SOLID WASTE AUTHORITY OF CENTRAL OHIO

SWACO GREEN ENERGY CENTER FINAL SCIENTIFIC REPORT

September 1, 2011

FINAL SCIENTIFIC REPORT

This Final Scientific Report is prepared pursuant to Award No. DE-FG36-06G086012; Pyramid Resource Center Green Energy Center in fulfillment of the $988,490.96 grant award. The project director for SWACO is the Director of Planning and Programs. Firm Green Fuels of Ohio was a subcontractor to this award.

I. Executive Summary

There are currently over 3,500 USA/Canadian landfills listed by the EPA/EC and like numbers in Europe that are producing methane-rich landfill gas (LFG). This gas is typically made up of 50% methane (CH_4), 35% carbon dioxide (CO_2), and 2 to 25% nitrogen and oxygen (N_2 & O_2), plus dozens of dilute contaminants. LFG is classified as a renewable fuel, because it is generated via biological decay of municipal solid waste, a constant byproduct of human activity. To date, most LFG has been allowed to escape into the atmosphere. On account of its high CH_4 content, LFG may contribute to climate change, as CH_4 is one of the most harmful greenhouse gases with 21 times the global warming potential of CO_2. Of the landfills that collect LFG, most simply flare it. In the past decade, some landfills have begun to use LFG for electricity generation or for direct combustion as "low Btu gas." Very few landfills upgrade LFG to "high Btu gas."

A patented CO_2 Wash™ process developed by Acrion Technologies Inc., and licensed to Firm Green Inc. shows promise as an economically and environmentally sustainable process to recover energy and prevent pollution from landfills. The CO_2 Wash™ has already been proven at lab-scale. It upgrades LFG, which consists of 50% methane (CH_4) + 35% carbon dioxide (CO_2) + 2 to 25% nitrogen + oxygen (N_2+O_2), 1 to 2% water vapor, and dozens of contaminants (which total a few hundred to a few thousand parts per million). CH_4, which by itself has an energy content of 1,012 British thermal units (Btu) per standard cubic foot (SCF), is the only component in LFG that contributes to its energy content, which is therefore about 400-550 Btu/SCF. Accordingly, raw LFG is usually referred to as "medium-Btu" gas. To be salable, it is necessary to remove essentially all the components besides CH_4, while keeping the vast majority of the revenue producing CH_4. This is "high-Btu" gas, yielding 850 to 1,000 Btu/SCF. The CO_2 Wash™ process upgrades LFG to about 930 Btu/SCF, and reduces the contaminants to levels that make it salable as a vehicle fuel in the form of compressed natural gas (CNG).

II. Project Accomplishments

Objective 1: To utilize landfill gas, a biomass product, as a feedstock for the production of electricity.

Product gas from the CO_2 Wash™ was used to generate electricity to power the SWACO Green Energy Center during the reporting period. The medium Btu gas (VOC free) powered an Ingersoll-Rand MT-250 microturbine. The MT-250 provided the power needed to take the facility completely off grid and power itself. The parasitic load of the facility was between 220-230 kW.

Objective 2: To utilize landfill gas, a biomass product, as a feedstock for the production of compressed natural gas (CNG).

The SWACO Green Energy Center was successful in converting landfill gas into CNG for vehicle use. Exhibit A contains analytical reports from a qualified laboratory comparing the raw landfill gas with the medium Btu gas (post CO_2 wash but before the membranes), and the high Btu gas.

Sample production reports for the facility are attached as Exhibit B. The GGE Sum is the gasoline gallon equivalents of CNG that were made during the production run. The Total Pounds sum is the pounds of high Btu gas made in the production run.

Objective 3: To demonstrate the commercialization of the created energies by powering SWACO's transfer fleet and facilities for research and development, training and other support activities.

SWACO converted or purchased 13 CNG powered vehicles (or bi-fuel) as a part of this project. In addition, SWACO made the fueling station available to local governments. From September 2008 to June 2010, SWACO had dispensed 13,407.557 gasoline gallon equivalents of CNG to be used as vehicle fuel.

