

# Dilute Methane Pollution Control That Produces Continuous Clean Renewable Energy

J. Blair\* and P. Fukumoto\*\*

\* FlexEnergy, Inc., Portsmouth, NH, joe.blair@flexenergy.com

\*\* FlexEnergy, Inc., Irvine, CA, paul.fukumoto@flexenergy.com

## ABSTRACT

Methane is a greenhouse gas that has 25 times the environmental impact of carbon dioxide. Millions of tons of manmade methane seep into the atmosphere each year. Much of this methane seepage is too dilute for current technologies to destroy. FlexEnergy manufactures the Flex Powerstation™ which turns these sources of methane emissions into electricity. Unlike other energy technologies, the Flex oxidizes a wide range of fuel gas heating values by diluting all gases down to 1.5% methane concentration prior to use. The IP protected Flex Pressurized Thermal Oxidizer keeps NOx and CO emissions below 1 ppm, exceeding the most stringent emission requirements.

Sources of problematic methane emissions, such as landfills, digesters, oil & gas fields, are now viable domestic clean energy sources. FlexEnergy's innovative technology transforms an environmental problem into a valuable asset by creating continuous domestic energy and clean air.

**Keywords:** emissions, methane, energy, waste, renewable

## 1 THE LANDSCAPE

Up until this point in time, generating energy from high quality waste gases, such as from landfills, digesters, and oil & gas fields, certainly has had its benefits. Traditional technologies can turn some of these waste products into useful energy while also eliminating a harmful pollutant, namely methane. After all, methane is known to be 25 times more harmful to the environment than carbon dioxide. Destroying methane while producing electricity seems like an obvious win-win scenario.

There have however been some unintended consequences as a result of this effort. The majority of methane gas burning technologies create pollutants such as NOx, CO, and VOCs, which can be harmful to human health. Even the EPA notes that NOx can "cause or worsen respiratory disease such as emphysema and bronchitis, and can aggravate existing heart disease, leading to increased hospital admissions and premature death." [1] While destroying methane is certainly beneficial to the environment, an ideal solution would do so without negatively affecting the surrounding air quality and community health.

## 2 FLEXENERGY

FlexEnergy has developed an innovative solution that generates renewable energy through the destruction of pollution, while simultaneously providing clean emissions. Furthermore, FlexEnergy has found a way to make these environmental cleanup projects commercially sustainable, such that they effectively pay for themselves.

In 2008, FlexEnergy began developing a technology that utilizes gradual oxidation to destroy methane while also emitting the world's cleanest emissions. From these origins, the Flex Powerstation™ was born. (Figure 1)

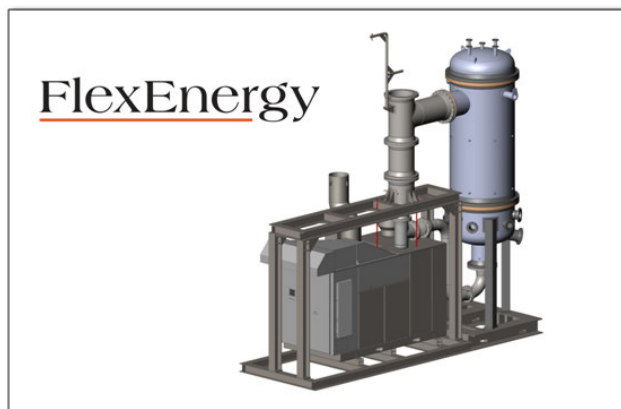


Figure 1: The Flex Powerstation

## 3 THE FLEX POWERSTATION

The Flex Powerstation (the "Flex") is a small, modular, technology that converts low energy fuels into electricity with very low emissions. It uniquely integrates a pressurized thermal oxidizer (the "Flexidizer") with a recuperated gas turbine. The Flex uses the oxidation characteristics of methane to produce clean, efficient energy capable of driving a gas turbine for the production of clean, green electricity. The process operates at low methane concentrations, 1.5% by volume. These two special characteristics provide a wide fuel operating envelope with ultra low emissions. FlexEnergy holds a key patent relative to the use of low energy gases.

The Flex Powerstation is the only gas turbine power plant that runs directly on low Btu fuel gas.

