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Massachusetts Department of Energy Resources

February 7, 2019

Subject: Clean Peak Energy Portfolio Standard (CPS) Stakeholder Questions

Thank you for the opportunity to provide feedback on Clean Peak Energy Portfolio Standard Stakeholder Questions. In addition to our responses provided to the Stakeholder Questionnaire, we would like highlight some of the special benefits thermal energy storage systems can provide as a Clean Peak Resource.

Thermal energy storage (TES) can time shift significant electrical demand to better utilize clean generation resources and relieve system peaks. Depending on the specific technology, it allows excess thermal energy to be stored and used hours to days later, at scales ranging from individual process, building, district, or town.

TES uses standard cooling or heating equipment, plus an energy storage tank to shift all or a portion of a building's thermal energy needs to more favorable production periods (e.g. off-peak periods when system demand and energy costs are lower and/or when the electric grid's marginal emission intensity is more favorable).

When compared to the project unit costs ($/kWh) for the Massachusetts Energy Storage Initiative, TES is highly competitive with large projects expected in the $300/kWh range. Thermal Energy Storage can be easily located in dense urban load pockets, it is capable of high ramp rates (e.g. 3-4 MW), long output durations (9-10 MWh equivalent), and unlike the more common electrical energy storage systems such as lithium ion, TES systems have 40-50 year operating lifespans with essentially no degradation in either system capacity or output rate over time.

Lastly, thermal energy storage systems can achieve round-trip efficiencies of up to 100% or higher under certain conditions when compared to producing the equivalent thermal energy to meet real-time demand. As an example, during summer peak electric demand periods, the significant difference in wet-bulb temperatures between overnight hours and late afternoon, combined with negligible round-trip efficiency losses, allows chilled water to be produced off-peak and stored for on-peak using less energy than generating chilled water to meet real-time demand. This type of time-shifting energy arbitrage captures the difference in thermal energy production efficiencies in a way traditional electric energy storage systems cannot achieve as electric energy storage efficiencies are largely unchanged by ambient conditions. Unlike electric energy storage systems which can shift energy generated outside of Clean Peak periods, but ultimately increase net energy consumption, thermal energy systems both move clean energy into peak periods and can reduce net grid consumption. For all of the above reasons, we encourage the Department to comprehensively include thermal energy storage systems as a valuable Clean Peak Resource.

We appreciate the opportunity to provide the following comments present inline to the CPS Stakeholder Questionnaire. It is our hope that these responses assist the DOER in developing a CPS that appropriately balances the need for programmatic simplicity without compromising rate payer savings and verifiable emission reductions. As reflected by the complexity of the stakeholder questions, achieving this outcome is not a trivial process.

Should you have questions on the content of this letter, we would be happy to discuss further at your convenience.

Sincerely,

Michael Macrae
Harvard Engineering & Utilities
Energy Analytics Manager

Clean Peak Standard (CPS) Draft Stakeholder Questions

Definitions of Key Terms

Clean Peak Resource

Clean peak resource is defined as "a qualified RPS resource, a qualified energy storage system or a demand response resource that generates, dispatches or discharges electricity to the electric distribution system during seasonal peak periods, or alternatively, reduces load on said system."

1. Should only resources interconnected to the electric distribution system be eligible to qualify, or should resources connected to the transmission system also be eligible to qualify?
2. Should DOER interpret the use of the term "electric distribution system" to mean that only facilities on the electric distribution system in the Commonwealth should be eligible to qualify as clean peak resources under the CPS? Should the CPS also include all distribution and/or transmission level resources connected in the ISO-NE control area? Should it include adjacent Control Areas such as NYISO, Quebec, or New Brunswick?

Response:

Yes - Resources that otherwise meet the eligibility requirements of the Clean Peak Standard should be allowed to connect at the distribution and transmission levels.

- 1: Both distribution and transmission level resources should be evaluated for qualification under the Clean Peak Standard. Further evaluation cost effectiveness of each connection type to ratepayer costs and verifiable emission reductions is necessary.
    - DOER should consider a "distributed generation adder" similar to how ISO-NE applies a demand resource gross-up for transmission & distribution loss factors.[1]
    - DOER should consider a "transmission scale adder" if it is determined that factors such as economy of scale for larger transmission level resources provide a net benefit to rate payers.
- 2: Clean Peak Resources connected to a microgrid connected to the distribution system should qualify as they will accomplish the same functional result – reducing load on the system and/or providing clean generation. This appears consistent with the definition of Distributed Generation in Chapter 164, Section 1:

    "Distributed generation'', a generation facility or renewable energy facility connected directly to distribution facilities <u>or to retail customer facilities</u> which alleviate or avoid transmission or distribution constraints or the installation of new transmission facilities or distribution facilities.
- 2: If resources outside of the Commonwealth are excluded from CPS eligibility, rigorous analysis should be provided that the program is not arbitrarily excluding the least-cost resources to reduce ISO system peak loads, and the associated wholesale costs, system emissions, etc.
- 2: For resources outside of the ISO-NE control area, the DOER should consider how to determine if the unit was contributing to the amount of power being imported to ISO-NE (or reducing the amount of power exported). If during a Clean Peak Period (CPP) a resource outside the ISO-NE area is effectively reducing system demand within the ISO-NE control area, it should be evaluated as to if it can provide a least-cost option for program compliance. One potential complication could arise regarding REC or Clean Peak Credit tracking as other attribute tracking systems may not make the necessary updates required of the CPS.

[1] *Amended Avoided Energy Supply Components in New England 2018 Report,* *www.synapse-energy.com/sites/default/files/AESC-2018-17-080.pdf*

Demand Response Resource

Demand response resource is defined as "changes in electric usage by end-use customers in the commonwealth from their normal consumption patterns in response to: (i) changes in the price of electricity over time, including, but not limited to, time-of-use rates for residential and small commercial and industrial customers; or (ii) incentive payments designed to induce lower electricity use at times of high wholesale market prices or when system reliability is jeopardized."

3. What types of resources should be included in this definition?
4. Should electric vehicles (EVs) qualify?
5. How should DOER interpret the inclusion of different types of rate designs in this definition?
6. Should this definition only be limited to active demand response?
7. Should standalone energy storage resources (i.e. not directly connected to another resource type) be eligible to qualify as demand response resources? What requirements, if any should standalone energy storage resources face in order to qualify as demand response resources?
8. Should the DOER view thermal storage facilities as a Demand Response Resource? What requirements, if any, should thermal storage facilities face in order to qualify as demand response resources?

Response:

- 3 & 6: Both new Active and Passive Demand Resources (as defined by ISO-NE, excluding emitting resources like diesel generators, fossil-fuel fired fuel cells, etc.) should be considered for the program as they both are able to provide either electricity to the grid during seasonal peak periods, or alternatively, reduces load on said system. The CPS standard should reference the established ISO-NE market rules used to determine the contributions of such resources.[2] Avoided energy use frequently provides the greatest benefit and future development of such resources should be encouraged by the CPS.
- 6: The CPS should not outright exclude the electricity savings produced by passive demand resources. Consideration should be given, however, to the point that the ISO treats passive demand response as a Capacity-Only resource (i.e. not an energy market resource) whereas the CPS design as currently proposed appears to be more of an Energy Market program, awarding Clean Peak Credits (CPCs) to actual generation during Clean Peak Periods (CPPs).
- 7: Yes, standalone energy storage resources should be eligible to qualify as demand response resources. However, as most energy storage systems result in a net increase in grid energy consumption due to round trip efficiency losses, the DOER must verify that charging does not also result in a net increase in system emissions. *Energy storage frequently increase net system emissions*[3]. While acquisition of RECs by an energy storage system facility would allow them to claim use of renewable energy, it is entirely unclear if this claim would have any correlation with actual system emissions.
  To ensure the CPS results in verifiable emission reductions, the DOER needs to evaluate the impacts of energy storage using appropriately granular interval data (i.e. at a minimum hourly) of system *marginal* emission intensity. ISO-NE currently provides real-time marginal fuel type data, but it is unclear if it is "market settlement-grade" data at this time.
- 8: Thermal storage facilities should not be considered separately or distinct from any type of energy storage system with respect to qualification as a CPS Demand Resource. The definition provided for "Energy Storage System" in *Chapter 164, Section 1* supports this approach.

[2] ISO Manual M-MVDR: Measurement and Verification of Demand Reduction Value from Demand Resources and ISO Manual M-RPA: Registration and Performance Auditing. ISO Operating Procedure No. 14: Technical Requirement for Generators, Demand Resources, Asset Related Demands, and Alternative Technology Regulation Resources. ISO Operating Procedure No. 18: Metering and Telemetering Criteria

[3] Bulk Energy Storage Increases United States Electricity System Emissions, *Environ. Sci. Technol*. **2015**; The impacts of storing solar energy in the home to reduce reliance on the utility, *Nature Energy* **2017**

"…an energy storage system shall: (1) use mechanical, chemical or thermal processes to store energy that was generated for use at a later time; (2) <u>store thermal energy for direct heating or cooling use at a later time in a manner that avoids the need to use electricity at that later time</u>;…"

- General: The language in "(i)" is unclear about which customer classes are included. Clarification that both small, medium, and large C&I customers would be eligible in addition to residential customers is needed.

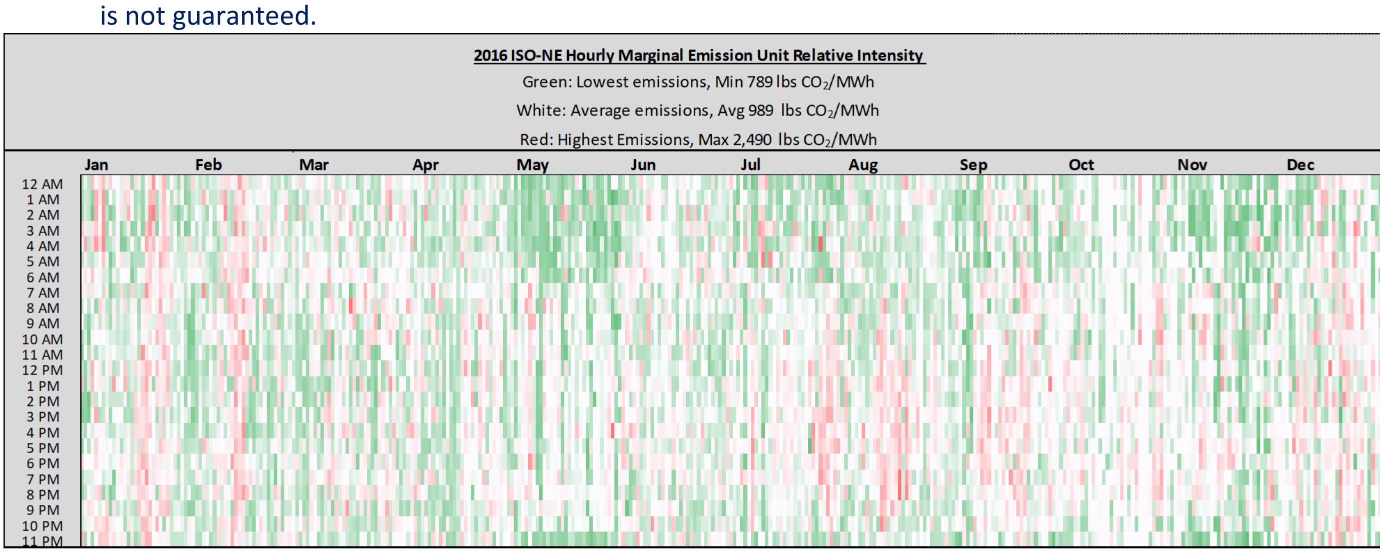
<u>Qualified Energy Storage System</u>

Qualified energy storage system is defined as "an energy storage system, as defined in section 1 of chapter 164, that commenced commercial operation or provided incremental new capacity at an existing energy storage system on or after January 1, 2019; provided, however, that such system operates primarily to store and discharge renewable energy as defined in said section 1 of said chapter 164."

