Green Peak Solar, LLC

VSPC Geotargeting Subcommittee
Use Models for Energy Storage

January 2017

Stacked Value Streams

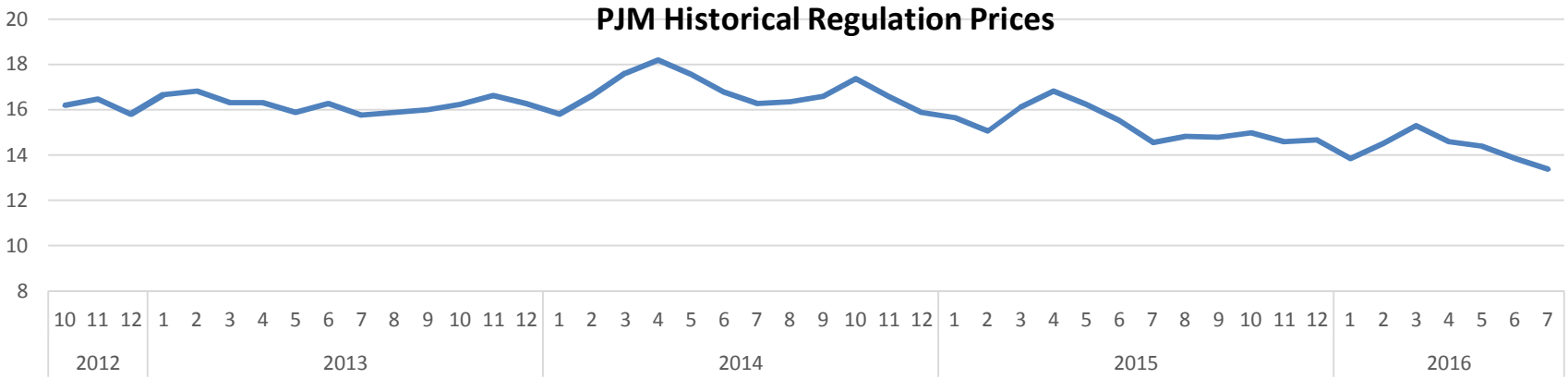
Use cases for Load Reducers (<5MW) leveraging deferred capacity, RNS, charges and "behind the meter" projects targeting demand charges

Projected Value Streams

- Frequency Regulation ISO-NE
- Capacity – based on ISONE Peak Load
- RNS Charges – based on VT Zone Peak Load
- Energy Arbitrage – opportunity for select arbitrage opportunities
- Demand Charge Reduction – a.k.a. economic DR
- Demand Response – utility or ISO specific
- Reliability (case by case) – depends on location of Project, nearby critical loads and protection scheme (difficult to implement and price at early stage)
- T&D Deferral (case by case) – very location dependent, locations are limited
- Tier III RECs – is there an opportunity for storage to qualify for Tier III?

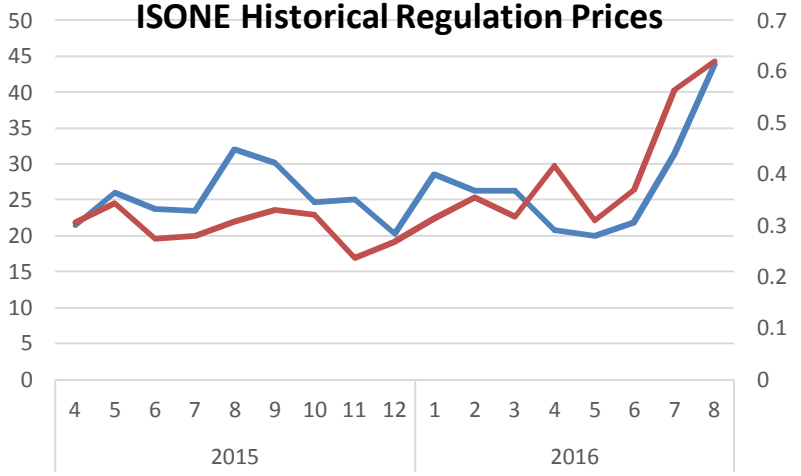
Frequency Regulation

Frequency regulation in ISO-NE is a merchant market with ~70MW of demand; advantage to first movers



