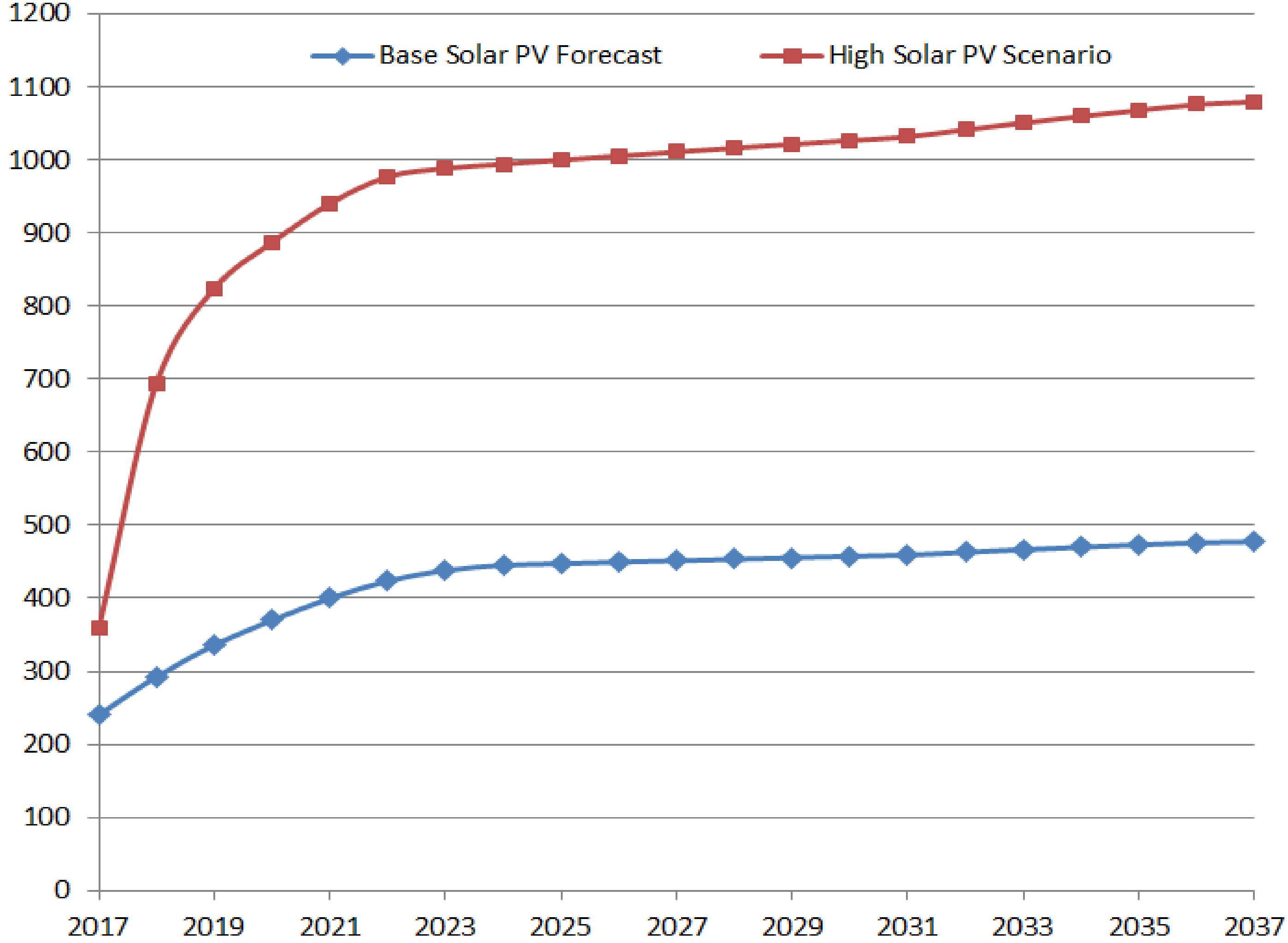
Summer load component forecasts



Winter load component forecasts



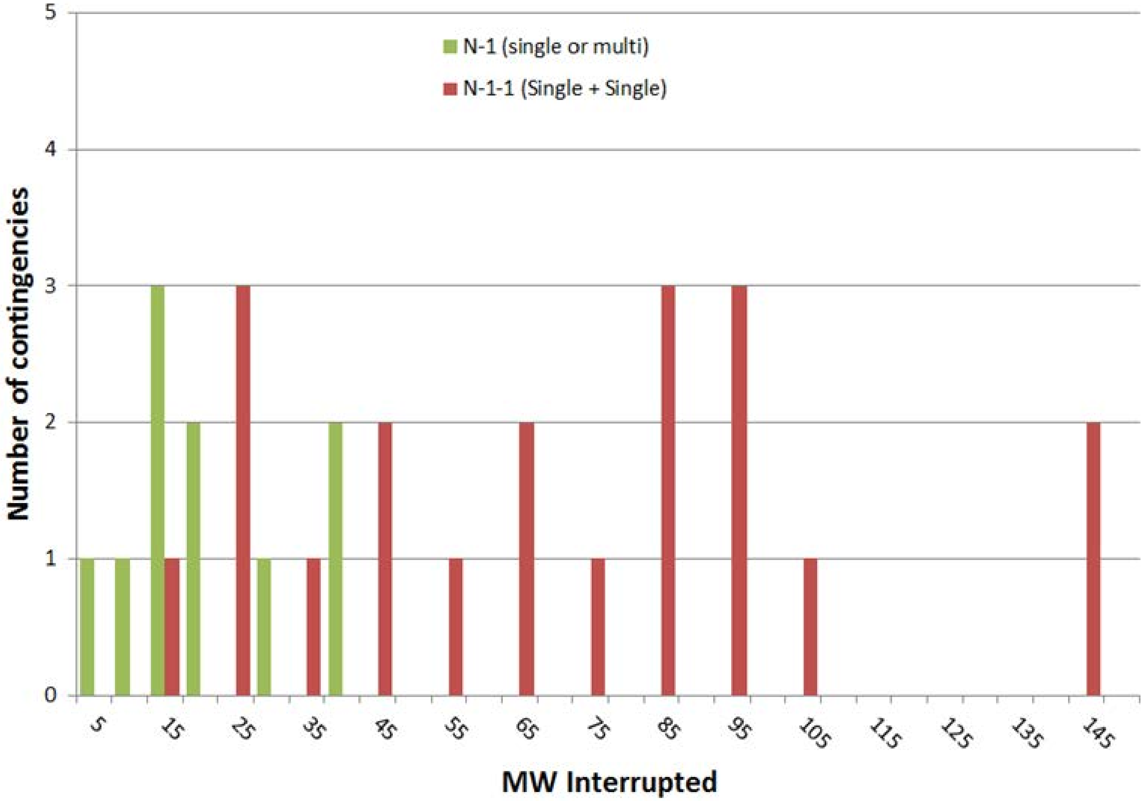
High solar PV scenario