9. How should DOER define what constitutes "incremental new capacity at an existing energy storage system"?
10. How should DOER interpret the requirement that a Qualified Energy Storage System operate "primarily to store and discharge renewable energy"?
    a. Would alignment with the federal ITC requirement that storage is eligible for a credit as long as the battery is charged by a renewable energy system more than 75 percent of the time be appropriate?
    b. If not directly physically or electrically connected to a renewable energy resource, how can the qualified energy storage system demonstrate that it operates primarily to store and discharge renewable energy? Purchase and retirement of RECs? Some other means?
11. How should DOER view thermal storage facilities with respect to eligibility as a qualified energy storage system?

<u>Responses:</u>

- General: The DOER should carefully consider the impacts that the CPS will have regarding energy storage systems on net grid emissions. While increased deployment of storage could allow for greater energy arbitrage, thereby increasing the energy delivered to the electric grid from off-peak to on-peak demand periods, it is unclear that this will result in a net reduction in emissions from the electric sector.[4] Based on the illustrative heat map below depicting hourly averaged marginal emission intensities, Energy storage could move energy from lower marginal emitting units into periods with higher marginal emissions, but this is not guaranteed.



[4] Bulk Energy Storage Increases United States Electricity System Emissions, *Environ. Sci. Technol*. **2015**; The impacts of storing solar energy in the home to reduce reliance on the utility, *Nature Energy* **2017**;

- We propose that the DOER expand their consideration of the question "*if energy storage systems are not directly connected to a renewable resource are they able to operate in a manner so as to 'primarily to store and discharge renewable energy*'" to evaluate the actual emission impacts using marginal emission data. In doing so, the DOER should evaluate if there a sufficient difference in the marginal carbon intensity between off-peak and on-peak so as to make up for the round-trip efficiency losses inherit to storage. Even if the transfer of RECs between an RPS resource and an energy storage resource is allowed under the CPS, the marginal unit on the electric grid system will supply the incremental load to charge a battery and currently renewable resources are not marginal at a meaningful frequency.[5] Thus, the actual impact of energy storage appears to be the arbitrage of energy and emissions from the predominately fossil combustion resources supplying marginal load from one period to another.
  The following examples are provided as an illustrative process of how the DOER might evaluate this question:
    - The *2016 ISO-NE Air Emissions Report*[6] indicates the average marginal emission intensity was 1,007 lbs CO_2/MWh.[7]
    - The marginal emission intensity during clean peak periods would thus need to be at least 1,057 – 1,208 lbs CO_2/MWh for an energy storage system with 5-20% round-trip efficiency losses to result in no net increase in emissions from the annual average value. The on peak emissions would need to be higher than this range to yield any actual emission reduction.
    - In reviewing the ISO-NE *2016 Marginal Real-time CO_2 Emission Rate* report[8], showing marginal CO_2 emissions rate (lb/MWh) for 2016 in 5 minute intervals, it is unclear if low enough off-peak marginal emission rates and high enough on-peak marginal rates exist for storage to effectively reduce emissions.
    - Absent a real-time signal from ISO-NE indicating the marginal fuel type and appropriate time-level metering, it is unclear how a standalone grid connected energy storage system could verifiably deliver net emission reductions. Narrowly, while the emissions from energy provided during a clean peak period may be lower due to energy storage, the Clean Peak Standard could fall short of providing actual seasonal or annual net electric system emissions without correctly addressing this point.[9]

- 10b: With respect to interpreting the requirement "*…that a Qualified Energy Storage System operate "primarily to store and discharge renewable energy*",
    - If ownership and retirement of a Renewable Energy Certificate allows retail sellers of electricity to "*obtain a percentage of the electricity they serve to their customers from qualifying renewable energy facilities*."[10], does this also mean energy storage system operators could similarly utilize REC ownership and retirement to demonstrate their storage system operates *"primarily to store and discharge renewable energy*" even when not physically connected to Renewable Generating units

[5] See "2018 Spring Quarterly Markets Report", https://www.iso-ne.com/markets-operations/market-monitoring-mitigation/internal-monitor/. Also see Figure 13 in the Supplemental Figures.
[6] https://www.iso-ne.com/system-planning/system-plans-studies/emissions/
[7] The draft 2017 *Air Emission Report* includes an important update underway with the ISO, namely that previous reports grossly overstate the frequency wind as a marginal resource (see footnote 18 in the Draft *2017 Annual Air Emission Report*)
[8] https://www.iso-ne.com/committees/planning/environmental-advisory/ (see: "*2016 Marginal Real-time CO2 Emission Rate*" showing average marginal CO2 emissions rate (lb/MWh), for 2016 in 5 minute intervals.)
[9] Bulk Energy Storage Increases United States Electricity System Emissions. *Environmental Science and Technology*, **2015**; Estimating the Quantity of Wind and Solar Required To Displace Storage-Induced Emissions. *Environmental Science & Technology* **2017;** Tradeoffs between revenue and emissions in energy storage operation. *Energy*. **2017;** How much wind and solar are needed to realize emissions benefits from storage? *Energy Systems*. **2017;** Carbon dioxide emissions effects of grid-scale electricity storage in a decarbonizing power system. *Environmental Research Letters*. **2018;** *Managing the Future of Energy Storage.* **2018**; Parameters driving environmental performance of energy storage across grid applications. *Journal of Energy Storage* **2017**
[10] https://www.mass.gov/service-details/program-summaries

and instead charging from output of marginal unit serving the grid? Or is the RPS policy more appropriate for annualized accounting of renewable energy where the focus is on the attributes of energy delivered and not the consequences of energy arbitrage?

  - For storage to be effective as part of a Clean Peak Standard, the interaction between the timing of Renewable Energy generation and timing of storage charging might be important in a way that is not relevant for an annual RPS obligation (particularly in that it that allows banking RECs up to two years). If a REC-like instrument could be created that includes hourly generation details, retirement of such certificates matched against hourly energy storage charging could demonstrate storage charged when Renewable Energy was being produced. However, as RPS resources (e.g. wind, solar, etc.) are not currently marginal resources at a meaningful frequency[11], the increased energy demand from energy storage resources will presumably be met predominately by fossil gas, oil, and coal resources.
  - With this in mind, the DOER should rigorously evaluate if cost effective, verifiable emission reductions can be achieved by energy storage systems not directly connected to a renewable resource. To do so appears to require storage show it charges only when grid marginal emission intensity is comparatively low and discharges energy when the marginal emission intensity is sufficiently high enough to mitigate the increase in emissions resulting from round trip efficiency losses. A real-time, settlement-grade signal from ISO-NE detailing the unit-specific emission intensity of the marginal unit serving the load zone, capacity zone, p-node, etc. in which the energy storage resource is located would be a requirement. Currently the ISO provides the marginal fuel type based on the system Locational Marginal Price[12]. Further refinement of this signal would be necessary to appropriately meet the CPS requirements (provide marginal unit emissions, weighted by contribution to system load, not LMP; provide marginal unit by capacity zone, load zone, p-node, etc.; provide plant-specific emission proxy using historic on peak/off peak emission intensity by month; etc.)
  - Is the effective "cost of carbon" necessary to incentivize energy storage system operators to co-optimize costs (i.e. demand charge avoidance, TOU rates, etc.) and emission savings competitive with established social costs of carbon (e.g. EPA social cost of carbon)?[13]

- 10: It is presumed that the CPS aims to reduce net electric grid emissions, but it appears some resources identified as renewable energy generation may not be consistent with this objective.
  - *'Renewable Energy'* per Chapter 164, Section 1 is defined in part as "*…fuel cells; landfill gas; waste-to-energy…*" and "*…that renewable energy supplies shall not include coal, oil, natural gas except when used in fuel cells, and nuclear power.*" Inclusion of Fuel Cells and Waste to Energy appears problematic if clean power generation (i.e. CO_2, NO_x, SO_x, PM, etc. emissions less than coal, oil, natural gas, etc.) is desired as part of the CPS.
  - Waste-to-energy facilities have some of the highest emissions of any combustion-based electric generation[14] and the DOER is encouraged to consider exactly how and why WTE facilities should be

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[11] See "2018 Spring Quarterly Markets Report", https://www.iso-ne.com/markets-operations/market-monitoring-mitigation/internal-monitor/

[12] ISO-NE Web Services Data, https://www.iso-ne.com/participate/support/web-services-data/

[13] Unintended Effects of Residential Energy Storage on Emissions from the Electric Power System, *Environ. Sci. Technol.* ***2018***

[14] See NEPOOL-GIS reports detailing "Carbon Dioxide (lbs/MWh)" for the Waste-to-energy facilities in ISO-NE territory. The values range from 2,800 – 3,900 lbs CO_2/ MWh. Also note that State-level heat-content data for municipal solid waste streams are not readily available. However, the EPA publishes an annual report detailing the national average content of municipal solid waste, by weight. The Energy Information Agency has converted that data into a biogenic fraction by heat content. According to their analysis, about half of the heat content of municipal solid waste is biogenic. Thus even discounting the biogenic portion, the emission profile of WTE is still comparable to coal. See Energy Information Agency, September 18, 2012, http://www.eia.gov/todayinenergy/detail.cfm?id=8010. See also Energy Information Agency, April 8, 2016, http://www.eia.gov/todayinenergy/detail.cfm?id=25732.

allowed to contribute to the CPS when they can and do emit CO_2 at double the rate of a coal facility. Furthermore, it should be evaluated how frequently WTE power generating facilities face curtailment such that an energy storage system would allow for beneficial energy arbitrage.

  - Fuel cells powered by natural gas do not appear to provide any emission benefit when compared to new combined cycle natural gas fired turbines or combined heat and power (CHP) generation units. (Supporting details available on request). If Fuel Cells burning fossil natural gas are considered "renewable energy" and are allowed to provide said energy to qualified energy storage systems, but have comparable or worse emission profiles to CHP units, would CHP also be eligible as a CPS Resource and able to provide renewable energy to storage? If not, please provide clarification why they are excluded when fuel cells powered by fossil natural gas are included.
  - Net emissions can vary considerably among types of biomass-derived fuels (taking into account the feedstock and the technologies used for energy conversion). A power plant burning woody biomass can emit more CO_2 per megawatt-hour at the stack than a coal-fired power plant. Even when biomass fuel is sourced from true forestry residues, such as tops and limbs that would otherwise have been left to decompose in the forest, rather than whole trees, cumulative CO_2 emissions can be greater than fossil emissions for decades.[15] In addition, biomass power plants are significant sources of conventional pollutants such as NO_x, SO_2, and particulates as well as hazardous air pollutants.[16] Generating additional power from biomass fuels during peak demand periods could exacerbate air pollution problems, especially in the summer when air pollution levels are highest. Bioenergy requires careful carbon accounting to determine net emission impacts and should not be included as eligible generation for the Clean Peak Standard unless it provides a significant net emissions reduction benefit.

- 11: Thermal energy storage facilities that utilize electricity as their primary energy source should be subject to the same requirements as other energy storage systems. However, unlike electrical energy generally generated far from load, thermal energy must be produced, stored, and used in close proximity to load. Given the unique opportunities for increased efficiency and energy arbitrage from off-peak to on-peak periods that thermal storage provides, allowing thermal energy storage systems "not directly physically or electrically connected to a renewable energy resource" to demonstrate they primarily store and discharge renewable energy is both necessary and appropriate. Additionally, as thermal energy storage systems can have round trip efficiencies much higher[17] than electric storage systems, the effective marginal emission intensity range that can produce verifiable emission reductions from thermal energy arbitrage is more favorable.

<u>Qualified RPS Resource</u>

Qualified RPS Resource is defined as "a renewable energy generating source, as defined in subsection (c) or in subsection (d) of section 11F that has: (i) installed a qualified energy storage system at its facility; or (ii) commenced commercial operation on or after January 1, 2019."