III. Project Activities

The facility collects and cleans raw landfill gas using CO_2 Wash^{TM}, a patented technology developed in Ohio by Acrion Technologies. The cleaned methane is then converted into compressed natural gas for use in CNG powered cars and medium duty trucks. Given SWACO's plan to fuel its vehicles with CNG derived from a portion of the processed LFG, it was essential that the resulting BioMethane be pure enough to meet OEM specification for CNG fuel.

Construction of the SWACO Green Energy Center commenced in July 2006. The facility utilizes a CO_2 Wash^{TM} unit to process 300scfm of LFG into ultra-pure medium Btu methane that powers a 250kW microturbine to generate electricity for the facility, and high Btu methane for use as vehicle fuel for SWACO vehicles. The high Btu methane is compressed on site, and then piped to above-ground CNG storage tanks. The CNG is then dispensed at a fueling station located adjacent to the building that houses the gas processing equipment.

The methane purification plant consists of a modular CO_2 Wash^{TM} facility. A process diagram is attached as Exhibit C. This plant is a scalable module that is currently designed to process up to 300 scfm of raw landfill gas daily. The process, in general, is easily scaled. This allows for expansion of processing capacity with increasing landfill gas yield. The CO_2 Wash^{TM} produces a primary methane stream consisting of approximately 60% methane, and 40% CO_2, which is equivalent to medium-Btu pipeline gas (600 Btu/scf). The primary methane stream is suitable for direct use as medium Btu fuel, or can be routed to a secondary processing stage for further CO_2 removal. Secondary processing is in the form of membrane separation, resulting in CO_2 concentrations of 50 ppm or less and elevation of the methane stream to high-Btu grade.

Removal of sulfur from the raw landfill gas is accomplished via an iron-bed reactor. Removal efficiencies for sulfur allow categorization of secondary processed high-Btu methane as "natural gas" or the more stringent "pipeline natural gas" pursuant to 40 CFR §72.2 (U.S. EPA Acid Rain Program).

Nominal operating conditions are -50°F and 360 psig. Such a low temperature and high pressure lead to high operating expense (OPEX). In addition, the high pressure requires a robust compressor, and thick walled vessels, both of which lead to high capital expense (CAPEX).

The MT-250 produces sufficient power to support the SWACO Green Energy Center operations. This allows SWACO to become independent of the local electrical grid, and become "self-powered" from on-site renewable fuel resources. At a consumption rate of approximately 100 cfm, the MT-250 represents a fuel and emissions efficient mode of small scale generating capacity. The MT-250 is fueled via a medium-Btu (600 Btu/scf) process stream from the CO_2 Wash™ facility. Relative to air pollutants produced the emissions profile of the MT-250 compares very favorably to comparable emission rates for regional electrical utility power plants.

The entire cost of the project was $4,859,000 with an operation cost of $13,000 per month. Projecting a production of 685 GGE for 330 days per year; depreciating capital and operational cost over 10 years, the estimated production cost per GGE would be approximately $2.60 per GGE. The higher CAPEX of this system resulted in approximately $1.00 per gasoline gallon equivalent cost hurdle compared with CNG available from a natural gas pipeline.

Accomplishments of the Project

The SWACO Green Energy Center proves the technical and economic feasibility of a smaller scale high-Btu landfill gas project. The project has accomplished its goals with a technology and facilities design that:

- It is self-sustaining; generates enough electricity for its own operations with a microturbine powered by a portion of the cleaned landfill gas
- It creates a flexible business model that can sell electricity to the grid, produce vehicle quality fuel and/or pipeline quality natural gas
- It demonstrates that smaller landfill operations have a viable LFG utilization option that not only improves air quality at the site, but can provide a stable, long term source of alternative fuel for their fleet operations that is cleaner than the fossil-based fuel it replaces.
- Enables SWACO to respond effectively to national environmental policy mandates with respect to waste utilization, greenhouse gas reduction, and fleet emission standards with a single project.

