Executive Summary: Draft PA No. 11 – Fuel Cells

Description

This assessment estimates the energy generation and potential GHG reduction potential from the development of local fuel cell projects. Fuel cell systems could be installed on property owned by SCWD or SqCWD. The fuel cell systems could produce energy to directly provide power to the desalination facility, to other SCWD and SqCWD facilities, or could connect to the overall electrical grid to indirectly provide power to SCWD or SqCWD facilities.

Amount of GHG Reduction

Fuel cells can use natural gas or biogas to produce energy, water, heat and GHGs including CO_2, and a small amount of other gases. The GHG emissions from a SCWD or SqCWD fuel cell system project would be compared to the PG&E emission factor to determine the potential net GHG reduction from a fuel cell energy source. The GHG emission factors of natural gas-supplied fuel cells, while less than the US average grid electricity emission factor, are in most cases higher than the PG&E emission factor. This is because PG&E grid electricity has a higher percentage of renewable and non-fossil fuel energy than many other utilities. Therefore, in comparison to grid electricity from PG&E, the fuel cell systems with natural gas would not provide a reduction in GHG emissions. Currently, local biogas sources are being used for energy production, therefore local biogas fuel cell projects do not appear to be feasible for GHG reduction.

Project Life and Sustainability

A fuel cell project would provide energy for the life of the project. The project would be sustained by normal routine maintenance and periodic replacements of the fuel cell stacks as necessary. However, this project would not provide GHG reductions (as noted above).

Project Cost

Cost information for a lease for a SOFC fuel cell (Bloom) and a MCFC fuel cell (FCE) are provided in ES-1. There is no capital cost since the systems are leased. Since the fuel cells' GHG emission factors are higher than PG&E's emission factors, there are no GHG reductions and the lifecycle GHG reduction cost is not applicable. Since the energy and fuel costs for the Bloom fuel cell are lower than the PG&E energy costs, there is an average annual net savings and a negative lifecycle energy cost. The energy cost from the FCE fuel cell is similar to the PG&E energy costs. However, the additional cost for labor and the different between the estimated inflation and utility/fuel cost escalator rates cause the FCE fuel cell to be slightly more expensive than the energy savings each year, resulting in an average annual net cost.

Table ES-1: Estimated Fuel Cell Costs

Fuel Cell Type	Life (yr)	Capital Cost ($)	Average Annual Net Cost ($/Yr)	Lifecycle Energy Cost ($/KWh)	Lifecycle GHG Reduction Cost ($/MT)
SOFC (Bloom)	20	$0 Lease	-$8,300	-$0.0024	N/A
MCFC (FCE) without heat recovery	20	$0 Lease	$157,000	$0.0131	N/A

Draft Project Assessment No. 11 – Fuel Cells

Description

This assessment estimates the energy generation and potential GHG reduction potential from the development of local fuel cell projects.

Background

A local fuel cell project would entail installing fuel cells on SCWD (or potentially the City of Santa Cruz) and SqCWD properties to provide a local energy source that reduces the use of grid electricity and potentially the associated indirect GHG emissions. Fuel cell systems could be installed on the ground on property owned by SCWD or SqCWD. The fuel cell systems could produce energy to directly provide power to SCWD or SqCWD facilities, or could connect to the overall electrical grid to indirectly provide power to SCWD or SqCWD facilities. If or when the fuel cell system is not producing energy, electrical power could be obtained from the overall electrical grid through Pacific Gas and Electric (PG&E).

With regard to coordinating with PG&E and connecting to the overall electrical grid, there are four options for fuel cell projects, similar to solar photovoltaic projects: 1) Behind the Meter; 2) Virtually Behind the Meter; 3) Virtual Meter Aggregation; and 4) In-front of the Meter. These categories are described in detail in the Local Solar Project Assessment.