12. Given the requirement that RPS resources that commenced commercial operation prior to 2019 must be paired with a qualified energy storage system in order to qualify for the CPS, what, if any, requirements should DOER adopt regarding how much energy storage needs to be installed?
    a. Should there be a minimum percentage threshold on the ratio of the size of the energy storage to the size of the renewable resource (e.g. minimum installed storage capacity equal to 25% or more than installed renewable capacity)?

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[15] Not carbon neutral: Assessing the net emissions impact of residues burned for bioenergy. *Envir. Research Letters*, **2018**

[16] Trees, Trash, and Toxics: How Biomass Energy Has Become the New Coal. http://www.pfpi.net/wp-content/uploads/2014/04/PFPI-Biomass-is-the-New-Coal-April-2-2014.pdf

[17] Energy Storage: A need for the grid (and for microgrids), an opportunity for district energy, *District Energy*, **2017**: http://www.districtenergy-digital.org/districtenergy/2017q2?pg=8#pg8

13. With respect the quantity of its capacity that a Qualified RPS Resource can qualify under the CPS, should the DOER discount a Qualified RPS Resource's eligible capacity based on the capacity it can supply through the duration of each seasonal peak period (e.g. a 2 MW solar resource that can only provide 50% of its capacity value over the peak period would qualify as a 1 MW facility)?
14. Should DOER adopt any additional requirements regarding the CPS eligibility of renewable energy generating sources as defined in subsection (c) or in subsection (d) of section 11F (e.g. emissions thresholds, fuel sourcing, etc.)?

Responses:

- 12: The qualification of existing (i.e. pre-2019) RPS resources as CPS resources via the installation of energy storage should not allow arbitrary eligibility or windfall profits to existing resources. Criteria such enabling the delivery of clean energy for the duration of the Clean Peak Period should be considered in addition to a minimum size threshold.
- 12: In addition to considering energy storage capacity requirements, attention to the ability of the RPS resource plus energy storage system to actually provide power to the system during Clean Peak Periods is necessary and relevant. If the RPS resource is already subject to export constraints during Clean Peak Periods, how would adding energy storage provide any additional benefit under the CPS? Should any qualified RPS resource, regardless of the commercial operation date or presence of an energy storage system, located in an export constrained zone qualify as a CPS resource? Would that qualification potentially change depending on binding constraints on the transmission system? How should RE generators located in zones that are export constrained only during one (i.e. summer peak), but not necessarily during other (i.e. shoulder seasons or winter) seasonal peak be qualified?
- 12: It is unclear what is more important to reducing rate payer costs while delivering verifiable emission reductions when considering storage capacity, instantaneous output rating or duration? Does a 1 MW, 16 MWh battery provide the same Clean Peak emission and cost savings as a 2 MW, 8 MWh battery if the Clean Peak Periods are to be 1-4 hours in duration? Requiring a '*minimum percentage threshold based on the ratio of the size of the energy storage to the size of the renewable resource*' may not entirely capture the necessary metrics to fully assess the value energy storage brings to existing RPS resource eligibility for CPS participation. This analysis should be considered as part of the initial CPS program deployment, as well as periodically revisited to ensure the program is providing the most value.
- 13: It is unclear why the quantity of capacity that an RPS Resource could qualify under the CPS is important, instead of simply evaluating the resource solely on the basic of energy production during Clean Peak Periods and subsequently awarding Clean Peak Certificates based on that output.

Seasonal Peak Periods

Establishing Seasonal Peak Periods

DOER is required to establish seasonal peak periods, which are defined by that statute as "the daily time windows during any of the 4 annual seasons when the net demand of electricity is the highest; provided however, that a seasonal peak period shall be not less than 1 hour and not longer than 4 hours in any season, as determined by the department."

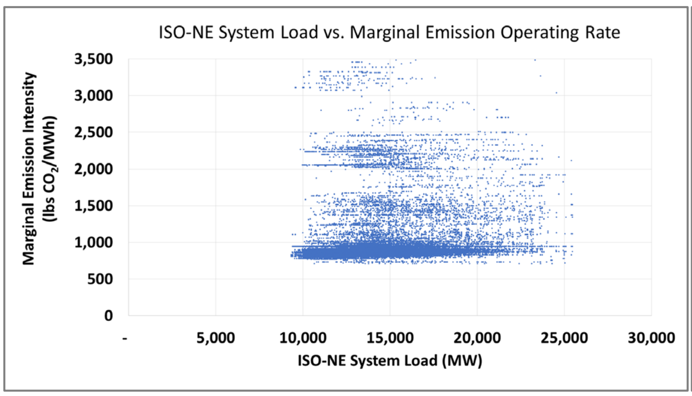
15. Given these limitations, how should DOER establish different seasonal peak periods to both optimize cost reductions for ratepayers and emissions reductions for the Commonwealth?
16. DOER is considering announcing seasonal peak periods on an annual basis based on 1 to 3 years of historical data.
    a. What formula should DOER use to set the seasonal peak periods to reflect real time operating conditions?
    b. What data sources should DOER use to determine seasonal peak periods?
    c. What time period(s) should each of the 4 annual peak periods cover?

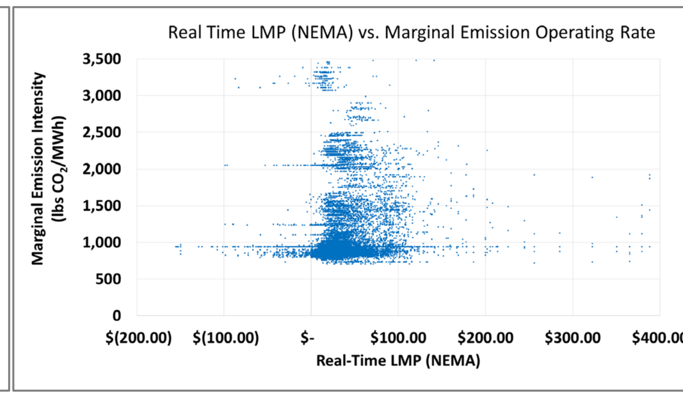
d. Should seasonal peak periods be different lengths depending on the season?
e. How often should the seasonal peak periods be examined and/or adjusted to reflect changes in seasonal peak demand over time? What should be the trigger and/or the process for making such adjustments?

17. Are there alternative methods of establishing seasonal peak periods the DOER should consider?

Responses:

- 15: A quantitative assessment of the relationship between seasonal peak electric demand periods, the marginal emissions rates, and the wholesale energy market costs during those times needs to be evaluated. Absent understanding the interaction of these three factors, it is unclear how cost reductions and emission reductions could be verifiably achieved. As an illustrative example, currently available data from ISO-NE does not indicate consistent correlations between system load or system LMP with the marginal emission rate. The DOER is encouraged to use ISO-NE data for such evaluation, and to work with the ISO to develop more robust reporting on marginal emission rates.





- 15: Under current ISO-NE market rules, the single hour in which the annual peak load occurs has a disproportionate impact on wholesale market costs (Capacity Supply Obligations, Installed Capacity Requirements, etc.). How will reducing peak net demand of electricity for the other three seasons similarly provide comparable cost savings, particularly if Clean Peak Certificates are fungible (at least annually)?
- 15: Would providing energy from CPS resources during ‘peak wholesale market costs periods’ provide greater ratepayer savings than during ‘seasonal peak net demand of electricity periods’? Can the former be reliably predicted?
- It is unclear if Clean Periods would be every day, albeit potentially for seasonally different daily time windows, throughout each season or only occur during certain grid conditions. While predictability is helpful in project financing, revenue from the CPS should not be distributed arbitrarily.
- The DOER should evaluate if the window in which the peak daily electric demand occurs reliably corresponds to the highest wholesale market costs and to the highest marginal emissions. The illustrative heat maps provided below indicate the hourly average value by month for the 2016 marginal emissions, system load, and LMP (NEMA) and could be used as a basis for such investigation. Ideally, a Clean Peak Period should be a “red” period for each of the three criteria. While some correlation is evident, a more rigorous evaluation is necessary, particularly for energy storage resources to account for round trip efficiency losses. Additional analysis could evaluate if off-peak periods show significant renewable generation curtailment, when binding constraints are more prevalent, etc. Larger images are provided in the Appendix.

Hourly Average Marginal Emissions												
Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	1,077	1,015	968	933	868	952	929	983	938	958	876	972
1 AM	1,059	1,039	1,004	925	881	940	877	964	937	952	892	981
2 AM	1,086	1,025	1,033	972	935	997	933	942	990	925	874	935
3 AM	1,079	1,035	973	931	852	944	1,020	967	960	949	876	1,022
4 AM	1,145	1,033	932	937	850	966	1,032	921	910	918	946	974
5 AM	1,013	1,026	945	929	899	963	1,009	913	914	916	908	988
6 AM	1,004	1,044	1,004	936	910	1,042	949	921	977	939	914	988
7 AM	1,047	1,050	984	971	935	971	931	926	1,058	972	986	1,012
8 AM	1,016	1,094	1,067	992	1,009	944	950	957	1,000	982	973	1,009
9 AM	949	996	1,007	1,007	966	966	969	942	992	1,000	996	1,065
10 AM	964	996	1,022	989	932	997	995	1,004	1,011	1,021	972	1,042
11 AM	995	1,038	943	991	947	929	992	981	1,000	973	969	985
12 PM	1,062	1,012	949	1,012	955	934	1,052	1,025	1,031	1,011	940	1,133
1 PM	1,090	1,011	967	1,005	959	962	1,033	1,103	1,085	982	942	1,056
2 PM	989	988	982	957	956	933	1,026	1,055	1,033	1,010	942	1,122
3 PM	991	960	987	968	967	952	1,103	1,086	1,099	992	924	1,049
4 PM	991	971	1,018	997	1,014	1,021	1,070	1,108	1,073	953	955	996
5 PM	1,007	1,021	948	950	966	968	1,147	1,089	1,060	993	1,017	1,084
6 PM	1,038	1,024	983	920	989	992	1,059	1,058	1,038	1,041	1,041	1,043
7 PM	1,014	1,013	992	1,014	965	965	1,091	1,112	1,067	1,070	984	1,092
8 PM	1,010	1,066	1,006	996	969	964	1,000	1,107	1,032	1,029	1,028	1,038
9 PM	1,049	940	1,008	974	951	936	973	1,000	996	959	960	1,014
10 PM	1,064	1,007	989	939	923	990	975	985	1,000	921	938	1,074
11 PM	1,081	1,007	923	1,007	869	1,004	931	916	953	931	875	1,046

