# All-Electric Solid Oxide Fuel Cells as an Energy Efficiency Measure

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# 1. EXECUTIVE SUMMARY

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 put processes and tools in place to ensure that energy efficiency administrators continuously screen emerging technologies and include those that pass the screening as part of the optimal suite of solutions to achieve state policy goals.

All-electric solid oxide fuel cells (SOFC) can help program administrators achieve their energy efficiency goals. SOFCs are a natural gas or biogas always-on distributed generation resource. In addition to providing electricity system benefits (e.g., avoiding energy, capacity, transmission, and distribution costs), SOFC technology offers: (1) avoided carbon emissions through a combination of high electrical efficiencies and high capacity factors, (2) avoidance of criteria air pollutants through a combination of a non-combustion process and high capacity factors, (3) elimination of power plant-associated water use and harmful wastewater discharges, and (4) un-interrupted power generation during outages of the electric grid.

The purpose of this whitepaper is to foster consideration of all-electric SOFCs as a cost-effective component of energy efficiency programs. All-electric SOFCs should be considered as a measure in energy efficiency programs because:

- Fuel cells reduce the energy used to generate electricity, while avoiding line losses and providing improved energy services for end-users in the form of more reliable power sources. Thus, fuel cells are compatible with the definition of energy efficiency.
- All-electric fuel cells are already being promoted in ten states using public benefits funds under programs that are not necessarily specified as energy efficiency programs.[1] Recently, several states have taken action to also specifically include all-electric fuel cells as an eligible measure in energy efficiency programs.[2]
- All-electric SOFCs can deliver highly efficient and reliable power without the need for a matching thermal load.
- All-electric SOFCs can be cost-effective today using the best practices for benefit-cost analysis developed in the National Standard Practice Manual (NSPM). States that value

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[1] Connecticut, Vermont, Maine, Illinois, Pennsylvania, Ohio, New York, Delaware, Maryland, and Massachusetts.

[2] Massachusetts, Maryland, New York (PSEG-Long Island)

lower carbon emissions, cleaner air and water and increased resiliency should also account for those benefits in cost-effectiveness modeling.

- Fuel cells can help states achieve energy and emission reductions and economic development goals with greater electric system efficiency, lower emission profiles, and higher capacity factors when compared to the grid. The 24/7/365 generation profile of SOFC systems accumulates significant environmental benefits over the lifetime of the system.
- The flexibility of SOFCs as an asset in changing times. As a modular and scalable solution with a changeable fuel source, the lifetime and carbon profile of the SOFCs can adapt over time to meet state needs. SOFCs can also provide on-site generation to support heating and transportation electrification, serve as the backbone for micro-grids that integrate other distributed energy resources (DERs), and avoid transmission and distribution investments.

Fuel cells in all-electric applications can be a cost-effective energy efficiency measure that produces valuable co-benefits including reduced local air pollution, avoided water impacts, increased customer and system resiliency, and avoided transmission and distribution investments. Synapse recommends that states with these policy goals use the National Standard Practice Manual discussed in Section 5 below to update their cost-effectiveness test to account for these benefits.

# 2. INTRODUCTION

All-electric SOFCs are an always-on distributed generation resource that can use natural gas or biogas to provide continuous on-site power using a modular building block that is scalable to a given facility's needs. Assembled using solid-state ceramic construction, SOFCs generate electricity through an electrochemical reaction that generates electricity at the highest electrical efficiencies commercially available without emitting the most harmful pollutants associated with combustion— SO2, NOx, and PM 2.5. 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.[3] SOFCs have been in commercial operation since 2006. SOFC customers are usually mid-to-large sized commercial and institutional end-users who prize reliability and overall power quality.[4]