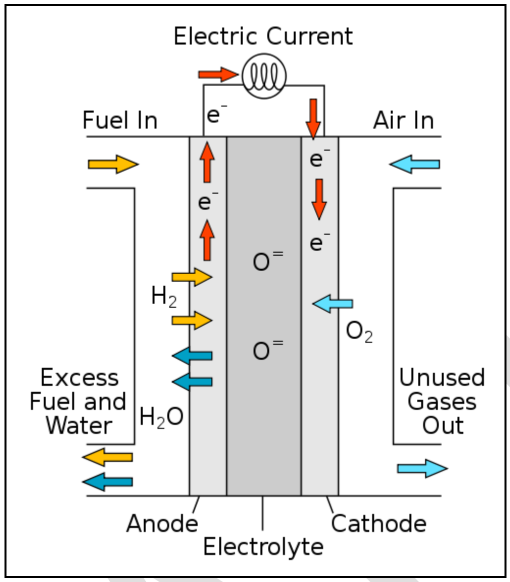
Fuel Cell Technology

Generally, fuel cells use natural gas (methane) as a fuel source and produce energy, water, heat and GHGs including CO_2, and a small amount of other gases. Fuel cells work like batteries, making electrical energy from chemical energy without combustion. Compared to a natural gas combustion generator, a fuel cell can produce the same amount of energy using less natural gas fuel and producing fewer emissions. A fuel cell system could produce fewer GHGs than electricity from the grid depending on the emission factor of the utility providing electricity over the grid. This is discussed in more detail below.

In a fuel cell, a catalyst known as the "fuel reformer" is generally required to extract hydrogen from the methane gas. Fuel reformers break the methane molecule and separate the hydrogen for use by the fuel cell. Natural gas is the cleanest and preferred fuel if pure hydrogen gas is not available. However, other hydrogen rich gases such as propane, or methane from biological processes, could also be used as a source for fuel cells.

Like a battery, a fuel cell has one positive electrode (the cathode) and one negative electrode (the anode) with an electrolyte between them. The hydrogen is fed to the anode and air (oxygen) is fed to the cathode. A catalyst on the surface of the anode splits the hydrogen into protons (hydrogen ions) and electrons. As the hydrogen ions move from the anode to the cathode through the electrolyte, electricity is created. Electrons cannot flow through the electrolyte and, as a result, flow through an external circuit as an electric current. At the cathode, a catalyst on the surface recombines the hydrogen ions and electrons with oxygen to produce water and heat. A diagram of a typical fuel cell is shown in Figure 1.

Figure 1: Diagram of Fuel Cell Technology



Source: U.S. Dept. of Energy: http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html

The fuel cell process is different than the traditional process of combustion in which fuel first is burned and the subsequent heat is used to produce power. Avoiding this two-step process makes the fuel cells more efficient than combustion technologies.

A single fuel cell generates a small amount of electricity, so in practice many fuel cells are typically assembled into a stack to generate the desired power output. Fuel cells produce direct current (DC) electricity and use a power inverter to convert from DC to alternating current (AC) for consumptive uses.

Types of Fuel Cells

Fuel cells differ based on type of electrolytes and operating temperatures. The four primary fuel cell technologies are described below.

Phosphoric Acid Fuel Cells (PAFC): PAFCs use liquid phosphoric acid as the electrolyte. The PAFC is the oldest technology used today. Generally, PAFCs have higher capital costs and lower efficiencies than other types of fuel cells such as MCFC and SOFC. PAFCs are generally large and heavy and require warm-up time, making them most appropriate for stationary applications. Efficiencies of approximately 35 to 45 percent are achievable with PAFCs.

Molten Carbon Fuel Cells (MCFC): MCFCs use an electrolyte composed of a molten carbonate salt mixture. These fuel cells operate at high temperatures and have efficiencies as high as 45 to 60 percent. However, the high operating temperatures accelerate component breakdown and corrosion, decreasing the life of the cell and increasing operating cost.

Solid Oxide Fuel Cells (SOFC): SOFCs use a hard ceramic compound as the electrolyte. SOFCs also operate at high temperatures, with efficiencies approximately 45 to 60 percent. This technology is still at a relatively early stage of development compared with other fuel cell technologies, and is not as commercially available.

Proton Exchange Membrane Fuel Cells (PEMFC): Development of PEMFCs has generally been driven by the automotive sector because of their low temperature operation, which allows them to start quickly. Their light weight also makes them advantageous for automobile use. PEMFCs use a thin solid membrane for an electrolyte. They are generally good candidates for smaller applications and have efficiencies of approximately 35 to 50 percent.

