

2.3

Fuel Cells

The ETV Program's Greenhouse Gas Technology (GHG) Center, operated by Southern Research Institute under a cooperative agreement with EPA, has verified the performance of two fuel cell technologies that generate electricity at the point of use. Fuel cells can reduce emissions of carbon dioxide (CO₂), methane, nitrogen oxides (NO_x), carbon monoxide (CO), and total hydrocarbons (THCs). CO₂ and methane are greenhouse gases linked to global climate change. CO, THCs, and the various compounds in the NO_x family, as well as derivatives formed when NO_x reacts in the environment, cause a wide variety of health and environmental impacts.

Available sales data indicate that a capacity of 15 megawatts (MW) of ETV-verified fuel cells have been installed in the United States since the verifications were completed. Based on the analysis in this case study, the estimated benefits of these existing installations include the following:

- ❖ Emissions reductions of 17,000 tons per year of CO₂ and 120 tons per year of NO_x, with associated climate change, environmental, and human health benefits. At least 29% of the fuel cells are installed in combined heat and power (CHP) applications, potentially providing emissions reductions in addition to those estimated here.

- ❖ Increased utilization of renewable fuels, such as anaerobic digester gas, resulting in reductions in the consumption of natural resources. Systems that utilize anaerobic digester gas represent 2 MW of the currently installed capacity and contribute 14,000 tons per year of the CO₂ reductions estimated above.
- ❖ Potential reductions in emissions of other greenhouse gases and pollutants, with additional environmental and human health benefits.

As the capacity of fuel cells installed increases, emission reductions and other benefits also will increase. In fact, based on the analysis in this case study and assuming annual sales continue at the same rate as in 2005, the ETV Program estimates the total installed capacity of ETV-verified fuel cells will reach 34 MW in the next five years,¹⁹ with the following benefits:

- ❖ Emissions reductions of 41,000 tons per year of CO₂ and 270 tons per year of NO_x, with associated climate change, environmental, and human health benefits. The percent of fuel cells installed in CHP applications would increase to at least 38%, resulting in even greater additional emissions reductions.
- ❖ Utilization of renewable fuels would increase, resulting in additional reductions in natural resource consumption. Systems that utilize anaerobic digester gas represent 5 MW of

¹⁹ This estimate includes the 15 MW that the ETV Program estimates have already been installed. It represents 134 fuel cells total.

the estimated future capacity and would contribute 36,000 tons per year of the CO₂ reductions estimated above.

- ❖ Increasing reductions in emissions of other greenhouse gases and pollutants, with additional environmental and human health benefits.

In addition, vendors and users estimate that fuel cell installations can result in cost savings for the user. Fuel cells also can provide reliable backup power to emergency services facilities and shelters in the event of a natural disaster or other event.

2.3.1 Environmental, Health, and Regulatory Background

EPA estimates that, in 2002, the United States emitted almost 6.4 billion tons of CO₂ and nearly 22 million tons of NO_x.²⁰ Electricity generation is the largest single source of CO₂ emissions, accounting for 39% of the total. Electricity generation also contributes significantly to NO_x emissions, accounting for 21% of the total (U.S. EPA, 2004e). A variety of other pollutants also are emitted during electricity generation, including CO and THCs. Each of these emissions can have significant environmental and health effects. Conventional electricity generation also consumes finite natural resources, with environmental and economic repercussions.

CO₂ is the primary greenhouse gas emitted by human activities in the United States. Its concentration in the atmosphere has increased 31% since pre-industrial times. As a greenhouse gas, CO₂ contributes to global climate change. The Intergovernmental Panel on Climate Change (IPCC) has concluded that global average surface temperature has risen 0.6 degrees centigrade in the 20th century, with the 1990s being the warmest decade on record. Sea level has risen 0.1 to 0.2 meters in the same time. Snow cover has decreased by about 10% and the extent and thickness of northern hemisphere sea ice has decreased significantly (IPCC, 2001a). Climate changes resulting from emissions of greenhouse gases, including CO₂ and methane, can have adverse outcomes including the following:

- ❖ More frequent or severe heat waves, storms, floods, and droughts
- ❖ Increased air pollution
- ❖ Increased geographic ranges and activity of disease-carrying animals, insects, and parasites
- ❖ Altered marine ecology
- ❖ Displacement of coastal populations
- ❖ Saltwater intrusion into coastal water supplies.

