Natural Gas Fuel Cells: Technology, Advantages and Opportunities

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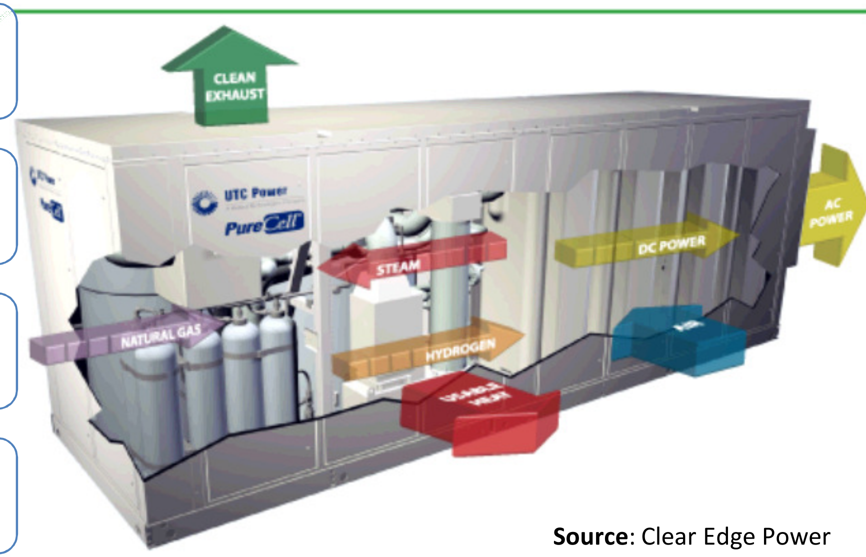
Fuel Cell Basics

A fuel cell is an electrochemical device that converts the chemical energy from the methane in natural gas into electricity through a chemical reaction with oxygen

- Fuel cells have no moving parts—they are quiet and reliable with durability of up to 20 years
- Through the process below fuel is converted directly to electricity and heat with a total system efficiency that can be much higher than other generation sources given the same amount of fuel

1. **Fuel Processor**
   - Converts natural gas fuel to hydrogen
2. **Fuel Cell Stack**
   - Generates DC power from hydrogen and air
3. **Power conditioner**
   - Converts DC power to AC power
4. **Heat recovery**
   - On board heat exchanges for recovering useful thermal energy



Source: Clear Edge Power

Fuel Cell Benefits

Efficiency in comparison to other forms of distributed power generation

- Fuel cells offer clear efficiency advantages in comparison to other forms of distributed power generation.
- Natural gas producers should be drawn to fuel cell power due to its highly efficient use of natural gas and high thermal efficiency
- For example, Clear Edge Power Fuel Cells are 42% efficient in the generation of electrical power and, depending on the application, up to 90% efficient overall with full heat recovery (when the byproduct heat is used)[1].

Reduction of negative environmental impact caused by conventional fossil fuel consumption

- Fuel cell power creates a clean alternative for on-site power that replaces the dirtier diesel generators
- Low emissions of pollutants—nitrogen oxides (NOx), sulfur oxides (SOx), volatile organic compounds (VOC), particulate matter, carbon dioxide (CO2) and reductions in methane emissions
- Use of fuel cell generators may qualify for certain Renewable Energy Credit (REC) certifications like the LREC program in Connecticut or certain carbon offsets

Fuel Cells and Fracking

Fuel cells placed at hydraulic fracturing sites could create environmental benefits and cost efficiencies for drillers

- GP Renewables has done extensive work on making the economic case for the use of fuel cells at natural gas wells to capture excess gas that is normally vented or flared in a wasteful and environmentally detrimental practice called Flaring
- Excess natural gas could be captured to provide clean distributed power generation on-site

Source: ClimateDesk.org

- In certain instances, gas is vented through pressure relief valves as a result of constraints on pipeline capacity, which cause unplanned over-pressuring of plant equipment
- There are many situations in which this stranded gas can be used as the power source for drilling operations

Emissions Reductions

Reductions in Methane (CH_4) Emissions:

- EPA estimates that 2% of the natural gas is emitted through venting or leakage[2] as of 2011
- Natural gas can contain 70-99% methane which is around 25 times stronger a greenhouse gas than carbon dioxide[3]
- These emissions during natural gas production and processing are estimated to make up around 20% of total GHG emissions from natural gas (based on emissions from the Marcellus Shale gas production to combustion)[4]
- Using a fuel cell to capture and convert this excess gas to energy to power the natural gas production systems results in a 567 kg CO2e (carbon dioxide equivalent) reduction in emissions for every MMBTU (million British Thermal Units) of natural gas captured

Estimated Total Emissions Reductions from Fuel Cell:
For every MMBTU of vented natural gas that is captured and used with a fuel cell

Methane and CO2:	567 kg CO2e/MMBTU
Nitrogen Oxides (NOx)	0.73 kg/MMBTU
Volatile Organic Compounds (VOC)	1.86 kg/MMBTU

Highlights calculations of CO2 and methane emissions offset by use of Fuel Cell: (assuming previous use of diesel generators)

	kgCO2e/mmbtu	Calculation
Fuel Cell emissions[5]	64.73	221kg/mWh (full heat recovery) / 3.413 MMBTU per mWh
Diesel emissions reduced[6]	-211.07	[.7202kgCo2/kwh(diesel gen) *kwh /3412.142btu]*10^6btu/mmbtu
Reduction in methane emissions[7]	-420.5	[0.66kg/m3 /35.325ft3/m3 /100btu/ft3] *10^6btu/mmbtu *25kgCO2/kg CH4 *90% methane
TOTAL	-567	

