Assessment of Potential Energy Storage Alternatives for Project 2015A in Peabody, Massachusetts

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Background

The Massachusetts Municipal Wholesale Electric Company (MMWEC) is proposing to build Project 2015A, a nominal 60 MW natural gas and oil peaking power plant in Peabody, Massachusetts. The purpose of the project is to respond to a need for additional electrical generating capacity in the Northeast Massachusetts zone of the ISO-NE system, especially during periods of peak demand.

Initially, fourteen municipal utilities agreed to purchase a portion of the facility to fulfill their capacity requirements. However, in April 2021, two of the municipal utilities filed with the Department of Public Utility to withdraw from the contract. Subsequently, the MMWEC board of directors authorized a minimum 30-day pause in the project during a special meeting held in early May. According to the Company's statement, the pause is meant "to address the concerns brought to the MMWEC Board, while also considering available options to fulfill its participants' required capacity obligations under the Independent System Operator's New England (ISO NE) rules." MMWEC later decided to extend the pause of the Project.[1]

Project 2015A was initially chosen after a request for proposals (RFP) issued by MMWEC in 2016, calling specifically for a capacity resource fueled by natural gas and ultra-low sulfur oil as a secondary fuel. Technologies considered before the issuance of the RFP included combined-cycle and simple-cycle combustion turbine technologies. While the awarded peaker proposal outperformed the operational requirements and presented a low cost at the time, new capacity technologies like storage have become viable and increasingly cost-competitive.

Recent examples from leading utilities show how clean energy portfolios can meet capacity needs at a lower cost than gas: the Rocky Mountain Institute identified 11 recent procurements by utilities serving >6 million customers that illustrate how all-source procurements can harness competition to lead to lower-cost outcomes for customers while maintaining reliability. Crucially, in these leading examples, only ~10% of procured capacity came from gas plants, while ~90% of new capacity procured was from clean energy resources (wind, solar, storage, efficiency, and demand response). All-source RFPs are now the preferred approach to procure capacity resources.[2]

[1] Update of the Massachusetts Municipal Wholesale Electric Company, DPU 21-29, submitted on June 14, 2021

[2] L. Shwisberg, M. Dyson, G. Glazer, C. Linvill, M. Anderson, How to Build Clean Energy Portfolios A Practical Guide to Next-Generation Procurement Practices, March 2021

In addition to this, the state's Next-Generation Roadmap Bill was signed into law this year. The bill requires municipal utilities to get to net zero emissions by 2050 and mandates the deployment of additional wind and solar in the state, creating further need for flexible technologies to integrate them into the grid. The bill also aims to ensure increased outreach to environmental justice populations and requires more engagement from state agencies as they carry out their duties.

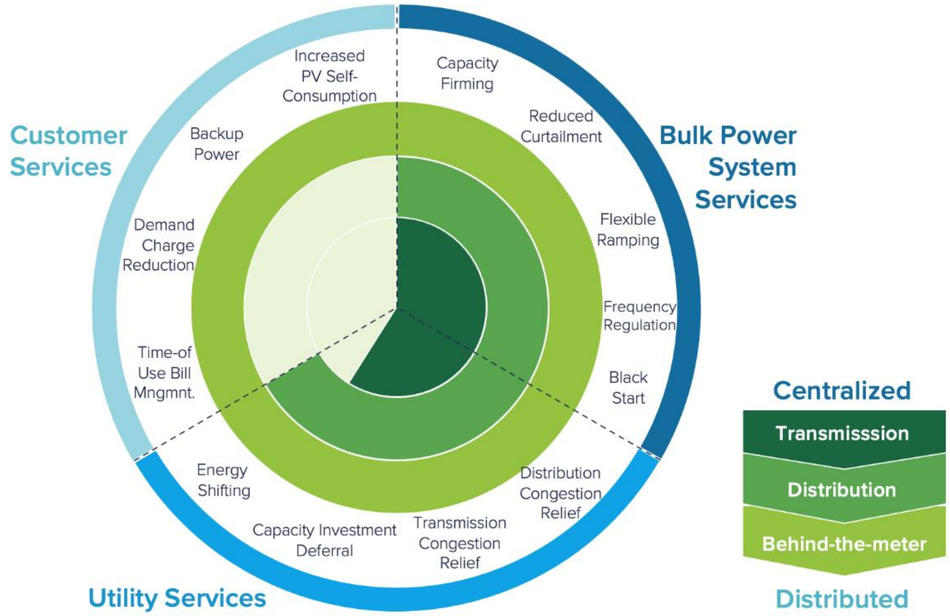
Recognizing that much has changed in policy and technology since the project was first proposed several years ago, the 30-day pause was meant to provide an opportunity for re-assessment and investigating whether the capacity need can be met by a resource that is not fossil fuel-fired. To this end, the Clean Energy Group (CEG) together with the Massachusetts Climate Action Network (MCAN) explored energy storage as an alternative option to fulfill the participant's capacity obligations.

In this briefing, Strategen provides information about the feasibility of using storage or other solutions to meet the capacity needs of MMWEC in place of the proposed Project 2015A. Specifically, this report provides information about the ability of storage to replace peaker plants, including a short list of recent energy storage projects that have been deployed to replace fossil-fueled peakers. This report then investigates the economics of replacing the proposed peaker with energy storage. The investigation examines Project 2015A and energy storage in terms of capacity provision, affordability, and emissions. The report concludes that energy storage is not only a viable replacement option, but that it also results in emissions and cost savings.

Recent Energy Storage Project Examples

Key services that utility-scale battery storage provides to the grid include energy time shifting, ancillary services, and variable generation integration, resource adequacy, transmission & distribution congestion relief, and investment deferral. On top of their environmental advantages, as technology costs continue to fall, portfolios including renewables, energy storage and distributed energy resources (DER) are becoming significantly more cost-effective than fossil fuel technologies.

