



An Evaluation Guide for Fuel Cell Deployments at EPA Superfund Sites

FINAL REPORT (1/31/12)

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* DOE Fuel Cell Technologies Program, “Procuring Fuel Cells for Stationary Power: A Guide for Federal Facility Decision Makers,” http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fed_facility_guide_fc_chp.pdf, October 2011.

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1.0 INTRODUCTION

This guidebook aims to educate potential project site personnel and regional planners on various considerations to be evaluated when pursuing a hydrogen fuel cell project on an Environmental Protection Agency (EPA) Superfund site for on-site energy generation needs. The guidebook leads a fuel cell non-expert through many of the drivers, real world issues, and decision points they would face and need to evaluate in considering whether – and determining how – to implement a fuel cell project. The assumption made in the document is not that a fuel cell project will necessarily happen (thus providing the implementation steps) but rather that the decision-maker must determine if their site is a good match for a fuel cell, or where a fuel cell would work best over a portfolio of potential sites. Therefore, this guidebook is essentially an “evaluation tool,” which lays out a variety of considerations that a decision-maker may come across and would need to “evaluate” before considering a fuel cell project. To that end, the guidebook does not evaluate all of the EPA cleanup program sites but rather sites managed under the agency’s Superfund (Comprehensive Environmental Response, Compensation and Liability Act of 1980 [CERCLA]) cleanup program where a long-term pump and treat remedial system has been selected or implemented. The purpose of refined site criteria is not intended to exclude other types of cleanup program sites. Use of these refined criteria intends to focus and fine-tune the direction and considerations evaluated in the guidebook.

The initial portion of this document outlines the basics of fuel cell technology and the various applications in which fuel cells are deployed in the world today. Additionally, different “active” remedy technologies are briefly discussed to provide the reader with a sense of the breadth for which fuel cell technologies can be applied to cleanup sites. The document then discusses the drivers for how fuel cell projects can meet on-site energy service needs as well as support strategic agency objectives, sustainability requirements, and other factors contributing to a fuel cell discussion, followed by an overview of the two primary audiences for the document – EPA Remedial Project Managers (RPMs) and regulators/directors. This background information is essential to gain a basic understanding of the broad factors that contribute to any fuel cell discussion and the roles of each stakeholder in a deployment strategy.

The rest of this document addresses the considerations in evaluating the feasibility of a fuel cell and the broad steps and pathways for deployment. It is important to re-emphasize that the considerations, broad steps, and pathways are tailored to the site characteristics presented earlier but that fuel cells could be proven feasible at other EPA cleanup sites, and many of the considerations and pathways





overlap. As of the writing of this document, there are no real-world examples of fuel cells deployed at Superfund sites. However, potential scenarios are applied to actual Superfund project descriptions to emphasize and exemplify the variety of considerations explained in this document. The appendices of the document provide the reader with additional resources for more in-depth research on the individual technologies, applications, characteristics, etc.

This guidebook will provide a basic understanding of fuel cell technology and an introduction into the factors that must be addressed in the planning stages of any deployment. Fuel cells are a specialized, advanced, and expensive technology, the application of which is likely small in the EPA cleanup site arena. However, if certain site, remedy, and economic factors are needed, fuel cells can provide the necessary high-quality power generation needed for long-term remedial systems with limited impacts on the natural environment.

2.0 OVERVIEW

This section provides a general overview of both fuels cells (describing their basic operating concepts, characteristics, and typical uses) and various remediation methods at EPA cleanup sites.

2.1 Fuel Cells

Fuel cells vary in characteristics and applications. The following sections describe the main characteristics and applications intended to provide the basic foundation of knowledge for decision-makers and to answer key questions related to the technology.

2.1.1 What is a Fuel Cell?

Fuel cells are an emerging technology used to generate electricity and heat, depending on the configuration and application. Unlike traditional generation, which uses combustion processes, fuel cells produce electricity through an electrochemical process, much like a traditional battery. A fuel cell has a continuous fuel supply, as opposed to standard batteries, which consume fuel and then are recharged or discarded. Fuel cells consume hydrogen, typically reformed from a hydrocarbon gas such natural gas or methane (CH₄), plus oxygen, producing electricity, heat, and water, with almost no other emissions.

Fuel cells are very efficient in converting fuel into electricity, with electrical efficiencies commonly in the 35 percent to 55 percent range. By comparison, the electrical efficiency of pulverized coal plants is 30 percent to 40 percent, natural gas turbines systems are 30 percent to 45 percent efficient, and microturbine systems are 28 percent to 35 percent efficient.¹ In addition, on-site fuel cells avoid the losses that occur when electricity is transmitted from a central generating station to the customer. Fuel cells are well-suited to provide reliable electric and thermal energy services for Superfund sites.

As an alternative to generating hydrogen from natural gas, fuel cells have been deployed in conjunction with renewable energy systems by creating hydrogen through electrolysis. Electrolysis is the process by which water molecules are split into hydrogen and oxygen using an electrical current. The hydrogen is then used to power a fuel cell. With this application, the electrical current



¹ DOE Energy Information Administration, "Assumptions to the Annual Energy Outlook 2010," DOE/EIA-0554(2010), April 2010.

that is needed for electrolysis can be generated by renewable sources such as wind, solar, or geothermal.

There are two terms used in this document to describe on-site fuel cell installations:

- **Distributed Generation (DG)** describes small, on-site systems that produce all or part of the electricity that a facility needs to operate, taking the place of purchased electricity from the grid. DG systems include fuel cells, engines, turbines, and other technologies.
- **Combined Heat and Power (CHP)** describes systems that produce electricity and thermal energy, such as steam or hot water. CHP simultaneously produces electrical and thermal energy at much higher efficiencies and lower cost than conventional separate production at a central power plant and on-site boiler/water heater. For the purposes of this document, CHP will not be discussed in great detail as the primary goal is to create electricity to power active remedial systems, but it is also important to recognize that fuel cells can be used in such a configuration to also provide the heat needed for some remediation applications.

2.1.2 Fuel Cell Characteristics

Each fuel cell system consists of three primary components (Figure 1):

- 1) **Fuel Cell Stack** – generates direct current (DC) electricity.
- 2) **Fuel Processor** — converts the hydrocarbon source (typically natural gas) into a hydrogen-rich feed stream, or electrolyzer — splits water into hydrogen and oxygen, via an electricity source.
- 3) **Power Conditioner** – processes the DC electricity into alternating current (AC) electricity.

Fuel Cell Stack

A fuel cell stack consists of several individual fuel cells placed in series or parallel circuits in order to generate sufficient voltage to power

the application. A fuel cell consists of three components: a cathode (positively charged electrode), an anode (negatively charged electrode), and an electrolyte (conducting medium in which current is carried by the movement of ions). During the chemical reaction, hydrogen (H_2) is supplied to the anode and oxygen (O_2) to the cathode. At the anode, hydrogen is disassociated, and the freed electrons flow out of the anode, forming the flow of electrons (DC electricity). The positively charged hydrogen ions flow through the electrolyte to the cathode. Oxygen is supplied to the cathode, which catalyzes a reaction in which the oxygen combines with the hydrogen ions and the flow of electrons to form water (H_2O).

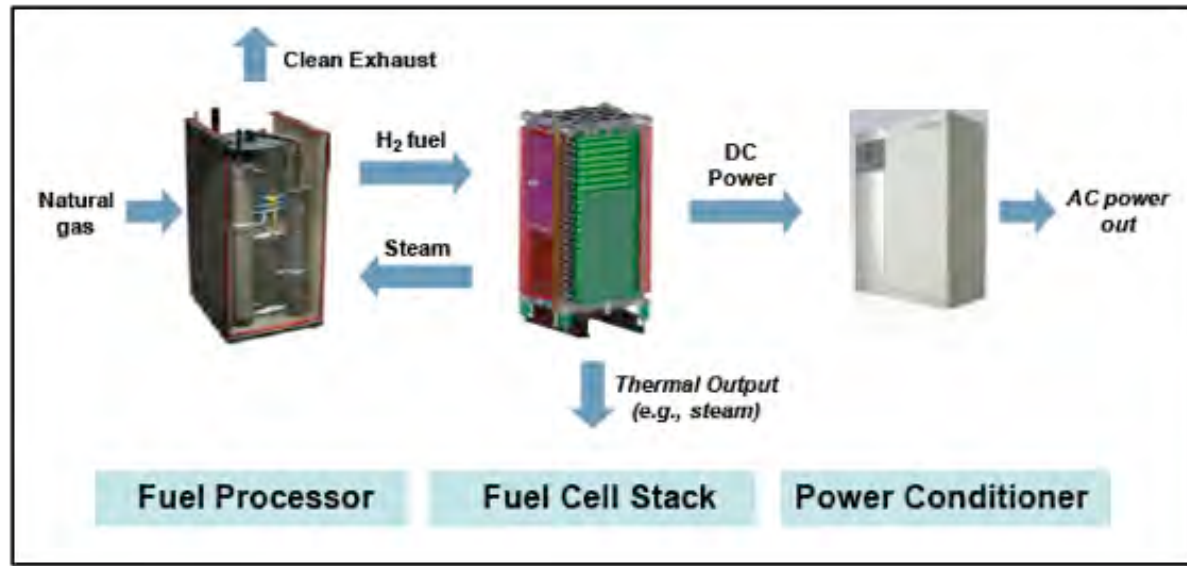
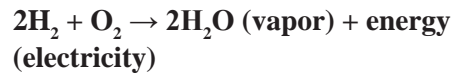


Figure 1. Major Components of a Fuel Cell System

The overall reaction in a fuel cell is as follows:



The typical output voltage of an individual fuel cell element is 0.55 to 0.80 volts. With hundreds of individual fuel cells arranged in a fuel cell stack, voltage is increased to the level adequate for the application. The fuel cell stack is assembled at the manufacturer and is designed to be replaced as a unit.

Fuel Processor

Although the fuel cell itself consumes hydrogen, the fuel processor component of a fuel cell system primarily uses natural gas, liquefied petroleum gas (LPG), or a renewable hydrocarbon source such as biogas. Biogas is a gas produced from the biological breakdown of organic matter in the absence of oxygen and consists mainly of CH_4 and carbon dioxide (CO_2). Typical sources of biogas include wastewater treatment plants and landfills. The fuel processor converts a fuel into a hydrogen-rich gas stream that is supplied to the fuel cell stack. Fuel processors combine oxygen with the carbon in the fuel source, which frees the hydrogen to be consumed in the fuel cell stack. Fuel processors are necessary for the practical application of fuel cells in most facilities.

The three main types of fuel processors are:

1. **Steam Methane Reformers (SMRs)** – use steam as an oxygen source to free hydrogen from the fuel source.
2. **Partial Oxidation Reformers** – use oxygen to free hydrogen from the fuel source.
3. **Autothermal Reformers** – use both steam and oxygen to free hydrogen from the fuel source.

SMRs are the most common fuel processor used in fuel cells. Steam and heat are reacted with natural gas in the presence of a catalyst to produce hydrogen and carbon monoxide (CO), which are further reacted to produce a high purity hydrogen stream and carbon dioxide. Partial oxidation reformers combust a portion of the natural gas fuel stream (partial oxidation) to produce heat and facilitate the separation into CO and hydrogen streams. Autothermal reformers use oxygen or CO_2 to split the fuel to produce a hydrogen-CO blend. The choice of reformers is a technical choice determined by the type of fuel cell, its operating temperature, and the specific characteristics of the particular fuel cell installation.

Fuel cells are becoming more common and their application broader.

For example, fuel cells are becoming more prevalent in forklift applications where the amount of time to recharge traditional batteries is limited and the refueling infrastructure can be centrally located serving an entire fleet forklifts. For more information on fuel cell applications on forklifts, please see the U.S. Department of Energy Study, “Identification and Characterization of Near-Term Direct Hydrogen Proton Exchange Membrane Fuel Cell Markets.”

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/pemfc_econ_2006_report_final_0407.pdf



Electrolyzer

Hydrogen can also be generated through the electrolysis of water. The basic electrochemical process is the opposite of the process within a fuel cell. By using a cathode and an anode and running an electrical charge through both, water molecules are split into oxygen and hydrogen molecules. This process takes place in an electrolyzer, which is well-suited for small-scale distributed hydrogen production.

This process can provide an alternative to the traditional sources used to create hydrogen, while utilizing renewable energy or grid electricity to run the electrolysis reaction. For more information on electrolytic processes as it relates to hydrogen fuel cells, please see: http://www1.eere.energy.gov/hydrogenandfuelcells/production/electro_processes.html.

Power Conditioner

Fuel cells generate DC electricity that must be conditioned to produce the AC electricity required for most applications. The voltage generated from the fuel cell system is delivered to the power conditioning system, which performs several important functions:

1. The power conditioner boosts the DC voltage to a higher voltage and delivers the power to an electronic inverter.
2. The inverter applies a modulation technique at high frequencies to generate simulated

AC output.

3. The inverter controls the frequency of the output, which can be synchronized with grid power and/or be adjusted for direct on-site power consumption.

Power conditioners are highly efficient with losses of 5 percent or less.

Table 1 summarizes some of the prevailing fuel cell technologies on the market today, along with some of the advantages and disadvantages of each technology. This table is not meant to be inclusive of all current types of fuel cells as the technology is constantly changing.

2.1.3 Typical Uses of Fuel Cells

Fuel cells have a variety of applications and, as such, range in size and characteristics. For example, fuel cells are deployed for transportation applications, such as cars and buses; for specialty vehicle applications, such as forklifts; and also for power installations, such as back-up power for telecommunications equipment, portable power units, and distributed generation. While some mobile and portable applications are small, more and more companies are seeking alternative, large-scale, on-site, energy-generation infrastructure. Table 2 displays the most common small and large applications of fuel cells.

Table 1. Comparison of Fuel Cell Technologies*			
FUEL CELL TYPE	APPLICATIONS	ADVANTAGES	DISADVANTAGES
Polymer Electrolyte Membrane (PEM)	<ul style="list-style-type: none"> • Backup Power • Portable Power • Distributed Generation • Transportation • Specialty Vehicles 	<ul style="list-style-type: none"> • Solid electrolyte reduces corrosion and electrolyte management problems • Low-temperature • Quick start-up time 	<ul style="list-style-type: none"> • Expensive catalysts • Sensitive to fuel impurities • Low-temperature waste heat
Alkaline (AFC)	<ul style="list-style-type: none"> • Military • Space 	<ul style="list-style-type: none"> • Cathode reaction faster in alkaline electrolyte, leads to high performance • Low-cost components 	<ul style="list-style-type: none"> • Sensitive to CO₂ in fuel and air • Electrolyte management
Phosphoric Acid (PAFC)	<ul style="list-style-type: none"> • Distributed generation 	<ul style="list-style-type: none"> • Higher temperature enables CHP applications • Increased tolerance to fuel impurities 	<ul style="list-style-type: none"> • Platinum catalyst • Long start-up time • Low current and power
Molten Carbonate (MCFC)	<ul style="list-style-type: none"> • Electric Utility • Distributed Generation 	<ul style="list-style-type: none"> • High efficiency • Fuel flexibility • Can use a variety of catalysts • Suitable for CHP applications 	<ul style="list-style-type: none"> • High-temperature corrosion breakdown of cell components • Long start-up time • Low power density
Solid Oxide (SOFC)	<ul style="list-style-type: none"> • Auxiliary Power • Electric Utility • Distributed Generation 	<ul style="list-style-type: none"> • High efficiency • Fuel flexibility • Can use a variety of catalysts • Solid electrolyte • Suitable for CHP and combined heat, hydrogen, and power (CHHP) applications • Hybrid/GT cycle 	<ul style="list-style-type: none"> • High-temperature corrosion and breakdown of cell components • High-temperature operation requires long start-up time and limits



* U.S. Department of Energy, Energy Efficiency and Renewable Energy, Fuel Cell Technologies Program, Comparison of Fuel Cell Technologies, http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/pdfs/fc_comparison_chart.pdf, February 2011.