Each of these outcomes can result in increased deaths, injuries, and illnesses (U.S. EPA, 1997a). Many of these impacts, however, depend on whether rainfall increases or decreases, which cannot be reliably projected for specific areas. Scientists currently are unable to determine which parts of the United States will become wetter or drier, but there is likely to be an overall trend toward increased precipitation and evaporation, more intense rainstorms, and drier soils (U.S. EPA, 2000a).

The various compounds in the NO_x family (including nitrogen dioxide, nitric acid, nitrous oxide, nitrates, and nitric oxide) and derivatives formed when NO_x reacts in the environment cause a variety of health and environmental impacts. These impacts include the following:

- ❖ Contributing to the formation of ground-level ozone (or smog), which can trigger serious respiratory problems
- ❖ Reacting to form nitrate particles, acid aerosols, and nitrogen dioxide, which also cause respiratory problems
- ❖ Contributing to the formation of acid rain
- ❖ Contributing to nutrient overload that deteriorates water quality
- ❖ Contributing to atmospheric particles that cause respiratory and other health problems, as well as visibility impairment
- ❖ Reacting to form toxic chemicals
- ❖ Contributing to global warming (U.S. EPA, 1998; U.S. EPA, 2003j).

Each of the other pollutants emitted during electricity generation also can have significant environmental and/or health effects.

²⁰ Values converted from gigagrams as reported in U.S. EPA (2004e).

THCs and CO can contribute to ground-level ozone formation, and CO can be fatal at high concentrations (U.S. EPA, 2000b; U.S. EPA, 2005n).

As discussed in detail in Section 2.3.2, fuel cells can reduce emissions of greenhouse gases or pollutants because they use hydrogen, or another fuel converted to hydrogen, to generate electricity, reducing the need to burn fossil fuels. Fuel cells can be used in vehicles and at stationary locations. Stationary fuel cells that generate electricity at the point of use are categorized as distributed generation (DG) technologies. These technologies also can employ heat recovery systems that capture excess thermal energy and use it to heat water and/or spaces. Systems that include this option are commonly termed CHP systems. As discussed in detail in Sections 2.3.2 and 2.3.3, DG and CHP technologies not only have the potential to reduce emissions, but also to conserve finite natural resources and utilize resources that would otherwise be wasted (e.g., anaerobic digester gas and landfill gas). In recognition of these benefits, EPA has established programs such as the CHP Partnership to encourage the use of CHP technologies, including those that use fuel cells. The CHP Partnership is a voluntary EPA-industry effort designed to foster cost-effective CHP projects. The goal of the partnership is to reduce the environmental impact of energy generation and build a cooperative relationship among EPA, the CHP industry, state and local governments, and other stakeholders to expand the use of CHP (U.S. EPA, 2005k).

One market sector targeted by the CHP Partnership is wastewater treatment facilities. Wastewater treatment facilities generate biogas from anaerobic digesters. This digester gas can be used as fuel for a DG technology like a fuel cell, instead of released to the atmosphere or burned using a flare, with a number of benefits for the facility and the environment (see box at right). DG technologies also offer an important security and safety benefit for wastewater treatment facilities. To help maintain public health, these facilities must operate, or come back on-line quickly, in the event of a power loss, such as a catastrophic event or natural disaster. DG

technologies can continue to provide power to these and other critical facilities in the event of a utility failure caused by these emergencies (U.S. EPA, 2006g).

In a related effort, EPA and many states are developing and using output-based regulations for power generators. Output-based regulations establish emissions limits on the basis of units of emissions per unit of useful power output, rather than on the traditional basis of units of emissions per unit of fuel input. The traditional, input-based approach relies on the use of emissions control devices, whereas output-based regulations encourage energy efficiency. Currently a number of states, including Connecticut and Massachusetts, have developed output-based regulations that recognize the energy efficiency benefits of CHP projects. Regulated sources can use technologies like the ETV-verified fuel cells as part of their emissions control strategy to comply with these regulations. EPA also has developed resources, such as *Output-Based Regulations: A Handbook for Air Regulators* (U.S. EPA, 2004f), to assist in developing output-based regulations for power generators (U.S. EPA, 2005l).