Figure 1. Energy storage value streams across the grid (adapted from Rocky Mountain Institute)[3]



The number of replacement portfolios that include energy storage, and specifically batteries, is continuously increasing as both regulators and utilities realize the technology's key role in transitioning to a clean grid. Globally, there is now a significant number of commercial, large-scale battery storage projects that are online, under construction or are contracted to be built in order to provide capacity during hours of peak demand. Below are just a few examples of some of these recent projects:

Oxnard, CA – Standalone storage

In 2019, Southern California Edison selected a 195 MW portfolio of batteries to supply local capacity needs around the coastal city of Oxnard, instead of the 262 MW natural gas peaker plant it had chosen previously. The portfolio includes a 100 MW / 400MWh battery in addition to smaller energy storage units ranging from 10 to 40 MW each. The 20-year resource adequacy contract leaves the batteries free to monetize on energy and ancillary benefits as a participant in the CAISO market when not called upon to fulfill its capacity

[3] Garrett, Mandel, Morris, and Touati. The Economics of Battery Energy Storage: How multi-use, customer-sited batteries deliver the most services and value to customers and the grid. Rocky Mountain Institute, September 2015.

obligation. This further improves the project economics relative to a system that only operates during peak events.[4]

The grid operator, CAISO, initially determined that energy storage could fulfill the reliability needs, but at nearly three times the price. That analysis, however, relied on outdated storage pricing data that exaggerated the technology's costs and stakeholders pushed for an evaluation of gas plant alternatives before regulators signed off on the gas project. Within months, the commissioners signaled their intent to reject the gas plant and directed SCE to launch a new solicitation to see exactly how competitive storage and other resources had become.

On June 29, 2021, one of the largest energy storage facilities in the United States was unveiled to the public: the Saticoy Energy Storage Site consisting of a 100MW battery storage system in Oxnard, California. The battery system went in between summer 2020 and December 2021 and is estimated to have cost less than half of what the gas plant would have, leaving ratepayers significantly better off while alleviating the environmental burden of an already impacted community. The battery site demonstrates how to locate large amounts of power within populated areas with no noise or pollution.

APS all-source solicitation, AZ – Standalone storage

Arizona Public Service (APS) issued an "all-source" request for proposals (RFP) in 2018, seeking 400 to 800 MW of capacity to meet peak energy needs, meaning that the capacity should be delivered between 3:00 p.m. and 9:00 p.m. when APS electricity demand is highest. As a result, APS bought 150 MW of stand-alone batteries with four-hour durations by 2021. The energy storage projects competed and won against new gas-fired peakers; however, the RFP was controversial because it designated that at least half the capacity come from gas-powered facilities. APS selected a 463 MW gas plant PPA that was competitive with storage by being an existing plant, not a new project. The existing peaker was contracted to deliver power only during the summer and only for seven years. APS has expressed its intention to build additional energy storage after the peaker contract expires and it gets more comfortable with the new storage technologies.[5]

ISO-NE, Capacity auction - Standalone storage

This year, Plus Power won two bids in the latest ISO-NE forward capacity auction. The two battery projects competed against fossil fuel plants and were contracted for seven years to deliver power during times of peak demand, starting in 2024. This was achieved without federal tax credits as they do not apply to standalone batteries. The 150 MW / 300 MWh battery in Massachusetts and the 175 MW / 350 MWh battery in Maine are the first standalone batteries to win competitive capacity auctions after the market was first opened to batteries by ISO-NE's implementation of FERC Order 841.[6]

Oakland, CA – Standalone and distributed storage

In 2019, Oakland's CCA, East Bay Community Energy, approved battery capacity contracts to incrementally replace a 40-year-old, 165 MW jet fuel-fired peaker plant. The first portion will be replaced with a 36.25 MW standalone battery and more will be added as the retirement of peaker units frees up space for development.[7] These utility-scale batteries will be complemented by a virtual power plant (VPP), leveraging residential solar and battery systems installed and managed by Sunrun. The VPP will deliver more than 2

[4] GTM, 2019. *Southern California Edison Picks 195MW Battery Portfolio in Place of Puente Gas Plant.* News article.

[5] Utility Dive, 2019. *APS to install 850 MW of storage, 100 MW of solar in major clean energy buy.* News article.

[6] GTM, 2021. *Plus Power Breaks Open Market for Massive Batteries in New England.* News article.

[7] S&P Global, 2020. *Vistra to increase Oakland battery storage project to 36.25 MW.* News article.

MWh of batteries on more than 500 low-income housing units, providing additional grid reliability capacity to East Bay Community Energy and resiliency capabilities to low and moderate income (LMI) communities. Both the standalone battery and the VPP carry 10-year contract periods starting in 2022.[8]

ISO-NE, Capacity auction - Distributed storage

Also in 2019, Sunrun won a 20-megawatt bid in the forward capacity auction for ISO New England. That auction ensures that enough capacity will be available in the grid three years in advance. Sunrun offered coordinated solar-plus-storage aggregations that competed in an open auction alongside conventional capacity resources such as gas plants. Becoming eligible to bid into the market took extensive procedural work, but now provides a precedent for the model to spread in New England. Sunrun's network of small solar-plus-storage installations will give backup power to around 5,000 customer homes and provide capacity for reliability across the region. The company is promising to deliver the necessary contracted power to the grid while using the revenues from the capacity market to reduce production costs for customers.[9]

While this report is focused on standalone, utility-scale batteries as a replacement option for gas peaker plants, aggregated and coordinated DER like Sunrun's VPP can be leveraged to design more diverse capacity portfolios. The cost and additional benefits of such portfolios are not calculated in this analysis but could be assessed going forward while considering their potential value for local communities and the grid.

[8] S&P Global, 2019. *Sunrun selected to replace part of Oakland plant with home solar, storage*. News article.

[9] Energy Storage News, 2019. *'Breakthrough moment': Sunrun's home solar-plus-storage to provide 20MW capacity in New England.* News Article.

Energy Storage Participation in ISO-NE Markets

Energy, Regulation, and Reserve Market

In the ISO-NE, a continued storage facility (CSF), like a battery, can participate simultaneously in energy, reserves, and regulations markets. Specifically, under phase 1 of the Energy Storage Device (ESD) project, ISO New England allowed participants with grid-sized CSFs to offer the full range of their asset's capability in the regulation market while continuing to operate as a dispatchable energy market resource. CSFs are registered as three asset types:

- An Alternative Technology Regulation Resource (ATRR)
- A non-regulation capable generator asset
- A dispatchable-asset-related demand (DARD) asset

These three asset types, combined, represent the single physical asset. This arrangement allows the asset to perform in the various markets.