Table 2. Common Fuel Cell Applications and Sizes	
SMALLER FUEL CELL APPLICATIONS	LARGER FUEL CELL APPLICATIONS
<ul style="list-style-type: none"> • Backup Power • Portable Power • Transportation • Specialty Vehicles 	<ul style="list-style-type: none"> • Military/Space • Distributed Generation • Electric Utility • Auxiliary Power

2.2 EPA Cleanup Sites

EPA land cleanup programs – Brownfields, Superfund, RCRA (Resource Conservation and Recovery Act), Emergency Response, Underground Storage Tank, and Federal Facilities Restoration and Reuse – support the cleanup of contaminated sites throughout the country. The cleanup of sites under these programs can involve complex remedial systems with active components that require high amounts of quality and consistent energy. These remedies are “active” as they require some level of energy to operate.² Some of these remedies are:

1. **Activated Carbon Treatment** – Carbon is used to filter harmful chemicals from polluted air or water. Air or water is pumped through carbon and contaminants are absorbed by the carbon.
Electrical Component – Power for pumps.
2. **Pump and treat** – The process by which contaminated groundwater is pumped to the surface and treated.
Electrical Component – Power for pumps.
3. **Incineration** – The process of burning hazardous materials to destroy harmful chemicals. This is typically done with a furnace.
Electrical Component – Power for creating heat.

4. **Air Sparging/Striping** – The process by which air is forced through contaminated groundwater or surface water to remove harmful chemicals. Air is pumped through a large tank filled with packing material.
Electrical Component – Power for pumps and air blowers.
5. **Chemical Dehalogenation** – The process by which halogens are removed from harmful chemicals, making them less toxic. Typically, soil is removed and mixed with chemicals and heated in a reactor.
Electrical Component – Power for pumps, as well as for creating heat for the reactor.
6. **In Situ Thermal Treatment** – Mobilizes harmful chemicals through heating so that they can be collected.
Electrical Component – Power to create heat and power injection applications.
7. **Soil Washing** – The process by which soil is “scrubbed,” removing portions of the soil that are most contaminated.
Electrical Component – Power for pumps associated with soil washing systems.
8. **Thermal Desorption** – Primarily used for soil remediation. Polluted soil is heated to where the harmful chemicals evaporate and are collected.
Electrical Component – Power for creating heat.
9. **Vitrification** – The process of permanently encapsulating harmful chemicals in a solid

block of glass-like material. Heat is used to melt soil, and, when it cools, it turns into a solid block of glass-like material.

Electrical Component - Electrical power to create the heat needed to melt soil.

Fuel cells can fill the power needs for active remedies while also providing additional benefits such as defrayed cleanup costs and heat. While the application of fuel cells to power cleanup can happen at any of these EPA cleanup sites, this document specifically looks at Superfund sites where pump and treat is the selected remedy. As such, this document does not seek to provide specific information on each of these cleanup programs; rather it explores various considerations when determining whether or not a fuel cell is appropriate for a given site.

² Remedies that involve bioremediation or capping would not be suitable for fuel cell deployment.

3.0 DRIVERS: MAKING THE CASE FOR FUEL CELLS AT SUPERFUND SITES

The sections that follow give an overview of various potential drivers that can aid in making the case for the deployment of fuel cells at Superfund sites. They range from many operational benefits to organizational considerations.

3.1 The Role of Fuel Cells at Superfund Sites

Fuel cells in DG applications can achieve high efficiencies. Conventional conversion of fossil fuels to electricity produces large quantities of waste heat as a by-product; often one-half to two-thirds of the energy is lost at the power plant. Conventional power plants simply reject to the environment through cooling towers or lakes and rivers. Between the power plant and the customer, transmission and distribution of the electricity results in additional losses of as much as 8 percent. Thus, the overall efficiency of grid-based electricity is as low as 31 percent because of the inefficiencies at the power plant and losses of delivering the power to the customer.¹

There has been an upsurge in interest in fuel-efficient distributed energy resources, including fuel cells, among developers at new and existing facilities. Fuel cell systems are more efficient than other options, deliver significant operational benefits, and can help overcome local electric system constraints.

3.2 Why Fuel Cells could be Attractive to Regional Managers

Fuel cells are highly reliable and can deliver a steady supply of power for grid-connected or independent operations. Fuel cell systems deliver other benefits that add value to the project through improved environmental or operational performance. Although these benefits can be difficult to quantify and include in a financial analysis, they represent an important part of the project development process.



¹ EPA, "Energy Portfolio Standards and the Promotion of Combined Heat and Power," http://www.epa.gov/chp/documents/eps_and_promotion.pdf, April 2009.

Fuel cells have several advantages over the grid and conventional distributed generation systems. Compared to engine and turbine systems, fuel cells are quiet and have minimal emissions, allowing them to be strategically located near the point of energy demand. State regulators recognize the superior environmental performance of fuel cells, which will streamline the air permitting process. The modular design of fuel cell systems facilitates systems to be scaled to match the energy demands of specific facilities. These features allow for the expansion of critical facilities and their related energy needs within existing building footprints.

3.3 Operational Benefits of Fuel Cell Systems

Fuel cell systems have a variety of operational benefits which can provide value to the site at which they are to be deployed. These benefits will factor into the range of considerations that decision-makers will face (further explained in section 5), and will need to be weighed and evaluated accordingly.

3.3.1 Reliability Benefits

Fuel cell systems are highly reliable, and energy delivery contracts have been written using 95

percent availability,² which includes scheduled downtime for maintenance (unscheduled downtime is lower). Fuel cells have higher reliability than other clean energy sources, such as wind or solar.

Systems can be configured to use the fuel cell as the primary source of power and use the grid as the backup supply. Many facilities install backup or emergency diesel generators to protect against the risk of power failures. Local grid reliability varies considerably, but fuel cell systems can meet a facility's energy requirements with reliability that can meet or exceed the performance of the grid.

3.3.2 Power Quality

Fuel cell systems can help overcome power quality issues, which can be a problem at some Superfund sites. Voltage sags, frequency deviations, transient voltage, and distortions of the waveform are examples of power quality issues faced by many facilities relying on grid power. Air and groundwater monitoring equipment and recordkeeping/communications systems may be disrupted or damaged by poor quality electricity. Because voltage and waveform are managed by the power conditioning unit, the system can deliver higher quality power than the grid, which is subject to multiple disruptive factors.

² Source: manufacturers' data, including company websites. UTC Power, <http://www.utcpower.com/products/purecell400>, Bloom Energy, <http://www.bloomenergy.com/customer-fuel-cell/sims-center-alternative-energy/>.

3.3.3 Peak Power

Demand charges that are based on peak consumption can be a significant part of the utility bill for many facilities. Electricity consumption can vary with remediation operations, cooling system demands, and lighting, creating periods of high electricity demand that can drive up demand charges. These demand charges can be reduced through effective energy management and fuel cell technology that can reduce demand for grid power. Because fuel cells operate in baseload operations, they reduce power demand during all periods. However, the reduction in peak power demand achieved by the fuel cell system is important and its value should be included the analysis of system benefits.

3.3.4 Environmental Benefits

Fuel cell systems offer considerable environmental benefits when compared with conventional production of grid-based electricity. Fuel cells systems can reduce greenhouse gases (GHG) by 50 percent and virtually eliminate criteria air pollutants such as CO, nitrogen oxides (NO_x), sulfur dioxide (SO₂), particulate matter (PM), and volatile organic compounds.³ Fuel cells achieve lower emissions by using cleaner fuels than grid-based generators, better efficiency and cleaner

³ EPA eGRID website: <http://www.epa.gov/eGRID>, U.S. DOE. Fuel Cell Technologies Record #11006 "Fuel Cells for Combined Heat & Power - CO2 and NOx Emissions." July 2011.

conversion of fuel to useful energy.

The large, stationary fuel cells described in this report use natural gas or similar fuels that are inherently cleaner than the coal, which powers the largest share of centralized power plants. Compared to coal, natural gas has lower carbon content, resulting in lower GHG emissions. In addition, natural gas has fewer impurities and is consumed completely in the fuel cell. Coal often contains impurities and toxins that result in significant emissions of SO₂ and PM, including mercury and other toxic air pollutants.

Another reason fuel cell systems reduce emissions is because of their higher efficiency. Fuel cells capture the heat that would otherwise be wasted from the production of electricity to improve efficiency. In electricity-only systems, the energy from the fuel cell stack is recovered and used to fuel processing subsystem. In CHP systems the recovered heat is available for onsite thermal applications such as space heating or hot water. By using energy more efficiently, fuel cell systems generate lower emissions.

Figures 2 and 3 show examples of the GHG emissions savings from an example 300 kW fuel cell installation. Figure 2 illustrates the reduced emissions associated with an electricity-only fuel cell. The average aggregate fuel input for centralized plants emits 156 pounds CO₂ per MMBtu, compared to 117 pounds CO₂ per MMBtu for the natural gas

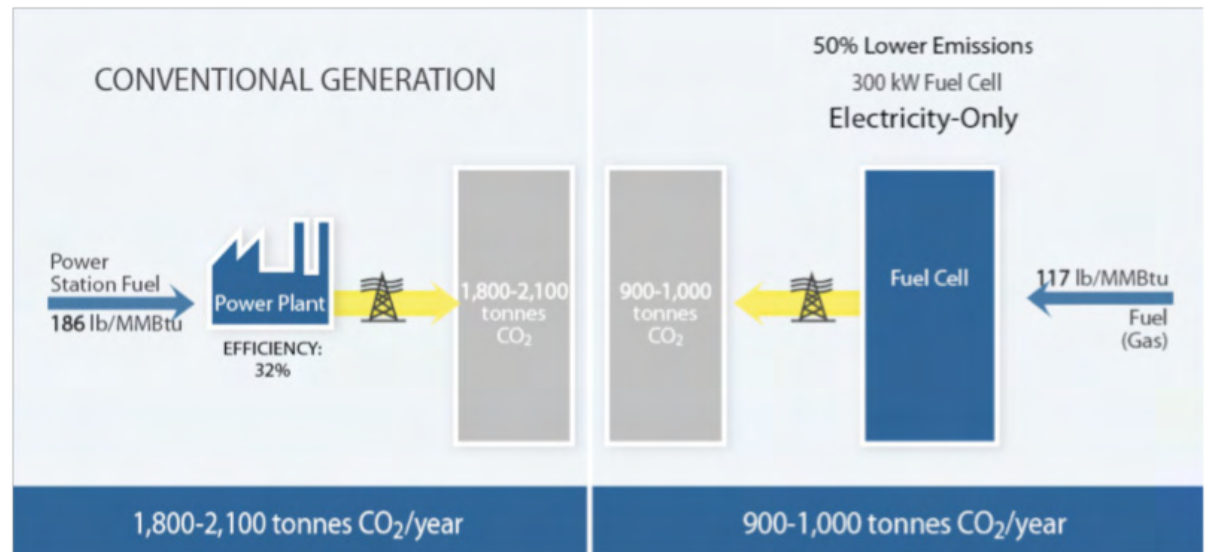


Figure 2. GHG Emissions Savings Comparison - Conventional Generation vs. Electricity-Only Fuel Cell

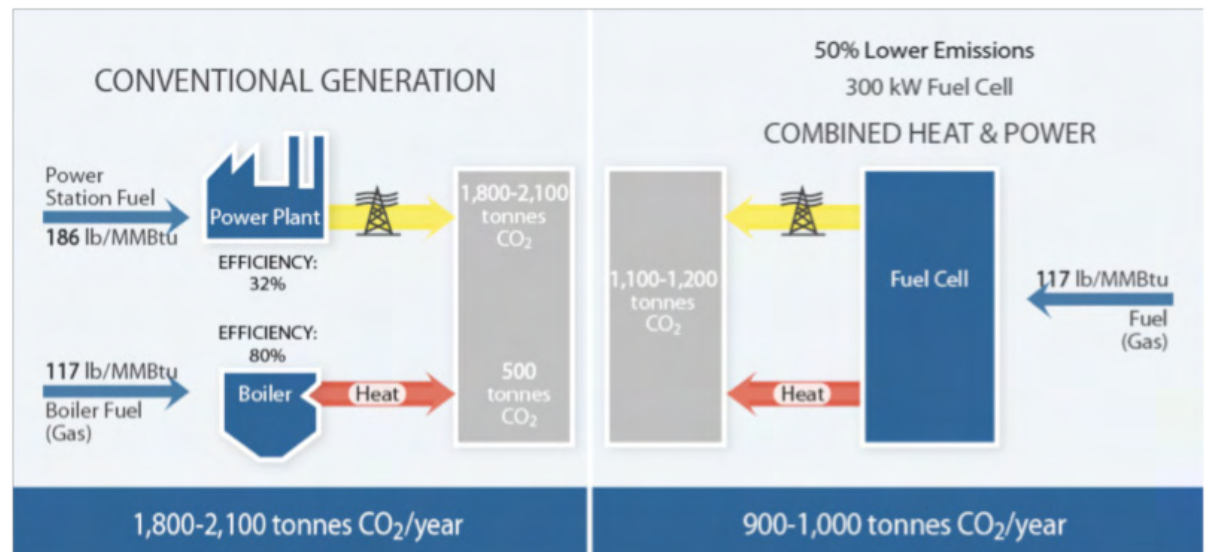


Figure 3. GHG Emissions Savings Comparison - Conventional Generation vs. CHP Fuel Cell

used in a fuel cell. The example fuel cell emits 900 to 1,000 tonnes of CO₂ per year, which is about half of the 1,800 to 2,100 tonnes per year for grid-based power.⁴

Figure 3 is based on a 300 kW fuel cell CHP application that produces electricity and useful heat. Conventional generation is based on the same grid-based power plus an onsite natural gas boiler to produce the heat. The gas boiler adds 500 tonnes CO₂ per year, bringing total emissions from conventional generation to 2,300 to 2,600 tonnes. Using the fuel cell in a CHP application reduces the electrical generation efficiency because the heat from the stack is no longer assistance the fuel processor because it is being used onsite. Fuel cell emissions increase slightly, to 1,100 to 1,200 tonnes per year, which is about half of the emissions from conventional generation.