States and localities also are undertaking efforts to promote the use of fuel cells. Based on data from Breakthrough Technologies Institute (2006), agencies in 43 states and the District of Columbia have undertaken activities supporting the use of stationary fuel cells.²¹ These activities include the following: demonstration projects, long-term plans, research support, regulations or

“CHP offers many benefits for wastewater treatment facilities because it:

- ❖ Produces power at a cost below retail electricity
- ❖ Displaces purchased fuels for thermal needs
- ❖ Qualifies as a renewable fuel for green power programs
- ❖ Enhances power reliability for the plant
- ❖ Offers an opportunity to reduce greenhouse gas and other air emissions.”

—EPA’s CHP Partnership Web site (U.S. EPA, 2006g)

21 Excludes states whose activities are limited to fuel cell vehicles or the production of hydrogen fuel.

standards, education partnerships, procurement standards, and business incentives (Breakthrough Technologies Institute, 2006).

2.3.2 Technology Description

Fuel cells use hydrogen as the fuel in an electrochemical process, similar to what occurs in a battery, that generates electricity (U.S. EPA, 2002b; U.S. DOE, 2006a, 2006b). Unlike a battery, however, fuel cells can operate indefinitely, as long as the supply of fuel is maintained (U.S. EPA, 2002b). Fuel cells consist of two electrodes, a cathode and an anode, separated by an electrolyte (U.S. EPA, 2002b; U.S. DOE, 2006a, 2006b). In the ETV-verified fuel cells, hydrogen-rich fuel reacts with the anode to produce positive ions and electrons. The positive ions pass through the electrolyte to the cathode, where they react to produce water and heat. The electrons must travel around the electrolyte in a circuit, generating an electric current (U.S. DOE, 2006a, 2006b). There are a number of different types of fuel cells, typically defined by the type of electrolyte used (U.S. EPA, 2002b; U.S. DOE, 2006b). The ETV-verified fuel cells include a polymer electrolyte membrane (PEM) fuel cell, in which a solid polymer membrane serves as the electrolyte, and a phosphoric acid fuel cell (PAFC), in which liquid phosphoric acid is the electrolyte (U.S. EPA, 2002b; Southern Research Institute, 1998, 2003c, 2004b).

Fuel cell technologies incorporate multiple stacks of paired electrodes. Many fuel cell technologies, including those verified by ETV, also incorporate a fuel processor or reformer. This system converts natural gas or another fuel, such as biogas, into a hydrogen-rich form for use by the fuel cell. Because only the fuel processing system involves combustion, fuel cells generate limited emissions (U.S. EPA, 2002b; U.S. DOE, 2006a). The primary byproducts of fuel cells are water and heat (U.S. DOE, 2006a, 2006b).

When used in stationary applications to generate electricity at the point of use, fuel cells reduce the need to generate electricity from sources such as large electric utility plants, which emit significant quantities of CO₂, NO_x, and CO. When coupled with heat recovery systems that

capture excess thermal energy to heat water and/or spaces, fuel cells also reduce the need to use conventional heating technologies such as boilers and furnaces. When well-matched to building or facility needs in a properly designed CHP application, fuel cells can increase operational efficiency and avoid power transmission losses, thereby reducing overall emissions and net fuel consumption.

Fuel cells also can be designed to operate using biogas from sources including animal waste, wastewater treatment plants, and landfills. Biogas is a renewable resource that otherwise goes unused because it is typically flared or vented to the atmosphere.

The first PEM and PAFC fuel cells were developed in the 1960s and 1970s, respectively (U.S. EPA, 2002b). Because they have seen limited commercialization, reliable performance data are needed on fuel cell technologies. The ETV Program responded by completing three verifications for two stationary fuel cell technologies (see Exhibit 2.3-1). One of these technologies is a small PEM fuel cell, sized for residential-scale use, that operated on natural gas in the ETV tests. The other is a larger PAFC technology, sized for commercial or institutional use. In the ETV tests, the latter technology operated on biogas from landfills and a wastewater treatment plant. Although none of the tests involved heat recovery in a CHP application, ETV did verify the potential for heat recovery in one of the tests, as discussed below.