IV. Projects Developed Under the Award

A. Publications

A full listing of SWACO publications relating to this project are attached as Exhibit D. In addition to these publications, Ralph Hirshberg, P.E. of Civil & Environmental Consultants, Inc. presented INNOVATIVE LANDFILL GAS UTILIZATION THE SWACO/FIRMGREEN™ ENERGY, INC. GREEN ENERGY CENTER© FRANKLIN COUNTY SANITARY LANDFILL GROVE CITY, OHIO at WASTECON 2007. That paper is also attached in Exhibit D.

B. Internet Sites

The SWACO Green Energy Center won the United States Environmental Protection Agency Landfill Methane Outreach Program project of the year in 2008. Information on the award can be found at: http://www.epa.gov/lmop/projects-candidates/profiles/swacogreenenergycenter.html

C. Collaborations Fostered

This project has fostered a closer relationship with Clean Fuels Ohio. Clean Fuels Ohio has taken on the responsibility of planning for CNG filling station locations in the Greater Columbus Metropolitan area to better promote the usage of CNG vehicles. The SWACO Green Energy Center has been successful in promoting CNG vehicles and the additional need of CNG fueling stations in Central Ohio. A link to the Clean Fuels Ohio website is: http://www.cleanfuelsohio.org/

D. Licensing Agreements

The technology used under this award are covered by US Patent Nos. 5,681,360, and 5,842,357. The Know-How Sublicense and Licensing Agreement, Patent Sublicensing Agreement, and Trademark License under these patents for SWACO use is attached as Exhibit E.

EXHIBIT A

SWACO Green Energy Center
Final Scientific Report

Gas Analytical

Atlantic Analytical Laboratory

Landfill Gas Analysis Report

Rutgers Eco Complex
1200 Florence Columbus Rd.
Bordentown, NJ 08508
(609) 499-3600 xt 226; Fax: (609) 499-3647
Attn: David Specca; Email: specca@aesop.rutgers.edu

AAL Number: 14931-1
Received On: 17 June 10
Report Date: 30 June 10
PO Number: S1358614

Sample ID: Landfill Gas; Sample # 1, Raw Landfill Gas.
Comment: Received in 2-1L Tedlar Bags, 1-500 cc Cyl #0540, and 1-Methanol Impinger.

Sample Date: 15 June 10
Location:

Composition (Normalized, % v/v) – ASTM D 1945 And SRM 1004

Non-Hydrocarbon Gases	Result	DL
Hydrogen:	0.45	0.05
Nitrogen:	2.93	0.01
Oxygen:	0.30	0.01
Carbon Monoxide:	nd	0.05
Carbon Dioxide:	40.8	0.05

Hydrocarbons	Result	DL
Methane:	55.51	0.001
Ethylene:	0.001	0.001
Ethane:	0.001	0.001
Propylene:	0.001	0.001
Propane:	0.002	0.001
Isobutane:	0.001	0.001
n-Butane:	nd	0.001
Butenes:	nd	0.001
Isopentane:	nd	0.001
n-Pentane:	nd	0.001
Pentenes:	nd	0.001
Hexanes +:	0.010	0.001

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Elemental Composition (Normalized, % w/w)

Element	Result
Carbon Content (% C, w/w):	41.7
Hydrogen Content (% H, w/w):	8.06
Oxygen Content (% O, w/w):	47.2
Nitrogen Content (% N, w/w):	2.95

Heat of Combustion & Physical Properties (by ASTM D 3588-91)

I. @ ASTM Base Conditions; 14.696 psia, 60°F, dry gas format		Result
Net Heat of Combustion	(Lower Heating Value, Btu/ft^3):	509
Gross Heat of Combustion	(Higher Heating Value, Btu/ft^3):	565
Gross Heat of Combustion	(Water Saturated Gas Format, Btu/ft^3):	556
Net Heat of Combustion	(Lower Heating Value, Btu/lb):	6,943
Gross Heat of Combustion	(Higher Heating Value, Btu/lb):	7,712
Molecular Weight:		27.82
Density (lb/ft^3):		0.0733
Specific Gravity (vs. dry/normal air):		0.9607
Compressibility Factor (z):		0.9969