One useful tool for calculating emission benefits is the EPA CHP Emissions Calculator, although there are other resources available on the Internet. The EPA CHP Emissions Calculator is an Excel spreadsheet that calculates CO₂, SO₂ and NO_x emissions from a fuel cell system and those from a separate heat and power system.⁵

⁴ Emissions calculations based on technology assumptions from EPA CHP technology characterizations (http://epa.gov/chp/documents/catalog_chptech_fuel_cells.pdf), information from the fuel cell manufacturers listed in Appendix A and electricity grid performance information from EPA's eGRID database (www.epa.gov/egrid).

⁵ Environmental Protection Agency, Combined Heat and Power Emissions Calculator, available at www.epa.gov/chp/basic/calculator.html

Compared to engine and turbine onsite power generation systems, fuel cells are quiet and have a low emissions profile that allows them to be located near the remediation operations. The low emissions also ease the permitting process, which can allow a fuel cell to be quickly sited and brought online.

3.3.5 Efficiency Benefits

Fuel cell technology can convert the energy in fuel to electricity at 50 percent efficiency, and using a fuel cell in a CHP application can boost efficiency to the 60 percent to 80 percent range. These efficiencies are much higher than conventional generation technologies, reducing fuel consumption and helping meet strategic efficiency targets. As stated in the previous section, a fuel cell system can reduce costs and increase efficiencies in two ways:

- Fuel cell technology is inherently efficient compared to other generation technologies;
- Using fuel cells in a CHP configuration increases efficiency by utilizing the heat from power production; and
- Fuel cells are an onsite generation technology that eliminates losses in delivering power to a site.

Like other onsite generation technologies, fuel cells deliver power directly to a site, bypassing the grid's transmission and distribution systems, which can increase losses by as much as 8 percent.

Figures 4 and 5 compare the efficiency of an example 300 kW fuel cell system and conventional generation. Figure 4 illustrates an electricity-only case in which conventional grid-based power generation consumes 125 units of fuel to deliver the same power as a 300kW fuel cell consuming 100 units of fuel. The overall efficiency of the fuel cell is 50 percent, or one and a half times as efficient as conventional generation (32 percent).⁶

Figure 5 illustrates the aggregate efficiency of separate production of electricity and useful thermal heat compared to production from a 300 kW fuel cell in a CHP application. In this example, the fuel cell CHP system consumes 100 units of fuel to produce 40 units of electricity and 35 units of hot water, resulting in a 60 percent to 80 percent overall efficiency. Conventional production consumes about 125 units of energy at the power plant plus about 44 units of energy at the boiler to meet the onsite energy needs, resulting in an overall efficiency of 40 percent to 50 percent.

3.3.6 Infrastructure Resilience

Fuel cell DG systems operating as base load energy supply improves the resilience of critical systems during extended grid disruptions. On-site energy production of a fuel cell DG

⁶ Efficiency calculations based on technology assumptions from EPA CHP technology characterizations (http://epa.gov/chp/documents/catalog_chptech_fuel_cells.pdf), information from the fuel cell manufacturers listed in Appendix A and electricity grid performance information from EPA's eGRID database (www.epa.gov/egrid).

system improves the ability to maintain operations and recover from natural disasters and attacks on the power grid.

Another advantage is that a fuel cell DG system operates efficiently as a primary energy source rather than an occasionally-used, less-efficient backup power supply. Operating as a primary energy source turns what is often a sunk cost (backup generators) into a productive asset.

3.3.7 Opportunity Fuels

Much of this guide is written from the perspective of using natural gas as a fuel source for the DG system. However, some facilities may have renewable opportunity fuels that can further reduce costs and emissions relative to natural gas powered systems. Examples of opportunity fuels include biogas from wastewater treatment facilities, methane collected from landfilling operations, and renewable electricity.

Some states recognize fuel cells using natural gas as renewable energy generators. Using renewable fuels can realize additional financial and sustainability benefits.

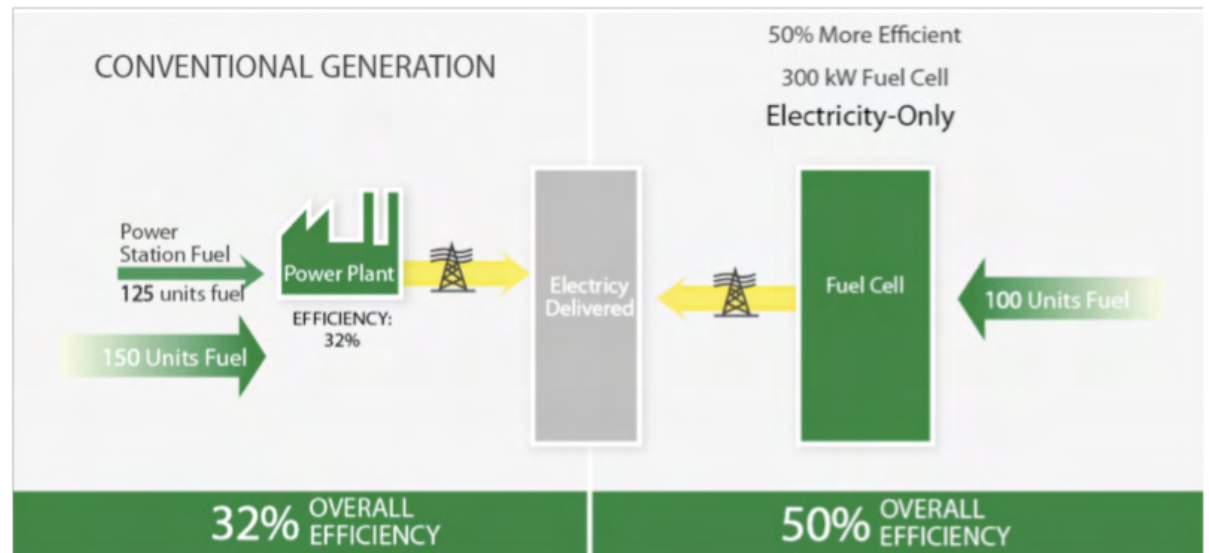


Figure 4. Efficiency Comparison - Conventional Generation vs. Electricity-Only Fuel Cell

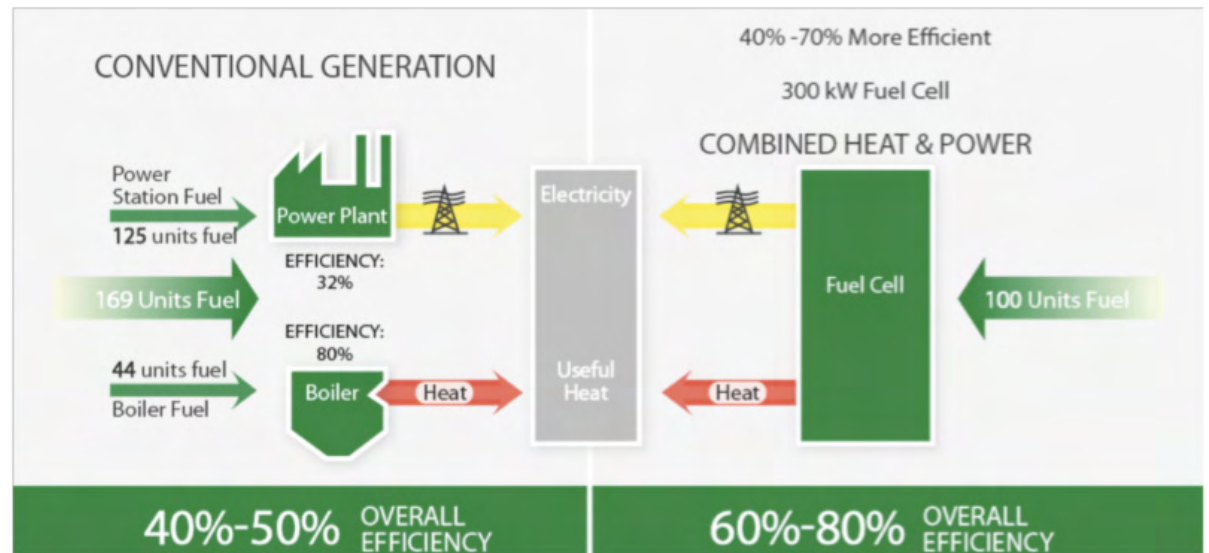


Figure 5. Efficiency Comparison - Conventional Generation vs. CHP Fuel Cell

3.4 Organizational Rationale for Fuel Cells at Superfund Sites

Fuel cell systems have many potential benefits at federal facilities. One is helping federal agencies meet energy management goals. This section describes legislation policies that may be of interest to federal agencies considering fuel cell technology.

3.4.1 Executive Orders

Fuel cell DG systems may help federal facilities meet the energy management goals outlined in various Executive Orders (further detailed in section 5.2.2.1). These Executive Orders have typically put forth provisions for federal facilities, which include reducing energy consumption, increasing use of renewable energy sources, and using alternative fuels in federal fleets. Use of fuel cells at Superfund sites may help meet some of these requirements.

3.4.2 Agency-Wide Planning

Sometimes the motivation for pursuing a fuel cell project may extend beyond the specifics of an individual project in order to be part of a larger effort and pursuit of broader policy goals. A fuel cell project may demonstrate leadership at the

site, department, or agency. Implementation of innovative fuel cell technology may represent an agency priority and the motivation for seeking appropriate fuel cell sites within an agency may reflect top-down organizational priorities such as:

- Renewable Portfolio Standard (RPS) compliance.
- Reducing air pollution emissions or GHG footprints on an agency-wide basis.
- General environmental or efficiency goals/benefits — either general department pursuits or mandatory compliance.
- Program visibility – Implementing innovative fuel cell technology at one site can raise the profile of the entire agency.
- Continuing the Federal Government’s leadership in the commercialization of clean energy technology.
- Promote environmental justice by bringing a clean energy technology to a community with a Superfund site.

Whether mandatory or voluntary, these drivers are characterized less by the project numbers and more by what it means to the organization to do the project at all. In those cases, it is not imperative that the project’s direct benefits are meticulously measured, verified, and tied back to the budget.

3.4.3 Greenhouse Gas Inventory Issues

Federal agencies are required to inventory their GHG emissions. These emissions are categorized as Scope 1 (on-site emissions), Scope 2 (emissions related to purchased energy), and Scope 3 (emissions associated with other procurements and waste disposal). Fuel cell projects will have implications for these inventories, which should be considered carefully.

Fuel cell DG projects using natural gas or other fossil fuels will generate on-site GHG emissions that are Scope 1. Typically, the electricity produced by the fuel cell will displace purchased electricity, which is Scope 2. Because fuel cells are highly efficient, they can achieve significant reductions in Scope 2 emissions.

4.0 PERSPECTIVES: PROJECT MANAGERS VS. REGULATORS

The concepts outlined and detailed in this guidebook aim to empower any decision-maker considering deploying a fuel cell project at a Superfund site — whether it is a project manager or regulator — with an understanding of all the complex issues that go into getting a project green light. However, each decision-maker will naturally have different priorities and concerns.

This document explains the considerations and evaluations from two different perspectives. The primary audience is those at the site-level – RPMs – who are considering different technology options for their sites and thus would need guidance on how and what to evaluate to determine if deploying a fuel cell on their site is feasible or not. The secondary audience would mainly be EPA regulators and directors, who manage a program and are looking for suitable sites and applications to deploy a fuel cell project. The primary audience would be looking at if, and (if so,) how to do a project at their sites, whereas the secondary audience would be looking at which site(s) to do projects on. Section 5 of the document explores intricacies of the two perspectives in more detail and brings both to a common recognition of each role in the evaluation process.

Some of the foremost thoughts that are likely to be crossing the minds of these different audiences are summarized in Table 3.



Table 3. Key Priorities and Concerns of Different Decision-Makers

POTENTIAL KEY PRIORITIES	REGULATOR	PROJECT MANAGER
Financial	X	X
Legal	X	
Environmental	X	
Technical		X
Operational		X

Section 5 of this document will delve into some of the decision-process considerations through these two perspectives. The discussion on the **regulator** perspective will initially explore current market realities, explaining market realities and providing projections on future market potentials. This will



be followed by a description of the potential choices available, given the current market.

The **project manager** will need to consider a variety of site and project characteristics. The discussion related to this perspective will aim to shed some light on the site realities and considerations in deploying a fuel cell project, looking into decision factors such as incentives available, feasibility of a fuel cell vs. a grid-tied system, electricity and heat needs of the remediation, and how to value intangibles (e.g., reliability, efficiency, environmental attributes).

5.0 CONSIDERATIONS IN EVALUATING THE FEASIBILITY OF DEPLOYING FUEL CELLS AT SUPERFUND SITES

This chapter walks environmental clean-up managers through some of the potential considerations that they may need to evaluate when deploying fuel cells at their sites and mirrors the “considerations questions” form that is included in Appendix B, in order to provide more detail on how to answer critical questions in the evaluation process. Since clean-up site characteristics range greatly, the considerations included may or may not be applicable to all sites, and other considerations not included may influence the evaluation process. This chapter is intended only to provide a framework for customizing an evaluation process for individual sites. It serves as a “first step” guidance, or initial screening tool, to enable decision-makers to evaluate whether it makes sense for them to move towards a more-detailed technical feasibility analysis or whether to abandon the pursuit altogether.



Fuel Cell CHP at the Department of Veterans Affairs:
Loma Linda, California
<http://www.lomalinda.va.gov/images/LLHCSweb.jpg>
Agency: Department of Veterans Affairs

5.1 Regulator Perspective

Fuel cell CHP systems can deliver superior technical and financial performance. If cost is the only consideration, other CHP technologies may be preferred. Before investing significant resources in a fuel cell CHP effort that does not come to fruition, facility managers are encouraged to consider available incentives, the local spark spread,¹ and the appropriateness of fuel cells for meeting their energy needs. Meeting these three hurdles is essential to achieving a successful fuel cell CHP project.

5.1.1 Considerations Based on Market Realities

Although a site may be a good candidate for fuel cells based on the initial screening, additional issues must be considered in the face of market realities:

- Fuel cells have high capital costs, and projects must be structured to take advantage of available

¹ The ratio of the local electricity price to the price of fuel.