In terms of current deployment, about 20 MW of grid-scale battery-storage projects have come online in ISO NE since 2015; more than 600 MW are planned, and that number will keep growing, under state mandates like Massachusetts' statutory goal of 1,000 MWh of energy storage by the end of 2025.[10] As of February 2021, nearly 3,000 MW of grid-scale stand-alone energy-storage projects were requesting interconnection.[11]

Forward Capacity Market

Separate from the energy market, ISO-NE also holds annual Forward Capacity Auctions (FCAs). The Forward Capacity Market (FCM) is a long-term market that ensures resource adequacy, both zonally and for the ISO-NE system as a whole. The market is designed to promote economic investment in capacity resources when and where they are needed. Capacity assets that may participate in the FCM include new and existing resources, comprised of generating resources, imports, demand response resources, and energy efficiency resources.

To purchase sufficient capacity to satisfy the region's future resource adequacy needs and allow enough time to construct new capacity resources, FCAs are held each year approximately three years in advance of the 12-month Capacity Commitment Period during which time the resources that clear in an FCA must meet their assumed obligation. Resources compete in the auctions to obtain a commitment to supply capacity in exchange for a market-priced capacity payment. Those that clear the auction receive a monthly capacity payment in that future year in exchange for their commitment to provide power or curtail demand when called upon by the ISO. The payments are in addition to the revenues those resources are eligible to receive in the ISO-NE energy and ancillary services and other markets.

New England's most recent annual capacity auction (FCA-15) for power system resources concluded in February 2021 with sufficient resources to meet peak demand in 2024-2025. Clearing prices ranged from $2.48/kW-month in Northern New England to $3.98/kW-month in Southeast New England. More than 630 MW of battery storage cleared the NE market including two new standalone projects: a 150 MW/300 MWh system near a cranberry bog south of Boston, Massachusetts and a 175 MW/350 MWh battery in Gorham, Maine.

[10] MA government website. Energy Storage Initiative. Emerging Technology Division. Accessed June 2021.

[11] ISO NE, 2021. Resource Mix. Key Grid and Market Stats. Accessed June 2021.

Economic Comparison: Peaker vs. Standalone Energy Storage

Peaking power units are resources that supply electricity only during times of peak demand. Technically, these units are flexible and capable of fast ramping. However, these units have low utilizations because their high-marginal costs limit their dispatch and operation. Thus, peaking units provide little additional value in terms of energy or other grid services during the year beyond peak capacity. Battery storage units, on the other hand, are set up for high utilization across the year due to their low marginal costs. For this analysis, we first compare the cost of the two technologies and then examine the different value streams for each technology to understand their net cost.

Cost of New Entry in ISO-NE

In addition to the Strategen analysis, it is worth presenting some cost comparison results from ISO-NE. Specifically, the ISO-NE estimates the cost of developing new resources that could enter the FCM, known as the Cost of New Entry (CONE). At a high level, the CONE and Net CONE values are, respectively, estimates of the total and net costs of developing the most economically efficient type of new capacity resource in New England. The Offer Review Trigger Price (ORTP) values are estimates of the entry costs for all resource types that would reasonably be expected to participate in the FCM and are used to screen offers from new resources that may require further review per ISO New England's (ISO-NE) buyer-side market power mitigation provisions. ISO-NE evaluates technology types that are likely to participate in the FCM to identify which technology types require an ORTP to be calculated. ORTP is then calculated by estimating the gross entry costs and expected net market revenues based on assumptions about the technology's operating characteristics, its energy and ancillary service market participation, and other factors. ORTPs are based on market conditions expected to prevail in the upcoming auction rather than longer-term market conditions. The ORTP values reflect the low end of the competitive range of the offer price that commercial technologies can plausibly submit to the auction. Still, the values offer insights as to how the resources compare to each other in terms of net cost.

In preparation of FCA 16, ISO-NE engaged Concentric Energy Advisors (CEA) to conduct an independent analysis of the CONE/Net CONE and ORTP values.[12] Notably, the CEA ORTP costs indicated that the net costs of battery storage are significantly lower than the cost of a new combustion turbine. This means that although the installed costs may be higher for a battery storage resource relative to a combustion turbine, the ability of storage to capture additional revenue streams more than offsets the upfront cost, making storage a more cost-effective resource over the life of the asset.

Still, the CEA methodology for the storage ORTP was criticized by the Massachusetts Attorney General's Office, finding that the energy and ancillary services revenue estimates for energy storage were unreasonably low, meaning that ORTP prices for storage could be even lower in the state.[13] The New England Power Pool (NEPOOL) Participants Committee also agreed that optimally dispatching the resource could result in higher expected revenue and that CEA materially underestimated the amount of energy and ancillary services revenues a competent battery operator could expect to receive.

[12] Joint Filing of ISO New England Inc. and New England Power Pool Regarding Offer Review Trigger Prices, Attachment I-1b December 2020 CONE and ORTP Report (December 2020)

[13] Revenue for Energy Storage Participating in ISO-NE Energy and Reserves Markets, Alternative ORTP EAS Offset Estimates Massachusetts Attorney General's Office | B.W.Griffiths | Updated 11-3-2020

In its Order, the Federal Energy Regulatory Commission finds that both ISO-NE's and NEPOOL's proposed ORTPs for battery resources are just and reasonable, but that in this instance NEPOOL's estimate is preferable as it better reflects how a reasonable battery operator would operate the battery.[14]

Thus, based on market conditions expected to prevail in the upcoming auction, storage is expected to have a significantly lower net cost than other capacity resources, including simple cycle gas units. The revised ORTP values are presented below.

Table 1. Offer Review Trigger Prices for the Forward Capacity Auction[15]

Generating Capacity Resources	
Technology Type	**Offer Review Trigger Price ($/kW-month)**
Simple Cycle Combustion Turbine	$5.355
Combined Cycle Gas Turbine	$9.811
On-Shore Wind	$0.000
Energy Storage Device – Lithium Ion Battery	$2.601
Photovoltaic Solar	$1.381

Economic Analysis: Project 2015a vs Standalone Storage

As a peaking unit, Project 2015A is forecasted to run very infrequently. Specifically, MMWEC states an upper limit of 1,250 hours of full-load operation per twelve-month rolling period at maximum firing rate, of which a maximum of 250 hours per twelve-month rolling period will be on ULSD.[16] The project is estimated to run an average of only 2.72% of the time, equivalent to approximately 239 hours per year and accounting for only 0.535% of Project Participant energy needs.

In contrast, an energy storage system, can efficiently provide value to the grid during many hours of the year, not simply during peak load hours. For the purposes of this analysis, we model a standalone battery with a power rating of 60 MW and project the value streams from the energy, reserve, and regulation markets. Cost projections are based on the National Renewable Energy Laboratory's (NREL) Annual Technology Baseline (ATB) 2021.

