The Green Edge of Fuel Cells

October 2014

Doosan Fuel Cell
The Clean Energy You Count On

WP002

Going Green with Fuel Cells

Going green is good for the environment. You believe it, but you wonder whether you can do the right thing, and also improve the bottom line?

Where there are fuel cells, the answer is YES.

Fuel cells are environmentally and economically advantageous. They provide an immediate path to lower greenhouse gas (GHG) and air pollution emissions through increased energy efficiency, and this, in turn, leads to unique and substantial benefits for our planet, our personal health and our economy.

As business and industry strive to improve their environmental footprint, many are finding that cleaner, more efficient and more reliable power generation technologies, like fuel cells, are an important component of their energy portfolio. And why not, when many are also finding that such corporate sustainability efforts not only save energy, but deliver both higher productivity and greater profits.

Two studies confirmed that sustainability can be good for the bottom line. Research firm Verdantix, in a 2012 survey, found that many CFOs view sustainability as a key driver of financial performance.[1] This result matched the findings of a 2011 study on sustainability and innovation by the Massachusetts Institute of Technology.[2]

PureCell® Fuel Cell Systems are a Complete Green Energy Solution, Providing Continuous Baseload Power and Critical Power. They:

- Produce near-zero, ultralow air emissions, because electricity is generated in an electrochemical process without combustion
- Significantly cut GHG carbon emissions, because they are highly efficient and, therefore, consume less fuel
- Deliver reliable, high-quality power with widely available natural gas, the cleanest burning of all fossil fuels
- Save millions of gallons of water, because they operate in water balance, with no consumption or discharge of water in normal operations
- Operate quietly and have a small land footprint, with no negative environmental impacts
- Qualify for LEED® (Leadership in Energy and Environmental Design) points

PureCell® fuel cells operate steadily, 24 hours per day, 7 days per week. They work around the clock, unaffected by weather or time of day, and thus are a strong fit for customers seeking clean, reliable energy to meet their baseload power requirements. PureCell® fuel cell systems operate either independent of, or in parallel with, the electric grid. They are also ideally suited to clean energy microgrids, working in partnership with solar and wind renewables, to provide 100% grid independent capability.

1 What 250 CEOs Really Think About Sustainability, Verdantix, November 2012.

2 Knut Haanaes, Martin Reeves, Ingrid von Streng Velken, Michael Audretsch, David Kiron and Nina Kruschwitz. 2011 Sustainability & Innovation Global Executive Study and Research Project, MIT Sloan Management Review, 23 Jan. 2012, http://sloanreview.mit.edu/feature/sustainability-strategy

Why Should We Care About Air Pollution?

The simplest and shortest answer is that air pollution is dangerous and toxic to human health and our environment. Many of us are sick from it. Some of us are dying from it.

Big cities in America and around the world—Los Angeles, Mexico City, Beijing, Seoul, Cairo, to name a few—are well known for their pollution and unhealthy air. But it's not just a big city thing anymore. Pollution blows across state lines, indeed, across oceans, into cities and towns hundreds and thousands of miles away.

The American Lung Association (State of the Air 2013) identifies numerous cities across America as polluted for ozone and particulate pollution. These cities are in 50% or more of our states. In fact, over 131.8 million people—42% of the nation—live where pollution levels are too often dangerous to breathe. Numerous studies link ozone and particulate pollution to debilitating human health conditions, including respiratory illnesses, asthma, heart disease and cancer.

Even though air quality has improved in California in recent years, smog and soot levels remain above federal health standards for one-third of the state's population, according to the California Air Resources Board (January 2014). "It's visible and it's affecting our daily lives," said Dolores Weller, interim director of the Central Valley Air Quality Coalition. "Children are being kept indoors for days on end, and sporting activities are being cancelled. If there's been an improvement in the last 10 years, we're not seeing it here."

Climate change, particularly global warming, is another significant effect of air pollution, and bringing with it more frequent wildfires, longer periods of drought in some regions, and an increase in the number, duration and intensity of tropical storms. Global warming skeptics are dwindling, as all of us, either personally or through family and friends, are experiencing the devastation wrought by 21st century weather patterns here and around the world.