II. @ ASME Base Conditions; 14.73 psia, 60°F, dry gas format		Result
Net Heat of Combustion	(Lower Heating Value, Btu/ft^3):	510
Gross Heat of Combustion	(Higher Heating Value, Btu/ft^3):	567
Gross Heat of Combustion	(Water Saturated Gas Format, Btu/ft^3):	557
Net Heat of Combustion	(Lower Heating Value, Btu/lb):	6,943
Gross Heat of Combustion	(Higher Heating Value, Btu/lb):	7,712

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Raw Gas

Volatile Sulfur Compounds (VSC, ppm v/v)	Result ppm v/v	DL ppm v/v
Hydrogen Sulfide:	5.5	0.1
Carbonyl Sulfide:	0.4	0.1
Sulfur Dioxide:	nd	0.1
Methyl Mercaptan:	2.8	0.1
Ethyl Mercaptan:	0.4	0.1
Dimethyl Sulfide:	7.0	0.1
Carbon Disulfide:	0.1	0.1
Isopropyl Mercaptan:	0.3	0.1
t-Butyl Mercaptan:	0.3	0.1
n-Propyl Mercaptan:	nd	0.1
Methyl Ethyl Sulfide	0.1	0.1
sec-Butyl Mercaptan:	nd	0.1
Thiophene	0.4	0.1
Isobutyl Mercaptan:	0.1	0.1
Diethyl Sulfide:	nd	0.1
n-Butyl Mercaptan:	nd	0.1
Dimethyl Disulfide:	0.1	0.1
3-Methylthiophene:	0.1	0.1
Tetrahydrothiophene	nd	0.1
2-Ethylthiophene:	nd	0.1
2,5-Dimethylthiophene:	nd	0.1
Diethyl Disulfide:	nd	0.1
Unknown Sulfur Compounds:	0.1	0.1

Comments: Total Sulfur (as H_2S) = 17.9 ppm v/v

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Raw Gas

GC/MS Result

TO-14 Target List

Target Analyte	Pk ID/Cat Scan No.	Amt. ppm v/v
Freon-12	a/157	0.7
Methyl Chloride	--/171	nd 0.5
Freon-114	--/166	nd 0.5
Vinyl Chloride	--/172	nd 0.5
Methyl Bromide	--/197	nd 0.5
Ethyl Chloride	--/204	nd 0.5
Freon-11	--/222	nd 0.2
Vinylidene Chloride	a/256	0.4
Freon-113	--/310	nd 0.2
Dichloromethane	--/271	0.3
1,1-Dichloroethane	--/376	nd 0.2
cis-1,2-Dichloroethyle	a/406	0.2
Chloroform	--/448	nd 0.2
1,1,1-Trichloroethane	--/503	nd 0.2
1,2-Dichlorethane	--/512	nd 0.2
Benzene	a/547	1.3
Carbon Tetrachloride	--/568	nd 0.2
1,2-Dichloropropane	--/669	nd 0.2
Trichloroethylene	a/655	0.4
cis-1,3-Dichloropropylene	--/793	nd 0.2
trans-1,3-Dichloropropylene	--/870	nd 0.2
Toluene	a/858	12
1,1,2-Trichloroethane	--/890	nd 0.1
1, 2-Dibromoethane	--/988	nd 0.1
Tetrachloroethylene	--/984	0.6
Chlorobenzene	--/1101	nd 0.1
Ethylbenzene	a/1128	2.1
m+p-Xylenes	a/1149	3.2
Styrene	a/1209	0.1
o-Xylene	a/1214	0.8
1,1,2,2-Tetrachloroethane	--/1258	nd 0.1
4-Ethyltoluene	a/1388	0.4
1,3,5-Trimethylbenzene	a/1404	0.2
1,2,4-Trimethylbenzene	a/1468	0.4
1,3-Dichlorobenzene	--/1516	nd 0.2
1,4-Dichlorobenzene	--/1530	nd 0.2
Benzylchloride	--/1534	nd 0.2
1,2-Dichlorobenzene	--/1587	nd 0.2
1,2,4-Trichlorobenzene	--/1903	nd 0.2
Hexachlorobutadiene	--/1979	nd 0.2

Comments:

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Raw Gas

Toxic Substances Sub-17 Extended List

Compound	Cat/Scan No.	Amt. ppb v/v	DL ppb v/v
Chloroform	--/446	nd	10
1,2-Dichloroethane	a/527	200	10
Benzene	a/561	1,320	10
Carbon Tetrachloride	--/560	nd	10
Trichloroethylene	a/665	440	10
1,4-Dioxane	--/698	nd	10
1,1,2-Trichloroethane	--/878	nd	10
1,2-Dibromoethane	--/930	nd	10
Tetrachloroethylene	a/990	620	10
1,1,2,2 Tetrachloroethane	--/1267	nd	10
Methylene Chloride	a/286	300	10
1,1,1-Trichloroethane	a/516	10	10

Siloxanes (by GC/MS)

Target Analyte	Pk. ID. Cat./ Scan	Amt. ppb v/v	DL ppb v/v
Hexamethyldisiloxane (MM)	--/371	nd	20
Hexamethylcyclotrisiloxane (D3)	--/625	nd	20
Octamethyltrisiloxane	--/706	nd	20
Octamethylcyclotetrasiloxane (D4)	a/849	570*	20
Decamethyltetrasiloxane	--/914	nd	20
Decamethylcyclopentasiloxane (D5)	a/1024	180*	20
Dodecamethylpentasiloxane	--/1086	nd	20
Other Siloxanes	--/Various	nd	50

Peak ID Category:
A = computer library match **GT 900** and **retention time (t_r) match** with calibration standard.
B = computer library match **GT 900** but **not** confirmed by calibration standard.
C = computer library match **between 800 and 900** but **not** confirmed by calibration standard.
D = computer library match **LT 800**, potential structure and functional group information only.

Comments: *Siloxane results assume a total gas volume collected of 15.0 liters.

Reviewed By,

Richard F. Frisch

Attachments: None
Chromatograms on file; Notebook data on file

Atlantic Analytical Laboratory

Landfill Gas Analysis Report

Rutgers Eco Complex
1200 Florence Columbus Rd.
Bordentown, NJ 08508
(609) 499-3600 xt 226; Fax: (609) 499-3647
Attn: David Specca; Email: specca@aesop.rutgers.edu

AAL Number: 14931-2
Received On: 17 June 10
Report Date: 30 June 10
PO Number: S1358614

Sample ID: Landfill Gas ; Sample # 2, Medium BTU Gas.
Comment: Received in 2-1L Tedlar Bags, 1-500 cc Cyl #0509, and 1-Methanol Impinger.

Sample Date: 15 June 10
Location: --

Composition (Normalized, % v/v) – ASTM D 1945 And SRM 1004

Non-Hydrocarbon Gases	Result	DL
Hydrogen:	0.51	0.05
Nitrogen:	3.37	0.01
Oxygen:	0.37	0.01
Carbon Monoxide:	0.05	0.05
Carbon Dioxide:	34.9	0.05

Hydrocarbons	Result	DL
Methane:	60.79	0.001
Ethylene:	0.001	0.001
Ethane:	0.001	0.001
Propylene:	0.001	0.001
Propane:	0.002	0.001
Isobutane:	nd	0.001
n-Butane:	nd	0.001
Butenes:	nd	0.001
Isopentane:	nd	0.001
n-Pentane:	nd	0.001
Pentenes:	nd	0.001
Hexanes +:	nd	0.001

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Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Elemental Composition (Normalized, % w/w)

Element	Result
Carbon Content (% C, w/w):	43.9
Hydrogen Content (% H, w/w):	9.33
Oxygen Content (% O, w/w):	43.1
Nitrogen Content (% N, w/w):	3.61

Heat of Combustion & Physical Properties (by ASTM D 3588-91)

I. @ ASTM Base Conditions; 14.696 psia, 60°F, dry gas format		Result
Net Heat of Combustion	(Lower Heating Value, Btu/ft^3):	554
Gross Heat of Combustion	(Higher Heating Value, Btu/ft^3):	616
Gross Heat of Combustion	(Water Saturated Gas Format, Btu/ft^3):	605
Net Heat of Combustion	(Lower Heating Value, Btu/lb):	8,030
Gross Heat of Combustion	(Higher Heating Value, Btu/lb):	8,920
Molecular Weight:		26.20
Density (lb/ft^3):		0.0691
Specific Gravity (vs. dry/normal air):		0.9048
Compressibility Factor (z):		0.9971