Weekday Capacity Requirement

HE	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1	30	30	30	50	50	50	50	50	50	50	50	50
2	30	30	30	50	50	50	50	50	50	50	50	50
3	30	30	30	50	50	50	50	50	50	50	50	50
4	30	30	30	50	50	50	50	50	50	50	50	50
5	30	30	30	50	50	50	50	50	50	50	50	50
6	120	120	120	70	70	140	140	140	70	70	140	140
7	150	150	150	120	120	170	170	170	120	120	170	170
8	150	150	150	120	120	170	170	170	120	120	170	170
9	70	70	70	70	70	90	90	90	70	70	90	90
10	50	50	50	70	70	70	70	70	70	70	70	70
11	50	50	50	70	70	70	70	70	70	70	70	70
12	50	50	50	70	70	70	70	70	70	70	70	70
13	50	50	50	70	70	70	70	70	70	70	70	70
14	50	50	50	70	70	70	70	70	70	70	70	70
15	50	50	50	70	70	70	70	70	70	70	70	70
16	50	50	50	70	70	70	70	70	70	70	70	70
17	50	50	50	70	70	70	70	70	70	70	70	70
18	50	50	50	70	70	70	70	70	70	70	70	70
19	50	50	50	70	70	70	70	70	70	70	70	70
20	50	50	50	70	70	70	70	70	70	70	70	70
21	50	50	50	70	70	70	70	70	70	70	70	70
22	50	50	50	120	120	70	70	70	120	120	70	70
23	120	120	120	120	120	140	140	140	120	120	140	140
24	120	120	120	90	90	140	140	140	90	90	140	140



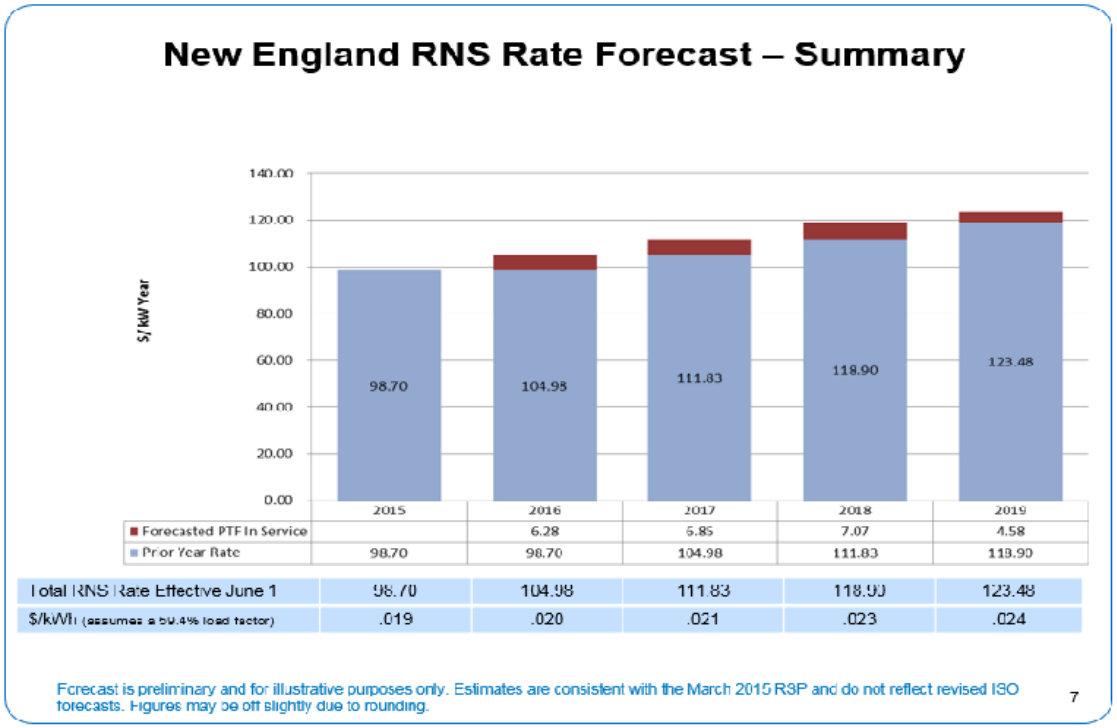
Capacity Component

Energy storage load reductions at the ISO Peak reduce capacity obligation (including reserve margin) – prices are expected to escalate