Emissions Reductions

Reductions in Nitrogen Oxides (NOx) Emissions:

- Hydraulic fracturing produces large amounts of nitrogen oxide (NOx) emitted at the drilling site from the fuel combustion powering the drills
- NOx traps heat and creates smog problems that increase healthcare costs
- Replacing diesel generators with fuel cells reduces NOx emissions by 0.73 kg/MMBTU
- (Total NOx emissions reductions are higher as this does not take into account emissions from natural gas leakage, venting, and flaring)

Reductions in Volatile Organic Compounds (VOC) Emissions:

- The gas industry is a significant source of VOCs, which contribute to the formation of ground-level ozone (smog)
- EPA's Natural Gas STAR Program show that some of the largest air emissions in the natural gas industry occur during the Flowback phase of the fracturing process
- Capturing excess gas reduces VOC emissions by 1.86 kg/mmbtu

Highlights calculations of NOx emissions offset by use of fuel cell process:

		Calculations
Diesel emissions reduced[8]	.732	5.5 lbs/mwh / 2.2 lbs/ kg / 3.143 mmbtu/mwh
Fuel cell emissions	negligible	
Total	-.732	

Highlights calculations of reductions in VOC emissions :

	Emissions
Reductions from VOC released in vented natural gas [9]	-4.1 lbs/mmbtu
Emissions from fuel cells	0.02 lbs/mwh
Total	-1.86 kg/mmbtu

Levelized Cost Comparison

A levelized cost of electricity (LCOE) comparison between Fuel Cells and conventional grid-supplied electricity supports the case that for operational, non-drilling costs at drilling sites, Fuel Cell deployment is a cost effective power source

LCOE Scenario 1: Grid Supplied Power	
Estimated Tranmission Infrastructure Upgrade Costs	$ 2,000,000
10 Year Commidity Cost Equivalent for 2 Fuel Cells *(approximately 7,000 mwhrs per year at 10 cents/kwhr)*	$ 7,000,000
Estimated 10 year all-in cost	**$ 9,000,000**

LCOE Scenario 2: Fuel Cell On site Generation	
Estimated installation and fuel cell equipment costs *(2 fuel cells with 400 kw capactiy)*	$ 5,400,000
ITC plus accelerated depreciation equate to 45% of cost	$ (2,430,000)
10 Year Fuel Cell O&M at $12,500 per Month	$ 1,500,000
10 Year Fuel Cell Insurance Costs at $35,000 per Year	$ 350,000
Estimated 10 year all-in cost	**$ 4,820,000**

Natural Gas Consumption Assumptions		10 Year Natural Gas Costs		Estimated All in Costs with Fuel Costs	10 Year Grid Supply LCOE Breakeven Equivalency ($/mwhr)
Fuel Cell Natural Gas Consumption per mwhr of Production	9.545	$0 /mmbtu	$ -	$ 4,820,000	$ 68.86
		$1 /mmbtu	$ 668,150	$ 5,488,150	$ 78.40
		$2 /mmbtu	$ 1,336,300	$ 6,156,300	$ 87.95
Fuel Cell mmbtu Consumption per Year	66815	$3 /mmbtu	$ 2,004,450	$ 6,824,450	$ 97.49
		$4 /mmbtu	$ 2,672,600	$ 7,492,600	$ 107.04
		$5 /mmbtu	$ 3,340,750	$ 8,160,750	$ 116.58

Additional Economic Factors

Installation and Integration Costs:

- At roughly $2.5 to $3 million per 400kw installation (turn-key costs), Fuel Cells need some additional incentives to reach parity with other gas consuming distributed generation technologies

Tax Benefits:

- Available from the Federal Government, is the 30% investment tax credit for renewable power generation investments, for which Fuel Cells qualify
- Additionally available from the Federal Government, is the accelerated depreciation treatment given to Fuel Cell equipment purchases

Grant Availability:

- Certain states, such as New York and New Jersey, have grants available for Fuel Cell installations which can be as much as almost 40% of the total installation cost

Cash-flow & Avoided Costs:

- As a base-load generator, a Fuel Cell can generate as much as 3500 mwhrs of electricity per year
- Fuel Cells can operate in-phase with grid supplied power or independent of grid supplied power and load-follow
- Fuel Cells make the most economical sense where there is the highest avoided cost of electricity

Takeaway Points

Fuel Cells offer a clean, reliable and efficient distributed power source

The economic case for Fuel Cells—on a levelized cost basis for remote areas where natural gas supply is high and with low economic value, like at gas drilling sites, Fuel Cells are more cost effective than grid supplied power

Additionally, the economic case completely discounts the value of all positive environmental attributes that result in capturing wasted gas that would otherwise be flared on site and using that gas to displace otherwise required fossil fuel generation

Financial, tax and state incentive programs included, Fuel Cells at gas drilling sites offer a cost-effective means of decreasing operational costs while simultaneously reducing negative environmental impact

GP Renewables & Trading

About GP Renewables & Trading

- A multifaceted Energy Services company that combines Consulting, Commodity Risk and Operations Management, and Project Development to provide a full array of services to clients in the North American wholesale, retail, and renewable power and natural gas industries

- Full suite of services includes:
  - Renewable and Clean Energy Project Development
  - Energy Management Services
  - Renewable Energy Credits Services
  - Preferred Supply Agreement Negotiations
  - Customer Book Sales and Merger & Acquisition Advisory

Thank You – Contact Us

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