II. @ ASME Base Conditions; 14.73 psia, 60°F, dry gas format		Result
Net Heat of Combustion	(Lower Heating Value, Btu/ft^3):	556
Gross Heat of Combustion	(Higher Heating Value, Btu/ft^3):	617
Gross Heat of Combustion	(Water Saturated Gas Format, Btu/ft^3):	607
Net Heat of Combustion	(Lower Heating Value, Btu/lb):	8,030
Gross Heat of Combustion	(Higher Heating Value, Btu/lb):	8,920

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. -- = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Medium BTU Gas

Volatile Sulfur Compounds (VSC, ppm v/v)	Result ppm v/v	DL ppm v/v
Hydrogen Sulfide:	1.7	0.1
Carbonyl Sulfide:	0.2	0.1
Sulfur Dioxide:	nd	0.1
Methyl Mercaptan:	nd	0.1
Ethyl Mercaptan:	nd	0.1
Dimethyl Sulfide:	nd	0.1
Carbon Disulfide:	nd	0.1
Isopropyl Mercaptan:	nd	0.1
t-Butyl Mercaptan:	nd	0.1
n-Propyl Mercaptan:	nd	0.1
Methyl Ethyl Sulfide	nd	0.1
sec-Butyl Mercaptan:	nd	0.1
Thiophene	nd	0.1
Isobutyl Mercaptan:	nd	0.1
Diethyl Sulfide:	nd	0.1
n-Butyl Mercaptan:	nd	0.1
Dimethyl Disulfide:	nd	0.1
3-Methylthiophene:	nd	0.1
Tetrahydrothiophene	nd	0.1
2-Ethylthiophene:	nd	0.1
2,5-Dimethylthiophene:	nd	0.1
Diethyl Disulfide:	nd	0.1
Unknown Sulfur Compounds:	0.1	0.1

Comments: Total Sulfur (as H_2S) = 2.0 ppm v/v

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Medium BTU Gas

GC/MS Result

TO-14 Target List

Target Analyte	Pk ID/Cat Scan No.	Amt. ppm v/v
Freon-12	--/157	nd 0.5
Methyl Chloride	--/171	nd 0.5
Freon-114	--/166	nd 0.5
Vinyl Chloride	--/172	nd 0.5
Methyl Bromide	--/197	nd 0.5
Ethyl Chloride	--/204	nd 0.5
Freon-11	--/222	nd 0.2
Vinylidene Chloride	--/256	nd 0.2
Freon-113	--/310	nd 0.2
Dichloromethane	--/271	nd 0.2
1,1-Dichloroethane	--/376	nd 0.2
cis-1,2-Dichloroethyle	--/406	nd 0.2
Chloroform	--/448	nd 0.2
1,1,1-Trichloroethane	--/503	nd 0.2
1,2-Dichlorethane	--/512	nd 0.2
Benzene	--/547	nd 0.2
Carbon Tetrachloride	--/568	nd 0.2
1,2-Dichloropropane	--/669	nd 0.2
Trichloroethylene	--/655	nd 0.2
cis-1,3-Dichloropropylene	--/793	nd 0.2
trans-1,3-Dichloropropylene	--/870	nd 0.2
Toluene	--/858	nd 0.1
1,1,2-Trichloroethane	--/890	nd 0.1
1, 2-Dibromoethane	--/988	nd 0.1
Tetrachloroethylene	--/984	nd 0.1
Chlorobenzene	--/1101	nd 0.1
Ethylbenzene	--/1128	nd 0.1
m+p-Xylenes	--/1149	nd 0.1
Styrene	--/1209	nd 0.1
o-Xylene	--/1214	nd 0.1
1,1,2,2-Tetrachloroethane	--/1258	nd 0.1
4-Ethyltoluene	--/1388	nd 0.1
1,3,5-Trimethylbenzene	--/1404	nd 0.1
1,2,4-Trimethylbenzene	--/1468	nd 0.1
1,3-Dichlorobenzene	--/1516	nd 0.2
1,4-Dichlorobenzene	--/1530	nd 0.2
Benzylchloride	--/1534	nd 0.2
1,2-Dichlorobenzene	--/1587	nd 0.2
1,2,4-Trichlorobenzene	--/1903	nd 0.2
Hexachlorobutadiene	--/1979	nd 0.2