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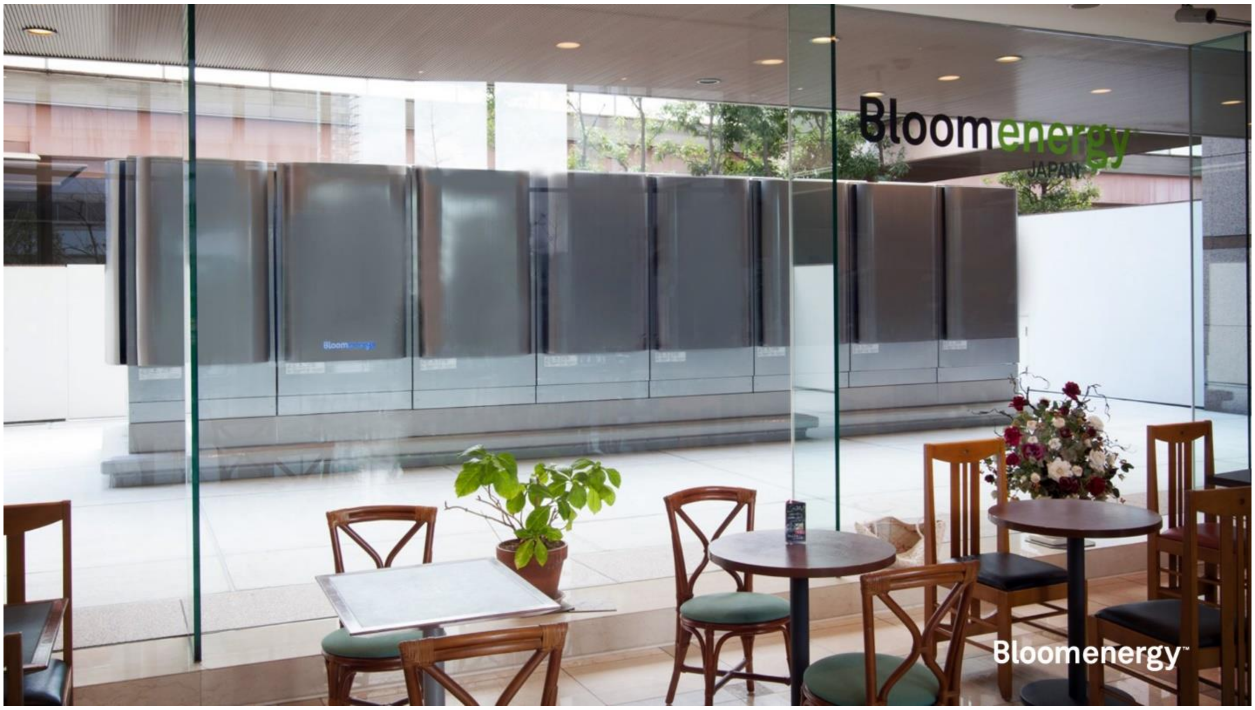
[3] U.S. Environmental Protection Agency. 2015. "Catalog of CHP Technologies. Section 6 – Technology Characterization – Fuel Cells." 6-2.

[4] Large-scale customers include AT&T, Caltech, Delmarva Power & Light Company, Equinix, The Home Depot, Kaiser Permanente and The Wonderful Company.

Figure 1 - 250kW Bloom Energy Solid Oxide Fuel Cell



The purpose of this whitepaper is to advocate for effective processes and tools to screen, and as they screen, include all-electric SOFCs as a component of utility or third-party administered energy efficiency programs.

Fuel cells reduce the energy used to generate electricity, while avoiding line losses and providing improved energy services for end-users in the form of more reliable power sources. Thus, fuel cells are compatible with the definition of energy efficiency. Also, SOFCs can be cost-effective today, delivering reduced CO2 emissions, avoided healthcare costs resulting from avoided fine particulate and ozone emissions, avoided water use and water pollution, increased reliability and resilience, and avoided transmission and distribution infrastructure requirements to the states in which they are deployed. All-electric SOFCs are a rapidly evolving clean energy platform that can help states achieve greenhouse gas reduction targets. As a modular solution capable of incremental upgrading/replacement over time, the lifetime and carbon profile of the SOFCs can adapt over time to meet state needs. SOFCs can also provide on-site generation to support heating and transportation electrification, serve as the backbone for micro-grids that integrate other distributed energy resources (DERs) and avoid transmission and distribution investments.

We begin by discussing the rationale for inclusion in more detail. We then discuss costs and benefits of SOFCs. Lastly, we provide a framework that states should use to evaluate the cost-effectiveness of SOFCs.