The simple cycle diagram (Figure 2) below shows the Flex Powerstation with its unique components clouded. Fuel is aspirated with air forming a 15 Btu/cubic foot mixture that is compressed and oxidized in a pressurized gradual oxidizer (the “Flexidizer”); the energy released is used to generate electricity. The Flex does not require a fuel compressor or fuel conditioning system. No matter what the initial fuel content, it is diluted with air down to 15 Btu/cubic foot (1.5% methane, or 1.5% the strength of natural gas). The power output of the Flex is the same as from a traditional power plant. The mixing of the fuel with atmospheric air to achieve a uniform gas mixture of 15 Btu/scf allows the Flex to operate on wide range of gaseous, and potentially liquid, fuels. The Flexidizer operates in almost the same manner no matter what the base fuel.

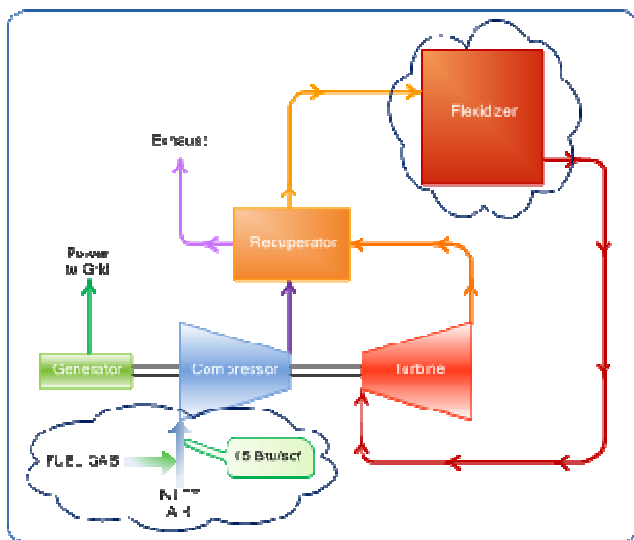


Figure 2: Flex Cycle Diagram

By keeping temperatures below 2000 F, the Flexidizer avoids NOx formation. The Flexidizer also provides a long residence time, allowing both CO and VOCs to be destroyed. The NOx, CO, and VOC emissions from the Flex are far lower than from a traditional power plant, each well below 1 ppm. The Flex’s fuel flexibility and low emissions create the potential for utilizing weak fuels that no other power plants can use.

#### 4 EMISSIONS REGULATIONS

FlexEnergy’s goal is not to simply comply with current emissions regulations; instead, FlexEnergy aims to exceed these regulations for the sake of both community and environmental wellbeing. Across the industry, emissions regulations are driving the exhaust emissions signatures to significantly lower levels. Nationally, the EPA has already proposed tighter regulation on reciprocating internal combustion engines.

California has enacted Distributed Generation regulations for which the 2013 criteria emissions limits for generators operating on waste gas sources (landfills, digesters, and oil fields) will now be the same as a pipeline natural gas combined cycle power plants. California emission regulations are closely watched internationally and are generally accepted as some of the most stringent regulations in the world.

The Flexidizer uses the oxidation characteristics of methane to produce clean, efficient gas energy capable of driving a recuperated gas turbine. Flex Emissions Table (Table 1) shows the Flex development test data on 1.5% methane. It compares the Flex measured emissions to key standards that will regulate the waste gas to energy technology emissions. To date, the Flex Powerstation is the only technology that will meet the California Air Resources Board 2013 emissions requirements for NOx and CO.

Emissions Standards PPMV @ 15% O2	NOx		CO	
	Current	2012/2013	Current	2012/2013
Flex Powerstation	<1	<1	<1	<1
CARB Dist Gen Waste Gas Rule	<10	~1	120	<3
SCAQMD Landfill/Digester IC Engines	36 /45	11	2000	250

Table 1: Flex Emissions

#### 5 MARKET OPPORTUNITY

FlexEnergy will enable the utilization of a whole host of low Btu fuels that today are a considerable source of greenhouse gas emissions. These low Btu fuels will become a source of clean, green energy with minimal greenhouse gas emissions.