Vendors

More than 60 companies worldwide are involved in the development of fuel cells. Generally, most companies focus on one of the primary types of fuel cell technologies. Example companies for each type of fuel cell include:

Table 1: Types of Fuel Cells and Associated Vendors

Type of Fuel Cell	Vendors
PAFC	• UTC Power (UTC) • Fuji Electric Company • Mitsubishi Electric Corporation
MCFC	• Fuel Cell Energy (FCE) • Hitachi
SOFC	• Siemens Westinghouse Power Corporation • SOFCo • ZTEK Corporation • Bloom Energy (Bloom)
PEMFC	• UTC Power • ReliOn • Ballard Generation Systems • Nuvera Fuel Cells

This assessment evaluates the MCFC fuel cells provided by Fuel Cell Energy (manufactured in Connecticut), the PAFC fuel cells provided by UTC Power (manufactured in Connecticut), and the SOFCs provided by Bloom Energy (manufactured in California). These types of fuel cells have operating experience at commercial and municipal facilities.

Capacity of Fuel Cells

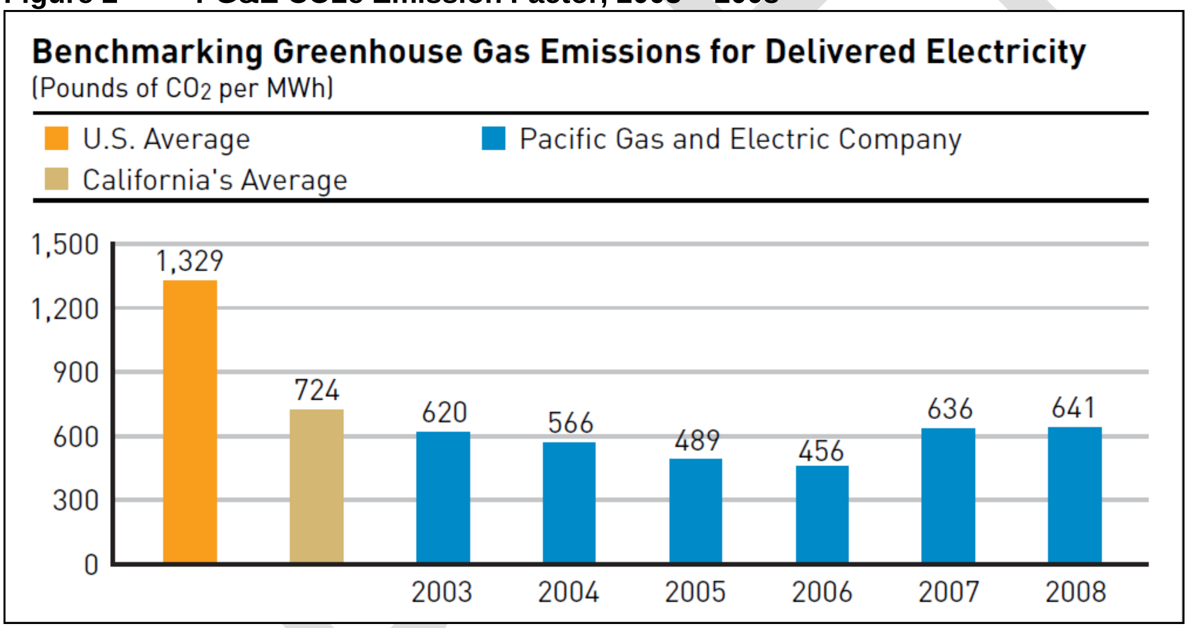
Fuel cells are generally modular units and the amount of energy produced depends on the type of fuel cell and the configuration. SOFC fuel cells by Bloom can be purchased starting with a 200 kW unit, then additional increments of 100 kW. MCFC fuel cells by Fuel Cell Energy are available in a 1,400 kW unit. Fuel Cell Energy also has a 300 kW unit available, but these are only available as a special order and are in limited production. This limitation makes these units much more expensive per kW than the 1400 kW unit, and therefore the 300 kW units are not included in this evaluation. UTC Power has a 400 kW unit available which can be deployed in multiple units to provide additional energy.