# 3. RATIONALE FOR INCLUDING FUEL CELLS IN ENERGY EFFICIENCY PROGRAMS

Fuel cells are efficiency measures because they reduce primary energy consumption by displacing less efficient marginal generation from the grid while also avoiding system inefficiencies such as line losses. For these reasons and others, Massachusetts, Maryland, and New York have recently moved to make all-electric fuel cells eligible for their ratepayer-funded energy efficiency programs.[5] Many other states, including Connecticut, Vermont, Maine, Illinois, Pennsylvania, Ohio, New York, Delaware, Maryland, and Massachusetts provide programs for all-electric fuel cells under the auspices of renewable energy or clean energy programs. [6]

Utilizing energy efficiency programing to support fuel cells can help states achieve energy and emission reductions and economic development goals cost-effectively, while simultaneously advancing other objectives including customer resiliency, electric system efficiency, avoided transmission and distribution infrastructure. Virtually every state across the country has a long-running energy efficiency program, and in most states, these programs are revised on an ongoing basis as new technologies and approaches are brought to market. States with broader energy goals that encompass both energy savings and energy generation are working to better coordinate energy efficiency and energy generation programs. In many cases, program funds come from different sources, programs are subject to different regulations on varying time tables, and programs are managed and delivered by different entities. In its Brooklyn Queens Demand Management Program, Con Edison deployed distributed solar, fuel cells and efficiency measures to meet power needs at cost that was lower than building a new $1.2 billion substation. Greater integration and coordination of programs minimized the cost to ratepayers by encouraging distributed energy resource deployments where the grid needed them the most.[7]

# 4. COSTS AND BENEFITS OF SOLID OXIDE FUEL CELLS

SOFCs provide customers with a lower cost, on-site power generation alternative to electricity purchases from electric utilities or competitive generation providers. Though fuel cells require a substantial upfront investment, medium to large commercial customers with high electricity loads recoup their costs over time by avoiding energy and demand charges and other ancillary equipment costs.[8] SOFC providers also offer financing solutions that enable customers to spread these costs out over time. In this section, we

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[5] According to the American Council on an Energy Efficiency Economy Massachusetts and Maryland administer the number one and number ten ranked energy efficiency programs in the nation. https://aceee.org/state-policy/scorecard

[6] DSIRE Database, available at: programs.dsireusa.org.

[7] Spiegel, Jan Ellen. *Another $1.2 Billion Substation? No Thanks, Says Utility, We'll Find a Better Way*. Inside Climate News. April 4, 2016, available at: https://insideclimatenews.org/news/04042016/coned-brooklyn-queens-energy-demand-management-project-solar-fuel-cells-climate-change

[8] The best economics for solid oxide fuel cells such as Bloom's Energy Server are often achieved with continuous operation (baseload function).

provide an overview of the costs and benefits of SOFC deployments. For a more detailed analysis of SOFCs, please see the Massachusetts-specific cost-effectiveness brief.[9]

## 4.1. Costs

Like other distributed generation resources, much of the cost of a fuel cell is in the upfront capital investment, including purchasing and installing the equipment and interconnecting it with the grid. Other costs, such as those associated with operating and maintaining the fuel cell and replacing key components, are collected from customers through a pre-defined annual service fee. Also, customers need to pay for the fuel to power the generating unit. All up-front and ongoing costs are included in this analysis.

## 4.2. Benefits

The many benefits of fuel cells make them a cost-effective investment for a range of different customers and a diversity of applications. Once state energy policies are appropriately accounted for in cost-effectiveness testing, fuel cells can be a cost-effective option for program administrators administering energy efficiency programs.

### Energy Benefits

The energy-related benefits of fuel cells include: avoided electricity, avoided capacity, avoided transmission and distribution, and avoided electricity and capacity demand reduction-induced price impacts (DRIPE), and increased electric system efficiency.

Avoided energy and capacity: With fuel cells, large energy consumers avoid the need for the utility to purchase electricity and capacity by generating power on their own and can even sell energy back to the grid.

Avoided transmission and distribution: Fuel cell projects help to avoid transmission and distribution system investments over the longer term by locating generation in close physical proximity to their power needs. Sites can also be identified and targeted to relieve transmission and distribution constraints.