RESULTS

Peak load results within 10-year horizon

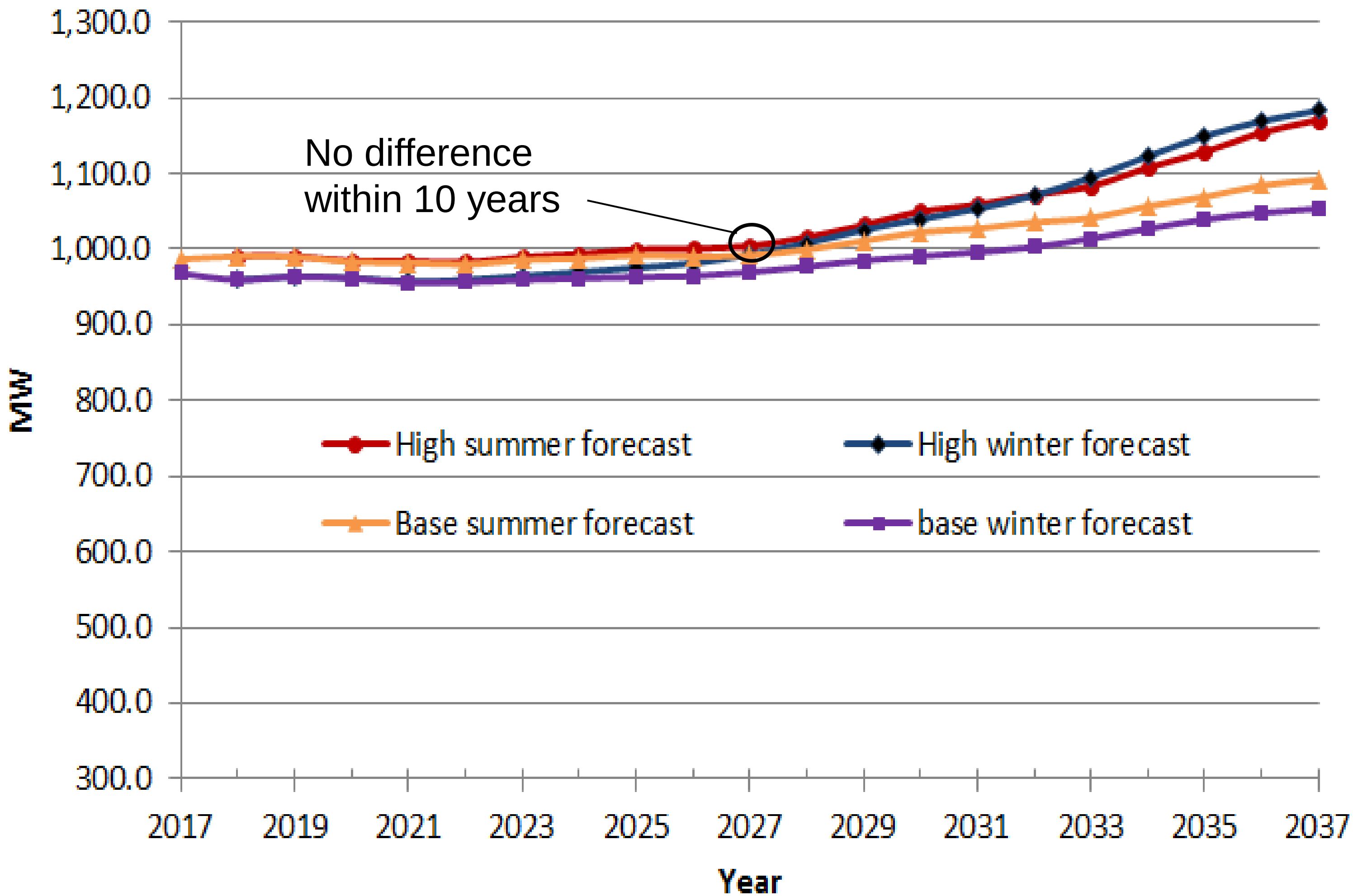
- No concerns at the bulk and predominantly bulk levels
  - Bulk issues addressed by tie line adjustments
  - Predominantly bulk issues addressed by lower loads and the Rutland Area Reliability Plan
  - Acceptable loss of load exposure