MMWEC is projecting costs of $76.6 million with an additional ten percent ($7.7 million) as a contingency for COVID-19-related issues,[17] indicating capital costs of $1,243/kW.[18][19] Based on the available data, it is unclear whether this cost includes the emission control technology costs, which would make Project 2015A an even more expensive option.

[14] Docket No. ER21-1637-000, Order Accepting In Part And Rejecting In Part Proposed Tariff Revisions And Directing Compliance, Issued June 7, 2021

[15] Docket No. ER21-1637-001; ISO New England Inc., Compliance Filing to Conform Tariff to Commission Acceptance of Offer Review Trigger Prices for FCA 16, June 22,2021

[16] MassDEP, Draft Air Quality Air Approval, August 2020

[17] Joint Direct Testimony of Ronald C. Decurzio and Glenn R. Trueira, Attachment 3.

[18] The capital cost estimate used in the analysis excludes the cost of upgrading the local substation ($400,000) that might be needed regardless of the selected generating technology. The cost also excludes the COVID contingency, and the capitalized costs.

[19] NREL ATB 2021 estimates capital expenses of $919/kW for a new Combustion Turbine in 2021 (in $2019), without including the cost of the emission control technologies.

NREL estimates that the cost to install a standalone battery storage facility designed to provide peaking power in the 2021 timeframe could be as low as $744/kW for a 2-hour battery and $1,250/kW for a 4-hour battery (in $2019). However, for this analysis, we are using NREL's moderate cost projection for a 2-hour battery ($763/kW) and a 4-hour battery ($1,318/kW). The projections were in 2019 dollars and were inflation-adjusted for the purposes of the analysis.

As already described, utility-scale batteries with a duration of two hours cleared FCA 15. Still, in this brief, we examine both 2hr and 4hr batteries to better understand how the economics of the proposed peaker compare to its alternatives. Historical data from peaker operations in the Northeast Massachusetts and Boston Zone (NEMA), where the capacity need has been identified, do not support the need for a longer duration. Specifically, the 2019 and 2020 operations of Medway, Framingham, and M Street Jet, three peaking resources in NEMA, could be covered by a battery with the same power capacity as the plant and a duration of four hours.[20] ISO NE does not require batteries to have a longer duration to participate in the ancillary services or capacity markets.[21]

Table 2. Cost comparison for peaking resource options

Technology	Estimated Delivery Year	Est. Initial Capital Cost (2021$/kW)	Est. Annualized Cost (2021$ Millions)[22]
Project 2015A Combustion turbine *With NOx and CO controls	2022	1,243	7.3
2-hour BESS – Moderate cost	2022	791	2.0
4-hour BESS – Moderate cost	2022	1,329	5.8

Importantly, these capital costs represent the total cost of a project before market revenues and operations costs, which will drive the net cost of the facility. While capital costs are a useful metric to represent the cost of energy technologies, they are non-specific for the ISO-NE market nor the Boston region. The net costs, on the other hand, are closer to the actual bidding price of these energy assets because they are estimated using data on specific markets and regions.

Based on 2019 historical energy and regulation data from ISO-NE for the project location, and reserve price data as outlined in the CEA ORTP model, [23] Strategen estimates annual revenues for the gas plant and the storage assets. To estimate the storage revenue, Strategen developed an optimal dispatch model that maximizes the expected revenue across the three markets including the Forward Reserve Market (FRM): those are depicted below as Energy and Ancillary Services (AS) Revenue.[24] For Project 2015A, the revenue is estimated based on the energy generation during the highest-priced hours of the year up to the projected

[20] Based on historical data from the S&P Market Intelligence Platform for the hourly generation of the Medway, Framingham, and M Street Jet units in 2019 and 2020

[21] The ORTP calculation in the Joint Filing of ISO New England Inc. and New England Power Pool Regarding Offer Review Trigger Prices, Attachment I-1b December 2020 CONE and ORTP Report (December 2020) assumes participation of a two hour battery in energy, regulation, reserve, and capacity markets without restrictions.

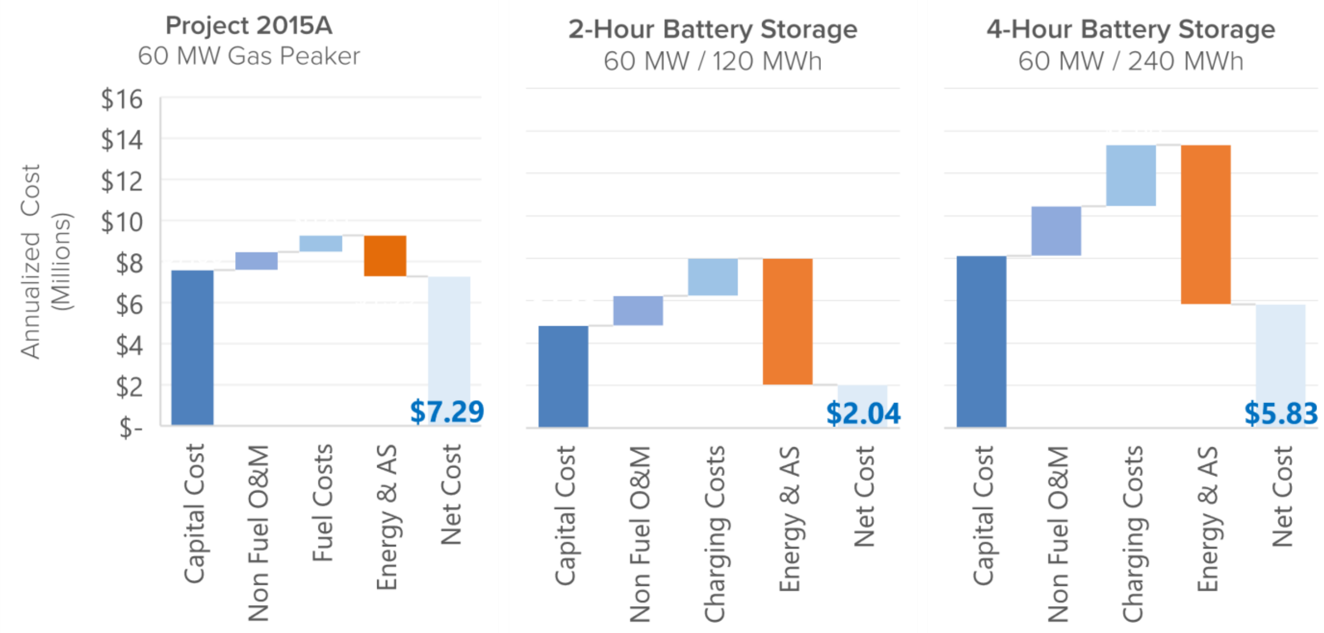
[22] Capital costs annualized based on lifetime of 20 years and weighted average cost of capital of 8%. Energy & ancillary services prices based on 2019 historical data. Technology, operation and maintenance, and fuel costs based on NREL ATB projections. Locational marginal prices, ancillary services prices, fuel, and operations costs assumed to escalate with the inflation rate. Charging costs for the battery are not inflated, as we assume zero marginal cost energy to be increasingly available.