During each test, the ETV Program verified power production and emissions performance. In one of the tests, ETV also verified potential heat production. In two of the tests (one for each technology), ETV verified power quality.

Power production tests measured electrical power output and electrical efficiency at selected loads. At full load under normal operations, electrical efficiencies ranged from 23.8% to 38.0%. In the test where potential heat production was verified, ETV measured heat production rate, potential thermal efficiency, and potential total system efficiency at selected loads. The potential thermal efficiency at full load and normal operation was 56.9%. ETV verified that, if the heat were recovered, potential total system efficiency would be 93.8%. In tests at less than full

ETV-VERIFIED FUEL CELL TECHNOLOGIES

EXHIBIT 2.3-1

Technology Name	Electricity Generating Capacity (kilowatts [kW])	Additional Information
Plug Power SUI Fuel Cell System	5	Tested at a private residence in Lewiston, New York. Included a fuel reformulation system to operate using natural gas. Excess power generated by the fuel cell, but not used by the residence, was directed to the electric utility grid.
UTC Fuel Cells PC25™ Fuel Cell (1)	200	In 1998, tested at municipal solid waste landfills in California and Connecticut. Included a gas processing unit to operate using landfill gas. The electricity produced was directed to a local grid system and sold to utility companies. In 2003, tested at a wastewater treatment facility in Brooklyn, New York. Included a gas processing unit to operate using anaerobic digester gas. Power produced by the fuel cell offset the need to purchase electricity from the facility's local utility.

(1) UTC Fuel Cells was known as International Fuel Cells Corporation in 1998, when the first verification was completed. The technology has since been renamed as the PureCell™ 200.

Sources: Southern Research Institute, 1998, 2003c, 2004b.

load, electrical efficiencies were lower, but thermal efficiencies were higher.

Power quality tests measured electrical frequency, voltage output, power factor, and voltage and current total harmonic distortion. Verified average voltage outputs were 121 volts (for the technology designed to produce 120 volts) and 488 volts (for the technology designed to produce 480 volts). Performance results for the other power quality parameters are available in the verification reports, which can be found at the links below.

Emissions tests measured emissions concentrations and rates at selected loads. Verified CO₂ emissions rates ranged from 1.31 to 1.66 pounds per kilowatt-hour (lbs/kWh). Verified NO_x emissions rates ranged from less than 6.97 x 10⁻⁷ to 0.013 lbs/kWh.²² The ETV Program also verified concentrations and emissions rates for other pollutants and greenhouse gases, including CO, THCs, and methane. Two of the verification reports, one for each of the technologies, also estimated total annual CO₂ and NO_x reductions. For the technology tested at a residence, these reductions were calculated compared to emissions generated by electricity obtained from the grid. For the technology operating on anaerobic digester gas, the basis of comparison also considered the emissions that were eliminated by using the gas in the fuel cell system, instead of

flaring it to the atmosphere. These estimates are presented in detail in Appendix B. More detailed performance data are available in the verification reports for each of the technologies (Southern Research Institute, 1998, 2003c, 2004b), which can be found at <http://www.epa.gov/etv/verifications/vcenter3-17.html> and <http://www.epa.gov/etv/verifications/vcenter3-14.html>.

2.3.3 Outcomes

The ETV Program used data from Fuel Cells 2000's Worldwide Stationary Fuel Cell Installation Database (Fuel Cells 2000, 2006) to estimate the number and capacity of ETV-verified fuel cells that have been installed in the United States since the verifications were completed. The ETV Program used these same data to estimate the number and capacity of ETV-verified fuel cells that could be installed in the near future. ETV extrapolated the number of fuel cells installed in year 2005 to each of the next five years and added this projection to the capacity currently installed.²³ Exhibit 2.3-2 shows the resulting estimates. Appendix B explains the derivation of these estimates in more detail. The ETV Program used these capacity estimates to estimate the emissions reduction outcomes shown below.

²² CO₂ and NO_x emissions results summarized here encompass those from two of the verification reports and cover both technologies. In the other report, emissions rates were reported on the basis of operating hours, rather than kWh, and, thus, are not in a comparable form.

