Bloom Energy Fuel Cells

A Cost-Effectiveness Brief

Prepared for Bloom Energy by Synapse Energy Economics

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Ratepayer-funded energy efficiency program administrators across the United States are often required to identify and assess new cost-effective measures to meet energy efficiency targets. These energy savings targets are increasing in alignment with state climate policies and goals, tightening federal standards, and technological advancements in the energy sector. As a result, a growing number of ratepayer-funded energy efficiency plans are expanding to include customer-sited clean energy, strategic electrification, and other cost-effective carbon-reducing measures. It will be appropriate to make further adjustments over time to ensure that program administrator energy efficiency plans consider emerging technologies when defining the optimal suite of solutions to achieve state policy goals.

The purpose of this brief is to facilitate the consideration of Bloom Energy solid oxide fuel cells as a cost-effective, greenhouse gas (GHG) and criteria pollutant emission-reducing measure for inclusion in energy efficiency program portfolios in 2019 and beyond.

Fuel cells are always-on distributed generation resources that use natural gas or biogas to provide continuous on-site power. Fuel cells, like batteries, are modular and scalable to customer needs. They generate electricity through an efficient electrochemical reaction. When large energy consumers reduce their electricity draws from the grid, less-efficient, costlier, and often dirtier generating units (including so-called "peak units") are less likely to be called into service. For example, energy use reductions during the winter peak provide emission reductions from the expensive oil power plants that are often ramped up during these periods of particularly high use.

Figure 1. 250 kW Bloom Energy Solid Oxide Fuel Cell

Bloom Energy Fuel Cells

Several varieties of fuel cell technologies compete in the distributed generation space. Differences in construction make each fuel cell type comparatively better-suited to different applications. The Bloom Energy Server™ consists of all-electric solid oxide fuel cells (SOFC) that employ solid-state ceramic construction. According to the U.S. Environmental Protection Agency (EPA), SOFCs offer several advantages over other kinds of fuel cells, including superior electrical efficiency, stability, and reliability.[1]

Bloom shipped its first Energy Server in 2006. Today, the company is responsible for well over 350 megawatts (MW) of capacity installed at more than 600 sites worldwide — including installations with 25 companies listed in the Fortune 100. Bloom's customers are usually mid-to-large sized commercial and institutional end-users who prize reliability, sustainability, cost predictability, and overall power quality. Though the capital cost of fuel cell installations is high, they deliver significant value to customers in the form of avoided energy and demand charges and to ratepayers in the form of reduced emissions and fuel consumption.

In addition to cost savings for customers, Bloom's fuel cells also provide:

- **Reliable energy services throughout the year, including during outages.** Bloom's service contract guarantees that installed units will achieve at least 95 percent of nameplate capacity and 24/7/365 availability. The cells' relative efficiency at lower capacities makes them flexible across different demand conditions.

> **"Fuel cells can shift from natural gas to biogas as states transition away from fossil fuels."**

- **Resilience during storms, natural disasters or other emergencies** without the emissions impacts of diesel generators.
- **Avoided grid infrastructure upgrade costs for targeted deployments**. New York City avoided a \$1.2 billion substation upgrade by investing in cost-effective non-wires solutions including 6.1MW of Bloom Energy Servers.
- **Reduced carbon emissions** that are particularly attractive for states with greenhouse gas emission reduction energy policies and targets.
- **Improved air quality**. Fuel cells can help prevent adverse health outcomes and costs by displacing higher emission generation. This pollution mitigation may occur near or far, depending on the locations of existing power stations and the fuel cell generating pattern. Ideally, distributed generation resources will reduce peak demand, when the most polluting generation units are often online, producing the greatest emission reductions.
- **Avoided water withdraws and degradation of water quality for power plant cooling.** Generators require large amount of water for cooling — water that is ultimately removed from the water supply or returned in an altered state. The most common ecological impact of water discharges from power plants is from higher discharge water temperatures. These warmer temperatures can destroy aquatic habitats, fish, and other wildlife and have been connected to algal blooms such as the one observed in the Lower Charles River Basin near the Kendall Station plant in Cambridge, MA.[2]
- **Flexibility.** Fuel cells can (1) shift from natural gas to biogas as states transition away from fossil fuels, (2) provide on-site generation to support heating and transportation electrification and (3) serve as the backbone for microgrids that integrate other distributed energy resources (DERs).