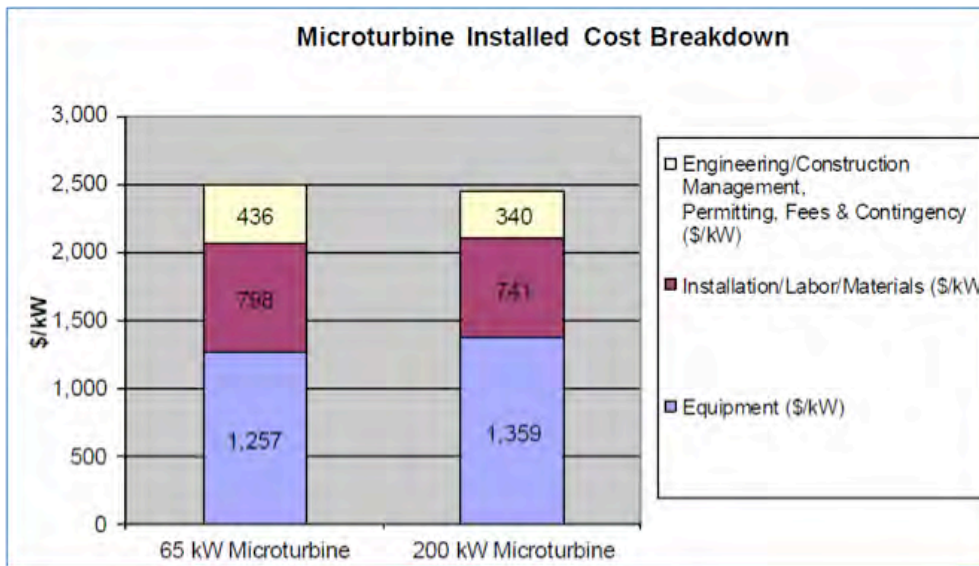
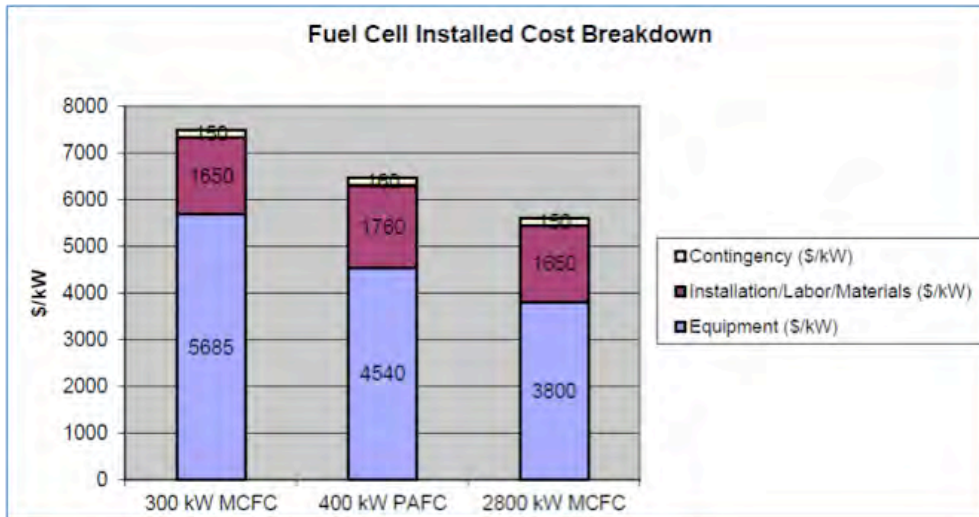


Figure 6. Comparison of Installed Cost Components for Fuel Cells versus Microturbines. *Source: Communications with manufacturers. Installed costs are intended to represent estimates for packaged system cost plus hot water interconnections, grid interconnection, site labor and materials, construction management, engineering, permitting, fees, contingency, and interest during construction. The 300 kW fuel cell system is based on the Fuel Cell Energy DFC 300 model with a 300 kW rating. The 400 kW fuel cell system is based on the UTC Model 400 PureCell System. The 2800 kW fuel cell system is based on the FuelCell Energy DFC3000, the 65 kW microturbine is based on the Capstone C65 system and the 200 kW microturbine system is based on the C200 kW Capstone system.*

incentives. Figure 6 compares the installed cost components of fuel cells versus traditional microturbines.

- Financing mechanisms, such as a Power Purchase Agreements (PPAs), may be required in lieu of outright purchase of the fuel cell to make a project “work” financially.
- Fuel cells may not be practical for a majority of sites despite best efforts to structure a viable project.

Realizing the benefits of federal and state financial incentives is essential to maximizing the financial performance of fuel cell projects. Most projects will not be viable without substantial financial support from state, local, and/or utility fuel cell incentive programs. Because incentives may be able to cover up to half of the capital cost of a system, a thorough screening process should include understanding federal requirements and the agency’s policies on incentives. In many cases, the Federal Government is ineligible for many of these incentives. Private developers, however, can take advantage of the tax credits, grants, and other incentives that encourage fuel cell and renewable technologies. Understanding the ability of federal/private parties being able to take advantage of these incentives is a key consideration in deciding whether to fund the project through direct appropriations or alternative financing.

Most states have energy incentive programs that help offset energy costs and promote innovative

and renewable energy technologies, including fuel cells, and can be in the form of direct financial grants, tax incentives, low-interest loans, or utility and environmental policies that increase the financial prospects for a project.

5.1.2 Is the Facility a Good Match for CHP?

Fuel cell CHP systems must be fully integrated at a facility to realize their potential benefits. Installing a fuel cell CHP system to a facility requires a significant investment of staff time and funding. The decision tree shown in Figure 7 is a simplified screening to determine whether a facility may be a good match for fuel cell CHP technology. Achieving a successful project is a significant challenge and many facilities will not be well suited because of technical considerations, an unfavorable spark spread (the difference between natural gas and electricity prices), or insufficient financial incentives.

For facilities that pass this screening process, the next step is to perform a simplified cost analysis. Section 6 of this report includes a discussion of the Department of Energy’s Fuel Cell Power Model and how it can be used to evaluate the feasibility of using a fuel cell at a site. Fuel cell manufacturers and others also provide basic cost analysis tools.

The first step is to gather information on the facility’s electrical and thermal energy demands—in particular, to identify the size of

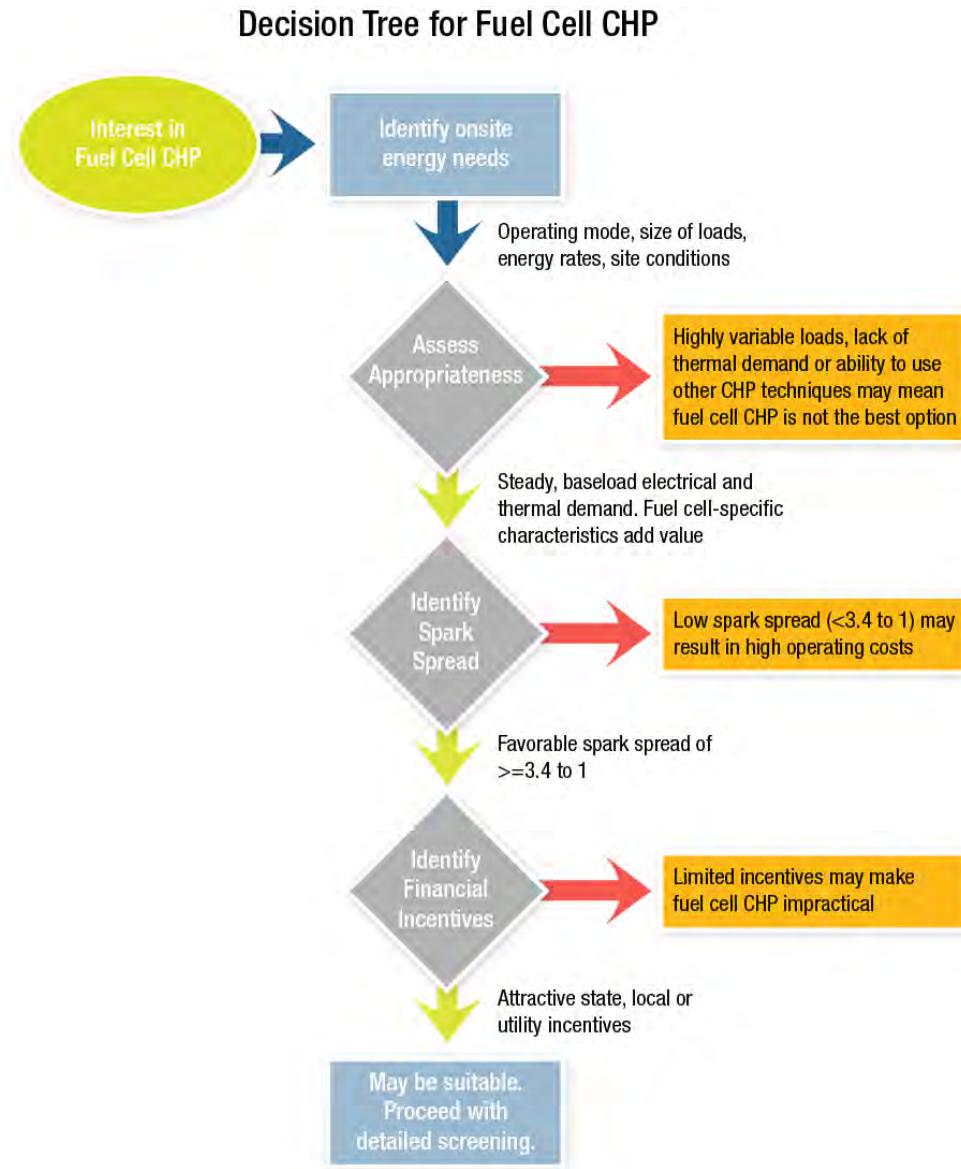


Figure 7. Decision Tree for Fuel Cell System



the electrical load and thermal loads expected to be served by the fuel cell CHP. This energy data can be obtained by analyzing recent utility bills or directly from on-site meters.

Good candidate sites will have characteristics that favor the operational and financial “sweet spot” of large, stationary fuel cell technology, including:

- Average electric load is 100 kW or higher.
- The ratio of average electric load to peak load is > 0.7 .
- Have a thermal load that must be met on a continuous basis. Examples include a central or district heating system or hot water for a medical facility.
- Thermal demand is matched to electric load on a daily and seasonal basis.
- Operate more than 6,000 hours per year.

In addition to the quantitative energy information listed above, facility managers should consider whether there are other considerations that would favor a fuel cell CHP system. As noted in the previous chapter, fuel cells have advantages over other CHP technologies and the electricity grid. However, fuel cells are usually more expensive than other options. If cost of delivered energy service is the only consideration, other options probably will meet these needs at lower cost than a fuel cell CHP system. Some factors that could

make a fuel cell CHP system the preferred option include strict air pollution limits, GHG emissions objectives, space availability (limited footprint), and the need for reliable power for critical systems.

5.2 Project Manager Perspective

5.2.1 Site Characteristics

5.2.1.1 Site Size

When evaluating a fuel cell for deployment on a Superfund site, site size is a critical consideration. For example, if the site is small, it may not have the physical area to accommodate the footprint needed for the fuel cell and associated infrastructure (e.g. gas storage). Since fuel cells range in their physical size due to the electrical output, managers should first determine what the electrical needs are for the desired application. Once fuel cell options that meet the electrical requirements of the application are identified, then a manager can effectively evaluate whether or not the site is large enough to support the desired fuel cell.

5.2.1.2 Location

Larger sites can offer many different viable locations for siting a fuel cell. Careful consideration must be given to certain characteristics of different site locations in

order to ensure maximum efficiency of the deployment and effectiveness of the remedy. For example, if a fuel cell is deployed in area of site that is inaccessible by road, installation and maintenance of the fuel cell can be difficult. If a fuel cell is deployed a large distance from the remedy, power transmission to the remedy can be difficult and require additional significant transmission infrastructure adding additional cost. Some siting characteristics include:

- Site access mechanisms (e.g., roads, rail)
- Distance to remedy
- Distance to electrical grid (if considering PPAs²)
- Fuel delivery infrastructure (e.g., roads, natural gas transmission infrastructure, landfill gas location)

5.2.1.3 Other Site Characteristics

Sites that are large enough and have viable locations to site fuel cells may also have other impediments that project managers should consider. For example, extreme temperatures and weather can affect the operation of some fuel cell technologies. Cold-weather operation can be problematic since fuel cell systems always contain water, which can freeze at low temperatures, and must reach a certain temperature to attain full performance. For example, if a fuel cell is deployed on a site where temperatures average below freezing, appropriate steps and additional infrastructure

may need to be implemented. Additionally, consideration must be given to requirements and standards relating to setback distances, such as distance to buildings on the property, dry vegetation and combustible material, and overhead utilities.³

5.2.2 Feasibility of Fuel Cell versus Traditional Grid Tied System

5.2.2.1 Agency or Local Greenhouse Gas Reduction Targets that can be met with a Fuel Cell

Many states and local municipalities have RPSs that require a certain amount of renewables as part of energy consumption and/or generation. Some of these standards include fuel cells as a renewable energy technology and the deployment of fuel cells on Superfund sites can assist in meeting these RPSs. For more information on state and local standards, please visit: www.dsireusa.org/.

There are also federal policies in place that require federal agencies to reduce their energy consumption and to increase the amount of renewable sources from which their electricity is procured. Below are descriptions of some applicable federal requirements for agencies to reduce their energy consumption and renewable energy sources.



2 PPAs are explained in more detail later on in this chapter.

3 See <http://www.hydrogen.energy.gov/permitting/index.cfm> for further details.

Executive Order 13423

Executive Order 13423, “Strengthening Federal Environmental, Energy, and Transportation Management,” was signed on January 24, 2007, with the goal of strengthening key goals for the Federal Government.⁴ Fuel cell systems may help federal agencies meet the energy management goals outlined in Executive Order 13423.

According to the executive order:

- Agencies shall reduce energy consumption per gross square foot by 3 percent annually, leading to 30 percent by the end of FY 2015, relative to the FY 2003 baseline.
- At least half of the statutorily required renewable energy consumed by federal agencies in a fiscal year must come from new renewable sources in service after January 1, 1999.
- Executive Order 13423 also outlines the process for providing credit toward energy efficiency goals from cost-effective projects. The guidance establishes that:
 - The Federal Government shall strive to reduce total energy use and associated greenhouse gas and other air emissions as measured at the source.
 - Agencies shall undertake life cycle cost-effective projects in which source energy decreases, even if site energy use increases.

- In such cases, agencies will receive credit toward energy reduction goals through guidelines developed by DOE.

This guidance applies directly to the use of fuel cell systems where on-site energy use may increase but overall efficiency increases as fuel cell production displaces grid power.

Executive Order 13514

Executive Order 13514, “Federal Leadership in Environmental, Energy, and Economic Performance,” was signed on October 5, 2009.⁵ This Executive Order states that the “Federal Government can and should lead by example when it comes to creating innovative ways to reduce greenhouse gas emissions, increase energy efficiency, conserve water, reduce waste, and use environmentally responsible products and technologies.”

Federal agencies are directed to use GHG reductions as the primary metric to integrate “sustainability” and budget planning. By January 4, 2010, agencies were required to submit reduction targets for GHGs by FY 2020, relative to the “baseline” of FY 2008. Among the activities that agencies are expected to consider were increasing agency use of renewable energy, which can include renewable biomass for a fuel cell.