Power generation, particularly via coal- and petroleum-fired power plants, remains among the largest contributors to particulate pollution, ozone, mercury, and climate change. Progress within the electricity generation industry is being made, though, thanks to tough, new Clean Air Act pollution standards, in conjunction with strict state regulations, and a growing awareness by business, industry, and the public of the importance of air quality to human health and our environment.

So much more needs to be done. Doosan FC well understands this, and is committed to basing its products on the cleanest, most efficient technology available today. We urge you to join with us and do your part. Reduce. Reuse. Recycle. Be more informed. Here are two excellent websites:

http://www.stateoftheair.org/2013/health-risks/infographic/
http://www2.epa.gov/learn-issues

PureCell® Fuel Cell Systems: Why They Have the Green Edge

Combined heat and power (CHP) fuel cell systems, like the PureCell® fuel cell systems, convert waste heat into useable energy, supplying baseload electric power, as well as heating and cooling, under normal and emergency operating conditions. The end result is reliable, efficiently produced energy—energy that also is 1) cleaner than any conventional power system today, and 2) continuous, without any of the intermittency issues associated with wind and solar systems.

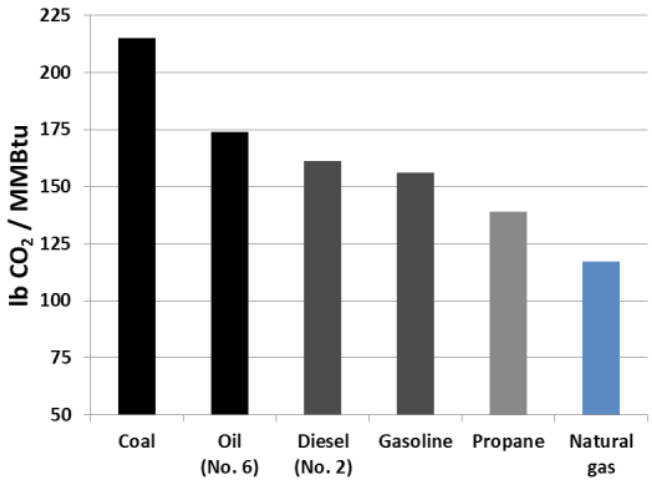

Figure 1. Natural gas has the lowest carbon intensity of all fossil fuels

According to the U.S. Department of Energy (DOE), CHP fuel cell systems can reduce GHG emissions by 60% and virtually eliminate criteria air pollutants.[3] A report by McKinsey reinforces CHP's substantial green benefit, suggesting that a 50-GW expansion of cogeneration capacity in the U.S. by 2020 would save 100 million metric tons per year of carbon dioxide (CO2) emissions.[4]

PureCell® fuel cell systems operate on natural gas, the cleanest burning of all fossil fuels. The GHG emissions associated with different sources of electricity vary significantly, depending on the carbon content of the fuel being used. Petroleum and coal are critical to the reliability of the U.S. electric grid, especially in certain geographic areas, but they emit significantly more CO2 emissions than natural gas, as can be seen in Figure 1.

PureCell® Model 400 generates 400 kW of continuous baseload power and over 1.5 MMBtu/h of thermal energy for combined space heating, hot water, and cooling applications. Typical Model 400 market sectors include large facilities (e.g., hospitals, data centers, mixed-use office/residential), institutions (e.g., pharmaceutical, educational, correctional and retail buildings) and industrial plants (e.g., bottling, food processing).

CHP Efficiency.