SUB-TRANSMISSION POTENTIAL RELIABILITY ISSUES GROUPED BY LOCATION

Location	Year Needed (Projects needed in past listed as 2017 in this table)	90/10 Load Forecast for Year (MW)	Contingency	Reliability Concern	N-1 Criteria Violation	Affected DUs	Lead DU
Ascutney	2025	992	Transformer Subtransmission	Low Voltage	Lafayette – Bridge St. – Bellows Falls	GMP / PSNH	GMP
Ascutney	2025	992	Transformer Subtransmission	Thermal	Highbridge – Ascutney	GMP / PSNH	GMP
Blissville	2025	992	Transformer	Low Voltage	Blissville area	GMP	GMP
Blissville	2030	1023	Transformer	Thermal	Blissville – Hydeville	GMP	GMP
Rutland	2017	< 970 Winter	Subtransmission End open	Low voltage	Snowshed (winter)	GMP	GMP
Montpelier	2031	1028	Transmission	Thermal	Marshfield – Danville GMP – Danville WEC	GMP	GMP
Montpelier	2017	< 987	Subtransmission End open	Low Voltage	Ryegate / Newbury	GMP	GMP
Montpelier	2017	970 Winter	Subtransmission End open	Low Voltage	Moretown – Irasville – Madbush (winter)	GMP / WEC	GMP
Montpelier	2017	< 970 Winter	Subtransmission End open	Thermal	Northfield – W Berlin (winter)	GMP / WEC	GMP
Burlington	2017	< 987	Transformer Subtransmission	Thermal	Gorge – McNeil	GMP / BED	GMP
St. Albans	2017	< 987	Subtransmission End open	Thermal	Welden St. – East St. Albans	GMP	GMP
St. Albans	2025	992	Transformer Transmission	Low voltage	Sheldon	GMP	GMP

High load scenario



- Any concerns that may occur during the second 10-year horizon would be advanced by 3 years, but still beyond 10-year horizon

Results of spring load (Saturday in April)

- System condition tested
  - Substation loads at 620 MW, losses pre small-scale solar PV at 30 MW
  - Plattsburg-Sand Bar flow at 0 MW, Comerford-Granite flow at 100 MW
  - Highgate at 225 MW capacity (227 MW at the border)

Generation	Amount	Generation	Amount
Utility-scale wind	151 MW	Landfill methane	11 MW
Utility-scale hydro	155 MW	Coolidge solar PV	20 MW
Utility-scale biomass	70 MW	Diesels and GTs	0 MW

- Results of base solar PV (448 MW) forecast
  - System losses increased by 8 MW
  - Greater SHEI impacts
    - Voltage collapse within SHEI and additional sections of the K42 line overloaded
    - Overloads south of Georgia depending on Plattsburg-Sand Bar tie flow

High solar PV scenario for year 2025

Zone names	Gross loads	Base solar PV forecast		1000 MW Solar PV scenario Spring 2025					
		Historical solar PV distribution		Same distribution as base solar PV forecast		MW load ratio share		MWh load ratio share	
		Installed capacity	Net loads	Installed capacity	Net loads	Installed capacity	Net loads	Installed capacity	Net loads
Newport	19.8	9.1	10.7	20.3	-0.5	36.9	-17.1	40.0	-20.2
Highgate	23.8	10.2	13.6	22.7	1.1	39.1	-15.3	38.0	-14.2
St Albans	39.7	31.0	8.7	69.3	-29.6	68.2	-28.5	63.6	-23.9
Johnson	6.6	4.0	2.6	8.9	-2.3	11.5	-4.9	12.0	-5.4
Morrisville	24.3	0.0	24.3	0.0	24.3	35.1	-10.8	36.7	-12.4
Montpelier	48.6	33.9	14.7	75.8	-27.2	86.0	-37.4	91.3	-42.7
St Johnsbury	14.7	7.7	7.0	17.3	-2.6	26.2	-11.5	28.9	-14.2
BED	39.8	1.3	38.5	2.8	37.0	61.9	-22.1	61.8	-22.0
IBM	60.6	0.0	60.6	0.0	60.6	62.4	-1.8	70.5	-9.9
Burlington	94.1	97.4	-3.3	217.7	-123.6	164.5	-70.4	142.4	-48.3
Middlebury	19.7	46.9	-27.2	104.9	-85.2	36.1	-16.4	30.5	-10.8
Central	37.6	66.2	-28.6	147.9	-110.3	67.5	-29.9	67.2	-29.6
Florence	22.6	0.3	22.3	0.6	22.0	25.6	-3.0	34.1	-11.5
Rutland	61.7	55.2	6.5	123.4	-61.7	93.0	-31.3	92.8	-31.1
Ascutney	39.5	21.4	18.1	47.9	-8.4	71.7	-32.2	69.7	-30.2
Southern	65.6	62.9	2.7	140.5	-74.9	114.4	-48.8	120.4	-54.8
Total	618.7	447.5	171.2	1000	-381.3	1000	-381.3	1000	-381.3