EXHIBIT 2.3-2	PROJECTED NUMBER AND CAPACITY OF ETV-VERIFIED FUEL CELLS ESTIMATED TO BE INSTALLED		
	Total Installed	Number of Fuel Cells	Capacity (MW)
	Currently	130	15
After Five Years	220	34	
Values rounded to two significant figures			

Emissions Reduction Outcomes

Emissions reductions from the application of fuel cell technology depend on a number of factors, including the electricity demand of the specific installation, the fuel cell emissions rates, and the emissions rates of the electric utility power plant that the fuel cell replaces. These factors vary geographically and by specific application. Given this variation, characterizing these factors for every potential ETV-verified fuel cell application is difficult. Therefore, ETV used estimates developed by Southern Research Institute for the test sites to extrapolate emissions reductions estimates for current and future installations. Appendix B describes the Southern Research Institute estimates and the method for using these estimates to project nationwide emissions reductions for the fuel cell capacities shown in Exhibit 2.3-2.

Exhibit 2.3-3 shows estimates of annual CO₂ and NO_x reductions generated using this method for the fuel cell capacity currently installed and the projected capacity after five years. In addition to the CO₂ and NO_x reductions shown in Exhibit

EXHIBIT 2.3-3	ESTIMATED EMISSIONS REDUCTIONS FOR ETV-VERIFIED FUEL CELLS ²⁴		
	Total Capacity Installed	Annual Reduction (tons per year)	
		CO ₂	NO _x
Currently	17,000	120	
After Five Years	41,000	270	
Values rounded to two significant figures			

2.3-3, the ETV-verified fuel cells also have the potential to reduce other emissions, such as CO and THCs. As discussed in Section 2.3.1, the environmental and health effects of CO₂, NO_x, and other greenhouse gases and pollutants are significant. Therefore, the benefits of reducing these emissions also should be significant.

Also, ETV-verified fuel cells can be and have been used in CHP installations. Based on data from the Fuel Cells 2000 database, at least 39 of the 134 fuel cells currently installed, or 29%, incorporate heat recovery for purposes including space heating and cooling and hot water. Projecting year 2005 CHP installations to each of the next five years results in a total of 85 of 224 fuel cells, or 38%, that incorporate heat recovery. These installations can further reduce emissions by replacing a conventional heat source, such as a hot water heater, boiler, or furnace. These conventional sources can emit significant quantities of CO₂, NO_x, and CO. Because the test sites did not incorporate heat recovery, the estimates in Exhibit 2.3-3 do not include these additional emissions reductions.

Resource Conservation Outcomes

In two of the verification tests, the fuel cells were powered by biogas—landfill gas in one test and anaerobic digester gas in the other. These waste fuels represent a renewable resource and using them results in the conservation of finite natural resources in the form of conventional fuels such as natural gas, oil, and coal. Currently, 10 of the 134 ETV-verified fuel cells operate on anaerobic digester gas, providing a generating capacity of 2 MW. After five years, ETV estimates these numbers would increase to 25 fuel cells with a capacity of 5 MW. These installations represent a significant use of a renewable resource. In addition, they account for most of the CO₂ emissions reductions estimated above: 14,000 tons per year currently and 36,000 tons per year after five years.²⁵

²³ As discussed in Appendix B, based on information from the vendor Web sites, ETV included fuel cells from the two vendors in its count even if the technology name was not specified or not identical to that used in the verification reports. The projection, however, does not include future installations of one of the technologies. The current and 2005 estimates also exclude short-term demonstration projects. Therefore, both the current estimate and future projection are likely to be conservative.

²⁴ Reductions vary based on the source for grid power or thermal supply (hydroelectric, coal, etc.). Reductions here account for CO₂ emissions from the fuel reformer or gas processing units associated with the fuel cells.

²⁵ As discussed in Southern Research Institute (2004b), a small portion of these CO₂ reductions are offset by increased emissions of methane, another greenhouse gas. The methane increase amounts to less than 1% of the CO₂ reduction in terms of greenhouse gas potential, or carbon equivalents.