The PureCell® Model 400 can achieve up to 90% system efficiency when all of the byproduct heat is utilized, a factor that both reduces fuel use for the same amount of electricity generated, and significantly lowers CO2 emissions. By contrast, more than half of the energy potential in centralized power generation goes up the stack as exhaust heat. Data from the U.S. Environmental Protection Agency (EPA) show a conventional power plant delivered efficiency of 33% based on eGrid 2012 (2009 data).[5]

3 Fuel Cell Technologies Record #11006. Fuel Cells for Combined Heat & Power - CO2 and NOx Emissions. U.S. Department of Energy, July 2011.
4 Unlocking Energy Efficiency in the U.S. Economy, McKinsey & Company, July 2009 (from a fact sheet produced by FC&HEA).
5 eGrid 2012; available at www.epa.gov/cleanenergy/energy-resources/egrid/index/html

Figure 2 compares PureCell® Model 400 fuel cell system CO2 emissions to fossil-fueled utility generation in various regions of the country. In electric-only mode, with 0% of the fuel cell's heat utilized, 1050 lb/MWh of CO2 emissions are emitted; with 100% of the heat utilized, CO2 emissions are reduced to less than 500 lb/MWh, a savings of over 50%. Utility grid generation, by comparison, is responsible for 1100 lb/MWh in California to over 2000 lb/MWh in the mid-western states (not shown). The PureCell® Model 400 can be compared to fossil fuel-based utility generation because the installation of the fuel cell will not have an effect on low-carbon utility generation such as nuclear and hydro-electric power plants. This method is in compliance with the guidelines of the U.S. EPA CHP Partnership (see sidebar).

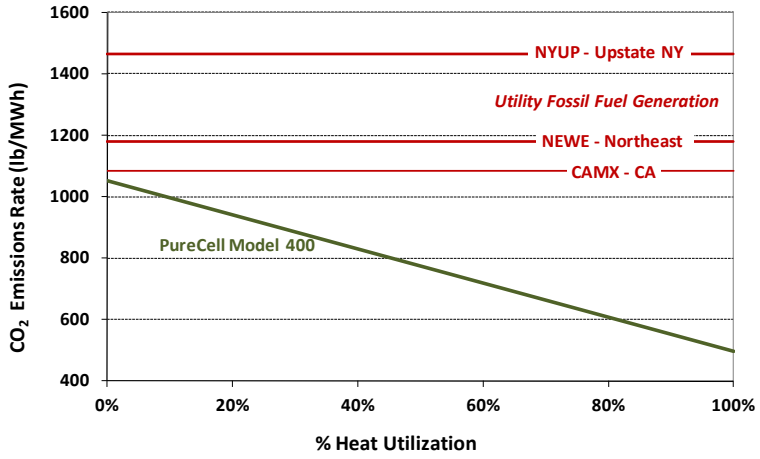

Figure 2. PureCell® Fuel Cell Systems Generate Fewer CO2 Emissions than Utility Generation

Carbon Savings

CO2 emissions by far are the largest source of GHG emissions in the United States today.[6] Of all carbon emissions, fossil fuel combustion accounted for 94% in 2012, with electricity generation as the primary contributor of the combustion.[7] This trend is nothing new. Since the Industrial Revolution, global atmospheric concentrations of CO2 have risen ~ 40%, principally due to the combustion of fossil fuels.[8]

6 DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2012. U.S. Environmental Protection Agency, February 2014.
7 Ibid.
8 (IPCC 2007 and NOAA/ESLR 2013)

Calculating the Effect of Fuel Cell CHP on GHG Footprint

This can be confusing to some (and even challenged by others) given the fact that natural gas-fueled power systems generate CO2 in the process of converting natural gas to electricity. So if a fuel cell emits CO2, how can it save CO2? The simple answer is that CO2 emissions released by the fuel cell are less than what would have been released by a traditional system (i.e., utility power plant for electricity, plus an on-site gas-fired boiler for heat), resulting in a net reduction in CO2 for the facility.

Doosan FC calculates CHP fuel and CO2 emissions savings using the methodology recommended by the U.S. EPA CHP Partnership, in conjunction with its Emissions & Generation Resource Integrated Database (eGRID), a comprehensive data source on the environmental characteristics of electric power generation in the United States. Displaced grid electricity is calculated based on the heat rates and emissions factors of the eGRID subregion where the PureCell® fuel cell system is located. For more detail, refer to the sources below.

Fuel and Carbon Dioxide Emissions Savings Calculation Methodology for Combined Heat and Power Systems, U.S. Environmental Protection Agency, Combined Heat and Power Partnership, August 2012.