Tested high solar PV scenario based on historical distribution

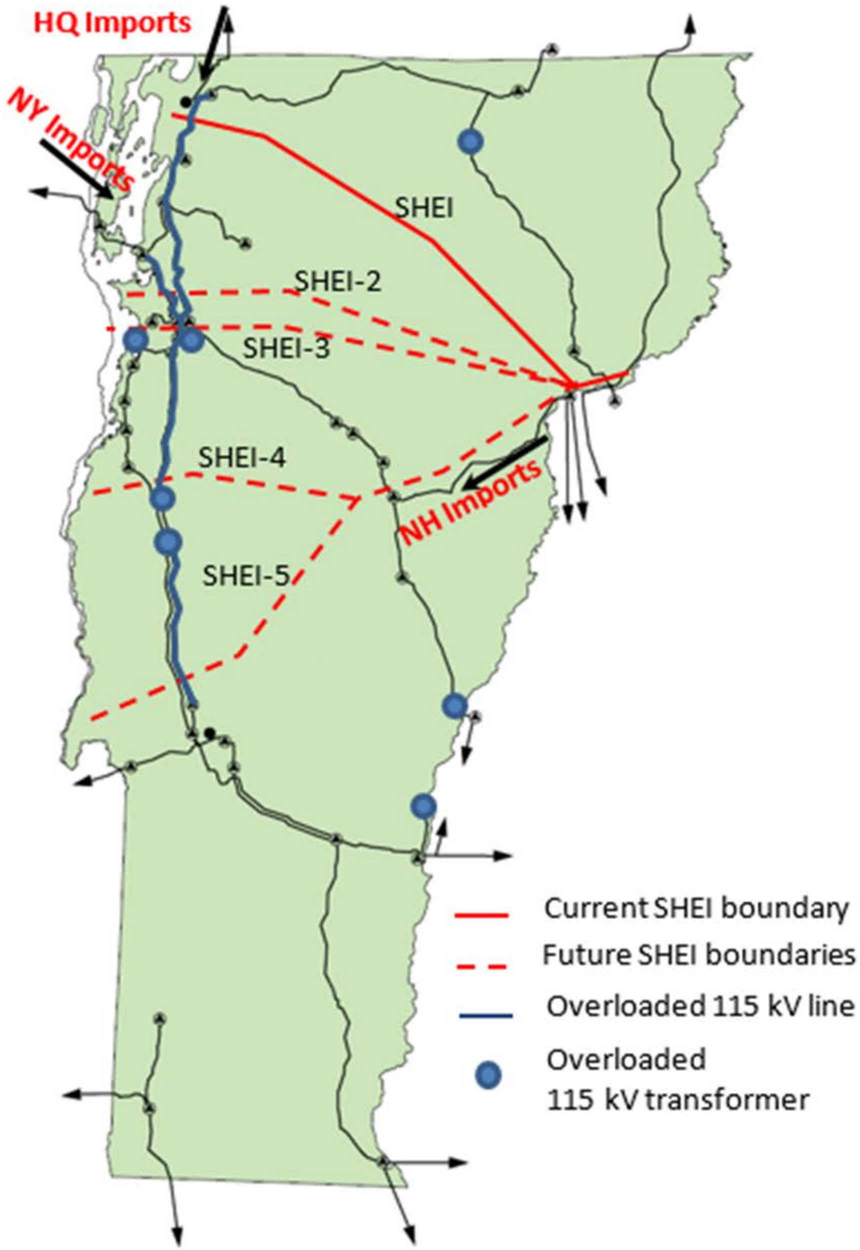
Distribution by Utility	Solar PV Capacity (MW)
BED	3
GMP	930
VPPSA	11
VEC	47
WEC	9
State	1000