Hourly Average System Load												
Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	12,860	12,764	11,685	11,065	10,721	11,750	14,197	14,343	12,042	10,678	11,130	12,806
1 AM	12,675	12,592	11,547	10,922	10,475	11,394	13,749	14,016	11,733	10,491	10,921	12,604
2 AM	12,531	12,475	11,459	10,868	10,395	11,262	13,486	13,860	11,628	10,387	10,946	12,522
3 AM	12,563	12,475	11,438	10,864	10,365	11,245	13,281	13,731	11,564	10,327	11,000	12,555
4 AM	12,828	12,738	11,620	11,048	10,497	11,345	13,282	13,755	11,670	10,505	11,200	12,740
5 AM	13,359	13,256	12,163	11,503	10,911	11,603	13,487	14,009	12,105	10,974	11,788	13,269
6 AM	14,492	14,330	13,188	12,336	11,798	12,367	14,133	14,497	12,985	12,053	12,792	14,140
7 AM	15,364	15,109	13,967	13,140	12,683	13,426	15,097	15,382	13,722	12,943	13,587	15,002
8 AM	15,596	15,363	14,143	13,373	13,125	14,113	15,964	16,312	14,247	13,239	13,785	15,347
9 AM	15,658	15,417	14,163	13,456	13,429	14,631	16,825	17,113	14,693	13,375	13,815	15,382
10 AM	15,637	15,396	14,124	13,468	13,646	15,104	17,633	17,909	15,056	13,450	13,814	15,309
11 AM	15,519	15,300	13,975	13,391	13,754	15,471	18,289	18,574	15,307	13,443	13,735	15,208
12 PM	15,374	15,144	13,761	13,228	13,785	15,715	18,755	19,093	15,468	13,388	13,637	15,100
1 PM	15,327	15,063	13,639	13,109	13,840	15,977	19,185	19,593	15,672	13,417	13,638	15,106
2 PM	15,306	14,979	13,522	12,967	13,844	16,143	19,489	19,932	15,818	13,413	13,674	15,148
3 PM	15,502	15,093	13,528	12,935	13,896	16,313	19,693	20,206	16,013	13,510	13,935	15,420
4 PM	16,263	15,564	13,798	13,129	14,074	16,513	19,892	20,456	16,284	13,802	14,739	16,533
5 PM	17,384	16,623	14,313	13,437	14,290	16,633	19,976	20,519	16,472	14,288	15,532	17,422
6 PM	17,365	17,033	14,890	13,676	14,325	16,449	19,676	20,137	16,439	14,866	15,492	17,282
7 PM	16,941	16,636	15,156	14,065	14,327	16,082	19,125	19,625	16,589	14,760	15,069	16,882
8 PM	16,358	16,059	14,811	14,211	14,503	15,866	18,747	19,371	16,088	14,170	14,484	16,346
9 PM	15,417	15,148	13,941	13,418	13,825	15,344	18,064	18,313	15,003	13,244	13,592	15,510
10 PM	14,235	14,025	12,801	12,294	12,553	13,979	16,587	16,755	13,671	12,112	12,500	14,347
11 PM	13,260	13,133	11,942	11,422	11,379	12,630	15,157	15,316	12,554	11,199	11,630	13,350

Hourly Average LMP (NEMA)												
Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	25	22	16	23	17	17	21	22	22	19	20	43
1 AM	20	23	16	22	17	18	17	22	22	19	18	45
2 AM	21	23	20	22	11	14	16	13	18	16	16	43
3 AM	30	20	13	21	13	15	14	17	15	15	16	43
4 AM	27	24	15	23	11	13	18	21	18	14	19	47
5 AM	25	32	19	25	16	7	18	22	20	17	19	47
6 AM	43	24	23	28	14	9	13	19	29	24	25	56
7 AM	52	28	23	33	20	22	18	25	28	29	29	60
8 AM	40	33	19	31	23	23	22	27	30	28	27	61
9 AM	38	29	17	32	23	22	25	27	28	30	27	57
10 AM	35	28	16	32	24	22	28	30	28	34	25	55
11 AM	36	31	17	29	24	23	33	38	32	32	26	56
12 PM	35	27	17	30	23	25	36	43	35	30	25	49
1 PM	33	28	16	31	24	28	38	57	38	32	23	47
2 PM	32	26	14	28	26	29	46	97	39	31	23	50
3 PM	32	27	13	27	24	29	45	73	42	29	24	54
4 PM	36	28	17	28	29	30	48	93	43	33	33	70
5 PM	53	34	20	31	25	32	53	110	45	37	44	77
6 PM	47	35	22	30	26	29	47	75	40	50	35	68
7 PM	41	32	24	35	30	27	38	40	44	45	29	60
8 PM	40	31	21	37	29	26	37	43	30	32	26	58
9 PM	35	28	17	29	24	26	30	32	25	23	22	56
10 PM	23	25	11	24	19	20	26	26	22	19	22	50
11 PM	20	22	11	22	18	15	18	15	20	17	20	42

- Is "seasonal peak period" defined as when the Commonwealth's net demand for electricity is the highest, or the entire ISO system demand is the highest? DOER should evaluate if those are the same from a grid cost impact and an emissions impact, and if not, is it appropriate to pursue one vs. the other considering the program is funded only by rate payers within the Commonwealth.

<u>Atypical Peak Events</u>

Not all system peaks occur within the same 1-4 window throughout the course of a season (e.g. a 95 degree day on a weekday in May will almost certainly not have a peak that occurs at a similar time of day as the bulk of peak periods in the same month).

18. Should DOER establish peak periods other than the seasonal peak periods during which clean peak resources are eligible to generate clean peak certificates?
    a. If so, what criteria should DOER use to establish these periods and what mechanism(s) and should be used to trigger and announce these events in advance of them occurring?
    b. Should DOER specifically target ISO system peaks?

<u>Responses:</u>

- If a real-time marginal emission rate proxy was made available by ISO-NE, a formulaic approach to atypical peak events could be made available in advance of any such occurrences. By determining a combination of 5-minute LMP thresholds, system load, and a corresponding marginal emission rate threshold (based on the marginal unit's contribution to system load, not purely LMP price setting[18]) for which qualified clean peak resources generate cost effective savings to ratepayers and net emission reductions, no additional trigger mechanism or announcements would be necessary.
- As significant ratepayer cost can be incurred during atypical peak events, strong consideration should be given to including these periods in the CPS. Triggers such as the ISO-NE Pay-for-Performance (PFP) events, abnormally high system load and/or price deviations, etc. should be included in evaluating atypical peak events. The DOER could conceivable coordinate with the ISO to determine performance during PFP events and base distribution of clean peak certificates accordingly.

<u>Generation of Certificates</u>

Some clean peak resources may only be capable of generating clean peak certificates during a portion of a seasonal peak period. For example, a solar resource trying to deliver energy for the duration of a summer seasonal peak period that lasts from 6-9 PM may generate a significant number of certificates in the early part of that window compared to the latter.

[18] https://www.iso-ne.com/static-assets/documents/2018/07/2018-spring-quarterly-markets-report.pdf (Section 3.2 *Marginal Resources and Transactions*)

19. Should only resources that can provide value for the entire duration of a peak period be able to generate certificates?
20. Should there be different values provided to resources that can provide value for a portion of a peak period versus the entire peak period? If so, how should DOER differentiate these value streams?
21. Should there be a penalty (i.e. negative credits) if a resource under-produces during the actual monthly peak?
22. How should resources participating in other state programs (e.g. section 83 procurements, SMART, EE programs, etc.) interact with the CPS?
23. Should qualified energy storage systems that can demonstrate they were charged during minimum load windows be provided additional incentives or benefits under the CPS? If so, how should these be structured and how should minimum load windows be established?

Responses:

- 19: A sustained output for the duration of the 1 to 4 hour peak period is generally to be desired so as to reduce the global peak electric demand and not focus it into a narrower duration window. However, to the extent that a resource like solar might shift the peak to later hours in the Clean Peak Period, if this results in lowering the highest peak interval and reduces emissions, it would seem the resource should still be eligible for Clean Peak Certificates. The impact of either requiring or incentivizing Renewable Generating resources to store energy produced outside the peak periods and deliver during peak periods must be rigorously evaluated so as to avoid unintended consequences of actually increasing emissions.[19]
- 20: An understanding of the aggregated MW and MWh output ability of all Clean Peak Resource should be developed prior to creating differential pricing and/or “types” of Clean Peak resources. For example, if solar resources produce heavily in earlier hours, but drop in later hours *and* both net cost and emissions reductions can be demonstrated this should not be discouraged. With time, those later hours will become harder for new solar resources to provide cost savings and verifiable emission reduction, in turn sending market signals for resources to provide clean energy in the later hours.
- 21: It is unclear if negative credits would provide a better market signal to encourage appropriate production than increased credit value due to market scarcity.
- 22: If a resource otherwise meets the CPS eligibility criteria, exclusion based on participation in other state programs does not seem to be a requirement. However, for larger programs (i.e. section 83 procurements) that could have significant certificate market value impacts due to scale, consideration should be given to providing a consistent and reliable market incentive for new and existing Clean Peak resources.
- 22: It is unclear if a solar generating unit enrolled in SMART should be able to generate Clean Peak Certificates for the MWh produced that are also accounted for as RECs under the SMART program. If the Renewable Energy Certificate embodies all of the positive environmental attributes of the energy, and the REC is retired for other programs (e.g. regulatory requirements or voluntary claims), how is double counting of the environmental benefits avoided? As the owner or operator of a SMART program resource automatically relinquishes the REC to the Utility Company, would this also imply the Utility Company subsume ownership of the Clean Peak Credit? Both the CPS and the SMART program rules must work together to send the appropriate market and investment signals to the appropriate parties.
- 23: Charging during minimum system load windows should only be provided additional incentive or benefits when those windows are also lowest wholesale market energy costs *and* the lowest verifiable marginal

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[19] Unintended Effects of Residential Energy Storage on Emissions from the Electric Power System *Environ. Sci. Technol.* ***2018;*** Bulk Energy Storage Increases United States Electricity System Emissions. *Environmental Science and Technology*, **2015**; Estimating the Quantity of Wind and Solar Required To Displace Storage-Induced Emissions. *Environmental Science & Technology* **2017;** Tradeoffs between revenue and emissions in energy storage operation. *Energy*. **2017;** How much wind and solar are needed to realize emissions benefits from storage? *Energy Systems*. **2017;** Carbon dioxide emissions effects of grid-scale electricity storage in a decarbonizing power system. *Environmental Research Letters*. **2018;** *Managing the Future of Energy Storage.* **2018**; Parameters driving environmental performance of energy storage across grid applications. *Journal of Energy Storage* **2017;** *https://www.edf.org/blog/2019/02/06/not-all-energy-storage-clean-it-might-even-increase-emissions*

emission periods. Further analysis is required to demonstrate low system load actually consistently represents either of these two core Clean Peak Standard criteria (see Supporting Figures 4-9). Qualified Energy Storage systems should be provided incentives and/or benefits only if they can demonstrate that they were charged during periods of minimum LMP and marginal emission rate periods outside of Clean Peak periods. Additional incentives and/or benefits could be considered if the energy storage achieved this base requirements and contributed to other system benefits (e.g. flattening duck curve).

Metering

Verification of Metered Data

DOER proposes that all clean peak resources be registered with NEPOOL GIS as Non-NEPOOL participants. This would mean that, as required by the NEPOOL GIS operating rules, all resources would be required to report their eligible output to NEPOOL GIS by a DOER approved Independent Third-Party Meter Reader. This entity would be responsible for verifying the accuracy of the reported data before uploading it to NEPOOL GIS for the creation of certificates.

To ensure that all data is collected, reviewed, and reported to NEPOOL GIS in a consistent manner, DOER would select a single entity to act as the Independent Third-Party Meter Reader, similar to the process used under the SREC programs, in which the Production Tracking System at the Massachusetts Clean Energy Center serves in this role.

24. Do you support this proposal? If not, please describe why.

25. If DOER procures the services of a single Independent Third-Party Meter Reader:
    a. What criteria should DOER use to evaluate the capabilities of the entity that is selected to act as the Independent Third-Party Meter Reader?
    b. Do you support the establishment of a fee structure to support the ongoing services provided by the Independent Third-Party Meter Reader?
    c. How should this Third-Party verification take place?

Responses:

- 24: If the CPS and the NEPOOL-GIS are both able to accommodate all types of clean peak resources, using the NEPOOL-GIS would be advantageous so as to avoid the need for a separate certificate tracking system. The success of the MassCEC and the PTS as a Third-Party meter reader should be a model for the CPS. The owner of the Clean Peak Resource should also be the owner, installer, and operator of the appropriate revenue grade meter.

Metering Specifications and Requirements

Because clean peak certificate creation is dependent not just on the quantity of energy output, but also its timing, more sophisticated metering will be required than that which is required for many RPS eligible systems, which only require monthly meter reads.

26. Describe in as much detail as possible the metering standards and requirements (type, accuracy, etc.) that DOER should employ to ensure the accurate collection of data.
27. Should different standards apply to different sizes and types of facilities? If so, please describe your recommendations in as much detail as possible.