Capacity Forecast	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2018	$7.03	$7.03	$7.03	$7.03	$7.03	$9.55	$9.55	$9.55	$9.55	$9.55	$9.55	$9.55
2019	$9.55	$9.55	$9.55	$9.55	$9.55	$7.25	$7.25	$7.25	$7.25	$7.25	$7.25	$7.25
2020	$7.25	$7.25	$7.25	$7.25	$7.25	$8.00	$8.00	$8.00	$8.00	$8.00	$8.00	$8.00
2021	$8.00	$8.00	$8.00	$8.00	$8.00	$8.16	$8.16	$8.16	$8.16	$8.16	$8.16	$8.16
2022	$8.16	$8.16	$8.16	$8.16	$8.16	$8.32	$8.32	$8.32	$8.32	$8.32	$8.32	$8.32
2023	$8.32	$8.32	$8.32	$8.32	$8.32	$8.49	$8.49	$8.49	$8.49	$8.49	$8.49	$8.49
2024	$8.49	$8.49	$8.49	$8.49	$8.49	$8.66	$8.66	$8.66	$8.66	$8.66	$8.66	$8.66
2025	$8.66	$8.66	$8.66	$8.66	$8.66	$8.83	$8.83	$8.83	$8.83	$8.83	$8.83	$8.83
2026	$8.83	$8.83	$8.83	$8.83	$8.83	$9.01	$9.01	$9.01	$9.01	$9.01	$9.01	$9.01
2027	$9.01	$9.01	$9.01	$9.01	$9.01	$9.19	$9.19	$9.19	$9.19	$9.19	$9.19	$9.19
2028	$9.19	$9.19	$9.19	$9.19	$9.19	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37	$9.37
2029	$9.37	$9.37	$9.37	$9.37	$9.37	$9.56	$9.56	$9.56	$9.56	$9.56	$9.56	$9.56
2030	$9.56	$9.56	$9.56	$9.56	$9.56	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75	$9.75
2031	$9.75	$9.75	$9.75	$9.75	$9.75	$9.95	$9.95	$9.95	$9.95	$9.95	$9.95	$9.95
2032	$9.95	$9.95	$9.95	$9.95	$9.95	$10.15	$10.15	$10.15	$10.15	$10.15	$10.15	$10.15
2033	$10.15	$10.15	$10.15	$10.15	$10.15	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35	$10.35
2034	$10.35	$10.35	$10.35	$10.35	$10.35	$10.56	$10.56	$10.56	$10.56	$10.56	$10.56	$10.56
2035	$10.56	$10.56	$10.56	$10.56	$10.56	$10.77	$10.77	$10.77	$10.77	$10.77	$10.77	$10.77
2036	$10.77	$10.77	$10.77	$10.77	$10.77	$10.98	$10.98	$10.98	$10.98	$10.98	$10.98	$10.98
2037	$10.98	$10.98	$10.98	$10.98	$10.98	$11.20	$11.20	$11.20	$11.20	$11.20	$11.20	$11.20
2038	$11.20	$11.20	$11.20	$11.20	$11.20	$11.43	$11.43	$11.43	$11.43	$11.43	$11.43	$11.43
2039	$11.43	$11.43	$11.43	$11.43	$11.43	$11.65	$11.65	$11.65	$11.65	$11.65	$11.65	$11.65
2040	$11.65	$11.65	$11.65	$11.65	$11.65	$11.89	$11.89	$11.89	$11.89	$11.89	$11.89	$11.89
2041	$11.89	$11.89	$11.89	$11.89	$11.89	$12.13	$12.13	$12.13	$12.13	$12.13	$12.13	$12.13
2042	$12.13	$12.13	$12.13	$12.13	$12.13	$12.37	$12.37	$12.37	$12.37	$12.37	$12.37	$12.37
Levelized	**$9.11**	**$9.11**	**$9.11**	**$9.11**	**$9.11**	**$9.34**	**$9.34**	**$9.34**	**$9.34**	**$9.34**	**$9.34**	**$9.34**

RNS Component

Energy storage load reductions during the Vermont peak hour reduce Vermont's proportion of RNS costs – prices expected to escalate