Fuel Cell GHG Emissions with a Natural Gas Source

Fuel cells produce energy, water, heat and GHGs including CO_2, and a small amount of other gases. The GHG emissions from a SCWD or SqCWD fuel cell system project would be compared to the PG&E emission factor to determine the potential GHG reduction from a fuel cell energy source. In implementing the agency-specific Energy Minimization and GHG Reduction Plans for the Project, the actual PG&E emission factor for each year would be used to determine the actual GHG reduction.

Indirect GHG emissions associated with electricity from the grid in Santa Cruz were calculated using PG&E California Climate Action Registry reported and verified electricity CO_2e emission factors. The annual report can be found at: https://www.climateregistry.org/CARROT/Public/Reports.aspx. As shown in Figure 2, the emission factor fluctuates annually and is often greater in dry and drought years due to less available hydropower. The PG&E emission factor is less than the California average and significantly less the US average emission factors. This is due to PG&E's relatively larger percentage of renewable and non-GHG energy sources. The 2008 PG&E emission factor is the most recent as of this analysis.

Figure 2 PG&E CO2e Emission Factor, 2003 – 2008



Source: PG&E, 2009 Corporate Responsibility and Sustainability Report.

Table 2 below provides the manufacturer provided emissions factor for the different types of fuel cells assuming natural gas is used a fuel source. The US and CA average, and the 2003 to 2008 range of PG&E grid electricity emission factors are also tabulated for comparison.

Note that fuel cell GHG emission factors, while less than the US average grid electricity, are in most cases higher than the PG&E emission factor. Therefore, in comparison to grid electricity from PG&E, the fuel cell systems with natural gas would not provide a reduction in GHG emissions. The MCFC fuel cell from FCE could potentially incorporate the recovery of waste heat from the fuel cell process to help offset other energy requirements. FCE provided a potential high and low range of emission factors for their MCFC fuel cell with a heat recovery system (shown in Table 2). With waste heat recovery, the FCE fuel cell may or may not reduce GHG emissions compared to PG&E energy depending on the actual emission factors. The SOFC fuel cell from Bloom and PAFC fuel cell from UTC do not create useable amounts of waste heat.

Table 2: Energy Source and Fuel Cell System GHG Emission Factors

Energy Source / Fuel Cell Type	GHG Emissions Factor (lbs CO_2/MWh)
US Average Grid Electricity	1,329
CA Average Grid Electricity	724
PG&E Grid Electricity	456 to 641
SOFC (Bloom)	773
MCFC w/o heat recovery (FCE)	980
MCFC w/ heat recovery (FCE) (high emissions)	680
MCFC w/ heat recovery (FCE) (low emissions)	520
PAFC (UTC)	1,100

Fuel Cell GHG Emissions with a Biogas Source

If digester gas is used as the source of methane, it must first be cleaned to remove impurities such as siloxanes and hydrogen sulfide. Impurities can poison the fuel cell catalyst, which limits its ability to ionize hydrogen and reduces the fuel cell efficiency, or can result in catastrophic failure. A fuel cell operating on biogas produces emissions including CO_2, and a small amount of other gases. However, these emissions are not accounted for as “GHG emissions” because they come from a non-fossil fuel source. The fuel cell process simply converts the more potent GHG (methane) to less potent GHG (carbon dioxide) while extracting energy in the process.

The same reasoning is applied to combustion generation of biogas. For example, the emissions of CO_2, and a small amount of other gases from the digester biogas combustion generator at the Santa Cruz wastewater treatment plant (WWTP) are not accounted for as “GHG emissions” because they come from a non-fossil fuel source, and would be released with or without the digester biogas combustion generator system. Therefore, the energy produced from biogas methane fuel cells and combustion generators is considered to be “GHG free energy.”

History and Technical Maturity

Primitive fuel cells were invented over 100 years ago. The space program drove their commercial development in the1960s. In 1997, a PAFC was the first modern fuel cell operated on digester gas at a wastewater treatment plant in New York. Since that time an increasing number of fuel cells have been installed using digester gas, most using either PAFC or MCFC technologies. Today, there are about 50 fuel cell installations in California totaling over 25 MW, about 10 MW of which is at wastewater treatment plants. The largest fuel cell plant in the world is a 5.6 MW FCE plant in Korea. About 90% of FCEs U.S. installations in the past several years are fueled by digester gas.