28. What other verification mechanisms could be deployed to simplify the process, particularly for small-scale systems for which some types of metering solutions may be cost-prohibitive?

Responses:

- 26: For qualified Renewable Energy generators directly connected to the electric grid and not utilizing storage, revenue grade meters capable of recording hourly generator MWh data appear to be sufficient to demonstrate that energy was delivered during a Clean Peak Period. For Energy Storage systems, hourly interval metering may not be sufficient to guarantee reductions in rate payer costs and verifiable emission reduction (see Supporting Figures 10-12).
- 27: While it is generally true that more sophisticated metering will be required for the CPS, programmatic simplicity and transparency should be central to development of the standards. Thermal energy storage should meter the thermal energy output delivered during the clean peak period. The Thermal energy delivered during the Clean Peak Period (e.g. ton-hours) should be converted to avoided on-peak electrical energy (e.g. MWh) using a "best available technology" efficiency rating (e.g. kW/ton) applicable to the type/size of useful-thermal energy generating system supplying the thermal energy storage system.

Value of Certificates

DOER must establish an alternative compliance payment rate and potentially other mechanisms that will help establish the value of clean peak certificates. Please describe in as much detail as possible:

29. How much value is likely needed on a per MWh basis to incentivize different types of existing resources to operate during peak windows and/or new resources developed or financed using CPS revenue streams?
30. How should DOER establish these values?

Long-term Contracts

In establishing certificate values, DOER "may include a process by which electric distribution companies competitively procure clean peak certificates from clean peak resources and enter into long-term contracts, subject to the approval of the department of public utilities."

31. If DOER does require competitive procurements:
    a. What types of facilities should be able to participate in solicitations? Should it be limited to certain types of facilities (e.g. facilities that are either new and/or not already supported by another type of long-term contract or financing tool)?
    b. How frequently should solicitations take place?
    c. How large should the procurements be (e.g. percentage of total load or annual requirement)?
    d. How should the contract price be established? Pay as bid? Reverse auction mechanism with a single clearing price for all resources? Other?

Post-2019 Minimum Standard Requirements

DOER has established a baseline Minimum Standard requirement of 0% for 2019. Each year after 2019, DOER is required to establish a Minimum Standard requirement for retail suppliers that increases at a rate of at least 0.25% of total retail sales annually.

32. What methodology should DOER use to establish post-2019 Minimum Standard requirements (e.g. fixed annual requirements in a published schedule, supply reactive formula, other)?
33. How large should the minimum standard be?

Demand Response Resource Carve-out

Separate from the total Minimum Standard requirement, DOER is required to establish “a minimum percentage of clean peak certificates that must be derived from demand response resources.”

34. How should DOER interpret this requirement?
35. What methodology should DOER use to establish this carve-out of the larger Minimum Standard?

Other

36. Please discuss any other implementation issues not addressed above.

Responses:
If Clean Peak Credits (CPC) are to be used for compliance with the Clean Peak Standard, there is potential for double counting with Renewable Energy Certificates (RECs). Double counting can occur where, for example, the REC is sold to a voluntary purchaser or used for a voluntary renewable energy product and a CPC is also issued and used for CPS compliance for the same megawatt-hour. In this case, if the CPS is a part of the RPS and therefore (or otherwise) represents peak delivery to grid customers, then the same MWh is being delivered to both the voluntary customer and the utility’s customers for compliance. Regardless, a MWh used toward CPS compliance (and the associated REC) cannot be considered purely voluntary or surplus to regulation.

To avoid double counting and maintain regulatory surplus for the voluntary renewable energy market, RECs and CPCs must to stay “bundled” together.

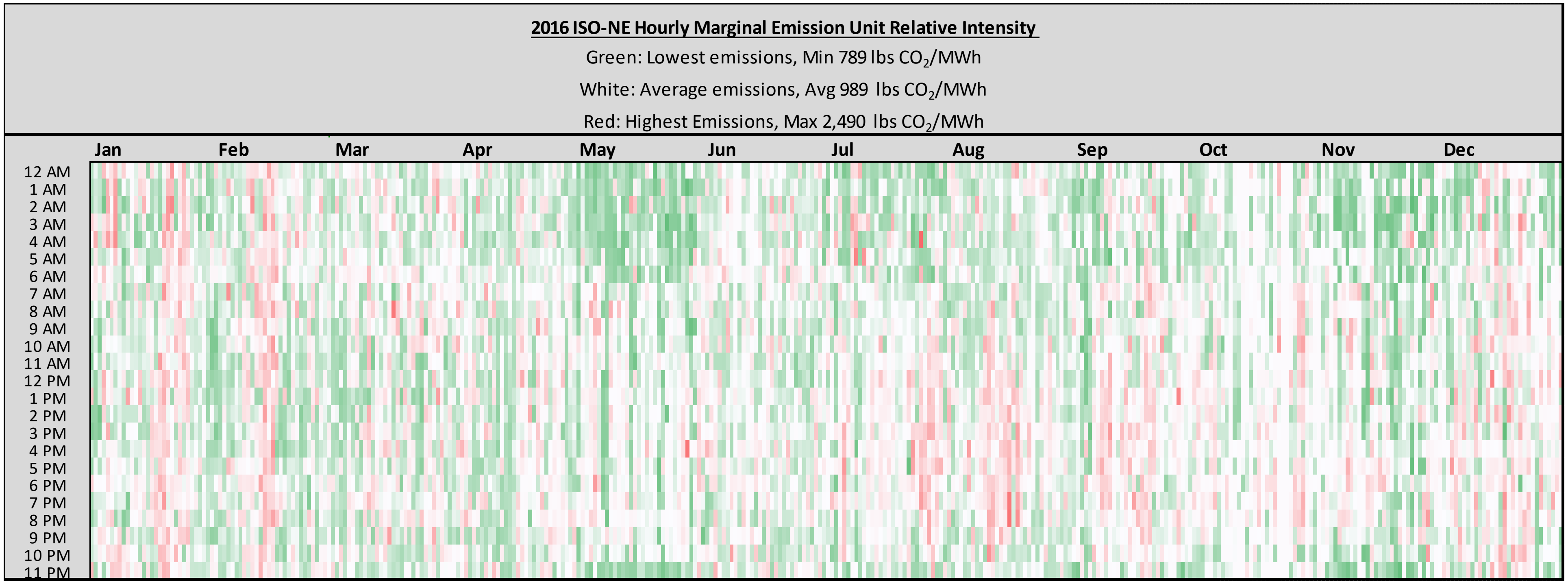
Significant consideration must be given to the question as to if the CPC do or do not represent and/or convey generation attributes. Do CPC represent and/or convey avoided emission attributes and can/should that be disaggregated from other positive environmental attributes? Are they only a state compliance mechanism, or do they represent generation, storage, environmental, etc. attributes? Unambiguous and appropriate regulatory guidance on this will help to avoid confusion between RECs and CPCs definitions in state law, tracking system rules, and the voluntary market.

Finally, it may be possible to use RECs to track and verify compliance with a CPS instead of creating CPCs as a separate certificate, in which case this would be preferred and obviate potential double counting. If the necessary hourly production data were tracked with RECs and other potential challenges related to ensuring that the REC represents consistent production during the peak window were addressed, these RECs could be “tagged” as Peak-RECs (PRECs), for example, and used for CPS compliance. Similar consideration for RECs generated off-peak and used to charge energy storage systems off-peak would be required.

Supplemental Figures

These figures are provided to encourage DOER to evaluate the currently available marginal emission data provided by ISO-NE. While these figures are representative of the emissions, the DOER should complete their own independent analysis. Harvard and a group of stakeholders have been actively engaged with the ISO in the development of how marginal emission data is presented and we would be happy to meet with the DOER to discuss the ISO-NE source data, questions and concerns regarding how it is reported, as well as our own analysis of the information.

Figure 1. 2016 Hourly ISO-NE Marginal Emissions Heat Map. Periods of relatively cleaner generation (i.e. efficient natural gas units) are represented in green, average emission intensities in white, and high-emission marginal units in red. During winter periods, extended cold periods can lead to higher natural gas prices resulting in more oil and coal on the margin, as evident by the red vertical bands in December, January, and February. Summer peak electric demand periods can be inferred from the red clusters in late afternoon during July, August, and September. Similarly, shoulder seasons when gas prices and system demand are low can be inferred from the greener bands in May.



Note: the marginal emission intensity represented here are reported consistent with the methodology outlined in the ISO-NE Internal Market Monitor's Quarterly report. Intervals in which more than one generating unit is dispatched as marginal (i.e. multiple marginal units) are evaluated by the unit's actual contribution to system load.

Figure 2. Heat Map showing 2016 hourly average marginal emission intensity overlaid with current Eversource Cambridge Large Time of Use Rate structure (G-3). While Energy Storage could move energy (and embodied emissions) from off-peak, lower marginal emission intensity (green cells) to on-peak, higher marginal emission hours (red cells) within the black boxes, it is not always the case. This is particularly true when accounting for the round-trip efficiency losses for electrical energy storage devices. The issue is exacerbated in the winter months of 2016 when overall marginal emissions were consistently high.

Cambridge
Large General Time of Use - 13.8 kV Service (G-3)
On Peak DST: 9am - 6 pm M-F
On Peak ST: 4pm - 9 pm M-F

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	1,077	1,015	968	933	868	952	929	983	938	958	876	972
1 AM	1,059	1,039	1,004	925	881	940	877	964	937	952	892	981
2 AM	1,086	1,025	1,033	972	935	997	933	942	990	925	874	935
3 AM	1,079	1,035	973	931	852	944	1,020	967	960	949	876	1,022
4 AM	1,145	1,033	932	937	850	966	1,032	921	910	918	946	974
5 AM	1,013	1,026	945	929	899	963	1,009	913	914	916	908	988
6 AM	1,004	1,044	1,004	936	910	1,042	949	921	977	939	914	988
7 AM	1,047	1,050	984	971	935	971	931	926	1,058	972	986	1,012
8 AM	1,016	1,094	1,067	992	1,009	944	950	957	1,000	982	973	1,009
9 AM	949	996	1,007	1,007	966	966	969	942	992	1,000	996	1,065
10 AM	964	996	1,022	989	932	997	995	1,004	1,011	1,021	972	1,042
11 AM	995	1,038	943	991	947	929	992	981	1,000	973	969	985
12 PM	1,062	1,012	949	1,012	955	934	1,052	1,025	1,031	1,011	940	1,133
1 PM	1,090	1,011	967	1,005	959	962	1,033	1,103	1,085	982	942	1,056
2 PM	989	988	982	957	956	933	1,026	1,055	1,033	1,010	942	1,122
3 PM	991	960	987	968	967	952	1,103	1,086	1,099	992	924	1,049
4 PM	991	971	1,018	997	1,014	1,021	1,070	1,108	1,073	953	955	996
5 PM	1,007	1,021	948	950	966	968	1,147	1,089	1,060	993	1,017	1,084
6 PM	1,038	1,024	983	920	989	992	1,059	1,058	1,038	1,041	1,041	1,043
7 PM	1,014	1,013	992	1,014	965	965	1,091	1,112	1,067	1,070	984	1,092
8 PM	1,010	1,066	1,006	996	969	964	1,000	1,107	1,032	1,029	1,028	1,038
9 PM	1,049	940	1,008	974	951	936	973	1,000	996	959	960	1,014
10 PM	1,064	1,007	989	939	923	990	975	985	1,000	921	938	1,074
11 PM	1,081	1,007	923	1,007	869	1,004	931	916	953	931	875	1,046

Figure 3. Heat Map showing 2016 hourly average marginal emission intensity overlaid with current Eversource Boston Large Time of Use Rate structure (B-3). While Energy Storage could move energy (and embodied emissions) from off-peak, lower marginal emission intensity (green cells) to on-peak, higher marginal emission hours (red cells) within the black boxes, it is not always the case. This is particularly true when accounting for the round-trip efficiency losses for electrical energy storage devices. The issue is exacerbated in the winter months of 2016 when overall marginal emissions were consistently high.