Economic and Financial Outcomes

Section 2.3.2 reports the verified efficiencies of the ETV-tested fuel cell technologies. In general, these efficiencies compare favorably with those of separate heat and grid power applications, particularly when coupled with heat recovery in CHP applications. In addition, because they generate and use electricity onsite, fuel cells avoid losses associated with the transmission of electricity, which can be in the range of 4.7% to 7.8% (Southern Research Institute, 2001a, 2001b, 2003a, 2004b). In addition to the efficiency increases, systems that operate on biogas can result in cost savings for the user by using a “free” waste fuel rather than an expensive conventional fuel. While cost savings can vary depending on the configuration of the individual installation and the cost of electricity and fuels, these savings can be significant (see box at right).

Technology Acceptance and Use Outcomes

The large number of ETV-verified fuel cells currently installed (see Exhibit 2.3-2) provides evidence that the technology is becoming accepted. In addition to the emissions reduction and resource conservation benefits discussed above, another benefit that has contributed to this acceptance is the technologies’ ability to provide reliable backup power in case of a natural disaster or other emergency. This benefit is particularly important for critical emergency services facilities and facilities that serve as emergency shelters. Examples of facilities that have benefited from ETV-verified fuel cells in this manner include the following:

EXAMPLES OF COST SAVINGS FROM ETV-VERIFIED FUEL CELLS

At two colleges in New Jersey:

- ❖ “Officials anticipate the plant will cut energy costs by over \$81,000 annually, recovering the college’s investment within four years.”
- ❖ “Combined heat and power operating cost savings are estimated to be \$259,000 per year.”

At a hospital in Rhode Island:

- ❖ “Produces one-third of hospital’s electricity during peak hours, saving \$60,000–\$90,000/year.”

—Fuel Cells 2000 database (Fuel Cells 2000, 2006)

- ❖ A high school in New York, where the fuel cell “will allow the high school to become an emergency shelter during community disasters” (Fuel Cells 2000, 2006)
- ❖ A high school in Connecticut that serves as a regional emergency shelter (Fuel Cells 2000, 2006; UTC Power, 2006a)
- ❖ A government office building in New York, where the fuel cell powers the state’s regional emergency management office (Fuel Cells 2000, 2006)
- ❖ A police station in New York City’s Central Park, a facility routinely affected by power shortages prior to installation, where the fuel cell provided uninterrupted power during the blackout of 2003 (UTC Power, 2006b).

ACRONYMS USED IN THIS CASE STUDY:

CHP	combined heat and power	kW	kilowatts
CO	carbon monoxide	lbs/kWh	pounds per kilowatt-hour
CO ₂	carbon dioxide	MW	megawatts
DG	distributed generatio	NO _x	nitrogen oxides
GHG Center	ETV’s Greenhouse Gas Technology Center	PAFC	phosphoric acid fuel cell
IEEE	Institute of Electrical and Electronics Engineers	PEM	polymer electrolyte membrane fuel cell
IPCC	Intergovernmental Panel on Climate Change	THCs	total hydrocarbons

Appendix B. Methods for Fuel Cell Outcomes

Number and Capacity of ETV-Verified Fuel Cells

The ETV Program used data from Fuel Cells 2000's Worldwide Stationary Fuel Cell Installation Database (Fuel Cells 2000, 2006) to estimate the number and capacity of ETV-verified fuel cells that have been installed in the United States since the verifications were completed. Specifically, to estimate current installations, ETV searched the database for all U.S. projects involving PAFC fuel cells installed by UTC Power and PEM fuel cells installed by PlugPower and examined the details of each project found. In determining whether to count a given project, ETV included PureCell™ and PureComfort™ systems from UTC Power and GenSys systems from PlugPower. Although these technology names are not the same as those in the verification reports (PC25 and SU1), information from the vendor Web sites indicates that these are likely new brand names for the same technology.⁶² ETV also included projects where the technology name was not specified, if the fuel cells were of the same capacity as those verified. ETV excluded from its count the following types of projects:

- ❖ Projects installed before the verifications were completed (1998 for UTC Power and 2003 for PlugPower)
- ❖ Projects that provide backup or emergency power only

- ❖ Projects that have been decommissioned or are no longer operating
- ❖ Short-term demonstration projects.