The Eastern Municipal Water District installed three MCFC 250 kW fuel cells by Fuel Cell Energy that operate on digester gas at their Moreno Valley Regional Water Reclamation Facility. The fuel cells provide the District with enough energy to operate 40 percent of the plant at peak hours. They have indicated that the capacity factor of the fuel cells has been in the mid-ninety percent over the past year and half.

SOFC (Bloom Energy) cells have been installed in numerous locations, with some being in operation for more than 2 years. Heat output is negligible. Kennedy/Jenks had conversations with two of Bloom Energy's current customers who have been using the Bloom cells for more than 2 years, and they indicated that there have been no interruptions in power output aside from scheduled maintenance. They stated that even though the Bloom cells are a relatively new immature technology, the systems have run well.

Reliability and Operational Complexity

While fuel cell technology is relatively new and has had a poor performance record in the past, the technology seems to have recently matured sufficiently to provide reliable power to businesses and municipal agencies. Vendors have overcome poor performance by only leasing and not selling fuel cells. Vendors also include an accompanying Operation and Maintenance (O&M) contract as part of the lease. This enables the vendors to have complete control over the fuel cell and sell the power output to the host agency/business through a Power Purchase Agreement (PPA).

The service agreement provided by FCE provides all O&M requirements for these systems. With this arrangement very little staff time would be required. This would also be true under the Energy Service Agreement (ESA) with UTC Power, or the PPA with Bloom Energy.

Sustainability

A fuel cell project would continue to provide energy for the life of the project. The project would be sustained by normal routine maintenance and periodic replacements of the fuel cell stacks as necessary. Based on the fuel cell and PG&E emission factors, the projects do not appear likely to reduce GHGs unless they are fueled by biogas.

Local Considerations

Economy

The SOFC (Bloom) fuel cells are manufactured in California; the others are manufactured predominantly on the east coast (especially Connecticut). Purchasing an SOFC cell would bolster the California economy by supporting local (Silicon Valley) manufacturing. Vendors would use local contractors for installation, which would further benefit the California economy. If a fuel cell system were installed at a SCWD or SqCWD facility, the City or District could create a potentially very popular local educational experience. Education materials as bill stuffers, information on websites, sign boards or an electronic kiosk at the facility could be used. Tours of the facility to the public could also be made available.

Environmental Impacts

Air: Fuel cells emissions include water, CO_2, and a small amount of other gases. With respect to impacts on air quality, fuel cells produce fewer emissions than other fossil fuel generation options. Because air emissions from fuel cells are very low, they are currently exempt from many Clean Air Act permitting requirements.

Land: The standard configuration for the MCFC 1.4 MW fuel cell (FCE) requires an area of approximately 2,500 square feet, plus a small amount of additional space for maintenance access. A 1.4 MW SOFC (Bloom) system requires an area of approximately 5,700 square feet, and 1.4 MWs of PAFC fuel cells (UTC PureCell 400s) would require an area of approximately 4,200 square feet (including maintenance access). Both Bloom and UTC Power sell smaller increments of fuel cells (100 KW for Bloom and 400 KW for UTC Power) and they would take up proportionately less space.

Water: The 1.4 MW MCFC fuel cell (FCE) requires approximately 5,800 gallons per day during full power operation. A significant portion of the water evaporates, and the remaining water is discharged at approximately 2,900 gallons per day. Typically the water can be discharged directly to the sanitary sewer. The SOFC (Bloom) fuel cells require minimal water use only at start-up (approximately 120 gallons).

Noise: Fuel cells are relatively quiet. At the distance of three feet, noise emissions from a MCFC fuel cell (FCE) are expected to be just above the level of sound of a normal human conversation. Noise from the SOFC fuel cell (Bloom) is expected to be less than 70dBA at 6 feet. Noise from the PAFC (UTC Power) fuel cell is expected to be less than 65 dBA at 33 feet (without heat recovery), and less than 60 dBA at 33 feet (with heat recovery).