Boston
B3, G6 - Time of Use - 14 kV Service (G-3)
On Peak, June - September 9 am - 6 pm M-F
On Peak, October - May 8 am - 9 pm M-F

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	1,077	1,015	968	933	868	952	929	983	938	958	876	972
1 AM	1,059	1,039	1,004	925	881	940	877	964	937	952	892	981
2 AM	1,086	1,025	1,033	972	935	997	933	942	990	925	874	935
3 AM	1,079	1,035	973	931	852	944	1,020	967	960	949	876	1,022
4 AM	1,145	1,033	932	937	850	966	1,032	921	910	918	946	974
5 AM	1,013	1,026	945	929	899	963	1,009	913	914	916	908	988
6 AM	1,004	1,044	1,004	936	910	1,042	949	921	977	939	914	988
7 AM	1,047	1,050	984	971	935	971	931	926	1,058	972	986	1,012
8 AM	1,016	1,094	1,067	992	1,009	944	950	957	1,000	982	973	1,009
9 AM	949	996	1,007	1,007	966	966	969	942	992	1,000	996	1,065
10 AM	964	996	1,022	989	932	997	995	1,004	1,011	1,021	972	1,042
11 AM	995	1,038	943	991	947	929	992	981	1,000	973	969	985
12 PM	1,062	1,012	949	1,012	955	934	1,052	1,025	1,031	1,011	940	1,133
1 PM	1,090	1,011	967	1,005	959	962	1,033	1,103	1,085	982	942	1,056
2 PM	989	988	982	957	956	933	1,026	1,055	1,033	1,010	942	1,122
3 PM	991	960	987	968	967	952	1,103	1,086	1,099	992	924	1,049
4 PM	991	971	1,018	997	1,014	1,021	1,070	1,108	1,073	953	955	996
5 PM	1,007	1,021	948	950	966	968	1,147	1,089	1,060	993	1,017	1,084
6 PM	1,038	1,024	983	920	989	992	1,059	1,058	1,038	1,041	1,041	1,043
7 PM	1,014	1,013	992	1,014	965	965	1,091	1,112	1,067	1,070	984	1,092
8 PM	1,010	1,066	1,006	996	969	964	1,000	1,107	1,032	1,029	1,028	1,038
9 PM	1,049	940	1,008	974	951	936	973	1,000	996	959	960	1,014
10 PM	1,064	1,007	989	939	923	990	975	985	1,000	921	938	1,074
11 PM	1,081	1,007	923	1,007	869	1,004	931	916	953	931	875	1,046

Figure 4. Heat Map depicting the 2016 hourly average marginal emission intensity rates (lbs. CO_2/MWh)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	1,077	1,015	968	933	868	952	929	983	938	958	876	972
1 AM	1,059	1,039	1,004	925	881	940	877	964	937	952	892	981
2 AM	1,086	1,025	1,033	972	935	997	933	942	990	925	874	935
3 AM	1,079	1,035	973	931	852	944	1,020	967	960	949	876	1,022
4 AM	1,145	1,033	932	937	850	966	1,032	921	910	918	946	974
5 AM	1,013	1,026	945	929	899	963	1,009	913	914	916	908	988
6 AM	1,004	1,044	1,004	936	910	1,042	949	921	977	939	914	988
7 AM	1,047	1,050	984	971	935	971	931	926	1,058	972	986	1,012
8 AM	1,016	1,094	1,067	992	1,009	944	950	957	1,000	982	973	1,009
9 AM	949	996	1,007	1,007	966	966	969	942	992	1,000	996	1,065
10 AM	964	996	1,022	989	932	997	995	1,004	1,011	1,021	972	1,042
11 AM	995	1,038	943	991	947	929	992	981	1,000	973	969	985
12 PM	1,062	1,012	949	1,012	955	934	1,052	1,025	1,031	1,011	940	1,133
1 PM	1,090	1,011	967	1,005	959	962	1,033	1,103	1,085	982	942	1,056
2 PM	989	988	982	957	956	933	1,026	1,055	1,033	1,010	942	1,122
3 PM	991	960	987	968	967	952	1,103	1,086	1,099	992	924	1,049
4 PM	991	971	1,018	997	1,014	1,021	1,070	1,108	1,073	953	955	996
5 PM	1,007	1,021	948	950	966	968	1,147	1,089	1,060	993	1,017	1,084
6 PM	1,038	1,024	983	920	989	992	1,059	1,058	1,038	1,041	1,041	1,043
7 PM	1,014	1,013	992	1,014	965	965	1,091	1,112	1,067	1,070	984	1,092
8 PM	1,010	1,066	1,006	996	969	964	1,000	1,107	1,032	1,029	1,028	1,038
9 PM	1,049	940	1,008	974	951	936	973	1,000	996	959	960	1,014
10 PM	1,064	1,007	989	939	923	990	975	985	1,000	921	938	1,074
11 PM	1,081	1,007	923	1,007	869	1,004	931	916	953	931	875	1,046

Figure 5. Heat Map depicting the 2016 hourly average system load (MW)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	12,860	12,764	11,685	11,065	10,721	11,750	14,197	14,343	12,042	10,678	11,130	12,806
1 AM	12,675	12,592	11,547	10,922	10,475	11,394	13,749	14,016	11,733	10,491	10,921	12,604
2 AM	12,531	12,475	11,459	10,868	10,395	11,262	13,486	13,860	11,628	10,387	10,946	12,522
3 AM	12,563	12,475	11,438	10,864	10,365	11,245	13,281	13,731	11,564	10,327	11,000	12,555
4 AM	12,828	12,738	11,620	11,048	10,497	11,345	13,282	13,755	11,670	10,505	11,200	12,740
5 AM	13,359	13,256	12,163	11,503	10,911	11,603	13,487	14,009	12,105	10,974	11,788	13,269
6 AM	14,492	14,330	13,188	12,336	11,798	12,367	14,133	14,497	12,985	12,053	12,792	14,140
7 AM	15,364	15,109	13,967	13,140	12,683	13,426	15,097	15,382	13,722	12,943	13,587	15,002
8 AM	15,596	15,363	14,143	13,373	13,125	14,113	15,964	16,312	14,247	13,239	13,785	15,347
9 AM	15,658	15,417	14,163	13,456	13,429	14,631	16,825	17,113	14,693	13,375	13,815	15,382
10 AM	15,637	15,396	14,124	13,468	13,646	15,104	17,633	17,909	15,056	13,450	13,814	15,309
11 AM	15,519	15,300	13,975	13,391	13,754	15,471	18,289	18,574	15,307	13,443	13,735	15,208
12 PM	15,374	15,144	13,761	13,228	13,785	15,715	18,755	19,093	15,468	13,388	13,637	15,100
1 PM	15,327	15,063	13,639	13,109	13,840	15,977	19,185	19,593	15,672	13,417	13,638	15,106
2 PM	15,306	14,979	13,522	12,967	13,844	16,143	19,489	19,932	15,818	13,413	13,674	15,148
3 PM	15,502	15,093	13,528	12,935	13,896	16,313	19,693	20,206	16,013	13,510	13,935	15,420
4 PM	16,263	15,564	13,798	13,129	14,074	16,513	19,892	20,456	16,284	13,802	14,739	16,533
5 PM	17,384	16,623	14,313	13,437	14,290	16,633	19,976	20,519	16,472	14,288	15,532	17,422
6 PM	17,365	17,033	14,890	13,676	14,325	16,449	19,676	20,137	16,439	14,866	15,492	17,282
7 PM	16,941	16,636	15,156	14,065	14,327	16,082	19,125	19,625	16,589	14,760	15,069	16,882
8 PM	16,358	16,059	14,811	14,211	14,503	15,866	18,747	19,371	16,088	14,170	14,484	16,346
9 PM	15,417	15,148	13,941	13,418	13,825	15,344	18,064	18,313	15,003	13,244	13,592	15,510
10 PM	14,235	14,025	12,801	12,294	12,553	13,979	16,587	16,755	13,671	12,112	12,500	14,347
11 PM	13,260	13,133	11,942	11,422	11,379	12,630	15,157	15,316	12,554	11,199	11,630	13,350

Figure 6. Heat Map depicting the 2016 hourly average LMP (NEMA)

Hour	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
12 AM	$ 25	$ 22	$ 16	$ 23	$ 17	$ 17	$ 21	$ 22	$ 22	$ 19	$ 20	$ 43
1 AM	$ 20	$ 23	$ 16	$ 22	$ 17	$ 18	$ 17	$ 22	$ 22	$ 19	$ 18	$ 45
2 AM	$ 21	$ 23	$ 20	$ 22	$ 11	$ 14	$ 16	$ 13	$ 18	$ 16	$ 16	$ 43
3 AM	$ 30	$ 20	$ 13	$ 21	$ 13	$ 15	$ 14	$ 17	$ 15	$ 15	$ 16	$ 43
4 AM	$ 27	$ 24	$ 15	$ 23	$ 11	$ 13	$ 18	$ 21	$ 18	$ 14	$ 19	$ 47
5 AM	$ 25	$ 32	$ 19	$ 25	$ 16	$ 7	$ 18	$ 22	$ 20	$ 17	$ 19	$ 47
6 AM	$ 43	$ 24	$ 23	$ 28	$ 14	$ 9	$ 13	$ 19	$ 29	$ 24	$ 25	$ 56
7 AM	$ 52	$ 28	$ 23	$ 33	$ 20	$ 22	$ 18	$ 25	$ 28	$ 29	$ 29	$ 60
8 AM	$ 40	$ 33	$ 19	$ 31	$ 23	$ 23	$ 22	$ 27	$ 30	$ 28	$ 27	$ 61
9 AM	$ 38	$ 29	$ 17	$ 32	$ 23	$ 22	$ 25	$ 27	$ 28	$ 30	$ 27	$ 57
10 AM	$ 35	$ 28	$ 16	$ 32	$ 24	$ 22	$ 28	$ 30	$ 28	$ 34	$ 25	$ 55
11 AM	$ 36	$ 31	$ 17	$ 29	$ 24	$ 23	$ 33	$ 38	$ 32	$ 32	$ 26	$ 56
12 PM	$ 35	$ 27	$ 17	$ 30	$ 23	$ 25	$ 36	$ 43	$ 35	$ 30	$ 25	$ 49
1 PM	$ 33	$ 28	$ 16	$ 31	$ 24	$ 28	$ 38	$ 57	$ 38	$ 32	$ 23	$ 47
2 PM	$ 32	$ 26	$ 14	$ 28	$ 26	$ 29	$ 46	$ 97	$ 39	$ 31	$ 23	$ 50
3 PM	$ 32	$ 27	$ 13	$ 27	$ 24	$ 29	$ 45	$ 73	$ 42	$ 29	$ 24	$ 54
4 PM	$ 36	$ 28	$ 17	$ 28	$ 29	$ 30	$ 48	$ 93	$ 43	$ 33	$ 33	$ 70
5 PM	$ 53	$ 34	$ 20	$ 31	$ 25	$ 32	$ 53	$ 110	$ 45	$ 37	$ 44	$ 77
6 PM	$ 47	$ 35	$ 22	$ 30	$ 26	$ 29	$ 47	$ 75	$ 40	$ 50	$ 35	$ 68
7 PM	$ 41	$ 32	$ 24	$ 35	$ 30	$ 27	$ 38	$ 40	$ 44	$ 45	$ 29	$ 60
8 PM	$ 40	$ 31	$ 21	$ 37	$ 29	$ 26	$ 37	$ 43	$ 30	$ 32	$ 26	$ 58
9 PM	$ 35	$ 28	$ 17	$ 29	$ 24	$ 26	$ 30	$ 32	$ 25	$ 23	$ 22	$ 56
10 PM	$ 23	$ 25	$ 11	$ 24	$ 19	$ 20	$ 26	$ 26	$ 22	$ 19	$ 22	$ 50
11 PM	$ 20	$ 22	$ 11	$ 22	$ 18	$ 15	$ 18	$ 15	$ 20	$ 17	$ 20	$ 42