By June 2, 2010, agencies were required to submit to the Office of Management and Budget and the

Council on Environmental Quality their Strategic Sustainability Performance Plans, in concert with their FY 2012 budget submissions.

5.2.2.2 Cost Differential between a Traditional Grid-tied System and a Fuel Cell

The cost differential between a fuel cell and a traditional “grid tied” system is a substantial decision point for project managers. Because of the large upfront costs and potential lack of incentives, fuel cells probably will not make initial financial sense for the majority of Superfund sites. Careful consideration and analysis must be performed to determine if the benefits of fuel cells outweigh the high cost of fuel cells and if a business case is present or not.

When looking at the cost differential between fuel cell projects and grid power, the following costs — adjusted for inflation and market changes over the lifespan of the system — should be factored in when comparing to the cost of grid supplied energy:

1. **Initial Capital Cost** – This is the capital costs that are associated with the procurement of the fuel system itself.
2. **Installation** – Installation costs involve site preparation, including foundations for equipment, shipping of equipment, fuel connections, grid connections, and any meters and switches needed for the application.

⁴ DOE, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Executive Order 13423, available at <http://www1.eere.energy.gov/femp/regulations/eo13423.html>

⁵ DOE, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Executive Order 13514, available at <http://www1.eere.energy.gov/femp/regulations/eo13514.html>

- 3. **Fuel Costs** – Costs of fuel (e.g., natural gas, propane or hydrogen).
- 4. **Operating and Maintenance Costs** – Operating and maintenance costs include labor, lubricants, taxes, equipment (e.g., cell stack) and filter replacement, insurance, etc.

TECHNOLOGY	PROJECTED COST (LONG-TERM, UNINSTALLED)
Molten Carbonate Fuel Cells	\$1,200-1,500/kW
Solid Oxide Fuel Cells	\$1,000-1,500/kW
Proton Exchange Membrane Fuel Cells	Initially \$5,000/kW Long term \$1,000/kW

* The California Energy Commission, California Distributed Energy Resource Guide, available at http://www.energy.ca.gov/distgen/equipment/fuel_cells/cost.html

5.2.3 Combined Heat and Power or Distributed Generation

As discussed earlier in this section, there are two terms used to describe on-site fuel cell installations – distributed generation and combined heat and power. Thermal energy generated by fuel cells is typically used to heat air, heat water, or create steam. This section describes the potential uses for heat in a combined heat and power installation.

Potential uses for heat generated by a fuel cell:

- Remedy – If the remedy has thermal component, a CHP installation would provide both the electricity and heat needed.
- Domestic Heating and/or Cooling – If there are on-site buildings, the thermal energy generated from the fuel cell can provide both the domestic heating and cooling needs for buildings.
- Industrial Processes – Thermal energy can be used for industrial process that are either on site or adjacent to the site. This can also present an opportunity to defray the cost of a fuel cell by selling excess thermal energy.

If managers decide to deploy a fuel with a thermal component, considerations for siting can change. The fuel cell should be sited to maximize the thermal energy and transportation of that energy needs to be considered.

5.2.4 Remedy Needs Requirements

Careful consideration must be given to the power and, if applicable, heat needs of the remedy or other uses.

Any fuel cell system must be designed around the expected lifespan and the power and heat needs of the remedy.

Demand refers the amount of power that the remedy requires over time. Managers should

look at the energy needs of remedy design to determine demand. The same concept applies to remedy heat requirements.

Duration refers to the amount of time that demand is needed. For example, if the remedy only operates during a specified amount of time or for a particular season of the year. The same concept applies to remedy heat requirements.

Cycling is the difference in kW between the minimum demand and peak demand of a fuel cell system. It is important to recognize the demand characteristics so that a system can be appropriately engineered.

5.2.5 Fuel Characteristics

While natural gas is the most common fuel used to produce hydrogen for use in fuel cells, other fuel sources are viable as well. Renewable fuels or energy technologies can be used as direct fuel sources or to create hydrogen fuel through electrolysis. Some examples of renewable fuels are landfill gas and waste water treatment gas (biogas). Using renewable fuels can help bring to bear additional resources and incentives for a fuel cell project. Project managers must consider several factors to decide what the most viable source of fuel is for the fuel cell. Some of the considerations that come into play when deciding what fuel source to use are: fuel infrastructure, renewable energy, and alternate fuel sources.

California Self-Generation Incentive Program

The State of California offers a state rebate for fuel cells that generate 30 kW or more power. The maximum benefit is capped at 3 MW and pays \$2.25/W for distributed generation and CHP applications.

Database of State Incentives for Renewables & Efficiency, California Self-Generation Incentive Program, available at http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA23F&re=1&ee=1

5.2.5.1 Fuel Infrastructure

When evaluating fuel cells for Superfund sites, it is important to consider the delivery method of the fuel. For example, if there is no natural gas infrastructure available, other fuel sources should be investigated. This is critically important for sites that are in rural or remote areas where the likelihood of accessible natural gas is low. Some of these considerations are:

- Natural gas distribution infrastructure.
- Propane storage and delivery.
- Natural gas or propane cost.

5.2.5.2 Renewable Energy

As described earlier the workbook, renewable energy can be used to power the electrolysis of water to create hydrogen. This installation is useful when sites are located in remote areas with good renewable potential and no access to other fuel infrastructure. It may also help with meeting various renewable energy goals. Project managers must consider what renewable energy technology is well-suited for a particular site. For example, a site with good solar potential can integrate photovoltaic panels into the fuel cell design in order to create the electricity needed for the electrolysis of water.

5.2.5.3 Alternate Fuel Sources

Depending on the location of the subject site, renewable biogas can be considered either as an

alternative source of energy or as a supplement to natural gas as the fuel for a primary power fuel cell. Many examples of businesses and municipal facilities exist where fuel cells make electricity and heat from biogas, which is collected from landfills or wastewater treatment plants. Additionally, fuel cells operating on biogas are sometimes considered renewable electricity generation. As such, federal and state incentives can be used to offset some of the initial capital costs and operating costs of a fuel cell. While the capital and operating costs for a biogas-powered fuel cell exceed those for one powered by natural gas (due to the additional biogas treatment equipment), these increased costs are offset over the lifecycle of the plant since the raw biogas is essentially free, and in a market of volatile natural gas prices, using biogas as a fuel becomes an attractive alternative.⁶ At the same time, power generated from biomass fuel is not only lower in cost than power generated from traditional fuels, it is also less expensive than other renewable energy sources, such as wind and solar, once capacity factor is considered.

5.2.5.4 Fuel Supply and Fuel Cell Poisoning

Different gases, such as CO and CH₄, have different effects on fuel cells, depending on the type of fuel cell. For example, CO is a poison to PEM fuel cells. However, CO can be used

⁶ Renewable Energy Focus (July 14, 2009), "EfW: could biogas be used to power fuel cells?" available at <http://www.renewableenergyfocus.com/view/2525/efw-could-biogas-be-used-to-power-fuel-cells/>

directly as a fuel for the high-temperature fuel cells such as the solid oxide fuel cell. Each fuel cell will accept different gases as fuels and experience poisoning or dilution. Therefore, the gas supply systems must be tailored to a specific type of fuel cell.

5.2.6 Financial Considerations and Support

Identifying and creatively applying incentives is necessary to making fuel cell projects financially viable. Because fuel cell projects carry a premium cost, project managers must consider how a project will be funded and whether or not the agency is willing shoulder that cost. Below are some descriptions regarding incentives and other support mechanisms for fuel cell projects. Since all sites and fuel cell projects are different, this workbook does not seek to provide a comprehensive listing of support mechanisms and incentives but highlights some of the typical mechanisms of support available.

5.2.6.1 Superfund Fund Lead versus Potentially Responsible Party (PRP) Lead

It is important to understand what mechanism is driving the cleanup of a site because that might determine what incentives, if any, are available to assist with the deployment of a fuel cell. For example, a “fund” lead site would not allow the agency to take advantage of local- and state-level incentives. Conversely,

municipally and PRP lead actions may qualify for such incentives. Proper due diligence and a clear picture of the financing is necessary in the planning stages of the project to determine whether a fuel cell may be viable.

5.2.6.2 Incentives

Incentives are important for a financially-viable fuel cell project. There are many federal, state, or local tax incentives that can be utilized to help with such projects. Unfortunately, these incentives change constantly as legislatures pass new programs, rules are written, and budget cutbacks render some incentives ineffective. For this reason, interested project managers should regularly check the available incentives for their sites’ state and locale. While this workbook does not seek to comprehensively identify incentives, a current listing of incentives can be found on the Database of State Incentives for Renewable Energy (DSIRE). The DSIRE database is maintained by North Carolina State University, and is recognized as a reliable source of information on incentives for renewable energy and energy efficiency investments.

Below is the basic search page for the DSIRE database (select Technology = “Fuel Cells”)

<http://www.dsireusa.org/searchby/index.cfm?ee=1&re=1>

5.2.6.3 Power Purchase Agreements

A PPA is a legal contract between an electricity



Figure 8. Planning Stages

Potential Windows of Opportunity for Deployment

The Superfund process follows a strict set of steps set forth by statute, it is important to recognize the potential entry points by which a fuel cell can be incorporated into a remedy. Below are some of the steps and mechanisms in the process where this can be done.

Preliminary Assessment/ Site Inspection is performed to evaluate the environmental conditions of a site and give a picture of the types of remedies that might be needed to clean up the site.

generator and a power purchaser where the purchaser buys energy from the generator in a contractual term that may last for a specified period of time. These agreements are an important consideration for deploying fuel cells on Superfund sites as they can help defray the costs of the project by generating income for excess energy generated.

Utilizing some PPAs, EPA can implement fuel cell projects by utilizing a third-party fuel cell developer. The developer installs, owns, and maintains the fuel cell and enters into an agreement with agency to buy the power that is generated over the contracted time period. In some PPA projects, the host (EPA) has the option to purchase the generating equipment from the PPA provider at the end of the term, may renew the contract with different terms, or can request that the equipment be removed. One of the key benefits of the PPA is that by clearly defining the output of the generating assets and the credit of its associated revenue streams, a PPA can be used by the PPA provider to raise non-recourse financing from a bank or other financing counterparty.

Since a fuel cell has never been deployed at Superfund site at the time this document was written, it is unclear whether or not third-party fuel cell developers would be interested in these types of projects. Certainly, liability would be of primary concern to a developer and project managers would need to address liability concerns prior to implementing a project.

For more information on PPAs, please see:

www1.eere.energy.gov/femp/financing/power_purchase_agreements.html

5.2.6.4 Other Mechanisms

In addition to PPAs, there are several other financing mechanisms that can be considered for fuel cell projects on Superfund sites.

Energy Savings Performance Contracts are agreements with an energy services company which incurs the cost of implementing energy conservation measures, which can include fuel cells.

Utility Energy Services Contracts are typically implemented on an agency-wide basis to provide energy- and water-related efficiency improvements. These agreements can include fuel cell projects.

Enhanced Use Leases are real estate agreements where developers compete for lease rights. Payments are either monetary or in-kind considerations which can include renewable energy.

5.2.6.5 Market Price for Natural Gas and Propane

As part of the financial analysis of any fuel cell project, managers must account for the cost of the fuel. Depending on the installation, fuel cells can use a variety of fuel sources, but most

commonly use natural gas. If natural gas or propane are the selected fuel sources, the cost for those fuels is integral into the overall cost analysis for the project. Since fuel prices often fluctuate due to a variety of market influences, it is important to be able to project costs into the future to draw an accurate picture of the overall cost to operate a fuel cell. DOE's Energy Information Administration collects data on energy costs for different classes of customers (residential, commercial, industrial).

This link shows recent retail natural gas prices for commercial customers by state. http://www.eia.gov/dnav/ng/ng_pri_sum_a_EPG0_PCS_DMcf_m.htm

This link shows recent residential pricing for propane per region of the country.

http://www.eia.gov/oog/info/twip/twip_propane.html

5.2.6.6 Other Support

Project managers should also consider what other kinds of support are needed to execute successful fuel cell projects. For example, community input and support early in a project is essential to achieving success. When engaging in fuel cell projects, project managers should consider what kind of support can be leveraged from potential partners. Some potential partners may be fuel cell manufacturers, academic institutions with

related research efforts, fuel cell organizations and associations, or political offices and organizations.

5.2.7 Legal Requirements

When considering a fuel cell for a Superfund site, careful consideration must be given to federal, state, and local legal requirements, as well as safety, codes, and standards. Regional project managers must consider the appropriate entry point for fuel cell deployment into the Superfund cleanup process, as well as how the legal requirements of the program can impact the inclusion of a fuel cell in a selected remedy. Moreover, there may be additional local permitting processes, codes, and standards that need to be investigated in the planning stages to ensure that a deployment is in compliance with federal, state, and local laws.

5.2.7.1 Superfund Legal Requirements

This workbook does not seek to interpret CERCLA or to comprehensively identify the legal requirements that are necessary for the deployment of a fuel cell. However, while the Superfund process follows a strict set of steps set forth by statute, it is important to recognize the potential entry points by which a fuel cell can be incorporated into a remedy. It is important the project managers consider fuel cells in accordance with CERCLA and that the remedy is not compromised by a fuel cell. The planning stages (preliminary assessment/site

Remedial Investigation/ Feasibility Study is conducted to comprehensively identify the environmental conditions of a site and identifies remedy technologies that can be used to clean up the contamination.

Record of Decision evaluates the different remedies for a site and explains the differences between the alternatives.

Optimization Studies are performed to improve the performance and efficiency of remedial systems after a selected remedy has already been implemented.

Five Year Reviews are performed to evaluate the performance of a remedy and its protectiveness of human health and the environment. Five Year Reviews are conducted every five years after the CERCLA response action is initiated for the duration for as long as future use of a site is restricted.

inspection, remedial investigation/feasibility study, records of decision), as seen in Figure 8, are the best times to perform this consideration, but there may be other entry points and mechanisms where fuel cells can also be considered.

5.2.7.2 State or Local Permitting

Permitting is one of the most important steps and can present a major obstacle in any fuel cell project. Project managers must ensure that proper and comprehensive due diligence is conducted on any fuel cell project to ensure that it is in compliance with all state and local permitting processes. For more information on these permitting processes, please visit: http://www.hydrogen.energy.gov/permitting/permitting_process.cfm. Project managers will need to engage in discussions with zoning, fire safety, and permitting officials from the authorities having jurisdiction to clearly outline required steps.

5.2.7.3 Noise

Fuel cells can offer an additional noise benefit to projects where noise ordinances may limit other electricity generating technologies. Fuel cells typically range in noise emissions but generally average 60 dBa, which is the approximate noise level of a typical conversation.⁷ As such, there are not too many noise concerns with deploying a fuel cell.