DRIPE: DRIPE refers to the reduction in wholesale market prices for capacity and energy resulting from the reduction in quantities of capacity and of energy required from those markets. When fuel cells generate always-on power they reduce the marginal wholesale price, which reduces energy costs for all wholesale customers. DRIPE benefits may be even greater during the winter peak period when reductions in wholesale energy demand can help prevent expensive oil powered plants from being brought online.

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[9] Takahashi, K., et al. 2018. “Bloom Energy Fuel Cell Cost-Effectiveness Brief.” Synapse Energy Economics.

## Additional Benefits

In addition to avoiding energy, capacity, transmission, and distribution charges, all-electric SOFCs also provide the following additional benefits:

**Reliable energy services throughout the year, including during outages.** SOFC units deliver lifetime average capacity factors of 95 percent or greater of nameplate capacity and 24/7/365 availability. The systems' relative efficiency at capacities as low as 200 kW makes them flexible across different demand conditions, and their ability to island during outages of the electric grid ensures un-interrupted power for customers

**Resilience during storms, natural disasters or other emergencies.** For instance, Bloom Energy solid oxide fuel cell projects continued operating during twenty-three separate outages during March 2018 storms in the northeast US, providing customers with un-interrupted power during widespread utility outages.

**Reduced carbon emissions.** Fuel cells reduce emissions by generating always-on power that reduces the need for more carbon-intensive marginal units. Emission reductions are most substantial in regions where significant generation is powered by carbon-intensive fossil fuels such as coal.[7]

**Avoided water withdraws and degradation of water quality for power plant cooling.** Generators either require large amount of water for cooling purposes— 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 a result of discharge water temperatures that are higher than the natural temperature of the waterway into which it is returned. 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[10].

**Flexibility**. The product can (1) shift from a natural gas to biogas or renewable-derived hydrogen feedstock as states transition away from all fossil fuel use and the availability of hydrogen both fuels increase in the future, (2) provide on-site generation support for heating and transportation end use electrification and (3) support community micro-grids.

**Improved air quality and reduced healthcare costs**. Fuel cells can help prevent adverse health outcomes and the associated costs by displacing generation at units that emit more air pollutants. Pollutant emissions associated with fossil energy generation may increase both sickness (morbidity) and death (mortality). 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 impacts for the Clean Power

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[7] For states with greenhouse gas emission reduction energy policies and targets or carbon trading program (like the Regional Greenhouse Gas Initiative in the Northeast), the avoided cost of compliance with environmental regulations is captured as a utility system benefit. The additional externality benefits beyond the cost of compliance are included as non-energy benefits.

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

Plan have taken an even narrower scope, estimating costs for just ozone and fine particulate matter (PM2.5).[11, 12]

There are several variables that influence the health costs from criteria pollutant emissions. Baseline pollution, topography, climate, season, and population demographics all influence results. Independent of these variables, the impact to communities near centralized pollution sources can be significant. For example, a recent study conducted by New York University School of Law found costs associated with emissions of fine particulate matter, nitrogen dioxide, and sulfur dioxide (and the avoided costs associated with reductions in emissions) to be as high as 16.2 cents per kWh in Queens County and around 3.6 cents per kWh in more rural Cattaraugus County.[13,14] Underlying these disparities in estimated costs are significant differences in the expected public health impacts of pollution remediation, as emissions reductions in comparatively dense and polluted places usually yield greater benefits, both on a per-capita and aggregate basis.

# 5. A FRAMEWORK FOR EVALUATING THE COST-EFFECTIVENESS OF SOFCS

The California Standard Practice Manual defines five tests to evaluate the cost-effectiveness of energy efficiency programs. Historically, states have chosen one of these five cost-effectiveness tests or combined elements of multiple tests to create their own. Many states do not properly apply the cost-effectiveness tests and thus underestimate the value of energy efficiency resources, leading to higher costs to utility customers and society.

For example, many states use the Total Resource Cost test, which should include all of costs and benefits of energy efficiency measures for the utility and its customers. However, states tend to ignore many non-energy benefits experienced by program participants, including the health benefits of cleaner air and reduced withdrawal, consumption, and discharges of water. Also, many states do not align the cost-effectiveness screening methodologies with state policy goals. Carbon emission reductions, job creation, energy independence, and health impact reductions from harmful pollutants may be a part of a state's

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[11] Environmental Protection Agency. 2015. "Regulatory Impact Analysis for the Clean Power Plan Final Rule." 4-11.