Sources of problematic methane emissions include landfills, digesters, oil & gas fields, coal mining operations, chemical plants, refineries, and other industrial processes. Dilute tail gas from biogas processing, biofuel plants, and ethanol plants can also power the Flex.

Applying the Flex in each of these market segments expands the traditional opportunity or creates a new solution to methane destruction and greenhouse gas control. For landfills, as an example, the Flex can double the useful output from a landfill, generating energy for decades after the fuel quality is no longer acceptable for other technologies.

The methane emissions opportunity table based on the U.S. EPA data is shown below (Table 2). Over 14,000 billion of cubic feet (BCF) of methane are being generated

by human activity each year [2]. Many of these potential energy sources are currently being flared or just vented as greenhouse gas emissions.

## 6 FLEX PROGRESS

FlexEnergy acquired the Energy Systems microturbine division from Ingersoll Rand in January 2011. This acquisition allows FlexEnergy to manufacture a complete Flex solution. FlexEnergy now has over 100 employees and access to worldclass service, manufacturing, and engineering resources.

To date, the Flex Powerstation has been demonstrated at two sites. The first is in Lamb Canyon, California, where a small, 100kW pilot version of the Flex Powerstation is installed and running directly on landfill gas. This site has demonstrated that the Flex can successfully run on landfill gas with 38% methane content and no fuel conditioning required.

The second site is the primary testing facility of the next-generation, 250kW version of the Flex Powerstation, located in El Cajon, California. At this site, the methane content of the fuel can be varied and proper performance parameters can be measured. To date, the results are extremely promising. The 250kW Flex Powerstation is currently producing 270kW of electrical power and is meeting emissions targets. (Figure 3)

World Wide Methane Emissions	Equivalent Billion of Cubic Feet (BCF) Per Year		Electricity Capacity Opportunity (MW)
	U.S.	Rest of World	Combined
Landfills	507	1,553	18,223
Waste Water	74	1,418	13,198
Manure	98	463	4,963
Coal Mine	185	1,010	10,571
Natural Gas Fugitive	335	2,233	22,717
Oil Fugitive	52	113	1,460
Enteric	328	4,417	41,975
Rice	16	1,655	14,782
Total	1,599	12,864	127,888

Table 2: Methane Emission Opportunities

Currently the U.S. EPA greenhouse gas estimates discount the possibility for recovery and utilization of most dilute methane. Capturing and limiting the greenhouse gas effect of these methane emissions sources is a 100,000 MW worldwide opportunity. The Flex with its low methane content capability has the potential to spur the capture and conversion of a significant portion of the dilute methane sources.

The domestic market opportunity in landfills, using the U.S. EPA methane source data [3], is over 1500 MW for the gas which is flared or oxidized. This collected gas represents an opportunity of about \$3 billion in just one segment of the U.S. methane market. (Table 3)

Domestic Landfill Methane Emissions	Equivalent Billion of Cubic Feet (BCF) Per Year	Electricity Capacity Opportunity (MW)
Vented/Not Recovered	367	2920
Flared	177	1270
Oxidized	45	320
Existing Gas to Energy	197	1410
Total	786	4510

Table 3: Domestic Emissions Table



Figure 3: 250kW Flex Powerstation

The first commercial 250kW Flex Powerstation was shipped to Fort Benning, Georgia, in March 2011 as part of a landfill gas to energy project funded by the Department of Defense. FlexEnergy expects this unit to be up and running by late May 2011. The landfill gas is 28% methane by volume, a gas that until now could only be flared. This site

will demonstrate the unique value proposition provided by the Flex Powerstation.

The Flex Powerstation is the cleanest power platform in the world. The Flex oxidizes previously unusable gases, especially weak and waste gases, to produce clean, green electricity. Today's emissions problem becomes a green energy source. The Flex Powerstation is simply the cleanest, most versatile emission elimination through energy generation solution in the world.

### **REFERENCES**

- [1] United States Environmental Protection Agency (US EPA), "Health", [Online] Available at: <http://www.epa.gov/airquality/nitrogenoxides/health.html>
- [2] US EPA, "Global Anthropogenic Non-CO2 Greenhouse Gas Emissions:1990 - 2020", Appendix B-1 to Appendix B-12, 2006
- [3] US EPA, "Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2007", 8-3, 2009