[1] *U.S. Environmental Protection Agency. 2015. "Catalog of CHP Technologies. Section 6–Technology Characterization–Fuel Cells." 6-2.*

[2] *http://blog.crwa.org/blog/kendall-plant-to-eliminate-thermal-pollution-in-the-charles-river*

Cost-Effectiveness Modeling Approach

Bloom contracted with Synapse Energy Economics, Inc. (Synapse) to model the cost-effectiveness of a representative fuel cell project. Synapse modeled this project using the total resource cost (TRC) benefit-cost model that Massachusetts energy efficiency program administrators are using to develop their 2019-2021 three-year plans.[3] Massachusetts' TRC test includes many of the costs and benefits experienced by the program administrator as well as its customers. We streamlined the model by removing unnecessary input and output tables, updated project size and performance inputs,[4] updated all cost inputs, and developed new output tables and figures. The avoided costs are from the most recent Avoided Energy Supply Costs in New England study.[5] We kept the real discount rate of 0.46 percent and Eversource-specific line losses of 8 percent. We also considered the incremental value of health benefits.

Project Size and Performance Inputs

The project size and performance inputs include capacity, heat rate, capacity factor, measure life, load shapes, and coincidence factors. We provide these inputs, the values included, and the sources of these values in Table 1.

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Table 1. Project Size and Performance Inputs

Project Size and Performance Inputs	Values	Sources
Capacity	2 MW	Bloom; based on a representative project; can vary based on project-specific factors
Heat Rate	6,750 btu/kWh	
Capacity Factor	95 percent	
Measure Life	15 years	
Summer Peak Energy	16 percent	AESC 2018; June through September, weekdays from 7am to 11pm
Summer Off-Peak Energy	17 percent	AESC 2018; June through September, weekdays from 11pm to 7am, plus weekends and holidays
Winter Peak Energy	32 percent	AESC 2018; October through May, weekdays from 7am to 11pm
Winter Off-Peak Energy	34 percent	AESC 2018; October through May, weekdays from 11pm to 7am, plus weekends and holidays
Summer Coincidence	100 percent	Bloom; based on a representative project
Winter Coincidence	100 percent	Bloom; based on a representative project

[3] *2019-2021 Three-Year Energy Efficiency Plan, available at: http://ma-eeac.org/plans-updates/*
[4] *Free ridership and spillover rates are assumed to be 0 percent. In-service and realization rates are assumed to be 100 percent.*
[5] *AESC 2018 Report - June Re-Release (AESC 2018), available at: http://www.synapse-energy.com/project/aesc-2018-materials*

Cost Inputs

The costs of a Bloom Energy Server represent total costs for the utility and customer over the lifetime of the measure[6] and include equipment and installation costs, annual average service fees, and natural gas fuel purchases. We provide the cost inputs, the values included, and the sources of these values in Table 2.

Table 2: Cost Inputs

Cost Inputs	Values	Sources
Equipment and installation costs	Dependent on site-specific variables and system configurations	Bloom
Service fees	Dependent on site-specific variables and system configurations, NPV of annual average payments	Bloom
Natural gas fuel purchases	Appendix C, Table 117, C&I gas non-heating	AESC 2018

Benefit Inputs

The benefits include avoided electricity costs, avoided capacity costs, avoided transmission and distribution costs, and avoided electricity and capacity demand reduction-induced price impacts (DRIPE). For the 2019-2021 plan years, Massachusetts program administrators also included the avoided GWSA cost of compliance. We estimate lifetime avoided carbon dioxide (CO_2) emissions of 123,000 short tons for the electricity saved and 98,000 short tons for the additional natural gas consumed, for a net lifetime avoided CO_2 emissions of approximately 25,000 short tons over the course of a 15-year project life. In addition, Synapse modeled the impact of avoided health costs not currently considered in cost-effectiveness modeling in Massachusetts.

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In the Summary of Results section, we show the results two ways.