Distribution by Regional Planning Commission	Solar PV Capacity (MW)
Northwest (NRPC)	69
Northeastern (NVDA)	40
Lamoille (LCPC)	9
Chittenden (CCRPC)	233
Central (CVRPC)	66
Addison (ACRPC)	119
Two (TRORC)	147
Rutland (RRPC)	114
Southern (SWCRPC)	50
Bennington (BCRC)	65
Windham (WRC)	88
State	1000

Results of high solar PV scenario

- Same system condition as base solar PV forecast analysis, but small-scale solar PV increased to 1000 MW
- Will introduce significant operational challenges
  - Very large flows pre-contingency
  - System losses increased by 45 MW
  - Transmission overloads extend south of SHEI towards Rutland
    - Even with the Plattsburg-Sand Bar tie flow at 0 MW
    - May run out of angle range on the Sand Bar phase angle regulator to maintain flows low enough to prevent overloads under some conditions
    - Any reduction in Northern Vermont generation will be annulled by NY-VT tie flows
  - Low voltage on the bulk system and high voltage on the subsystem
    - Managing pre- and post-contingency voltages will require dynamic voltage support

Bulk and predominantly bulk concerns



- SHEI is the current constraint interface
- SHEI-1 to SHEI-5 are expansions of the constraint

No.	Location	Upgrade	Need	Category	Length (Miles)	Estimated Cost	Affected DUs	Lead DU
1	SHEI	Install a 2nd 115 kV line between Highgate and Georgia substations	Voltage collapse	Bulk	17	$70M	All Vermont DUs	GMP
2	SHEI	Replace Irasburg transformer	Transformer overload at Irasburg substation	Predom-inantly Bulk	N/A	$5M	All Vermont DUs	GMP
3	Essex-Tafts Corner-Williston 115 kV lines	Install a 2nd 115 kV line between Limekiln and Williston substations	115 kV and 34.5 kV line overloads between Essex and Queen City substations. Transformer overload at Queen City and Tafts Corner	Bulk	11	$60M	All Vermont DUs	GMP
4	Williston-New Haven 115 kV line	Rebuild 115 kV line between Williston and New Haven substations	115 kV line overload between Williston and New Haven substations.	Bulk	21	$90M	All Vermont DUs	GMP
5	Middlebury-Florence 115 kV line	Remove terminal limitation at Middlebury substation	115 kV line overload between Middlebury substation & Florence Tap.	Bulk	N/A	$1M	All Vermont DUs	GMP
6	New Haven	Replace New Haven transformer	Transformer overload at New Haven substation	Predom-inantly Bulk	N/A	$5M	All Vermont DUs	GMP
7	Middlebury	Replace Middlebury transformer	Transformer overload at Middlebury substation	Predom-inantly Bulk	N/A	$5M	All Vermont DUs	GMP
8	Hartford	Replace Hartford transformer	Transformer overload at Hartford substation	Predom-inantly Bulk	N/A	$5M	All Vermont DUs	GMP
9	Windsor	Replace Windsor transformer	Transformer overload at Windsor substation	Predom-inantly Bulk	N/A	$5M	All Vermont DUs	GMP