Human activities are largely to blame. Fossil fuel-fired power plants are responsible for 67% of the nation's sulfur dioxide (SO2) emissions, 23% of nitrogen oxide (NOx) emissions, and 40% of man-made CO2 emissions.[9]

These emissions can lead to smog, acid rain, and haze, all of which increase the risk of climate change and serious, debilitating health conditions.

Natural gas-powered fuel cells generate fewer carbon emissions than fossil-fueled central utility generation, as is shown in Figure 3, because they make electricity more efficiently. With CHP fuel cell systems, like the PureCell® fuel cell Model 400 systems, environmental benefits are compounded because electric power and thermal energy (for heat/cooling) are generated in one energy efficient step.

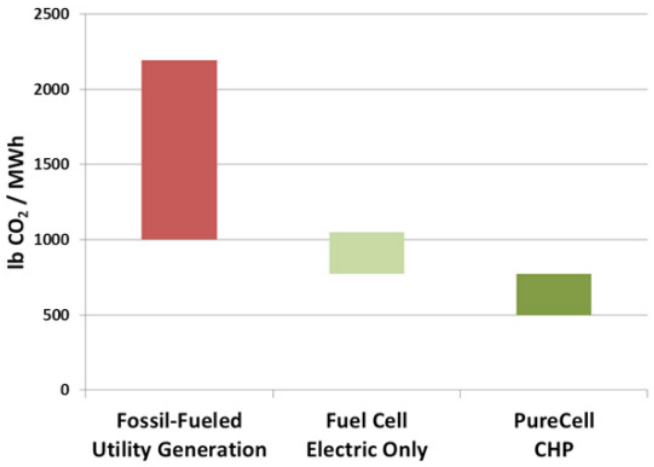

Figure 3. PureCell® Fuel Cell Systems Generate Fewer Carbon Emissions

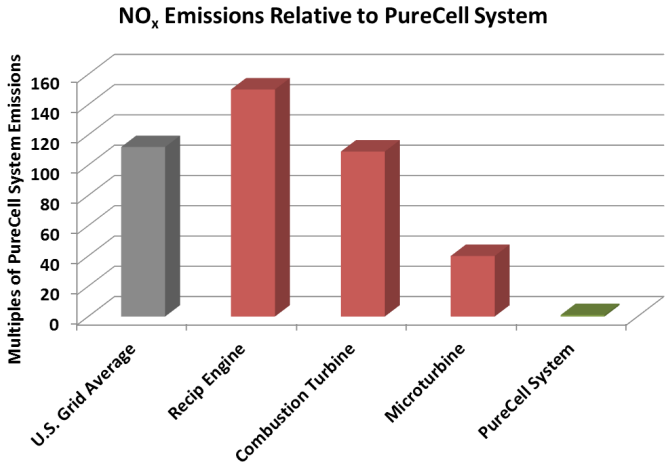

Figure 4. PureCell® Fuel Cell Systems Have the Lowest Air Emissions of Any Continuous-Duty Power Generation Option

Air Emissions Savings

In a fuel cell, the conversion of fuel to energy takes place via an electrochemical process, rather than by combustion; the process is highly efficient and results in near zero, ultra-low emissions. In fact, fuel cells produce the lowest air emissions of any available fuel-based power generation technology, with emissions levels of all common air pollutants (NOx, SO2, carbon monoxide (CO), volatile organic compounds (VOCs), particulate matter (PM)), significantly below utility-generated power and reciprocating engines.

Figure 4 graphs NOx emissions on a relative scale, demonstrating that the PureCell® fuel cell systems achieve several orders of magnitude lower emissions than the grid and competitive technologies. (Note: these calculations do not account for additional savings that would accrue from CHP systems, such as PureCell® fuel cell systems.)

9 http://www.epa.gov/cleanenergy/energy-and-you/affect/air-emissions.html

Just how environmentally friendly are PureCell® Fuel Cell Systems?