[12] Fine particulate matter may be emitted directly or may result from emissions of sulfur dioxide ($SO_2$) and nitrogen dioxide (NOx). The EPA thus estimated separate cost figures for fine particulate matter, NOx, and $SO_2$, but the latter two figures only reflect fine-particulate-matter mediated damage resulting from sulfur dioxide and nitrogen dioxide, and not other adverse consequences of ambient NOx and $SO_2$

[13] Shrader, J., et al. 2018. "Valuing Pollution Reductions: How to Monetize Greenhouse Gas and Local Air Pollutant Reductions from Distributed Energy Resources."

[14] The Queens figures were usually greater than the Franklin County figures, with few exceptions. Emissions of NOx during the winter and $SO_2$ during the winter and fall were marginally costlier in Franklin County.

energy policy goals. However, cost-effective screening methodologies do not often account for these benefits.

The National Standard Practice Manual (NSPM) was developed in 2017 to address these shortcomings.[15] The NSPM describes the principles, concepts, and methodologies for sound, balanced assessment of resource cost-effectiveness. The NSPM is applicable to all types of electric and gas utilities and jurisdictions where energy efficiency resources are funded by – and implemented on behalf of – electric or gas utility customers. When evaluating energy efficiency and other clean energy resources, it is imperative to apply the NSPM framework to evaluate cost-effectiveness to ensure that all relevant costs and benefits are evaluated appropriately according to state policy objectives.

At the heart of the NSPM is the Resource Value Test (RVT) Framework—a state-specific approach that reflects policy context and local priorities. The RVT encompasses the perspective of a jurisdiction's applicable policy objectives by including and assigning value to all relevant impacts, including costs and benefits. The NSPM describes a structured approach to formulating an RVT. For a jurisdiction or utility considering inclusion of fuel cells in a ratepayer-funded energy efficiency program, a critical first step is to articulate the policy context. While utility system costs and benefits will necessarily be considered in any case, context will determine how non-utility (i.e., participant/fuel cell owners and societal) costs and benefits enter the assessment.

Table 2 below provides a summary of non-utility impacts that commonly considered by jurisdictions for inclusion in primary cost-effectiveness tests. [16]

**Table 1. Summary of Commonly Considered Non-Utility Impacts**

| Non-Utility Impact | Subsection | Description |
|---|---|---|
| Participant impacts | 3.3.1 | Impacts on program participants, includes participant portion of measure cost, other fuel savings, water savings, and participant non-energy costs and benefits |
| Impacts on low-income customers | 3.3.2 | Impacts on low-income program participants that are different from or incremental to non-low-income participant impacts. Includes reduced foreclosures, reduced mobility, and poverty alleviation |
| Other fuel impacts | 3.3.3 | Impacts on fuels that are not provided by the funding utility, for example, electricity (for a gas utility), gas (for an electric utility), oil, propane, and wood |
| Water impacts | 3.3.4 | Impacts on water consumption and related wastewater treatment |
| Environmental impacts | 3.3.5 | Impacts associated with $CO_2$ emissions, criteria pollutant emissions, land use, etc. Includes only those impacts that are not included in the utility cost of compliance with environmental regulations |

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[15] The National Standard Practice Manual is available here: https://nationalefficiencyscreening.org/national-standard-practice-manual/

[16] The National Standard Practice Manual, p24. https://nationalefficiencyscreening.org/national-standard-practice-manual/

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|---|---|---|
| Public health impacts | 3.3.6 | Impacts on public health; includes health impacts that are not included in participant impacts or environmental impacts, and includes benefits in terms of reduced healthcare costs |
| Economic development and jobs | 3.3.7 | Impacts on economic development and jobs |
| Energy security | 3.3.8 | Reduced reliance on fuel imports from outside the state, region, or country |

*Please note that this table is presented for illustrative purposes and is not meant to be an exhaustive list.*

## Conclusion

Fuel cells in all-electric applications can be a cost-effective energy efficiency measure that produces valuable co-benefits including reduced local air pollution, avoided water impacts, increased customer and electric system resiliency, and avoided transmission and distribution investments. Synapse recommends that states with these policy goals use the NSPM to update their cost-effectiveness test to reflect these benefits.