VELCO

No.	Location	Upgrade	Need	Category	Length (Miles)	Estimated Cost	Affected DUs	Lead DU
10	Gorge-McNeil 34.5 kV	Rebuild Gorge-McNeil 34.5 kV line	34.5 kV Line overloaded	Subsystem	2.3		GMP and BED	GMP
11	Ryegate-McIndoes 34.5 kV	Rebuild Ryegate-McIndoes 34.5 kV line	34.5 kV Line overloaded	Subsystem	2.0		GMP and NGRID	GMP
12	Ryegate	Replace Ryegate transformer	Transformer overload at Ryegate substation	Subsystem	N/A	$5M	GMP	GMP
13	Fairfax Falls-E Fairfax 34.5 kV	Rebuild Fairfax Falls-E Fairfax 34.5 kV line	34.5 kV Line overloaded	Subsystem	3.3		GMP and VEC	GMP
14	N Troy-Mosher's 46 kV	Rebuild North Troy-Mosher's tap 46 kV line	46 kV Line overloaded	Subsystem	1.8		VEC	VEC
15	Bethel-Woodstock 46 kV	Rebuild Bethel-Woodstock 46 kV line	46 kV Line overloaded	Subsystem	16.3		GMP	GMP
16	Smead Rd-E Pittsford 46 kV	Rebuild Smead Rd-E Pittsford 46 kV line	46 kV Line overloaded	Subsystem	20		GMP	GMP
17	Quechee-Windsor#4 46 kV	Rebuild Quechee-Windsor #4 46 kV line	46 kV Line overloaded	Subsystem	14		GMP	GMP
18	Windsor-Highbridge 46 kV	Rebuild Windsor-Highbridge 46 kV line	46 kV Line overloaded	Subsystem	6		GMP	GMP
19	Seminary St-Middlebry Hy 46 kV	Rebuild Seminary St-Middlebury Hy 46 kV line	46 kV Line overloaded	Subsystem	2.6		GMP	GMP
20	Weybridge-New Haven 46 kV	Rebuild Weybridge-New Haven 46 kV line	46 kV Line overloaded	Subsystem	5.1		GMP	GMP
21	Bradford-Wells River 46 kV	Rebuild Bradford-Wells River 46 kV line	46 kV Line overloaded	Subsystem	13		GMP	GMP
22	Hartford-Norwich 46 kV	Rebuild Hartford-Norwich 46 kV line	46 kV Line overloaded	Subsystem	0.2		GMP	GMP

Dynamic voltage support to address high voltage on subsystem

Location	Reactive Power Capacity (MVAr)	Notes
Milton	1.5	
Danville	0.5	
Ryegate	2.0	10 MW battery can resolve thermal overloads 12 and 21
Richmond/ Hinesburg	1.5	Most effective at VEC Hinesburg
Thetford	1.5	
Alburgh	2.5	3.5 MVAr at Highgate 3 MVAr at South Alburgh 2.5 MVAr at Alburgh-Swanton Tap
Sheldon	3.0	Most effective at Sheldon Springs
Bolton	0.5	Most effective at Bolton Falls
Woodstock	1.0	
Bethel/Chelsea/ Leicester/Pittsford	Bethel: 3.5 MVAr Smead Road: 4.0 MVAr Leicester: 1 MVAr Sherburne: 2.5 MVAr	

Batteries to address overloads of subsystem transformers serving distribution

Bus Name	Capacity (MW)
NORWICH UNIV	0.5
MOORE_D	0.5
HEWITT RD_D	5.5
LEICESTER_D	2.0
MIDDLEBRY_D1	10.0
MIDDLBURY_D2	7.5
QUECHEE	1.5
NORWICH_D	2.5

All batteries are assumed to have four hours of energy

Batteries to address bulk, predominantly bulk and subsystem concerns

Location	MW	MVAr	Cost (mil $)
Essex 115	150	-	
Lowell 46	15	12	
Crossroads 46	35	25	
Pleasant St 46	5	4	
Bethel 46	47.5	33.5	
Hartford 46	8	6	
Ryegate 46	10.5	3	
White River Jct 46	30	25	
Windsor V4 46	16	12	
Leicester 46	1.5	1	
Smead Road 46	45	34	
Agrimark Tap 46	1.5	0	
Fairfax Falls 34	8.5	6	
Johnson 34	6	4	
Websterville 34	3	2	
Ryegate 34	12	10	
McNeil Tap 34	20	15	
Tafts Corner 34	15	12	
Queen City 34	10	8	

Conclusions

- No bulk or predominantly bulk concerns to be addressed within 10 years
  - High load scenario has minimal effects
- Flagged several potential subsystem issues to be further evaluated by the DUs
- Base solar PV results showed more severe SHEI concerns, and an expansion of constraints south of Georgia
- High solar PV scenario will cause significant challenges
  - Not all renewable energy needs to be developed within Vermont
  - May be managed with careful planning, upgrades, demand side management, Storage, and other strategies
  - The right tools, requirements, and processes need to be put in place to achieve long term renewable energy goals