[23] CEA ORTP model: https://www.iso-ne.com/static-assets/documents/2020/11/a4_a_i_cone_ortp_dispatch_models.zip

[24] The model follows CEA's assumption that the battery can provide up to 11% of its capacity for regulation. The model optimizes only for the Real time market; further revenues could be available if the Day Ahead market was also included in the optimization.

capacity factor and reserve provision through the FRM for the rest of the year. If the FRM were to sunset, project economics would remain significantly more favorable for energy storage compared to Project 2015A. The analysis results are presented below:

Figure 2. Annualized cost comparison: Project 2015A vs Standalone Storage



Our analysis shows that replacing the proposed peaker with energy storage is not only preferable from an environmental perspective but also results in significant cost savings for consumers. The analysis did not consider any tax incentive that could result from pairing the resource with renewable generation; eligibility for such a credit would result in increased savings.

MMWEC has already committed $9 million to the project.[25] However, this sunk cost is significantly lower than the 14 million of savings over the first 20 years of installing a four hour battery storage compared to Project 2015A.

MMWEC indicates that a longer duration resource might be needed.[26] Although this is not required for participation in the Forward Capacity or Forward Reserve Market and is not justified by the historical operations of other peaking units in the NEMA zone in 2019 and 2020, our analysis still indicates that under NREL's most aggressive cost projections a 385 MWh battery would result in the same net cost as the proposed peaker under the $85 million budget.

In addition to the economic savings, replacing the peaker with a battery will also eliminate the exposure of the municipal utilities and their customers to the increased volatility of fuel prices, effectively providing enhanced price stability for the customers of municipal utilities. Project 2015A is projected to generate energy very infrequently. Still, when energy generation will be needed, ratepayers will be exposed to the volatility of natural gas and oil prices. On the other hand, energy storage smooths peaks and reduces price differentials. As renewable penetration increases driven by declining costs and the state's clean energy

[25] Project 2015A Frequently Asked Questions

[26] MMWEC suggests that a 385 MWh battery would be needed in place of the proposed peaker, Project 2015A, Public Information Session, June 22, 2021

policy, zero marginal cost electricity will become increasingly available and storage resources will be able to charge at zero cost while reducing curtailment. This zero-cost energy will be shifted to peaking hours, reducing costs to ratepayers.

Emissions

The emission impacts of peakers can be, in part, quantified through the emission of local pollutants (SO_2 and NO_X), which cause incidences of respiratory illness, cancer, disease, premature mortality, as well as other damage near the source of emissions. Project 2015A emissions might be reduced due to the proposed control technologies, but will still exist as the project is designed to be fueled by natural gas and fuel oil. Specifically, the project is expected to have an SO_2 emissions rate of approximately 0.168 lbs/MWh and a NO_X emissions rate of 0.016 lbs/MWh.[27] In 2013, the US Environmental Protection Agency published a Technical Support Document (U.S. EPA 2013) describing an approach for estimating the average avoided human health impacts and monetized benefits related to emissions of $PM_{2.5}$ precursors including NO_X and SO_2 from 17 sectors.[28] According to EPA's analysis and based on the proposed peaker's projected NO_X and SO_2 emissions, Project 2015A could cost the state of Massachusetts an estimated $300,000 associated with local emissions over the first ten years (as shown in Table 3).

In addition to the local emissions, peakers also contribute to global emissions, specifically carbon dioxide. Global pollutants cause damage by concentrating in the atmosphere and have an impact on climate changes worldwide, regardless of where the source of emission is located. These climate changes signify societal impacts related to changes in net agricultural productivity, property damages from increased flood risks, human health, energy system costs, and other aspects of the economy. Based on the Social Cost of Carbon (SCC) suggested by the Environmental Protection Agency,[29] CO_2 emissions from the proposed gas peaker plant could cost society up to $459,000 just in its first year of operations, and $4.9 Million within the next decade.[30] Although the SCC value is not reflected within market prices, the RGGI value can be used as a proxy for quantifying the market value of reducing CO_2 emissions.

In its recent public information session on June 22, 2021, MMWEC claimed that Project 2015A reduces the generating fleet's emissions. This is incorrect. The peaking unit will emit local and global pollutants which will be adding to the fleet's emissions. The emission rate might be lower than some of the existing resources, but it is still positive and higher than alternative options. In fact, the emission rate of Project 2015A is higher than the 2019 marginal CO_2 and NO_X emissions rates for the marginal units in ISO NE.[31] The projected damage, as quantified in Table 3, is not insignificant.

[27] Strategen's calculations based on information from the MassDEP, Draft Air Quality Air Approval, August 2020

[28] U.S Environmental Protection Agency, Estimating the Benefit per Ton of Reducing PM 2.5 Precursors from 17 Sectors.

[29] U.S Environmental Protection Agency, The Social Cost of Carbon

[30] Project 2015A could potentially emit 50,780 tons of $C0_2$ annually. As reported in MMWEC Draft Plan Approval presented to the Massachusetts Department of Environmental Protection.