Aesthetic/Visual: Visual impacts from installation of a fuel cell depend on the location of the project, but in general they would have a low aesthetic/visual impact. If the fuel cell were located within the existing footprint of a water treatment plant, or the **scwd^2** desalination plant; there would be no tall emissions stacks or visible emissions and the aesthetic/visual impacts would be very low.

Waste By-Products: The waste by-products produced by fuel cells are discharge water (depending on the fuel cell chosen) and the fuel cells stacks. The fuel cell stacks need to be replaced every 3 to 5 years and are 100 percent recyclable.

Energy Production and GHG Reductions

Potential Local Natural Gas Fuel Cell Projects

SCWD and SqCWD could choose to offset some or all of energy related to the **scwd^2** desalination plant using natural gas fuel cells at the desalination facility or at other SCWD or SqCWD facilities. The proposed desalination plant, running at half capacity, would require a fuel cell system with an instantaneous generation capacity of approximately 0.8 MW and would use approximately 6,800 MWh per year. At full capacity, the proposed desalination plant would require a fuel cell system with an instantaneous generation capacity of approximately 1.6 MW and would use approximately 13,600 MWh per year.

As a first level of analysis, this project assessment evaluated a potential fuel cell system that would be located at the desalination facility to offset up to the full capacity of the facility. When the desalination plant is running at a lower capacity, the energy from the fuel cell system could be used to offset other SCWD or SqCWD energy demand through a virtual net metering approach.

Table 3 below summarizes the energy that could be produced and the associated GHG emissions difference between the natural gas fuel cells and PG&E grid electricity. While all the natural gas fuel cell systems could produce sufficient energy to meet the majority of the desalination facility power requirements, these systems would create more GHG emissions than PG&E grid electricity. Table 3 shows an increase in GHG emissions as a negative GHG reduction.

Like the proposed larger systems, smaller fuel cell systems running with natural gas at other SCWD or SqCWD facilities would also create GHG emissions as compared to PG&E grid electricity.

Table 3: Estimated Fuel Cell Energy Production and GHG Emissions

Fuel Cell Type	Total MW	Annual KWh Produced	GHG Emissions Factor (Lbs CO_2/MWh)	Average Annual Metric Tons of CO_2		Lifetime Metric Tons of CO_2 Reduced
				Net Reduction	Net Increase	
PG&E Grid Electricity	--	--	641	--	--	--
SOFC (Bloom)	1.4 MW	11,650,800	773		696	N/A
MCFC w/o heat recovery (FCE)	1.4 MW	11,650,800	980		1,790	N/A
MCFC w/ heat recovery (FCE) (high emissions)	1.4 MW	11,650,800	680		204	N/A
MCFC w/ heat recovery (FCE) (low emissions)	1.4 MW	11,650,800	520	640		12,800
PAFC (UTC)	1.4 MW	11,650,800	1,100		2,415	N/A

Potential Local Biogas Fuel Cell Projects

Local Santa Cruz area sources of biogas sources include landfill methane from the Santa Cruz Municipal Landfill and methane from the digesters at the Santa Cruz WWTP. The Santa Cruz Municipal Landfill currently uses combustion generators to produce energy from landfill biogas and has a long-term contract to supply the renewable energy to another agency.

The Santa Cruz WWTP currently uses combustion generators to produce energy from digester biogas to offset energy at the facility. Improvements to enhance the energy production from the biogas at the Santa Cruz WWTP are discussed in the Food Waste to Energy project assessment.

Therefore, since local biogas is currently not available, fuel cell projects using local biogas do not appear to be feasible for GHG reduction.

Cost

There are substantial incentives available for fuel cells through the California's Self Generation Incentive Program (SGIP) and from federal tax incentives. Because SCWD and SqCWD are tax exempt entities and cannot take advantage of the federal tax incentives; it makes purchasing fuel cells uneconomic (if they were available for sale). This is partially why the fuel cell manufacturers, or third party installers, will install fuel cell systems under a lease option. Under a lease arrangement, the manufacturer or third-party installer can take advantage of the available tax credits, and roll these into the lease costs, resulting in lower costs than if a tax exempt customer were to purchase a fuel cell without the available tax credits.