⁷ Fuel Cells 2000, Noise Emissions, available at <http://www.fuelcells.org/info/charts.html#noise>

5.2.7.4 Air Permitting and Fire Codes

Because a fuel cell consumes fuel – not through combustion reactions – as part of its energy generation process, project managers should be careful to ensure compliance with fire codes and state and local air permitting regulations. Although fuel cells are a very clean technology, they do have very low emissions that require air permits. State regulators recognize the superior performance of fuel cells systems and offer streamlined permitting processes typically based on their status as minor sources of pollution. Typically, air regulators will require an emissions inventory that captures the types and amounts of air contaminants the fuel cell will release to the outside air and also includes a public comment requirement. While the permitting process will not likely result in the installation of emission controls, the process for approval can take time and effort.

Because most fuel cells consume natural gas to produce hydrogen fuel, certain precautions must be undertaken to ensure safety. For more information on hydrogen safety, please visit the DOE Hydrogen Safety Program web site, at:

www.hydrogen.energy.gov/safety.html.

6.0 STEPS IN PLANNING AND DEPLOYING FUEL CELLS AT SUPERFUND SITES

This chapter explains a step by step process to execute a fuel cell project to generate electricity at a Superfund site. This chapter is written from the perspective of implementing a single system, although managers should look for opportunities to install more than one system on a single site or at multiple sites to obtain the most favorable pricing and to spread out overhead costs.

There are five major steps to plan and deploy a fuel cell:

1. Identify Goals and Drivers
2. Assemble Project Team
3. Evaluate Feasibility of Potential Deployment
4. Consider Legal and Administrative Requirements
5. Make a Financing and Contracting Decision

Each step requires the accumulation of new data, the cooperation of the site team and sound judgment to assure that the project is on track. Fuel cell projects present special technical and financial challenges that may not be overcome in every case. Managers must be prepared to adjust plans to realize a successful installation and realize that, unfortunately, there are sites where a fuel cell is not viable. As implementing a fuel cell project requires significant time, effort, and investment, it is highly recommended that before embarking on a fuel cell deployment effort, the various considerations explained in Section 5 of this document be thoroughly examined.

Step 1: Identify Goals and Drivers

There are many reasons for Superfund RPMs or EPA regulators to consider a fuel cell project. For Superfund sites, fuel cell energy production can help meet renewable energy targets by providing some or all of the energy required at a site. Fuel cells can generate electricity or electricity and heat using renewable fuels or natural gas. In either case, the fuel cell does not emit significant





quantities of the criteria pollutants associated with conventional power generation. Some of the potential goals for a fuel cell project may include benefits related to efficiency, the environmental factors, reliability, power quality, and peak power, as explained in Section 3.3.

Step 2: Assemble Project Team

At this point, a fuel cell project team should be identified. The team is important not only for getting the work done, but also for making sure that all issues are considered. Even small oversights can be costly in terms of dollars and time, and can even result in a failure to accomplish project goals.

One of the most important features of the team should be its alignment with the project's goals. The project goals can adjust with team input—and healthy debate on project questions is useful—but if any team member hasn't bought into the goals before being invited to join the team the project won't go smoothly. It's important to recognize that it takes a diverse group of people with a wide range of skills to bring a project to fruition.

The initial project team might be small and include only those members relevant to the immediate task; this type of team can grow as the project requires. As an alternative, the team could include—from its inception—everyone who has a stake in the project process. This

decision should be based on best judgment and staff availability.

If starting with a small team, the people who should participate, particularly in Step 3, where the site's screening step is evaluated, include the following:

- Fuel cell project manager - One person must champion the project to overcome the many hurdles to bring a project to completion.
- Contracting officer - Fuel cell projects will almost always require a financing mechanism and appropriate personnel should be included early in the process.
- Energy manager - The project has major energy procurement and consumption factors that require the participation and support of the energy manager.
- Environmental expert - Although fuel cells have very low emissions, there are permitting requirements that must be met.
- Site managers (if multiple people are responsible for different parts of the site).
- Fuel cell technology expert (depending on procurement option selected).
- Utility point of contact - Even if no power from the fuel cell will be exported to the grid, participation of the utility is necessary to manage interconnection and billing.

Several factors will ensure the team's success. For example, the EPA regional manager should participate. This person doesn't need to be involved in the details of the project, but should check in periodically to help move the project forward and overcome barriers that might otherwise stop or delay a project. It's also critical to select a contracting officer and legal advisor with strong leadership characteristics because it might take initiative and innovation to push a project through ambiguous areas of the procurement process. Team dedication and creativity are crucial as well because these traits are essential for finding innovative, cost-effective solutions, if necessary. The fuel cell system procurement process is relatively new, and although challenges are being addressed and resolved, issues may still exist. Navigating around these obstacles requires leadership, commitment, and creativity. After the team is assembled, its roles, responsibilities, and timelines should be established. Scheduling periodic meetings will keep the project moving forward on track.

Step 3: Evaluate Feasibility of Potential Deployment

This section outlines the information needed to evaluate options for the fuel cell system. DOE's Fuel Cell Technologies Program has developed the Fuel Cell Power (FCPower) Model, which

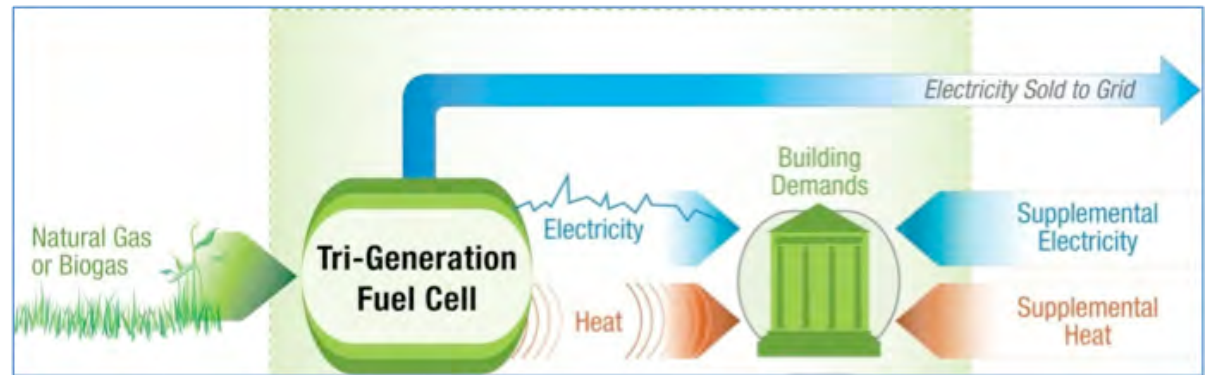


Figure 9. Fuel Cell Power Model

can be downloaded from DOE's Hydrogen and Fuel Cells Program website.¹ FCPower is a financial tool for analyzing high-temperature, fuel cell-based generation systems. It uses a discounted cash flow rate of return methodology to determine the cost of delivered energy, and it quantifies energy inputs/outputs and greenhouse gas emissions. Currently, the FC Power Model has two versions; molten carbonate fuel cell (MCFC) and phosphoric acid fuel cell (PAFC).

Using the FC Power Model requires the user to follow four simple steps:

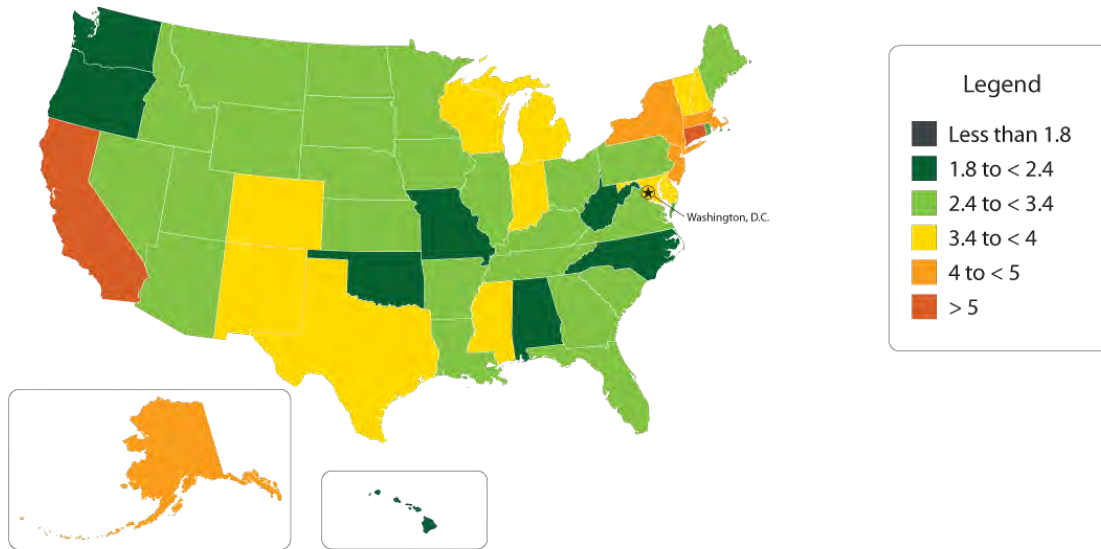
1. Click Process Flow Diagram
2. Configure the system on the Process Flow Diagram. Then, click the "Input Sheet" button to enter cost and performance values.

¹ DOE, Office of Energy Efficiency and Renewable Energy, Fuel Cell Technologies program, DOE Fuel Cell Power Analysis, available at http://www.hydrogen.energy.gov/fc_power_analysis.html

3. Enter cost and performance values using the Input Sheet as "Home Base."
 - a. The "Input Sheet Template" sheet is the main model interface
 - b. The subsequent slides will describe each section of the interface
 - c. Tools and defaults are available for most values
 - d. A lot of customization is possible for special case evaluations
4. Run the model by clicking the "Run Hourly Energy Profile" button.

The FCPower Model will identify the information that must be collected to make a comprehensive analysis of the fuel cell system.

In addition to evaluating the outputs of the FC Power Model, the project team should evaluate



Reference: DOE Energy Information Administration, Electric Power Monthly Table 5.6B, Natural Gas Monthly, ng_pri_sum_a_epg0_pcs_dmcf_a.xls

Figure 10. Spark Spread: Commercial Sector Ratio of Electricity to Natural Gas Prices

other factors that may affect the procurement decision. These include:

- Manufacturer’s warranty
- Available square footage
- Estimate of the system’s size
- Historic building issues
- Incentives (federal, state, local, utility, renewable energy credits [RECs])
- Siting and site access
- Capacity of the local industry to supply and maintain system
- Utility interconnection issues
- Electrical/mechanical room issues
- Size, condition, and efficiency of existing heating systems.

Spark Spread

One of the key factors in determining whether a fuel cell project will be practical are the relative prices of electricity available from the grid and fuel (e.g., natural gas) to use in the fuel cell. Fuel (e.g., natural gas) represents the largest operating cost of any onsite power generator. The ratio of the local electricity price to the price of fuel is known as the “spark spread.” This ratio is the most direct means of screening whether a fuel cell project can be financially viable in a particular location.

Historically, a spark spread of 3.4 or higher has been considered the level where onsite power production becomes competitive with electricity from the grid.

Figure 10 shows the spark spreads for each state for 2010, using information from DOE. Increased natural gas production in the U.S. has reduced prices from peaks seen in the past decade and DOE expects prices to remain below these peaks through 2035.² In 2007, three states had spark spreads of 3.4 or higher. In 2010, 16 states and the District of Columbia had spark spreads of 3.4 or higher. Facility managers should check with their local utilities to obtain actual electricity and fuel prices for their facility.

Step 4: Consider Legal and Administrative Requirements

As with any other aspect affecting a Superfund site, EPA managers must ascertain that a fuel cell project complies with the legal and administrative requirements associated with the remediation. Describing how to handle due diligence on the developer’s part has important contractual implications. Due diligence is the effort that a developer must put forth to fully understand the project and the risk of

² DOE Annual Energy Outlook 2011, Natural gas, available at http://www.eia.gov/forecasts/aeo/source_natural_gas.cfm

Example: Cost Analysis for Generating Electricity from a Fuel Cell

The cost of generating electricity from a fuel cell is dependent on many factors, including the initial capital investment, incentives, fuel costs, O&M, stack replacement and the value of useful thermal energy (if CHP). Figures A and B show the cost of generating electricity from a fuel cell and the cost of purchasing electricity from the grid for two cases: without CHP and with CHP. The values presented are simple examples based on project examples from DOE's Fuel Cell Technologies Program and manufacturers. Fuel cell projects are likely will be financed in a way that these specific costs are internal to the developer and not managed by the Superfund site manager.

In the electricity-only case (Figure A) the total cost of generating power is 12.9¢ per kWh, however, incentives can reduce the net cost to 10.1¢ per kWh. Some of the example inputs include:

- **Financing Cost:** This is the initial cost of the fuel cell (\$4,000 per kW) spread out over the 12 years with a 7% interest rate, representing 4.5¢ per kWh
- **O&M:** Maintenance of the fuel cell is not major but routine cleaning and checking of the equipment is necessary to assure reliable operation. Typical O&M costs are 2¢ per kWh.
- **Stack replacement:** Fuel cell performance declines gradually with age and, eventually, the entire fuel stack must be

replaced. Stack replacement may be necessary after about 10 years. Setting aside funds in a stack replacement reserve is one way to manage this cost. In this example the reserve is funded at 0.9¢ per kWh.

- **Fuel Cost:** This is the cost of fuel to operate the fuel cell. For this example, natural gas cost \$8.00 per MMBtu and represented 5.5¢ per kWh.
- **Incentives:** Federal, state, and local incentives can be substantial. This example is based on an incentive of \$2,500 per kW, which reduces costs by 2.8¢ per kWh.
- **Grid-Based Electricity:** In this example, power can be purchased from the grid for 12¢ per kWh.

Figure B illustrates a CHP example in which the electrical efficiency is slightly reduced but useful thermal energy is generated. The total cost of generating electricity is 8.5¢ per kWh. Incentives and the value of the thermal

energy reduce the net cost to 8.5¢ per kWh. The inputs are the same as in the electricity-only example with the following exception:

- **Fuel Cost:** This is the cost of fuel to operate the fuel cell, which consumes more fuel because it is also generating useful thermal energy. For this example, natural gas cost \$8.00 per MMBtu and represented 6.8¢ per kWh.
- **Thermal Credit:** This is the value of the useful thermal energy produced by the fuel cell. The cost of electricity is reduced by 3¢ per kWh. Although the CHP fuel cell uses more fuel than an electricity-only system, it produces thermal energy more efficiently than a standard boiler.

The cost of generating electricity with a fuel cell is less than the cost of purchased power in these examples, although the incentives are essential to achieving this goal. Site managers will have to make their own assessment of the financial viability of a project. In most cases, the project developer will perform their own analysis.