One way to answer that question is to compare the PureCell® systems' air emissions levels to air quality standards in California, the strictest in the nation. In the table below, note that the PureCell® fuel cell system emissions fall well below the California Air Resources Board (CARB) 2007 limits for distributed generation. Moreover, in Los Angeles, fuels cells are considered so nonpolluting that the South Coast Air Quality Management District has ruled that they do not require clean air permits.

Pollutant	**PureCell Model 400 System** (lb/MWh)	**CARB 2007 Limit** (lb/MWh)
NO_x	0.01	0.07
CO	0.02	0.10
VOC	0.02	0.02
SO_x	Negligible	Not applicable
PM	Negligible	Not applicable

Water Savings

PureCell® fuel cell systems are designed to operate in water balance; there is no consumption or discharge of water in normal operations. As a result, millions of gallons of water are saved every year, compared to central power generation, for which substantial fresh water is required to cool the turbine generators. This is an extremely important green benefit, considering the exceptional and extreme drought in many parts of our country, most notably, California, Nevada, Arizona, New Mexico, Texas, Colorado, Nebraska and Kansas. Consider these facts:

- PureCell® fuel cell systems require less than 1 gal of water per MWh[10]
- U.S. utilities use over 450 gal of fresh water per MWh

PureCell® Fuel Cell Systems and Renewable Technologies

PureCell® fuel cell systems are an attractive alternative to (as well as an attractive partner with) solar, wind and other types of distributed generation renewable energy. That said, it is also important to say that direct comparison of fuel cells to these renewables, based solely on GHG and air emissions rates, can be deceiving. Solar and wind are marvelous clean energy sources, producing essentially zero emissions for every MW hour generated, but due to the variability / intermittency of the sun and the wind, their utilization rates can be low.

10 The system is filled with water during initial startup. Also, some water intake is required when the weather is very hot.

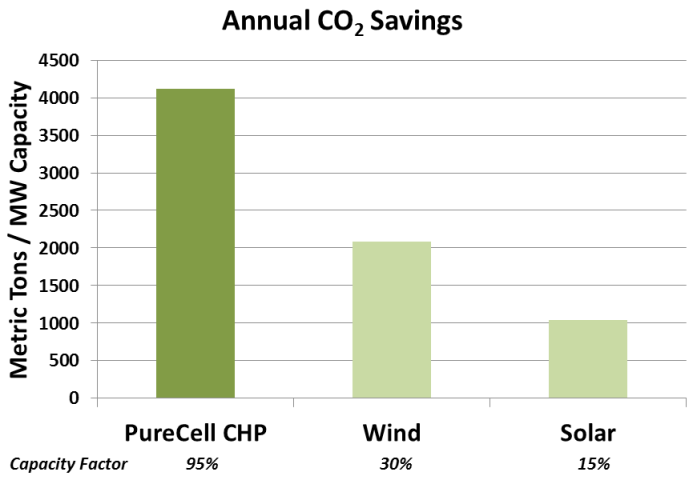

Figure 5. PureCell® Fuel cells can save more carbon than intermittent renewable generation

For example, a 1-MW installation of solar PV panels with an overall utilization of 15% will require the owner to purchase the balance of his/her energy requirements from the local utility. Thus, the PV panels alone only reduce emissions by 15%, whereas a 1MW installation of CHP fuel cells operating at 95% capacity will save four times more CO2 emissions. In short, though natural gas-powered fuel cells produce a small, but measurable, quantity of emissions, the net positive impact of fuel cells on emissions reduction is more significant than equivalent-sized installations of solar panels. Figure 5 illustrates this effect.

Land Friendly

Compared to solar photovoltaic (PV) and wind systems, PureCell® fuel cell systems have a much smaller footprint in terms of land use, and can be installed inside or outside and close to buildings, with no negative environmental impact. Figure 6 shows acres of land use required to generate one GWh of energy per year, enough energy to power around 90 average U.S. homes.[11]