Unfortunately, there is uncertainty related to future SGIP incentive payments. The program rules are currently being revised and the program only has appropriated funding through December 31, 2011. There is an on-going conversation at the legislature about if and how much of these incentives should be continued into 2012 and beyond. It is likely that the incentives for fuel cells will continue but at a lower amount, with an overall program cap on the total amount of incentives available, and potentially under different rules (i.e. – incentives based on GHG reductions rather than KWh generated). This means that the cost of fuel cells in the near future has the potential to go up from the estimates included herein.

Lease agreements typically include all the equipment necessary for operation – this is called a turn-key project. Typical project contracts include: the fuel cell stacks and reformer, fuel clean-up system, water treatment system (if necessary), heat recovery equipment, shipping, installation, commissioning, and on-going regular maintenance. Depending on the location, the lessee may need to make upgrades to their electrical system so that it can handle the electrical output of the fuel cell. For this assessment, it is assumed that the electrical system at the desalination facility is adequate for connection to the fuel cell system, and no additional cost for an electrical system upgrade is required.

The lease agreements also includes the cost of replacement stacks every 3-5 years and remote monitoring in order to provide full-time operating support. Under a lease agreement there are typically no up-front costs to the lessee. The SCWD or SqCWD would be responsible for paying the predetermined cost of electricity through the lease, and with the Bloom fuel cell the cost of fuel (natural gas). It is further assumed that the lease would be renewed after 10 years for a total project life of 20 years.

Cost information for a lease of a SOFC fuel cell (Bloom) and a MCFC fuel cell (FCE) are provided in Table 5. There is no capital cost since the systems are leased. The PAFC (UTC) fuel cell manufacturer did not supply costs for their lease agreement, thus, are not included. Since the fuel cells' GHG emission factors are higher than PG&E's emission factors, there are no GHG reductions and the lifecycle GHG reduction cost is not applicable.

The cost of electricity from the SOFC fuel cell from Bloom starts at $0.13/KWh and escalates at 4% per year. This includes the cost of the natural gas fuel and the lease costs for the fuel cell system. PG&E electricity purchases start at $0.15/KWh and escalates at about 2% per year. Since the energy and fuel costs for the Bloom fuel cell are lower than the PG&E energy costs, there is an average annual net savings and a negative lifecycle energy cost. Because there are no GHG reductions the lifecycle GHG reduction cost is not applicable.

The cost of electricity from the MCFC fuel cell from FCE would start at $0.15/KWh and escalates at 3% per year. This includes the cost of the natural gas fuel and the lease costs for the fuel cell system. PG&E electricity purchases start at $0.15/KWh and escalates at about 2%

per year. The additional cost for labor and the different between the estimated inflation and utility/fuel cost escalator rates cause the FCE fuel cell to be slightly more expensive than the energy savings each year, resulting in an average annual net cost. Because there are no GHG reductions the lifecycle CO_2 reduction cost is not applicable.

Table 5: Estimated Fuel Cell Costs

Fuel Cell Type	Life (yr)	Capital Cost ($)	Average Annual Net Cost ($/Yr)	Lifecycle Energy Cost ($/KWh)	Lifecycle GHG Reduction Cost ($/MT)
SOFC (Bloom)	20	$0 Lease	-$8,300	-$0.0024	N/A
MCFC (FCE) without heat recovery	20	$0 Lease	$157,000	$0.0131	N/A

Summary of Advantages and Disadvantages

Advantages:

- Large financial incentives available to lesser (but not available to the tax exempt City or District) make lease costs of electricity competitive with grid electricity from PG&E.
- More efficient power production than conventional IC engines.
- O&M is provided by manufacturer/installer through a renewable on-going contract that relieves the O&M burden and risk.

Disadvantages:

- In most circumstances by using natural gas, fuel cells emit more GHG emissions than purchasing electricity from PG&E.
- Emerging technology that still needs to prove its reliability and technical maturity.
- Cannot purchase, own and operate a fuel cell; only leases are available.

References

U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy. "Types of Fuel Cells." http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcells/fc_types.html Accessed August 2011.