Year	RNS ($/kW-year)	Growth Rate
2015	$98.7	n/a
2016	$105.0	6%
2017	$111.8	7%
2018	$118.9	6%
2019	$123.5	4%
2020	$128.2	4%
2021	$133.2	4%
2022	$138.3	4%
2023	$143.6	4%
2024	$149.2	4%
2025	$154.9	4%
2026	$160.9	4%
2027	$167.1	4%
2028	$173.5	4%
2029	$180.2	4%
2030	$187.1	4%
2031	$194.3	4%
2032	$201.8	4%
2033	$209.6	4%
2034	$217.7	4%
2035	$226.1	4%
2036	$234.8	4%
2037	$243.8	4%
2038	$253.2	4%
2039	$263.0	4%
2040	$273.1	4%
2041	$283.6	4%
2042	$294.5	4%
Levelized 2018-42	**$171.45**	**($/kW-yr)**
Levelized 2018-42	**$14.29**	**($/kW-mo)**

Predicting Peak

Vermont Peaks are moving faster than ISO-NE Peaks, use case assumes that load reduction is greater for months that are more predictable

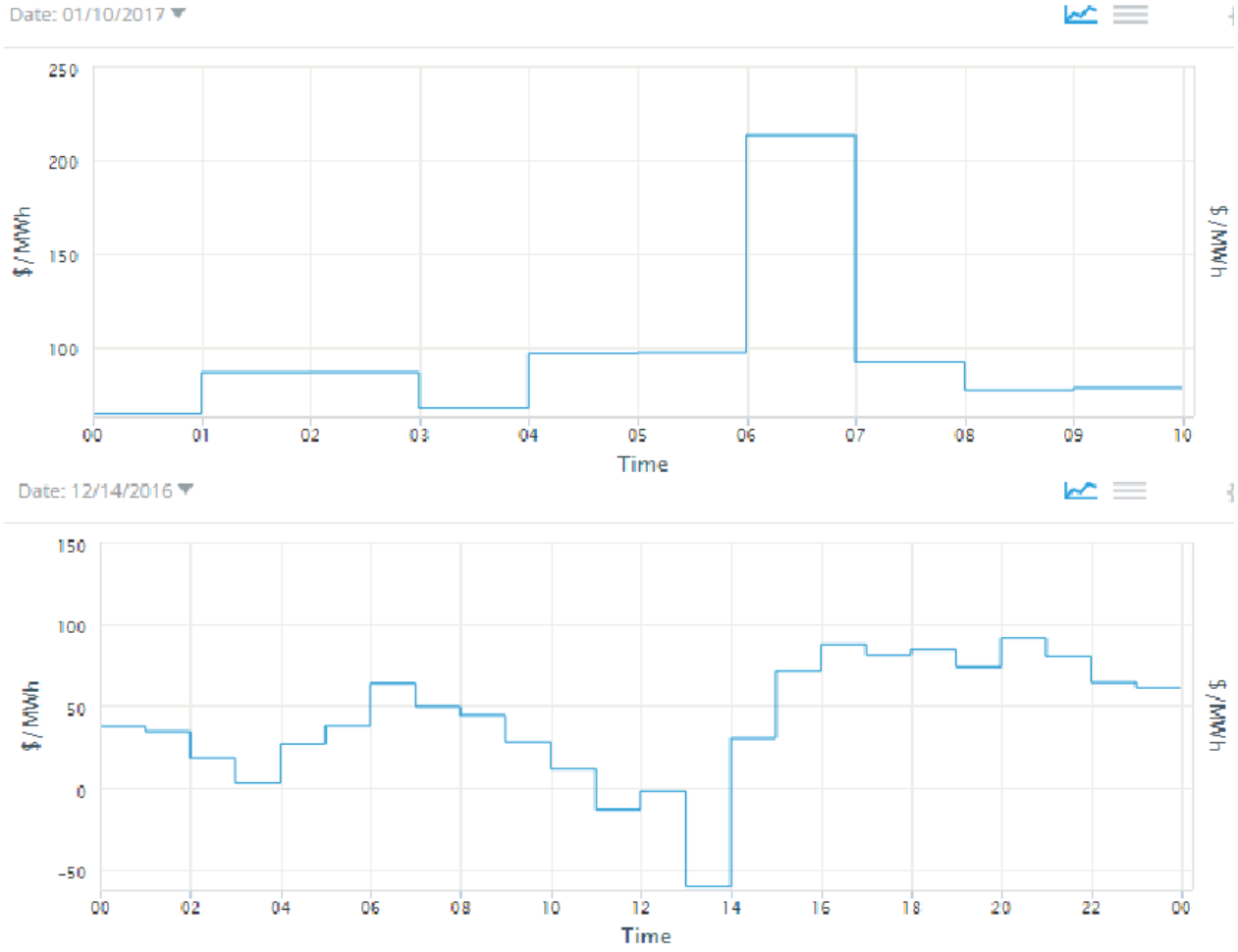
VT Peak Hour By Month (2012 - 2016)												
Year/Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2012	18	19	19	20	14	16	16	15	15	19	19	18
2013	18	19	19	21	16	14	14	18	17	19	18	18
2014	18	19	19	21	21	19	14	19	20	19	18	18
2015	18	19	19	21	16	19	18	21	20	19	18	18
2016	18	19	19	21	21							
Average Hour	**18.0**	**19.0**	**19.0**	**20.8**	**17.6**	**17.0**	**15.5**	**18.3**	**18.0**	**19.0**	**18.3**	**18.0**
Range	**0**	**0**	**0**	**1**	**7**	**5**	**4**	**6**	**5**	**0**	**1**	**0**