[31] ISO NE, 2019 ISO New England Electric Generator Air Emissions Report, March 2021

Table 3. Project 2015A emission costs

Pollutant	Potential Emissions (Tons/year)	First Year Economic Impact ($)	First Decade Economic Impact ($)
CO_2 (RGGI)	7,500	59,250	818,625
CO_2 (SCC)	7,500	458,748	4,884,027[32]
NO_x	1.1	17,338	181,847
SO_2	0.1	11,196	117,207

Installing batteries in place of the proposed gas peaker plant could bring economic benefits associated with the reduction of local and global pollutants. Estimating the reduction of emissions accurately is difficult as it depends on the emissions intensity of the generator whose output is used to charge the storage asset. As the grid transitions to higher renewable penetration levels, the emission intensity of the charging energy will keep declining. Still, even if the storage is not paired with a renewable resource and were to start operating today, it would result in reduced CO_2 and NO_X emissions. According to our dispatch model, the storage asset charges during off-peak hours, when the marginal CO_2 and NO_X emissions rates for the marginal units in ISO NE are lower than the project's rates, indicating potential emissions savings.[33] The absence of local emissions combined with the technology's modularity also increases siting flexibility, resulting in additional benefits.

In the effort to incentivize better utilization of clean energy technologies to supply power when electricity demand is at its peak, Massachusetts formulated the Clean Peak Standard (CPS). CPS, called for in legislation passed in 2018, creates credits for clean energy delivered during time windows identified as peak hours for a given season. Utilities in the state must obtain clean peak credits equal to a percentage of total electricity delivered in the year, starting at 1.5 percent in 2020 and growing annually. The goal is to create a price signal to shift clean power to the hours it's most valuable for the grid. CPS creates an opportunity for energy storage technologies such as batteries, which store electricity for use when desired. Energy storage systems can participate as standalone or co-located with storage units. However, per the Statute, municipal lighting plants (MLP) are exempt from the Clean Peak Energy Standard, which means that MLPs do not have a compliance obligation, and resources in MLP territories are ineligible to participate. Consequently, the analysis does not quantify any benefits from CPS eligibility.[34]

[32] Assuming a 7% escalation rate.

[33] ISO NE, 2019 ISO New England Electric Generator Air Emissions Report, March 2021

[34] M.G.L. c. 25A, § 17 (d) states that "this section shall not apply to municipal lighting plants."

Additional Considerations

Project Siting

Project 2015A, or the Peabody peaker project, is intended to be built on 0.6 acres of available land (yellow perimeter) within the 4-acre Water Rivers Station owned by PMLP (orange perimeter). The property already hosts a 115 kV substation[35], a 50-year-old 20 MW turbine and a 30-year-old 48 MW turbine, and three above-ground fuel-oil tanks with a 115,000-gallon capacity each.

Figure 3. Peabody development site at Water Rivers Station

The site's location and existing infrastructure make it suitable to host a new energy generation asset and, while it is too small for renewable energy generation, it could fit modular and energy-dense assets like batteries. In fact, storage can be rapidly and safely installed in small areas without the emission burden of gas peakers. Providers offering some of the most energy-dense utility-scale batteries can deploy about 83 MW of four-hour duration batteries in an acre. Tesla claims to be able to install a 250 MW, 1,000 MWh battery on a three-acre footprint in less than three months: four times faster than a traditional fossil fuel power plant of that size.[36] In a recently proposed project in California, Vistra Corp announced they could install a 600 MW, 4-hour battery on 22 acres. Using these examples, a 60 MW battery could be installed in a footprint ranging from 0.36 to 1.1 acres for a 2-hour battery duration or 0.72 to 2.2 acres for a 4-hour duration battery.

Depending on the battery provider and technology, the current project site may or may not be large enough to fit the battery system. While there are opportunities to optimize the use of space in the Water Rivers Station at Peabody,[37] battery storage systems are composed of modules that can be easily accommodated within the site or in distributed locations. In planning for project 2015A, MMWEC identified multiple alternative sites where available space, favorable zoning, and existing electric infrastructure would facilitate the installation of a new energy generator near the City of Boston, the load center. These locations, all in Massachusetts, include a 0.5-acre site in Fall River, a 0.4-acre site in Plymouth, and a second 3.5-acre site in Plymouth. While these sites are located near residential properties and thus were deemed less preferable

[35] Project 2015A contemplates an expense of $400,000 to replace circuit switches at PMLP substation.

[36] Tesla, 2019. Introducing Megapack: Utility-Scale Energy Storage. Press Release.

[37] Existing gas peakers in the site, with 30 and 50-years in service, are close and past the typical age of retirement for simple-cycle gas power plants. Retiring these plants and the associated fuel-oil reserve-tanks could free up two acres of land for the development of clean energy assets at Peabody.

for the gas peaker project, energy storage lacks the negative environmental externalities that would otherwise affect residents.

In addition to the utility-scale storage examined in this report, and as part of its planning going forward, MMWEC may wish to evaluate a VPP aggregating residential battery systems across the footprint of its member utilities. Considering that this would not be the first project of its kind in the state and that regulatory and technical barriers have already been overcome,[38] this option would reduce the space requirements at Peabody or any central location and could realize additional benefits from distributed capacity. Such benefits include building resiliency for customers from backup power, the relief of load pockets by reducing constraints at transmission and distribution lines, potential bill reductions for participating customers, and the advancement of the state's clean energy goals.

Environmental Justice

Project 2015A will be situated in an environmental justice community.[39] The Commonwealth's Next Generation Roadmap for the first time defines Environmental Justice populations in state statute. The definition is based on criteria of race, income, and language isolation. The roadmap law further amends the Massachusetts Environmental Policy Act (MEPA) to address environmental justice by introducing definitions for environmental benefits, environmental burden, environmental justice principles, and neighborhoods, and by providing new tools, protections, and public input for these communities. Specifically, it creates a new advisory council to work with state agencies to guarantee meaningful public participation in the decision-making process and remedy the legacy of how the state approves infrastructure and energy projects in environmental justice neighborhoods. Furthermore, following enactment of the Roadmap Law, an Environmental Impact report shall now contain additional information evaluating the environmental and public health impacts of the project, describing measures being utilized to minimize those, outlining unavoidable adverse short-term and long-term environmental and public health consequences, and investigating reasonable alternatives to the proposed project. The environmental impact report shall be required for any project that is likely to cause damage to the environment and/or to air quality and is located within a certain distance from an environmental justice population, assessing any existing unfair or inequitable environmental burden and related public health consequences impacting the environmental justice population from any prior or current private, industrial, commercial, state, or municipal operation or project that has damaged the environment. In the case of an existing unfair or inequitable environmental burden or related health consequence the report shall identify any:

(i) environmental and public health impact from the proposed project that would likely result in disproportionately adverse effect on such populations; and
(ii) potential impact or consequence from the proposed project that would increase or reduce the effects of climate change on the environmental justice population.