Figure A: Cost of Electricity – Fuel Cell without CHP

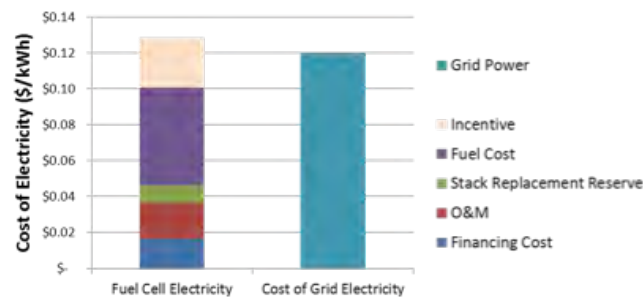
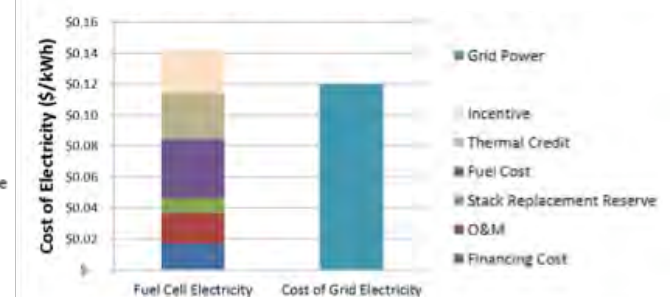


Figure B: Cost of Electricity – Fuel Cell with CHP



any unknowns that could arise. Contractually, the developer desires recourse if something unexpected comes up that is outside of its ability to perform or that will cause significant cost increases. In such circumstances, the developer might want to be able to walk away from the project or have the option to renegotiate. EPA's options include—but are not limited to—giving developers what they want contractually or telling developers to factor the risk into their proposals and handle any unexpected circumstances that arise. However, in general, government agencies do have language for equitable adjustments in price given increased scope of work.

Land-use agreements govern the site access given the developer during the term of the project. There can be two phases addressed by this agreement, the construction phase and the production phase. The site-access requirements during these two phases can be quite different, which is why they could have different limitations and may be handled separately. Contract terms with the developer should include land-use agreements that take the form of leases, easements, licenses, or land purchases that recognize the special circumstance of a municipally-owned Superfund site. Sample land use agreements are available on the DOE Federal Energy Management Program (FEMP) website.³

³ DOE, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, sample land use agreements, available at http://www1.eere.energy.gov/femp/financing/ppa_sampledocs.html#agreements

Indemnity is an important issue that can arise with a fuel cell project. Indemnity is protection from risk and can take several forms. If a contractor or utility installs and operates a fuel cell (as with a power purchase agreement) they may request indemnity from damage to facility equipment from the operation of the fuel cell system. For example, a malfunctioning power conditioning unit may result in frequency variations and an outage. Repairs to power conditioning unit and payment adjustments related to the loss of electrical and thermal production should be accounted for within the contract. However, if the frequency excursion resulted in damage to equipment served by the system, the responsibility for those losses may not be clearly defined.

Utilities and contractors vary in their policies but many will insist on having indemnification clauses included in their interconnection agreements. Federal and municipal agencies have their own policies with respect to indemnity and facility managers should familiarize themselves with their policies and determine whether they can sign an interconnection agreement that includes an indemnification clause.

Air Permitting

Fuel cells have very low emissions, making the air permitting process easier. State regulators recognize the superior performance of fuel cells systems and offer streamlined permitting

processes typically based on their status as minor sources of pollution. Typically, the contractor is responsible for submitting the necessary documentation to the permitting authority and managing the air permitting process.

While not likely to result in the requirement to install emission control systems, the air permitting process can be time consuming. For example, this process may take 12 weeks from the initial submittal to the issuance of a draft air permit in the South Coast Air Quality Management District (SCAQMD) of California.

Step 5: Make a Financing and Contracting Decision

Fuel cell projects require significant upfront investment and may not be appropriate for every facility. In some cases funds may be available to directly purchase a fuel cell but this may not be common; most will seek alternative financing structures to facilitate these projects. Fuel cells systems are integrated into a facility's essential electricity and thermal energy (if CHP) systems.

FEMP maintains an array of software and database tools to help government agencies analyze their energy use and to assist in the implementation of renewable energy, energy

efficiency, and water efficiency projects.⁴ FEMP also offers Webinars and workshops to educate participants on the different financing options available. After the project has passed initial screening and a project team has been formed, decisions about financing and contracting can move on to the next step: “Make a Financing and Contracting Decision.” Unless funding is designated for the project (i.e., the agency will fund the project), this can be a complex decision. If no direct funding is available, financing options must be considered. A financing expert needs to be contacted to discuss the specifics of the project and confirm the appropriateness of the financing decision.

There are multiple pathways to procure fuel cell power:

- Power Purchase Agreements
- Energy Savings Performance Contract (ESPC)
- Utility Energy Services Contract (UESC)
- Enhanced Use Lease (EUL)
- Direct Purchase of a Fuel Cell

Simply buying and operating a fuel cell system is the most obvious approach to pursuing a project at a Superfund site. This approach, however, has several major disadvantages that

make it a less desirable option. Most of the benefits of a fuel cell project can be realized without direct ownership of the equipment.

The primary reason not to directly purchase a fuel cell is that government agencies typically are not eligible to receive incentives for purchasing fuel cells. A fuel cell has very high upfront costs and most installations rely heavily on the incentives offered by governments and utilities. Most fuel cell projects will utilize a financing option that includes a financing partner that can take advantage of incentives.

There are several mechanisms for financing fuel cell projects. Typically, one or more options are possible for a particular site and the financing selection will depend on which option is best for the site. One of the most common financing arrangements is a PPA, which is described below. Other financing mechanisms are described at the end of this section. These other mechanisms are similar to PPAs but differ in ways that may make them appropriate for different situations.

Power Purchase Agreements

A PPA is a legal contract between an electricity generator (provider) and a power purchaser (buyer). Contractual terms may last anywhere between 10 and 30 years. During this time the power purchaser (the Superfund site) buys energy, and sometimes also capacity and/or ancillary services, from the electricity generator



⁴ DOE Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, project funding (available at <http://www.eere.energy.gov/femp/financing/mechanisms.html>); training (available at <http://www.eere.energy.gov/femp/services/training.html>)

(usually a developer). Such agreements play a key role in the financing of independently owned (i.e. not owned by a utility) electricity generating assets. For a PPA project the energy provider secures funding for the project, maintains and monitors the energy production, and sells the electricity (and thermal energy, if CHP) to the host at a contractual price for the term of the contract.

Financing for the project is delineated in the contract, which also specifies relevant dates of the project coming into effect, when the project will begin commercial operation, and a termination date for which the contract may be renewed or abandoned. In some PPA projects, the host has the option to purchase the generating equipment from the PPA provider at the end of the term, may renew the contract with different terms, or can request that the equipment be removed. One of the key benefits of the PPA is that by clearly defining the output of the generating assets and the credit of its associated revenue streams, a PPA can be used by the PPA provider to raise non-recourse financing from a bank or other financing counterparty.

There are ten major steps the PPA process:

1. Basic Power Purchase Agreement Issues

Before investing time and effort in pursuing a PPA, a manager should confirm that basic

issues have been settled. A manager would first need to confirm that PPAs are allowed in the state in which the project is located. One way to confirm eligibility is to contact the state energy office or public utility commission. Also, managers can contract DOE's Federal Energy Management Program, which maintains extensive resources on project financing.⁵

In general, PPAs typically are used only to implement larger projects (typically 100 kW or greater). This is based on several cost factors, including transaction costs, securing financing, and economies of scale that make the PPA electric price more acceptable. Where possible, multiple fuel cell projects can be aggregated into one larger project to make the financing more attractive.

Most PPAs require long-term contracts—generally 15 to 20 years—and managers may not have the authority to enter into utility contracts of this length. Congress might change this but, at present, a workaround is required. Western Area Power Administration (Western) can help with long-term contracts for sites in its area (<http://www.wapa.gov>). Western can negotiate and sign the PPA on behalf of the site, but the manager must select the fuel cell developer. Another option for long term agreements is to sign a long-term land-use agreement that includes a provision requiring

the fuel cell project developer to give the site hosting the fuel cell project right of first refusal on purchase of the power at a predetermined price. If the site does not purchase the power, then the developer is free to sell it to the local utility.

2. Consider a Request for Information (RFI) or Request for Qualifications (RFQ)

An RFI is a way to obtain feedback on the proposed project to help refine and develop the request for proposal (RFP). Recommendations of types of projects for a specific site typically are helpful. In many locations, local air pollution control authorities will prefer fuel cell projects sized to meet on-site loads. Responses to the RFI can help refine the government's requirements for the scope of work used in the RFP. An RFI also allows industry to comment on the proposed process.

Another optional step that has been used for at least one federal site is an RFQ. The purpose of the RFQ is to obtain a list of developers that are interested in the project and to learn about their specific qualifications. Developers that meet a stated qualification level can submit a proposal based on the RFP created in the subsequent step in the process.

⁵ DOE Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, project funding, available at <http://www.eere.energy.gov/femp/financing/mechanisms.html>

3. Develop a Request for Proposal

A request for proposal is the document issued to the public to solicit proposals; in this case, from fuel cell CHP developers. The RFP describes how the proposal process is to be conducted and provides information that can be used as a basis for a developer's proposal. Sample documents can be found at the FEMP PPA Web site.⁶ An RFP should include the following elements (listed alphabetically, and not in order of importance).

- Specific site-access requirements
- Fuel cell operating conditions requirements
- Evaluation criteria and process
- Timelines for proposal process
- Assignment of renewable energy attributes (ownership of the RECs)
- Current energy-consumption data
- Drawings and maps (if available)
- Building restrictions (e.g., for use of natural gas) such as code limitations
- Infrastructure requirements (if any), such as roads, fences, electrical system upgrades, tree removal, and determining which party

⁶ DOE Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Sample Documents for Power Purchase Agreements - Request for Proposal and Contracts, available at http://www1.eere.energy.gov/femp/financing/ppa_sampledocs.html#rfpc

is responsible for coordination and payment

- Environmental requirements such as the National Environmental Policy Act, the National Historic Preservation Act, Endangered Species Act, and other applicable federal, state, and local requirements
- End-of-project options
- Contracting officer representative information (if applicable)

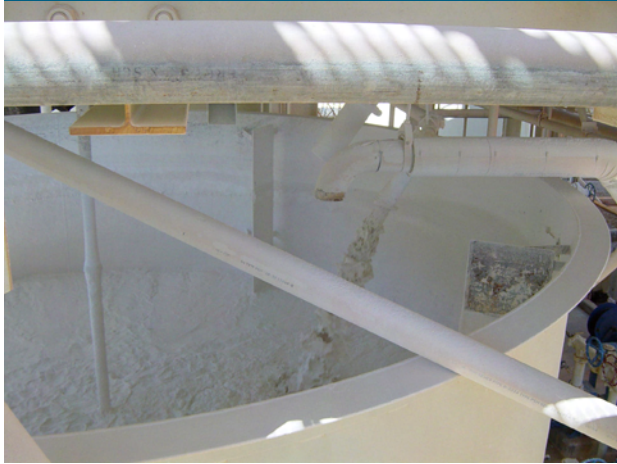
The system description should include expected technology type, size or performance range, location, and any site-specific considerations or limitations (e.g., access to natural gas and interconnection with existing thermal and electrical systems). Site information that should be provided, if available, includes pertinent electrical information and drawings, site characteristics, site load information (maximum/minimum demand for each month), consumption information (hourly if available), environmental factors, interconnection options, acceptable inverter locations, and any other pertinent information.

4. Issue a Request for Proposal

After the RFP is complete, announce it somewhere that developers can find it. Some options for posting RFPs include:

- Federal Business Opportunities, <http://www.fbo.gov>





- FedConnect, <http://www.fedconnect.net>
- Green Power Network, <http://apps3.eere.energy.gov/greenpower/financial>

After the RFP is issued, follow the defined timeline and described RFP process. This step may include site visits, pre-bid meetings, and correspondence related to questions and answers related to the project.

5. Evaluate the Proposals

Assemble a small team to evaluate the proposals received. The number of team members to include depends upon the specific project, but the team should have at least three people. Most of the people on this team probably will come from the project team. Other key people to consider including on this team are:

- Energy manager,
- Facilities manager,
- Legal/procurement expert,
- Project manager,
- Site manager (if managers for different areas of site), and
- Energy systems expert.

It is recommended that the merit-review sessions be set up well in advance to ensure the availability of key personnel. Follow the proposal evaluation criteria described in the RFP and, from the start, clearly define the

meaning of each criteria and score.

When evaluating proposals for pricing options, be aware that if an acceptable pricing structure is not specified in the RFP then many different options could be given. Common pricing structures include escalation factor (usually 1 percent to 3 percent), firm-fixed price, utility-rate linked, or a de-escalation factor. An escalator is the percentage that the PPA price per kilowatt-hour will increase annually. A first year price with escalator usually is less than a fixed price but will increase to more than the fixed price during the term of the PPA. Typically, an evaluation of these pricing structures can be based on lowest present cost for the expected production and term of the project.

The winning proposal should be compared to current utility rates and the expected future rates, including those developed by the Department of Commerce.⁷ Other price forecasts also can be used for comparison purposes to help the site decide whether a contract award is recommended. Other time- and project-specific requirements, such as when funds will be available to pay for production (e.g., a large amount of funds might be available in the first year of the project, but perhaps more significant funds will not be available until a subsequent year) also can be considered. As

⁷ National Institute of Standards and Technology (NIST) and DOE Energy Information Administration (EIA) "Energy Price Indices and Discount Factors for Life-Cycle Cost Analysis - 2011," available at <http://www1.eere.energy.gov/femp/pdfs/ashb11.pdf>

noted, standby charges and possible utility tariff changes should be compared to historic and projected utility costs.

6. Award the Contract

The process for contract award depends on the type of evaluation used, and could include negotiations with the proposers. Several options can be used for awarding the contract:

- **Award Based on Proposal.** The contract is awarded solely on the merits of the proposal as determined when the proposals were evaluated. This scenario is very unlikely, as discussion almost always is required.
- **Award with Discussions.** The contract is awarded on the merits of the proposal but is contingent in part on further discussions to clarify understandings, agreements, or responsibilities.
- **Award with Discussions and Negotiation.** The contract is awarded on the merits of the proposal but is contingent on further discussions and negotiations. This can be used in the case of receipt of a good proposal that requires adjustments to meet the specific needs of the project.
- **Award with Best Proposal.** In this process, a short list of developers is created based on the proposal. Those on the short list then are asked to develop their best final proposal revision (FPR). This request for FPR can

include information such as updated pricing and design specifications.

7. Design the Project

After the contract is awarded the project design phase begins, usually with a kickoff meeting to confirm project details for all parties. The design parameters that the system designer will work within should be clear from the RFP, the final revised proposal, any negotiations that occurred during the RFP process, and due diligence performed by developer.

8. Construct the Project

Coordination between the Superfund site manager and the developer is essential to completing the fuel cell project on-time. To enable a successful coordination during this phase, first identify a single point of contact. Major areas of coordination include the timing of work (particularly if construction could interfere with the site's mission), ensuring that critical deadlines are met (especially those regarding incentives), assisting with interconnection issues (including interconnection and net metering agreements), and handling incentive applications.