ISO-NE Peak Hour By Month (2012-2016)												
Year/Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
2012	18	19	19	15	17	17	17	16	16	19	18	18
2013	19	19	19	20	17	17	17	17	17	19	18	18
2014	19	19	19	20	14	17	15	17	15	19	18	18
2015	18	19	19	20	17	16	17	15	16	19	18	18
2016	19	18	19	20	18							
Average Hour	**18.6**	**18.8**	**19.0**	**19.0**	**16.6**	**16.8**	**16.5**	**16.3**	**16.0**	**19.0**	**18.0**	**18.0**
Range	**1**	**1**	**0**	**5**	**4**	**1**	**2**	**2**	**2**	**0**	**0**	**0**

Projected Peak Coincidence by Month												
Month	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
RNS Performance (kw-Month)	5000	5000	5000	2500	1000	5000	1667	2500	5000	5000	5000	5000

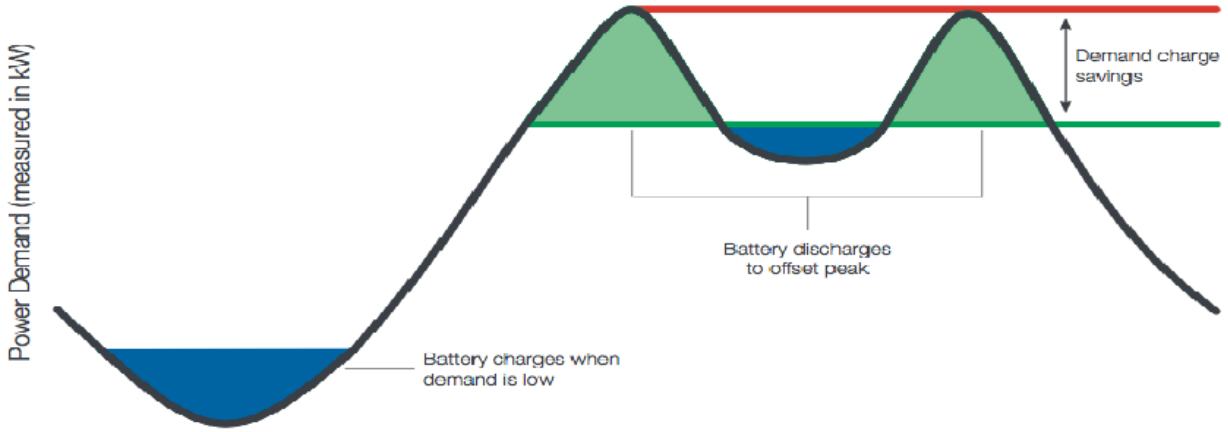
Energy Arbitrage

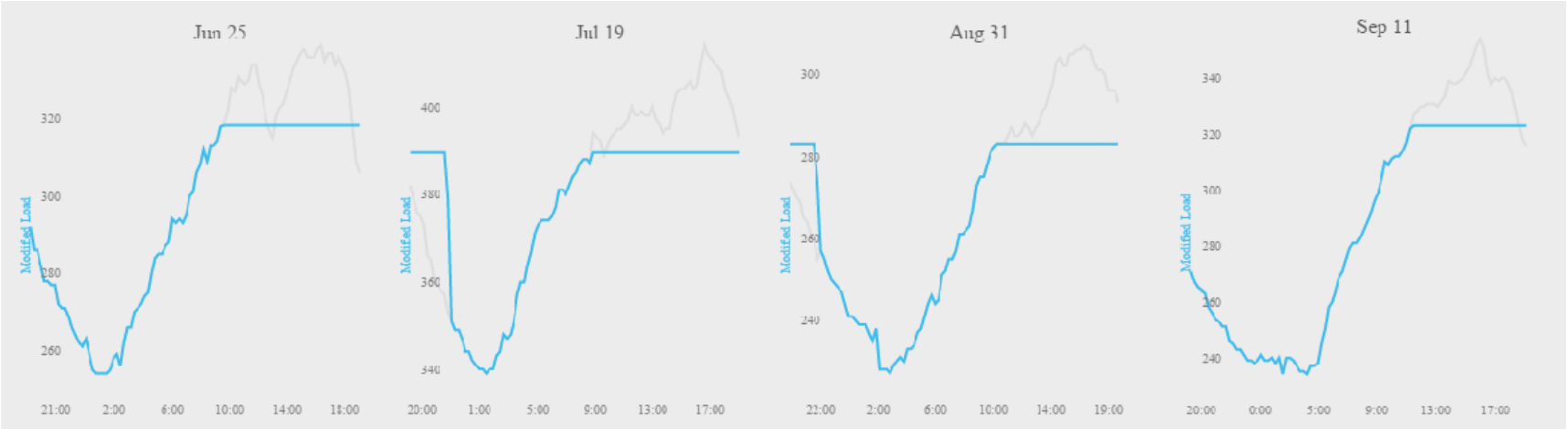
For most hours price differentials are less than energy storage round trip efficiency. Select opportunities for arbitrage exist, mostly in winter.



Demand Charge Management

Energy storage is used to reduce peak demand, thereby reducing customers demand charges – rule of thumb >$20/kw-mo





Demand Response