These MEPA amendments highlight the significance of environmental justice issues, especially in areas that are already suffering disproportionate pollution burdens. According to the Massachusetts Climate Action Network (MCAN), the proposed peaker plant is to be built less than half a mile away from two environmental justice communities and less than a mile away from seven local schools, a hospital, and several day-care centers. Besides the proposed peaker, the city of Peabody has several other sources of environmental pollution, including two natural gas peaker generators, three locations of toxic release, 15 air pollution

[38] See replacement use case in ISO-NE using distributed energy storage. Section on "Recent Energy Storage Project Examples", Page 3.

[39] Massachusetts 2020 Environmental Justice Populations

sources, and 85 sources of hazardous waste. The cumulative impact of these emissions contributed to Peabody, and neighboring communities, being some of the hardest hit by the COVID-19 pandemic in the State.[40]

The construction of another fossil fuel resource in the area will disproportionately affect the already disadvantaged communities. On the other hand, as renewable penetration increases, driven by declining costs and the state's clean energy policy, the alternative of energy storage is not only more economic, but also enables the use of more renewable energy positively impacting these communities.

Reliability

Even though it is an energy-limited resource, energy storage can meaningfully contribute to system reliability. The North American Electric Reliability Corporation has recently conducted analyses that underscore challenges presented with the acceleration of coal-fired generation retirements and the increased reliance on natural gas. The rapid shift to inverter-based resources (IBRs) that are variable energy resources due to their fuel source (e.g., wind, solar) creates potential challenges related to availability that may require additional resources to maintain the bulk power system's reliability. NERC notes that batteries could complement IBRs by providing some of the essential reliability services that are important to maintain reliability. Additionally, batteries provide elements of grid support, including flexible ramping support, fast frequency response, addressing the uncertainty of resource availability, and shifting energy to address new peaking conditions.[41]

NREL research has shown significant potential for energy storage to replace peaking capacity, and that this potential grows as a function of solar photovoltaic deployment. Specifically, the analysis demonstrated roughly 28 GW of practical potential for 4-hour storage providing peaking capacity, assuming current grid conditions and demand patterns.[42]

In a recent public information session, MMWEC questioned whether lower grid reliability lies ahead. They pointed to three issues: the at-home need for medical devices, the California rolling brownouts, and the recent Texas power crisis, indicating that renewables and storage would increase the risk for the Commonwealth. These are all misleading arguments.

First, distributed energy systems that include energy storage (and that could be part of a VPP setting as described above) would address the concern for the medically vulnerable population. Battery storage, especially when paired with solar PV (solar plus storage), increases grid resilience and helps mitigate this risk by providing reliable residential backup power in the event of an outage, allowing medically vulnerable residents to shelter-in-place or safely wait for evacuation in their own home. Second, resilient power can also help critical facilities, such as schools, hospitals, and nursing homes, provide community services through an outage or brownout.[43]

[40] In an analysis of 3,080 counties in the United States, researchers at the Harvard University T.H. Chan School of Public Health found that higher levels of the tiny, dangerous particles in air known as PM 2.5 were associated with higher death rates from COVID-19.
Wu, X., Nethery, R. C., Sabath, M. B., Braun, D. and Dominici, F., 2020. Air pollution and COVID-19 mortality in the United States.

[41] NERC, Energy Storage Impacts of Electrochemical Utility-Scale Battery Energy Storage Systems on the Bulk Power System, February 2021

[42] P. Denholm et al., The potential for battery energy storage to provide peaking capacity in the United States, Renewable Energy

[43] M. Mango, A. Shapiro, Home Health Care in the Dark: Why Climate, Wildfires and Other Risks Call for New Resilient Energy Storage Solutions to Protect Medically Vulnerable Households from Power Outages, Published By: Clean Energy Group, Meridian Institute, 06/04/2019

Finally, renewable energy and storage are simply not to blame for the California rolling brownouts and the Texas power crisis. MMWEC's mention of the two crises are misleading and shift blame away from what appear to be the root causes: the climate change induced extreme weather conditions, and the existing market conditions and practices.

In its final root cause analysis, the California Independent System Operator identified three major factors leading to the rotating outages: (i) the extreme heatwave across the western United States resulting in demand for electricity exceeding existing electricity resource adequacy (RA) and planning targets, (ii) the resource planning targets not keeping pace to ensure sufficient resources that can be relied upon to meet demand, and (iii) some practices in the day-ahead energy market exacerbating the supply challenges under highly stressed conditions.[44] In June 2021, California regulators adopted a decision to acquire 11.5 GW of electricity resources to support the state's grid after the Diablo Canyon nuclear plant and several natural gas plants are retired. Resources will mainly include zero-emitting generation, generation paired with storage, long-duration storage, demand response resources, and no incremental fossil fuel generation.[45]

The winter storm that roared into Texas on the weekend of February 14, 2021, precipitated a grid event of unprecedented severity, with power to millions of Texas electricity customers interrupted. The event was a critical combination of high demand and low supply. Freezing temperatures caused natural gas production and delivery to plummet, and ill-prepared power plants to go offline. At the same time, demand for both electricity and natural gas was soaring as Texans tried to heat their homes. With an islanded grid, the state could not import power from neighboring grids and a massive electricity generation failure occurred.[46] Although, the failures occurred across all types of generation, renewables included, the most significant energy gap resulted from natural gas and coal facilities.[47] For these reasons, statements blaming clean energy sources for the failures, or indicating that more gas power plants would have helped, are misleading.

Conversion to Hydrogen CT

One alternate energy solution under consideration by MMWEC is the use of combusted hydrogen in the turbine to replace the proposed fossil-fueled solution. MMWEC in its recent information session on June 22, 2021, stated that the project's existing turbine generator technology *likely* can operate with a fuel mix consisting of up to 25% hydrogen, while they are "in discussions with turbine manufacturer for developing the ability to increase the fuel mix to 100% green hydrogen", and that "development to green hydrogen fuel is a longer-term post-construction alternative". According to this statement, the proposed technology cannot operate with more than 25% hydrogen, and increasing this percentage would require additional investment. Still, even with a technology that can operate at 100% hydrogen, securing **green** hydrogen will pose additional technical and economic considerations, as further explained in this section. Based on the above, significant additional investment, far exceeding the costs of the alternative, would be required to make Project 2015 non-carbon emitting and in compliance with the Roadmap Law.