9. Commission the System

Although the system is owned and operated by a third party and the site is just purchasing the energy output of the system, the system

still is located on an active Superfund site. Commissioning of the system is the responsibility of the fuel cell developer; however, it is recommended that the site manager be aware of any issues and reports resulting from the commissioning. A successful commissioning includes resolution of any safety issues, including damaged wire insulation and unprotected high-voltage connections.

10. Monitor the Performance Period

During the period of performance the site manager should receive regular performance reports from the developer and these should be checked against the site's reports and be confirmed with onsite observations. O&M, payments, and resolution of outages should be handled according to the terms of the PPA. The manager should confirm plans for the disposition of the fuel cell equipment at the conclusion of the PPA contract period.

Other Contracting Structures

There are other financing mechanisms available to facilitate fuel cell projects. These mechanisms differ from PPAs and may help a site take advantage of its unique situation. Although briefly described here, there are additional resources available at the FEMP

website.⁸

- **Energy Savings Performance Contract.** ESPCs have a long history of use in the federal sector and have primarily been used for energy efficiency projects. They are a possible vehicle for a fuel cell project. An ESPC is a guaranteed savings contracting mechanism that requires no up-front cost. An energy services company (ESCO) incurs the cost of implementing a range of energy conservation measures (ECMs)—which can include fuel cells and is paid from the energy, water, and operations savings resulting from these ECMs. The ESCO and the agency negotiate to decide who maintains the ECMs. Payments to the contractor cannot exceed savings in any one year. These contracts are recommended for renewable energy projects only if energy-efficiency measures also are being performed.
- **Utility Energy Services Contract.** UESCs have been used in the federal sector primarily for energy efficiency projects. UESCs are starting also to be seen as a method of long-term financing, with the added benefit of usually being a sole source contract. A UESC is an agreement that allows a “serving” utility to provide an agency with comprehensive energy- and water-efficiency improvements and

demand-reduction services. The utility may partner with an ESCO to provide the installation, but the contract is between the federal agency and the “serving” utility. This contracting mechanism primarily is for bundled energy-efficiency and renewable energy projects, and typically is not used for standalone projects.

- **Enhanced Use Lease.** In the federal sector, EULs have been employed to implement infrastructure building projects. An EUL is a real estate agreement that focuses on underutilized land. Prospective developers compete for the lease, and payment can be either monetary or in-kind consideration (in this case, renewable power can be part of the consideration). The value of the lease is used to determine the amount of consideration. There are several factors that may limit the usefulness of EULs for fuel cell projects. An EUL typically is used for large projects, for example those having a capacity that is greater than the site load. Fuel cell projects are less likely to be oversized than other options, and EULs are not likely to be used for fuel cell projects.
- **Direct Purchase of a Fuel Cell.** In some cases it is possible for a site to directly purchase a fuel cell system without financing. This arrangement may forego taking advantage of substantial government incentives but may make sense if specific funding is made available for a procurement. Like any procurement,

a direct purchase requires the site to understand its energy requirements and work with project developers to design an appropriate system. O&M, stack replacement, and other issues are the responsibility of the site manager, although contracts can be established for these services.

⁸ DOE Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Project Funding, available at <http://www1.eere.energy.gov/femp/financing/mechanisms.html>

7.0 EXAMPLES OF POTENTIAL FEASIBLE PATHWAYS

This section describes two examples of feasible pathways for fuel cells to be installed at a Superfund site. As fuel cells have not yet been installed or specifically proposed for any site, there are no actual case studies to present. Instead, this section uses two real Superfund sites as starting points to show how fuel cell project could get done. Many of the specific facts about the sites have been changed to facilitate their use as an example fuel cell site. The use of the Bayou Bonfouca and Phoenix-Goodyear Airport Area Superfund site names in this section do not indicate that fuel cells are recommended for these sites.

The two example pathways are:

1. Bayou Bonfouca Superfund site in Slidell, LA

- a. For this example, the remediation plan is still being developed for this site.
- b. The fuel cell developer is willing to sign a 20-year PPA.
- c. The site is privately-owned.
- d. Pump and treat clean-up is proposed.
- e. Site has good road access.
- f. Site does not have access to natural gas but can bring in LPG by truck.

2. Phoenix-Goodyear Airport Area Superfund site outside of Phoenix, AZ

- a. For this example, the site is undergoing remediation and is preparing for its five-year review.
- b. The fuel cell developer is willing to sign a 15-year PPA.
- c. The site is municipally-owned.
- d. Pump and treat clean-up is used.
- e. Site has good road and rail access.
- f. Site has access to natural gas and electric grid interconnection.





Bayou Bonfouca Superfund site in Slidell, LA

History

Located in Slidell, LA, this 54 acre site previously was occupied by a creosote plant that had operated since 1882. In the early 1970s, a fire caused storage tanks to rupture spilling creosote onto the site and into the adjacent bayou. The spill caused an environmental disaster for the bayou and posed significant risks to both aquatic organisms and human health.

Contaminants

The primary contaminants of concern are the polycyclic aromatic hydrocarbons associated with creosote. These contaminants were found in surface soils, groundwater, and bayou sediments.

Remedy

The remedy will include excavation of contaminated soils and sediments, incineration, and the pump and treatment of groundwater to remove creosote oils.

Load Profile

The pump and treat system is to operate on a

continuous basis, needing approximately 20,000 kWh of energy per month.

Pathway to the Fuel Cell Project

In this example, the site has not yet undergone remediation. The site manager expects remediation operations to continue for more than a decade. It is expected that that the site will use approximately 20,000 kWh of electricity per month, however this demand is not uniform. Power demand rises with operations that occur when the site is fully staffed and declines during night time and weekend treatment operations. The peak power demand is nearly 50 kW, and the minimum power demand is 20 kW with an overall power demand of 27 kW.

The site manager sought out a developer to install a fuel cell system. After doing some preliminary research, the manager contacted several developers and began constructing an RFP. Several elements became central to the RFP and how the fuel cell project would proceed at the site:

1. **Not in place at startup:** Although the site manager expressed interest in the fuel cell almost a year before the remediation began, it was decided that the fuel cell would not be in place for the beginning of the remediation. The scheduling would not allow full integration of the thermal output of a fuel cell CHP system into the treatment

process. Instead, the fuel cell system would be installed after remediation had begun.

2. **Combined Heat and Power:** To achieve maximum efficiency, the fuel cell would be configured to be used in a CHP structure, with the thermal energy going to provide space heating and hot water to the site.
3. **Grid integration:** The power demand at the site averages 27 kW, which is smaller than the current fleet of larger, more efficient fuel cells on the market, which average 100 kW to 400 kW in capacity. Fuel cells operate best in a baseload operation with output being at or near the rated capacity of the fuel cell. For these reasons, the fuel cell will not be tied to the pump and treat operations. The fuel cell will be grid-connected and send all of its electrical output to the grid. The remediation activities will be powered by grid.
4. **LPG:** Most large fuel cell systems use natural gas as a fuel source, but it is not available at this site. LPG brought in by railcar will power the fuel cell. One railcar (33,000 gallons) can carry enough LPG to supply the fuel cell with more than two months of energy.

Power Purchase Agreement

In this theoretical example, a fuel cell developer is selected to install a PAFC. The fuel cell was

acquired through a PPA with the developer and the local utility.

- 400 kW PAFC.
- Operates at approximately 40 percent electrical efficiency.
- Produces 250oF hot water.
- The PPA is for 10 years with an option to extend the agreement for another 10 years.

Because this is a PPA, the developer acquires, operates, and maintains the fuel cell and sells electricity and hot water to the site. Under the terms of the PPA, the price of the electricity and hot water are indexed to the price of LPG, which the developer purchases on the local market. The current wholesale price of LPG is \$1.51 per gallon in the local market and under the terms of the contract, this means that the site will pay 10.5 cents per kWh for electricity and \$15 per MMBtu for hot water.

The electrical output of the fuel cell is metered and sent back into the grid through its own interconnection. Pump and treat remediation operations are not connected to the fuel cell. The hot water from the fuel cell is connected to the site's hot water system. Generally, the fuel cell supplies all of the hot water needed at the site, and an onsite water heating system is retained as a backup.





Phoenix-Goodyear Airport Area

History

Located outside Phoenix, AZ, the Phoenix Goodyear Airport Area site is comprised of two sections – PGA North and PGA South. PGA North is approximately 0.5 to 0.7 square miles in area, and PGA South is more than one square mile. PGA South housed a former U.S. Navy Air Facility (Litchfield Naval Air Facility) and an aerospace manufacturing facility (former Goodyear Aerospace/Loral) that was used primarily as an aircraft preservation and activation facility. PGA North housed a manufacturing plant for aerospace and defense equipment such as munitions, pyrotechnic devices and rocket propellant. These industrial processes have left the site with many environmental issues.

Contaminants

The primary contaminants of concern in the groundwater at the site include: chromium (PGA South only), trichloroethylene, perchloroethylene (PGA South only), dichloroethylene (PGA South only), chloroform (PGA South only), and carbon tetrachloride (PGA South only).

Remedy

The remedy for both the north and south portions of the site consist of multiple ground water extraction and treatment systems.

Load Profile

There are multiple pump and treat systems on the site. Their load profiles are the following:

Duration – always in operation.

- System #1 – 900-1,000 kWh/day
- System #2 – 190-250 kWh/day
- System #3 – 350 kWh/day
- System #4 – 200-500 kWh/day
- System #5 – 1,000 kWh/day

Pathway to the Fuel Cell Project

Remediation is already occurring at this site and the idea of introducing a fuel cell was precipitated by the upcoming five year review cycle. It is likely that the PGA South remediation will be complete in less than 10 years and the PGA North remediation will require more than 10 years.

An analysis of electricity bills shows that the site uses 80,000 to 90,000 kWh of electricity per month. The site manager is interested in having a fuel cell onsite that could continue production after remediation is complete. In addition, the fuel cell could provide hot water to be used by adjacent industrial operations.

Discussions with several developers were promising and the site manager worked with a consultant to write an RFP. Key elements of the RFP included:

1. **Option to continue operations after the site was cleaned up:** Local authorities were very interested in a fuel cell project that would continue to operate after the site remediation was completed. Additional project planning and negotiations were required for the developer to agree to a contract that would begin with the site as a customer and finish with the local municipality as the customer. This three-party PPA took more than a year to realize the fuel cell installation. Although not part of the remediation, the fuel cell project was planned in parallel with the five year review cycle.
2. **No Combined Heat and Power:** The project went forward as an electricity-only fuel cell. Initially, the site manager had strong interest in a CHP project in which the fuel cell would supply thermal energy to a nearby industrial site. Discussions of this option were time-consuming and were ultimately abandoned. It was decided that involving another party in the negotiations was too unwieldy and the thermal energy produced by the fuel cell would be too small (<300,000 Btu per hour) to justify the additional effort.

3. **Grid integration:** The power demand at the site averages 110 kW and is a good match for a stationary fuel cell installation. The site had reported power delivery problems with frequent need to use backup generators to maintain operations. The fuel cell's grid interconnection allows the fuel cell to be the primary energy source for remediation activities with the grid to be backup power supply and the diesel generators to remain as an additional backup.
4. **Natural gas:** The fuel cell would use natural gas, which is available onsite, as a fuel source.

Power Purchase Agreement

In this theoretical example, a fuel cell developer is selected to install a SOFC. Because the fuel cell is operating as a baseload unit in electricity-only mode, it achieves 50 percent efficiency. The fuel cell was acquired through a PPA with the developer.

- 100 kW SOFC.
- Operates at approximately 50 percent electrical efficiency.
- The PPA is for 15 years. When the remediation is complete, the local municipality will take over the PPA from the site. It is expected that the remediation will be complete in 5 to 7 years.





Under the terms of the PPA, the developer acquires, operates and maintains the fuel cell and sells electricity to the site. The price of electricity under the PPA is 9.5 cents per kWh and will increase 2 percent per year. At the conclusion of the period of performance of the PPA, ownership of the fuel cell stays with the developer. At that time, the local municipality or other entity may negotiate with the developer to take over ownership of the fuel cell or initiate a new PPA.

APPENDIX A:

LIST OF MAJOR U.S. FUEL CELL MANUFACTURERS

FUEL CELL TYPE	MANUFACTURERS
Phosphoric Acid (PAFC)	UTC Power Headquarters 195 Governor's Highway South Windsor, CT 06074 Telephone: (860) 727-2200 Web: www.utcpower.com
Molten Carbonate (MCFC)	FuelCell Energy 3 Great Pasture Road Danbury, CT 06813 Telephone: (203) 825-6000 Web: www.fuelcellenergy.com
Solid Oxide (SOFC)	Bloom Energy 1299 Orleans Drive Sunnyvale, California 94089 Telephone: (408) 543-1500 Web: www.bloomenergy.com

APPENDIX B: LINKS TO FUEL CELL INFORMATION

Fuel Cell and Hydrogen Energy Association (FCHEA)

<http://www.fchea.org/>

California Fuel Cell Partnership (CAFCP)

<http://cafcp.org/>

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Fuel Cell Technologies Program

http://www.eere.energy.gov/topics/hydrogen_fuel_cells.html

“Fuel Cell Financing for Tax-Exempt entities,” U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Fuel Cell Technologies Program

http://www1.eere.energy.gov/hydrogenandfuelcells/pdfs/fuel_cell_financing_fact_sheet.pdf

U.S. Department of Energy, Fuel Cell Power Analysis (FCPower Model)

http://www.hydrogen.energy.gov/fc_power_analysis.html

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program

<http://www.eere.energy.gov/topics/government.html>

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Federal Energy Management Program, Sample Documents for Power Purchase Agreements

http://www1.eere.energy.gov/femp/financing/ppa_sampledocs.html

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, Alternative Fuels Data Center

<http://www.afdc.energy.gov/afdc/>

United States Environmental Protection Agency, Combined Heat and Power Emissions Calculator

<http://www.epa.gov/chp/basic/calculator.html>

A Database of State Incentives for Renewable Energy (DSIRE)

<http://www.dsireusa.org>

Fuel Cells 2000 – The Online Fuel Cell Information Resource

<http://www.fuelcells.org/>

Fuel Cells 2000, State Fuel Cell and Hydrogen Database

<http://www.fuelcells.org/dbs/>

“State of the States: Fuel Cells in America,” Fuel Cells 2000, June 2011

<http://www.fuelcells.org/StateoftheStates2011.pdf>

“The Business Case for Fuel Cells: Why Top Companies are Purchasing Fuel Cells Today,” Fuel Cells 2000, September 2010

<http://www.fuelcells.org/BusinessCaseforFuelCells.pdf>

APPENDIX C: CONSIDERATIONS DOCUMENTS

Attached here are the responses received from EPA Remedial Project Managers to the list of consideration described in Chapter 5.

The considerations documents included here are for the following sites:

- Phoenix-Goodyear Airport Area, Site# AZD980695902, Maricopa County, AZ
- Bayou Bonfouca, Site# LAD980745632, Slidell, LA

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