Figure 7. 2016 ISO-NE System Load versus Real Time LMP (at NEMA)

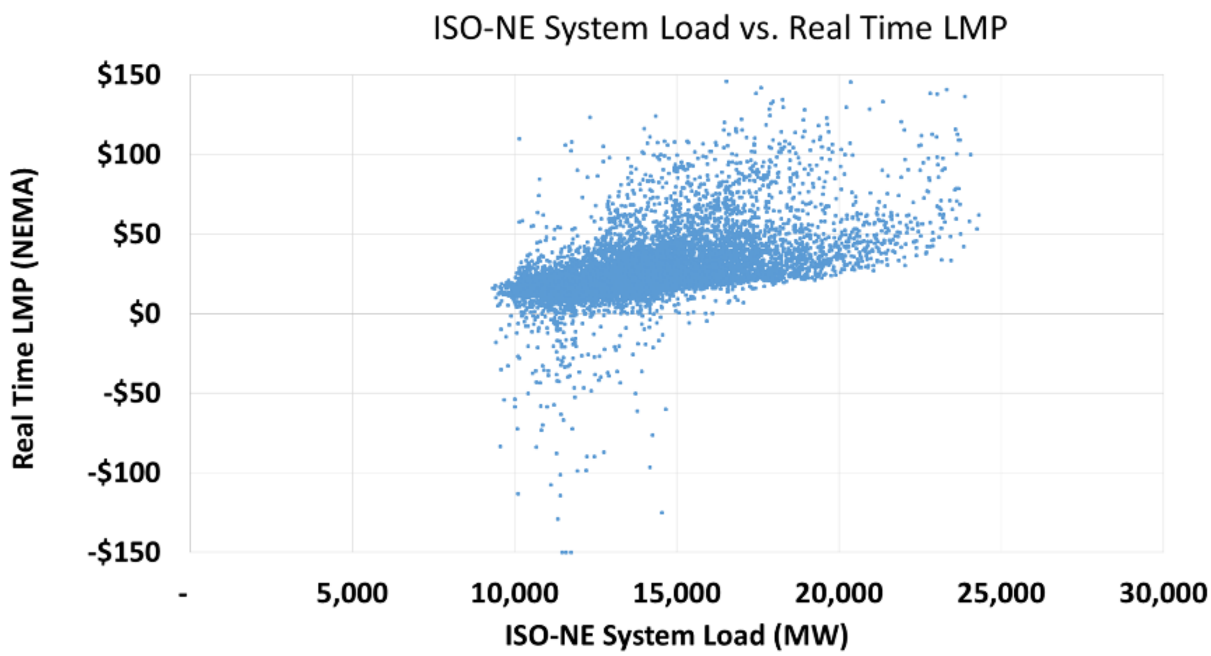


Figure 8. 2016 ISO-NE System Load vs. Marginal Emission Operating Rate. High system Load does not appear to necessarily indicate high marginal emissions.

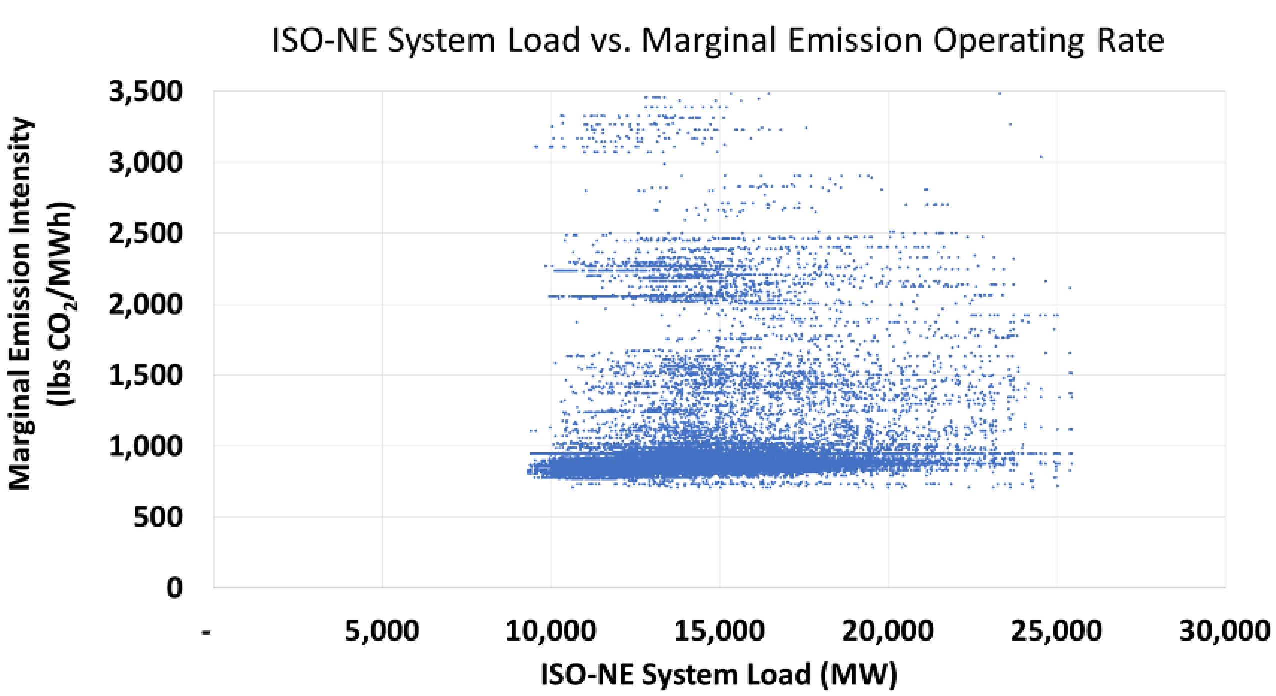


Figure 9. 2016 ISO-NE Real Time LMP (at NEMA) vs. Marginal Emissions Operating Rate. High LMP does not necessarily indicate high marginal emissions.

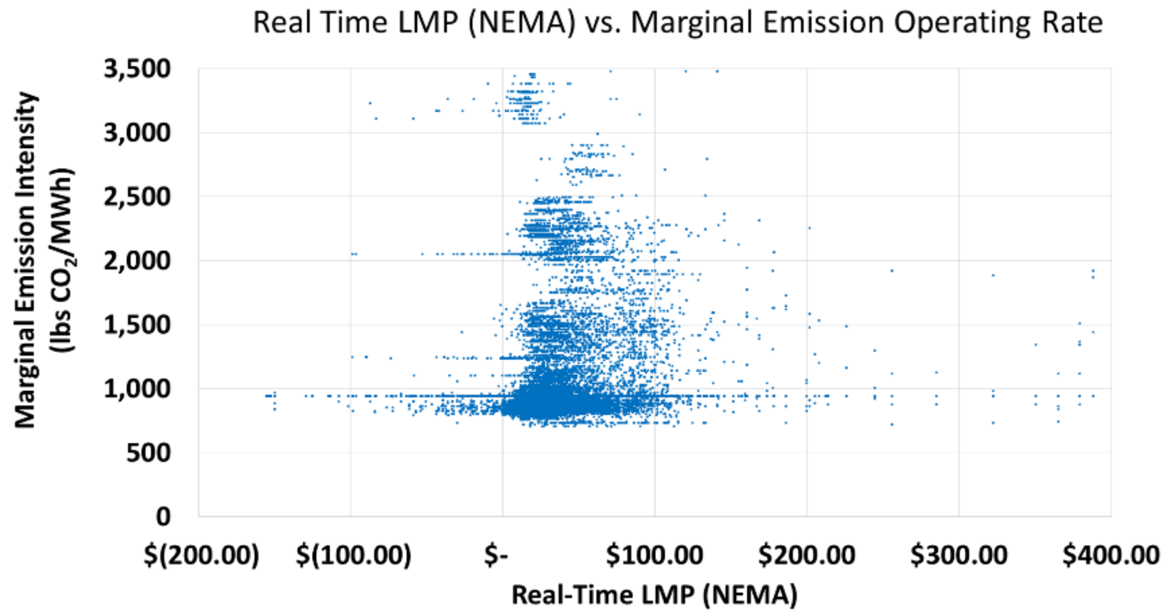


Figure 10. Time Series for 5-minute marginal emission intensity vs. system load on the 2016 Peak Demand Day. While marginal emissions were elevated during the annual peak hour, consistently higher marginal emissions were prevalent in the morning hours and in the late afternoon to evening hours.

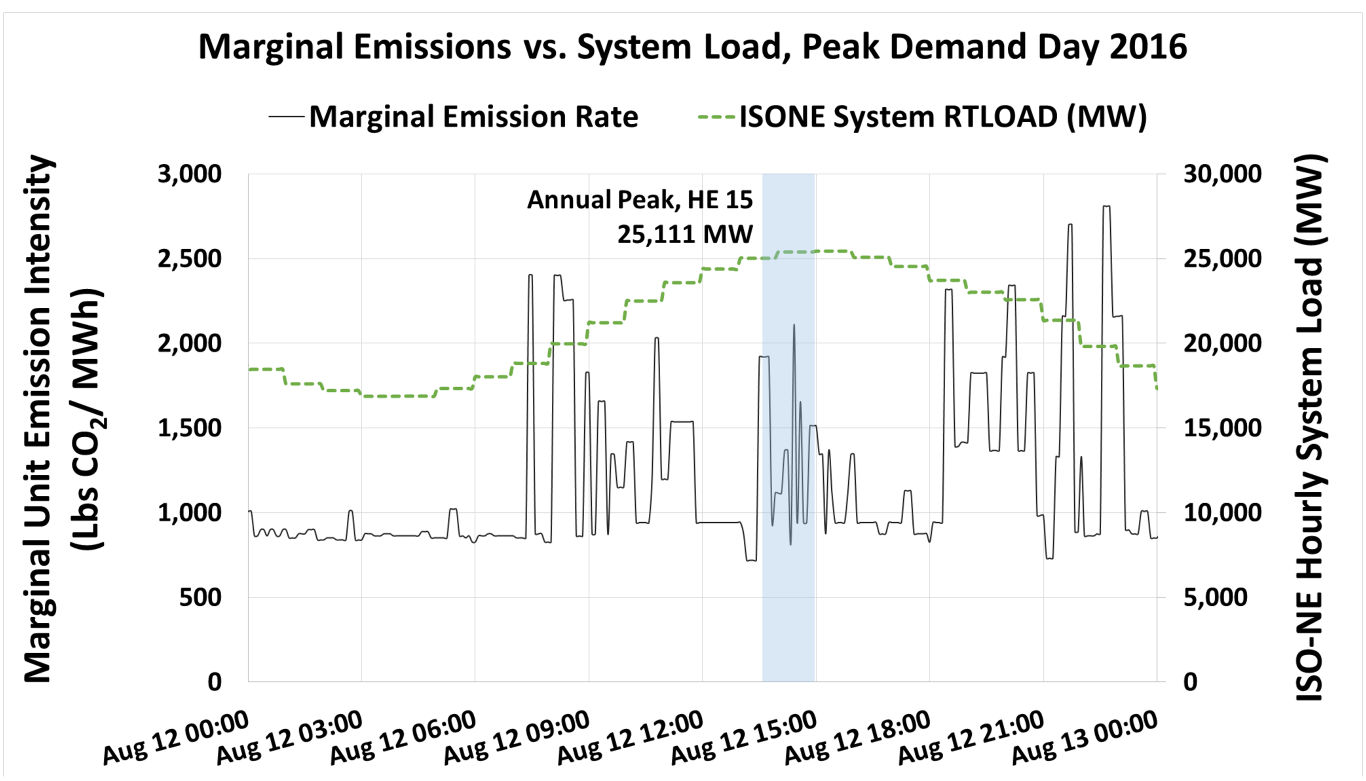


Figure 11. Time Series for 5-minute marginal emission intensity vs. system load on the "best" marginal emission day during 2016. Energy storage systems charging and discharging on such a day would only increase net emissions.