Hydrogen is a versatile energy option that has been used in small volumes for industrial processes for many years. However, the magnitude and scale of hydrogen that would be required to power a hydrogen turbine

[44] Final Root Cause Analysis, Mid-August 2020 Extreme Heat Wave, California Independent System Operator, California Public Utilities Commission, California Energy Commission, January 13, 2021

[45] California Public Utilities Commission, Decision Requiring Procurement To Address Mid-Term Reliability (2023-2026)

[46] E. Crooks, Wood Mackenzie, The Texas energy crisis: its causes and consequences, February 19, 2021

[47] C. Domonoski, National Public Radio, No, The Blackouts In Texas Weren't Caused By Renewables. Here's What Really Happened, February 18, 2021

would require significant commitment and upfront investment by MMWEC and its members. Furthermore, there still exist unresolved technical challenges around local pollutants, such as NOx, produced as a byproduct of hydrogen combustion. Combined, these challenges mean that a hydrogen turbine does not fit the needs of MMWEC, its members, or its community. This section lays out some of the key hurdles that would be required to implement a hydrogen turbine.

- Hydrogen supply: Hydrogen as an energy resource can come from a variety of sources – and not all of those are clean. In fact, most of the hydrogen in use today is "grey" hydrogen, which means it is produced from fossil fuel feedstocks. Thus, although the hydrogen itself may be a carbon-free energy storage medium, the production of the hydrogen can be extremely carbon-intensive. According to the International Energy Agency, clean or "green" hydrogen production accounts for only 0.1% of global production to date, with only $365 million invested in 94 megawatts (MW) of capacity.[48]

  Table 4. Comparison of hydrogen production processes[49]

Hydrogen Production Methodology	Carbon Impact ($kg\ CO_2$ / $kg\ H_2$)	Share of Hydrogen Produced Globally
Gray (Natural gas steam methane reformation)	8 - 12	71 %
Brown (Coal gasification and SMR)	18 - 20	23 %
Blue (Natural gas SMR plus carbon capture)	0.6 – 3.5	5 %
Green (Electrolysis from renewable energy)	0	1 %

  Even presuming that hydrogen is produced using non-emitting mechanisms, such as electrolyzers, significant infrastructure will likely be needed to meet the hydrogen production and volumes needed for a power generation plant.

- Hydrogen Combustion Emissions: While converting hydrogen to electricity using fuel cells is a clean and highly efficient process, many researchers and advocates have pointed to the fact that using hydrogen in combustion turbines leads to increased levels of NOx emissions.[50, 51] Furthermore, the US Department of Energy has noted that although technologies are being developed to attempt to control those higher NOx levels, they remain unproven.[52] As stated before, this kind of pollutant stays close to the emitting source, making them especially dangerous for local communities. Overall, If MMWEC were to propose retrofits on project 2015A to run on hydrogen in the near future (10-20 years) there are unresolved questions around cost-effectiveness and safety that the utility will need to address to

[48] International Energy Agency, 2019, The Future of Hydrogen.

[49] Green Hydrogen Coalition, 2020. Green Hydrogen Guidebook.

[50] The Union of Concerned Scientists (UCS), for example, noted that "when hydrogen is combusted (as opposed to used in a fuel cell), it can generate significant NOx emissions, commensurate with that of natural gas combustion—or worse". Accessible at:

https://blog.ucsusa.org/julie-mcnamara/whats-the-role-of-hydrogen-in-the-clean-energy-transition/

[51] Two European studies have found that burning hydrogen-enriched natural gas in an industrial setting can lead to NOx emissions up to six times that of methane. Accessible at: https://doi.org/10.1016/j.ijhydene.2017.05.107.

[52] US Department of Energy, 2020. *Hydrogen Program Plan*

provide its ratepayers with the promised rate-stability and demanded emission reductions from the power generation site.

- Hydrogen infrastructure: As a volatile substance, hydrogen requires significant transport and storage assets to ensure safe handling, storage, and use. First, “green” hydrogen production will require the use of electrolyzers or biowaste that can be gasified for hydrogen production. Today, there are fewer than 100 MW of electrolyzers in operation globally, with one of the largest in operation being 20 MW.

  Second, hydrogen transport today is primarily via truck or rail. However, at the volumes contemplated for this project, hydrogen would likely require a dedicated hydrogen pipeline or to be produced onsite, carrying additional infrastructure investments. Today, standard rules and regulations for hydrogen pipelines are unclear, as all hydrogen pipelines in operation are operated by private, unregulated companies. Third, hydrogen has a low density at ambient temperature meaning that it rapidly expands into large volumes, and it requires advanced storage methods like compression or cryogenic tanks. Although larger volumes of gas can be stored in geological formations more cost-effectively, these are locational-constrained opportunities and the demand at Peabody is far from sufficient to entail this kind of gas storage infrastructure.

  Finally, hydrogen combustion will require the retrofit or redesign of the proposed turbine. While many turbines in the market are designed to burn and run on a blend of hydrogen and natural gas,[53] it is unlikely that the peaker project proposed in 2016 can use 100% hydrogen fuel without significant changes in its design. Combined, requirements for production, transport, storage, and energy generation represent significant capital outlays. Investing in hydrogen combustion should not be undertaken lightly.

In conclusion, even if hydrogen is promising for future large-scale applications, it unfortunately cannot be part of the solution to meet the capacity need under consideration. The high cost of a still nascent technology, the economic and technical risks it entails, and the question around environmental externalities cannot compete against an already proven and commercially ready technology like batteries which at this scale can cost-effectively address the need. Building a gas unit with the promise of later converting it to green hydrogen when a better alternative is readily available is not recommended.

Recommendation

Given the advancements in the state of battery storage, it appears warranted to revisit the viability of this option in lieu of the proposed alternative. MMWEC could conduct an all-source RFP solicitation that clearly defines system needs and would be open to a variety of resources including (but not limited to), energy storage, solar plus storage including aggregated distributed resources, and demand response. This would allow for broad market participation to determine the most cost-effective mix of resources able to fulfill MMWEC’s peak capacity and reliability needs, resulting in cost and emissions savings for the Commonwealth of Massachusetts. Our analysis shows that energy storage would result in benefits in cost, global and local emissions, noise levels, and environmental justice issues.

[53] GE’s 9F.03 gas turbines can run on 50% hydrogen. MHPS has been developing gas turbines capable of using up to a 30% hydrogen and 70% natural gas fuel mixture.