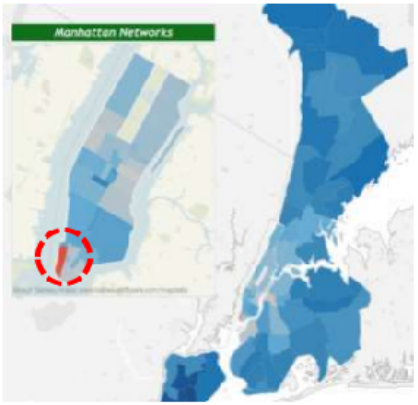
As utility and ISO demand response programs become available to energy storage, participation is expected to increase

- Example programs include Con Edison BQDM, DLRP & CSRP and NYISO EDRP & SCR Programs

Qualifying Neighborhoods in Brooklyn & Queens Program

Distribution Load Relief Program – 2 Hr Notification Program

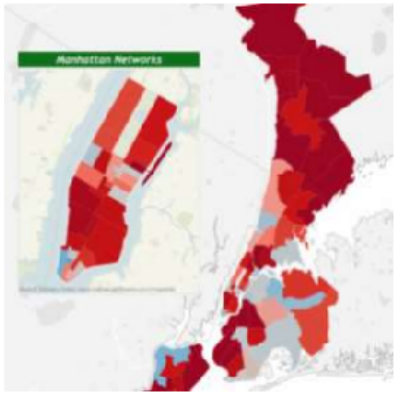
- Called on a network basis for contingencies



- Premium paid for 10 networks with higher need for demand response ("Tier 2" networks)

Commercial System Relief Program – 21 Hr Notification Program

- Called for network peak shaving



- 4 call windows to coincide with network peaks
- 3 events per year expected on average

5

Tier III Compliance

Potential for carbon emission reduction exists for energy storage replacing traditional frequency regulation assets.

"Examples of energy transformation projects may include …infrastructure for the storage of renewable energy on the electric grid." – VT Act 56

Battery → ISO new england ← Nat Gas

Frequency Regulation

Supply:

55% Renewable per RES increasing to 75%

Supply:

100% Thermal