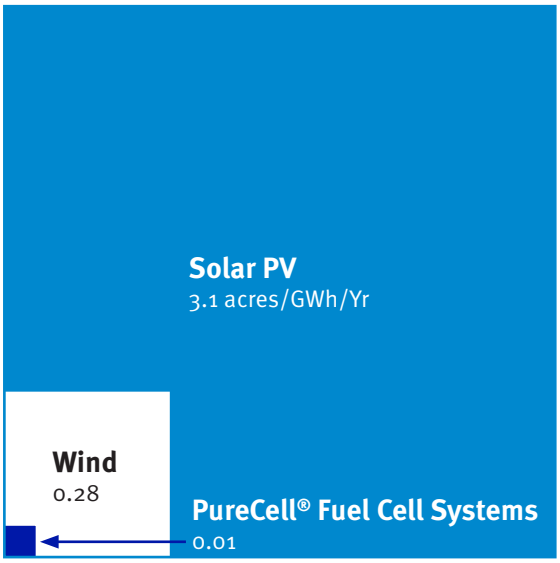

Figure 6. Land Use of PureCell® Model 400 System Compared to Solar PV and Wind Generation

Fuel Cells and Solar: A 'Perfect Marriage' for Clean Energy Microgrids

PureCell® fuel cell systems can work effectively with solar and wind installations to create a clean energy microgrid; i.e., an interconnected network of multiple electrical sources and multiple electrical loads that can operate either in parallel with the electric utility grid, or independent from the grid. In this way, the fuel cell systems can provide active balancing when the sun or wind is not available; i.e., they offer system owners the ability to offset the intermittency of solar and wind by actively controlling fuel cell output. For example, when a cloud rolls by, fuel cell output can be increased so that the grid is not impacted. This active balancing capability contrasts sharply with today's utility infrastructure, which was not designed to handle the intermittency requirements of renewables. Scaling conventional thermal power plants up and down on an hourly or daily basis presents both technical and economic challenges to the existing electric grid.[12]

11 www.nrel.gov/docs/fy13osti/56290.pdf ; www.nrel.gov/docs/fy09osti/45834.pdf ; www.eia.gov/tools/faqs/faq.cfm?id=97&t=3

12 "Integrating Renewable Electricity on the Grid," American Physical Society, November 2010. http://www.aps.org/policy/reports/popa-reports

University of Connecticut Microgrid Project

The University of Connecticut (UConn) at Storrs, in a continuing effort to reduce its carbon footprint and build a sustainable community, is partnering its existing 400-kW PureCell® fuel cell system with a demonstration-scale 6.6-kW photovoltaic solar panel array to create a grid-independent microgrid that will provide clean, reliable, uninterrupted power to a cluster of Depot Campus buildings during prolonged grid outages. Currently, the PureCell® fuel cell system delivers baseload power, as well as heating and cooling, to critical research labs and offices.

When the microgrid becomes operational in 2014, significant locations on campus will have heat and power, even during an extended power outage. This will allow UConn to provide critical services such as warming spaces for the public with kitchens, bathrooms, outlets for recharging electronic devices, and nearby charging stations for electric vehicles. The microgrid also will provide power for staging areas for emergency and storm recovery teams, and emergency command and response centers for police, fire, and other public safety professionals. Rich Miller, UConn's Director of Environmental Policy, said: "This will be a state-of-the-art, clean energy microgrid that will not only benefit our neighbors, but also help the University provide leadership and technical assistance to communities, schools, institutions, and businesses, as they adapt to and prepare for things like more frequent and severe storms."

University of Connecticut	Emissions Reduction*	Equivalent "Green" Benefit
CO_2 Emissions	831 MT †	Planting 192 acres of trees
NO_x Emissions	1.92 MT	Taking 110 cars off the road
Water Saved *	3.9 MG †	Saving enough water to fill ~6 Olympic pools

* Compared to central power generation. † MT = metric tons; MG = million gallons

Verizon Project

At nine Verizon sites in California, New Jersey and New York, 19 PureCell® Model 400 fuel cells are generating over 60 million kWh of electricity and saving approximately 6,000 metric tons of CO2 every year. The PureCell® fuel cell systems are part a massive fuel cell and solar energy project in 20 states that will enable Verizon to 1) generate more than 70 million kWh of its own clean energy—enough to power more than 6,000 single-family homes a year, and 2) eliminate more than 10,000 metric tons of CO2—enough to offset the annual carbon emissions from more than 1 million gallons of gasoline. This effort represents Verizon's latest move toward cutting its carbon intensity in half by 2020.