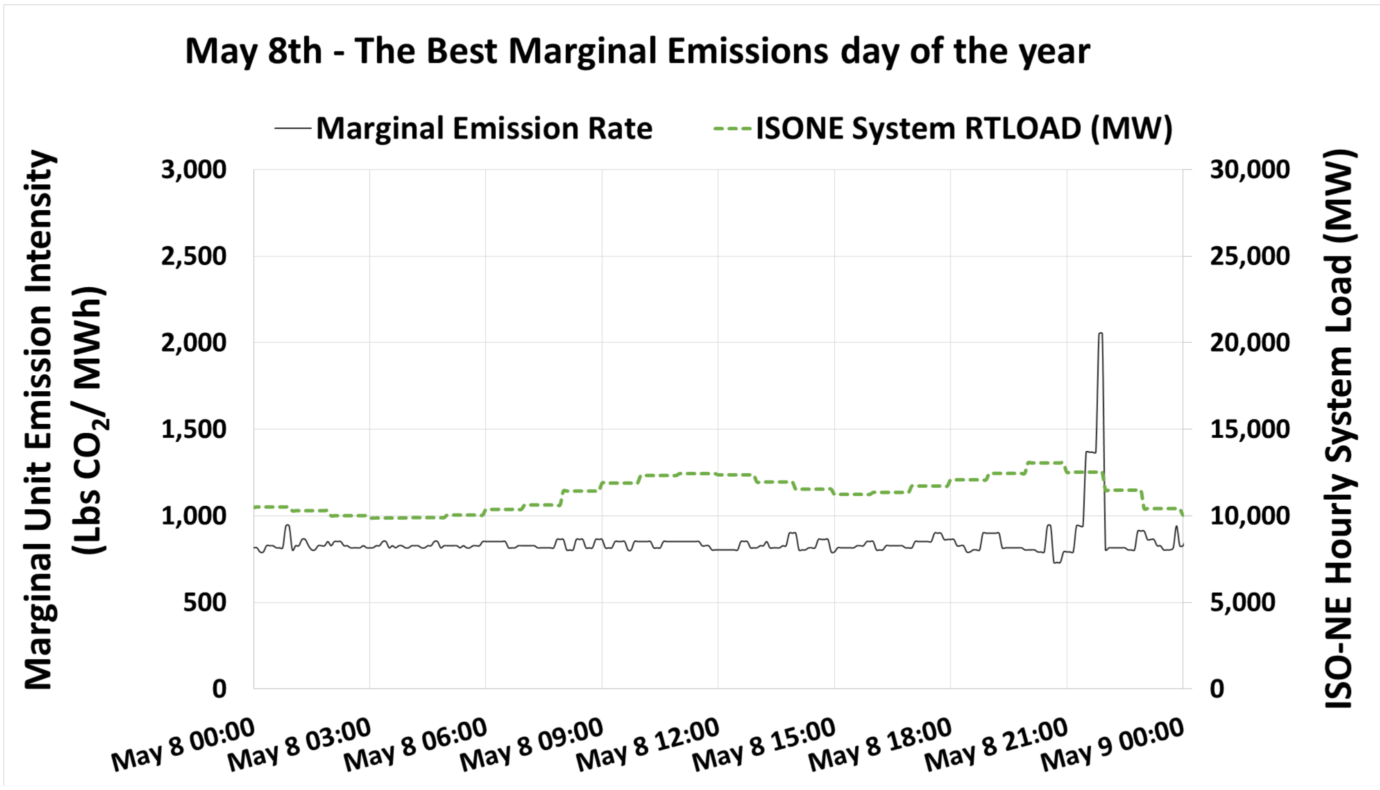


Figure 12. Time Series for 5-minute marginal emission intensity vs. system load on the "worst" marginal emission day during 2016. An energy storage system could charge during the lower marginal emission intervals, but to do so would require a real-time signal from the ISO reflecting the marginal fuel type.

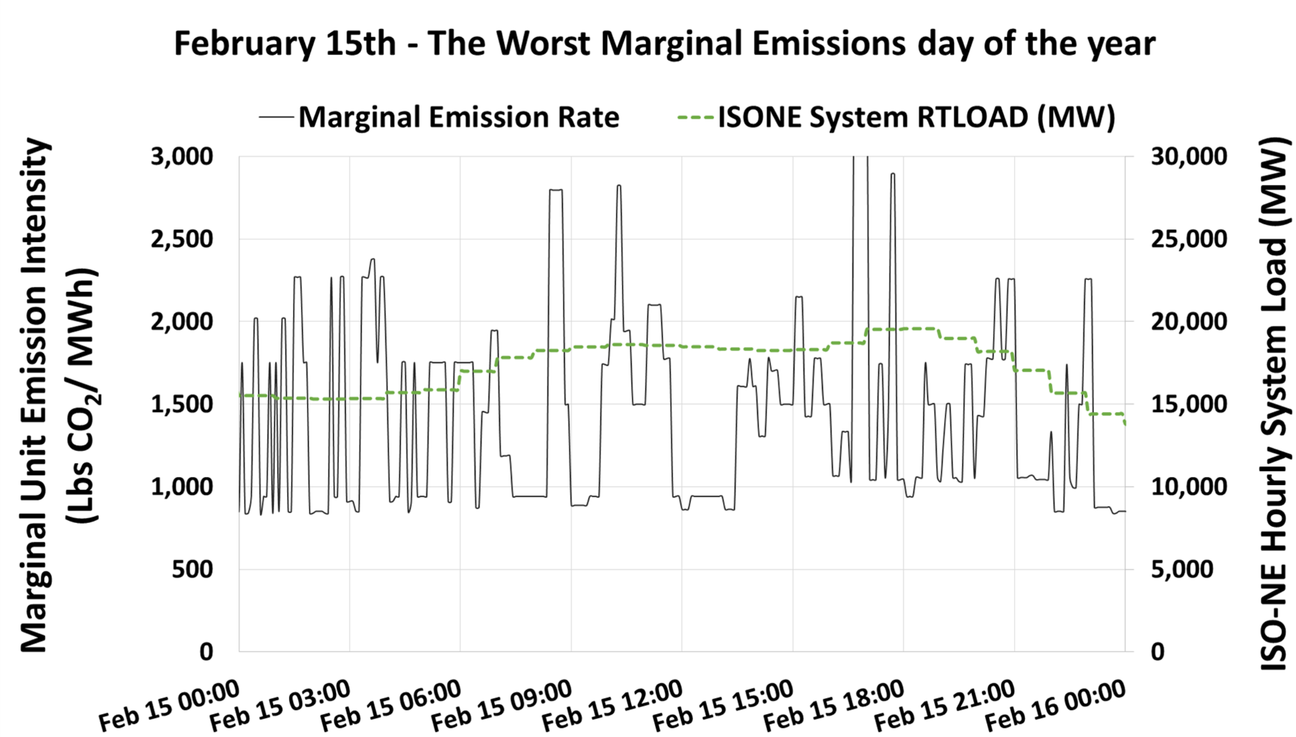
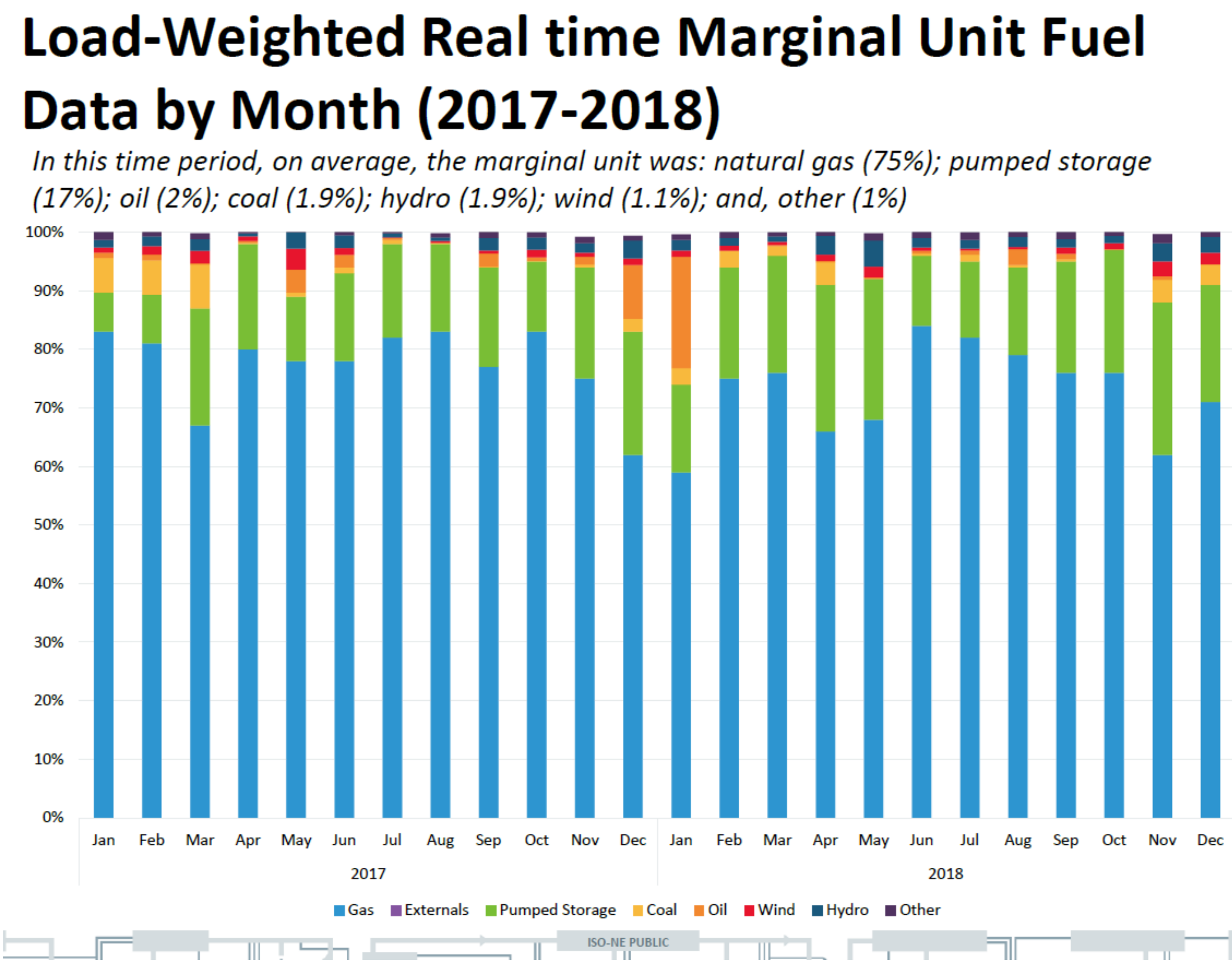


Figure 13. Monthly Marginal fuel type during 2017-2018. It should be noted that pumped storage hydro is not a "zero emission" resource when considering the embodied emissions of the marginal generating unit dispatched to meet the electrical load required to pump water into the storage reservoirs. If these resources operate with ~10-30% round trip efficiency, the effective marginal emissions resultant would be ~10-30% higher than that of the resource supplying marginal load during pumping. Truly non-emitting resources were marginal only 3-4% of the time. Energy storage deployed at any other time would presumably result in the increased output of a fossil fuel electric generating facility.



ISO-NE, *Environmental Regulatory Update*, slide 25; https://www.iso-ne.com/static-assets/documents/2019/01/envtlupdate_20190129.pdf