Using these guidelines, ETV estimated 134 verified fuel cells, with a total of approximately 15 MW of capacity, have been installed in the United States since verifications were completed and are currently operating. This estimate is conservative (low) in terms of number and capacity because it excludes projects that provide backup or emergency power only. These projects, however, likely operate only intermittently and would not contribute significantly to annual pollutant reductions. The estimate also is conservative because it excludes short-term demonstration projects. Some of these demonstration fuel cells might have remained in place and continued operating after the demonstration was complete, continuing to contribute to pollutant reductions.

To project future installations, the ETV Program examined projects that were installed in 2005. In making the projection, however, ETV did not include future installations of the PlugPower technology. Information from the vendor Web site and media sources (see, for example, Engle, 2005) suggest the company is now targeting the backup power market using hydrogen fuel directly, without a fuel reformer. Although verification results might contribute to future sales of the technology in backup power applications, the resulting installations would not contribute significantly to pollutant reductions.

⁶² The technology vendors were provided an opportunity to review this case study and did not comment on this assumption.

Excluding 2005 PlugPower sales, 18 fuel cells, with a total capacity of 3.8 MW, were installed in 2005. The ETV Program used this estimate of fuel cells installed in 2005 to project future installations over the next five years as follows:

$$18 \text{ fuel cells} \times 5 \text{ years} = 90 \text{ fuel cells}$$

$$3.8 \text{ MW} \times 5 \text{ years} = 19 \text{ MW}$$

Adding these values to 134 fuel cells currently installed, with 15 MW capacity, results in a future projection of 224 fuel cells with 34 MW capacity. This projection is conservative (low) because it excludes future PlugPower sales and assumes no growth in sales from 2005 levels.

Emissions Reductions

In developing the current estimate and future projection, the ETV Program maintained separate estimates in three categories, for use in estimating emissions reductions:

- 1) Small, residential-scale fuel cells operating on conventional fuels
- 2) Larger, commercial/institutional-scale fuel cells operating on conventional fuels
- 3) Larger, commercial/institutional-scale fuel cells operating on anaerobic digester gas

Emissions reductions from fuel cell applications vary on a site-by-site basis. Because of this variation, producing a precise nationwide estimate is difficult. To produce a rough estimate, the ETV Program assumed that applications that fell within the same fuel cell category produced identical emissions reductions. For categories

1 and 3, the ETV Program used the reduction estimates developed by Southern Research Institute in the verification reports to estimate the emission reductions from installations within those categories. For category 2, ETV modified the reduction estimate for one of the test sites to subtract the credit for eliminating emissions from the digester gas flare. Exhibit B-1 summarizes the category-specific reduction estimates. The verification reports (Southern Research Institute, 1998, 2003c, 2004b) describe the test sites and the baseline assumptions (e.g., displaced conventional power source) used to generate the reduction estimates in more detail. The reduction estimates account for CO₂ emissions from the fuel reformer or gas processing units associated with the fuel cells.

To calculate national emissions reductions for each category, the ETV Program used the following equation:

$$R_{TOTAL} = (C_{TOTAL} / C) \times R / 2000$$

Where:

- ❖ R_{TOTAL} is total CO₂ or NO_x reduction for a given category in tons per year.
- ❖ C_{TOTAL} is the total capacity in MW of ETV-verified fuel cells installed and varies for each category and for current and future installations.
- ❖ C is the individual fuel cell capacity in MW for the given category.
- ❖ R is the model site CO₂ or NO_x reduction in pounds per year and varies for each category.

ETV then summed the results for each category to estimate total national emissions reductions.

ASSUMED EMISSIONS REDUCTIONS PER FUEL CELL					
EXHIBIT B-1	Category and Facility Type	Fuel Cell Capacity (kW)	CO ₂ Reduction (pounds per year)	NO _x Reduction (pounds per year)	Source
	1) Small, residential-scale fuel cells operating on conventional fuels	5	723	44.3	Southern Research Institute, 2003c, Table 2-8
	2) Larger, commercial/institutional-scale fuel cells operating on conventional fuels	200	74,000	3,080	Southern Research Institute, 2004b, Table 2-6, subtracting credit for eliminating flare emissions
	3) Larger, commercial/institutional-scale fuel cells operating on anaerobic digester gas	200	2,850,000	3,640	Southern Research Institute, 2004b, Table 2-6
	Values rounded to three significant figures				