"This is a natural evolution of our sustainability efforts and of our use of alternative energy to power a variety of our facilities," said James Gowen, Verizon's Chief Sustainability Officer. "These projects will reduce our carbon footprint, relieve demand on the electrical grid, and enhance the resiliency of our proven service continuity -- even during outages."

Verizon PureCell® Installations (9)	Emissions Reduction *	Equivalent "Green" Benefit
CO_2 Emissions	5,376 MT †	Planting 1,240 acres of trees
NO_x Emissions	18 MT	Taking 1,062 cars off the road
Water Saved *	27 MG †	Saving enough water to fill 41 Olympic pools

* Compared to central power generation. † MT = metric tons; MG = million gal

There is no contradiction between a sound environment and strong economic growth; their [Verizon's] commitment to sustainability is evidence that good environmental strategy = good business strategy.

For the past three years, Verizon has been part of the Environmental Defense Fund's Climate Corps, a program that embeds specially trained graduate students in organizations as dedicated energy problem-solvers. EDF Climate Corps fellows have found $11 million in energy-saving opportunities at Verizon.

—Excerpted from a Verizon Corporate News Article, Verizon Invests Big in Clean Energy, by Guest Contributor Rory Christian, Director, New York Smart Power, Nov. 27, 2013

For more information on how your business can participate in EDF's Climate Corps, visit:

http://edfclimatecorps.org/

Conclusions

Doosan FC PureCell® fuel cell systems are a complete green energy solution, and represent an attractive and cost-effective alternative to renewable energy technologies like solar and wind. Our systems also make an ideal partnership with solar and wind, ensuring that clean energy microgrids will have 100% gridindependent capability around the clock.

PureCell® fuel cell systems are a high-efficiency power generation solution, and can be the basis for developing a cleaner, more reliable energy portfolio and improving corporate sustainability. Our systems operate with and without the grid, providing continuous power to meet our customers' electric and thermal energy needs every day of the year, as well as clean and critical backup power when the grid fails.

PureCell® fuel cell systems help our customers to "go green" and, at the same time, improve their bottom line. Our systems can achieve up to 90% efficiency when all of the byproduct heat is utilized, a factor that both reduces fuel use for the same amount of electricity generated and significantly lowers CO2 emissions.

All of the above, plus the following distinct environmental advantages, provide:

- Near-zero, ultra-low air emissions. Electricity is generated in an electrochemical process without combustion.
- Reduced GHG carbon emissions. High CHP efficiency leads to fuel conservation.
- Zero water consumption. Millions of gallons of water are saved every year. PureCell® fuel cell systems operate in water balance, with no consumption or discharge of water in normal operations.
- Clean-burning natural gas, with the lowest carbon intensity of all fossil fuels
- Quiet, land friendly. Systems operate quietly, have a small footprint (compared to solar and wind farms), and can be installed almost anywhere with minimal environmental impact.
- LEED® (Leadership in Energy and Environmental Design) qualified.

For more information about PureCell® fuel cell systems, visit www.doosanfuelcellamerica.com/contact/onlineevaluation

About Doosan Fuel Cell

Doosan Fuel Cell America, Inc. (Doosan FC) is a subsidiary of Doosan Corporation, a South Korea-based industrial company founded in 1896 with current operations in 38 countries. Doosan FC, headquartered in South Windsor, Conn., designs, engineers and manufactures stationary fuel cells for commercial and industrial applications. Formed in July 2014 following Doosan Corporation's acquisition of ClearEdge Power (formerly UTC Power), Doosan FC is the U.S. arm of the Doosan Fuel Cell Business Group and focuses on 400-kilowatt phosphoric acid fuel cells capable of supplying combined heat and power to building and utility systems. With its growing team, and focus on innovation and technology leadership, Doosan FC's stated vision is to be the global leader in the fuel cell industry.

For more information please visit www.doosanfuelcell.com.