1. Without avoided health cost benefits: Including the avoided electricity costs, avoided capacity costs, avoided transmission and distribution costs, avoided electricity and capacity demand reduction-induced price impacts (DRIPE), and the avoided GWSA cost of compliance; and,

2. With avoided health cost benefits: Including avoided electricity costs, avoided capacity costs, avoided transmission and distribution costs, avoided electricity and capacity demand reduction-induced price impacts (DRIPE), avoided GWSA cost of compliance and avoided health costs.

We provide additional detail on the avoided cost inputs starting on the next page. We then discuss the methodology and assumptions used to develop the avoided health costs. We also discuss other potential benefits associated with different types of fuel cell configurations.

[6] We assume all installation costs are born by a customer in this model.

Avoided Costs

Table 3 lists the types of avoided costs in the model, the values used, and the source of these values.

Table 3: Avoided Cost Inputs

Avoided Cost Input	Value	Source
Avoided electricity	NPV of annual values, Appendix B, Massachusetts	AESC 2018
Avoided capacity	NPV of annual values, Appendix B, Massachusetts	AESC 2018
Avoided transmission	$95.75/kW-yr	Eversource-specific
Avoided distribution	$201.69/kW-yr	Eversource-specific
Avoided electricity DRIPE	NPV of annual values, Appendix B, Massachusetts	AESC 2018
Avoided capacity DRIPE	NPV of annual values, Appendix B, Massachusetts	AESC 2018
Avoided GWSA cost of compliance	15-year levelized costs Electric: $19.33 (2018$/MWh)[7] Natural gas: $2.38 (2018$/MMBtu)[8]	GWSA 2018

Avoided Health Costs

While the range of harmful pollutants is wide, the EPA has traditionally focused on six criteria pollutants when regulating generation. Recent EPA analyses of health cost impacts—conducted during the Clean Power Plan program evaluation—assessed an even narrower subset: fine particulate matter (PM2.5) and precursors of PM2.5, sulfur dioxide (SO_2) and nitrogen dioxide (NOx). Ozone and CO_2, though harmful to human health, were not included in these analyses. While the EPA has used the sophisticated Environmental Benefits Mapping and Analysis Program (BenMAP) tool to monetize health impacts, its reduced-form CO-Benefits Risk Assessment (COBRA) Health Impacts tool provides an adequate and simpler approximation of BenMAP's results.

Synapse estimated avoided health costs for a Bloom Energy Server installation using COBRA. Table 4 shows Synapse's calculation of the avoided health costs. We assumed that the fuel cell was a component of a greater energy efficiency program that reduced total load by 100 MW. We estimated SO_2 and NOx emissions reductions using ISO NE data and PM2.5 emissions reductions using the Avoided Emissions and Generation Tool (AVERT) model. Table 4 shows Synapse's calculation of the avoided health costs.

Table 4: Avoided health cost sensitivities in 2017 dollars

Annual Avoided Health Cost Sensitivities	SO2, NOx, and PM2.5		
	Morbidity	Mortality	Total
Low	$1,075	$73,489	$74,564
High	$2,264	$166,429	$168,693

[7] *Avoided Costs of Massachusetts GWSA Compliance (GWSA 2018), Table 5, page 9, available at: http://www.synapse-energy.com/project/avoided-costs-massachusetts-gwsa-compliance*
[8] *Ibid, Table 6, page 10.*

Avoided Health Costs (cont'd)

We then input these reductions in critical pollutants into COBRA, which estimated the avoided health costs by first determining the number of illnesses (morbidity) and deaths (mortality) that this reduction in emissions would prevent. COBRA then priced these reductions using standardized values to estimate total avoided health costs.[9] It is important to note that mortality impacts, though less common than morbidity impacts, represent most of the cost.

Though mortality occurs less frequently because of pollution than morbidity, avoided mortality represents most of the avoided health cost benefits in our COBRA results. This is because mortality, valued using the standard "Value of a Statistical Life" (VSL) measure, is assumed to be much costlier on a per-incidence basis than morbidity. Yet the true cost of mortality may be even greater than the EPA's VSL suggests. As economist Frank Ackerman and legal scholar Lisa Heinzerling have argued, methodological issues may result in the VSL undervaluing the real cost of premature death by at least half, and probably much more – notwithstanding the distinct ethical issues associated with putting a dollar value on human life.[10]

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Other Potential Benefits

The Bloom Energy Server acts as a platform for energy solutions that are tailored to the customer's needs and can evolve with the facility over time. Depending on the configuration of the installation, the following benefits may also result from the project:

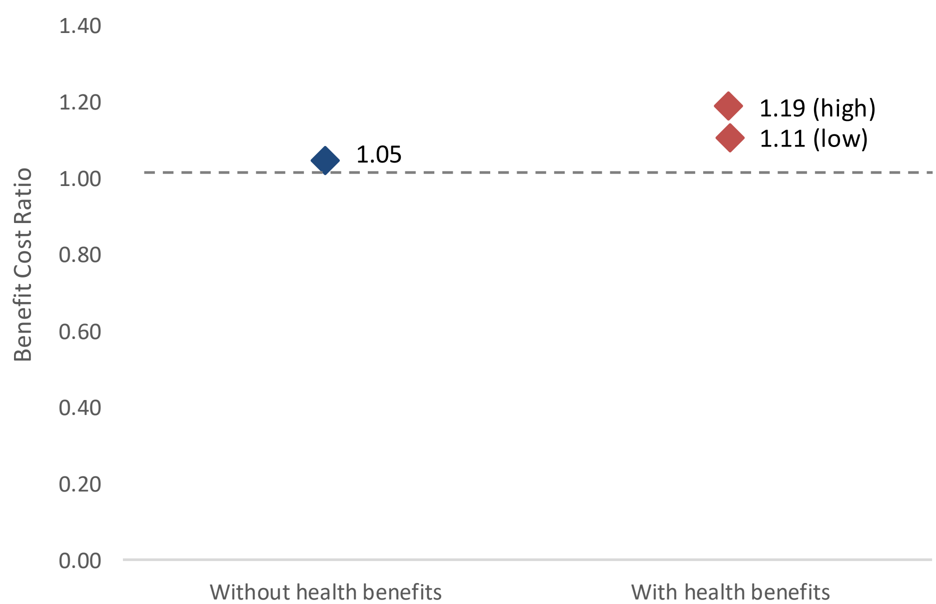
- **Avoided backup generation and related ancillary equipment installation and O&M costs.** As the reliability and power quality requirements of a facility increase, the equipment required to meet those requirements increases in cost and complexity. These equipment needs vary by facility and application but can include ultra-capacitors, switchgear, short duration energy storage, fuel, and fuel storage. Configurations of the Bloom Energy Server can comprehensively provide a facilities' baseload power and support more stringent backup capability requirements at a lower all-in cost.
- **Avoided air-permitting costs.** Larger on-site combustion systems often exceed emissions limits and may require detailed environmental evaluation, review, and permitting costs in order to install the system.
- **Avoided personnel to maintain and operate mission critical equipment**. Some mission-critical facilities such as large data centers employ 24/7 technicians to monitor backup equipment and to ensure that the facility is able to continue operations.
- **Avoided facility downtime**. The ability to carry the facility's load through outages may result in avoided costs or avoided loss of revenue.

[9] COBRA did not allow alignment of the discount rate assumed for future avoided morbidity and mortality with the discount rate of 0.46 percent used in the benefit cost modeling. The 3 percent discount rate assumed for avoided health costs results in smaller estimates as compared to a 0.46 percent discount rate.
[10] Ackerman, Frank and Lisa Heinzerling. 2004. "Priceless: On Knowing the Price of Everything and the Value of Nothing." The New Press, New York, NY.

Summary of Results

Bloom's fuel cell is cost-effective using current TRC modeling practices (i.e., including the avoided GWSA cost of compliance benefit) with a benefit cost ratio of 1.05. Including the avoided health cost benefits increases the cost-effectiveness of the fuel cell to between 1.11 and 1.19. In Figure 1, we present estimated benefits, costs, and cost-effectiveness for the Bloom fuel cell (1) without the avoided health cost benefit and (2) with the avoided health cost benefit.

Figure 1. Cost effectiveness ratio results



In Figure 2, we provide more detailed information on the components of the benefits and costs. The avoided health costs represent the high end of the range shown in Figure 1. The natural gas costs are a key driver of cost-effectiveness, as are avoided energy and transmission and distribution costs. Avoided GWSA cost of compliance and health benefits have a lesser impact on cost-effectiveness, as compared to other benefits.

Figure 2. Cost and benefit components