Comments:

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Medium BTU Gas

Toxic Substances Sub-17 Extended List

Compound	Cat/Scan No.	Amt. ppb v/v	DL ppb v/v
Chloroform	--/446	nd	10
1,2-Dichloroethane	--/527	nd	10
Benzene	--/561	nd	10
Carbon Tetrachloride	--/560	nd	10
Trichloroethylene	--/665	nd	10
1,4-Dioxane	--/698	nd	10
1,1,2-Trichloroethane	--/878	nd	10
1,2-Dibromoethane	--/930	nd	10
Tetrachloroethylene	--/990	nd	10
1,1,2,2 Tetrachloroethane	--/1267	nd	10
Methylene Chloride	--/286	nd	10
1,1,1-Trichloroethane	--/516	nd	10

Siloxanes (by GC/MS)

Target Analyte	Pk. ID. Cat./ Scan	Amt. ppb v/v	DL ppb v/v
Hexamethyldisiloxane (MM)	--/371	nd	20
Hexamethylcyclotrisiloxane (D3)	--/625	nd	20
Octamethyltrisiloxane	--/706	nd	20
Octamethylcyclotetrasiloxane (D4)	--/849	nd	20
Decamethyltetrasiloxane	--/914	nd	20
Decamethylcyclopentasiloxane (D5)	--/1024	nd	20
Dodecamethylpentasiloxane	--/1086	nd	20
Other Siloxanes	--/Various	nd	50

Peak ID Category:
A = computer library match **GT 900** and **retention time (t_r) match** with calibration standard.
B = computer library match **GT 900** but **not** confirmed by calibration standard.
C = computer library match **between 800 and 900** but **not** confirmed by calibration standard.
D = computer library match **LT 800**, potential structure and functional group information only.

Reviewed By,

Richard F. Frisch

Attachments: None
Chromatograms on file; Notebook data on file

Atlantic Analytical Laboratory

Landfill Gas Analysis Report

Rutgers Eco Complex
1200 Florence Columbus Rd.
Bordentown, NJ 08508
(609) 499-3600 xt 226; Fax: (609) 499-3647
Attn: David Specca; Email: specca@aesop.rutgers.edu

AAL Number: 14931-3
Received On: 17 June 10
Report Date: 30 June 10
PO Number: S1358614

Sample ID: Landfill Gas ; Sample # 3, High BTU Gas.
Comment: Received in 2-1L Tedlar Bags, 1-500 cc Cyl #0510, and 1-Methanol Impinger.

Sample Date: 15 June 10
Location: --

Composition (Normalized, % v/v) – ASTM D 1945 And SRM 1004

Non-Hydrocarbon Gases	Result	DL
Hydrogen:	0.07	0.05
Nitrogen:	4.74	0.01
Oxygen:	0.11	0.01
Carbon Monoxide:	nd	0.05
Carbon Dioxide:	0.49	0.05

Hydrocarbons	Result	DL
Methane:	94.59	0.001
Ethylene:	0.002	0.001
Ethane:	0.001	0.001
Propylene:	0.001	0.001
Propane:	0.003	0.001
Isobutane:	nd	0.001
n-Butane:	nd	0.001
Butenes:	nd	0.001
Isopentane:	nd	0.001
n-Pentane:	nd	0.001
Pentenes:	nd	0.001
Hexanes +:	nd	0.001

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. -- = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

Elemental Composition (Normalized, % w/w)

Element		Result
Carbon Content (% C, w/w):	----------	68.3
Hydrogen Content (% H, w/w):	----------	22.6
Oxygen Content (% O, w/w):	----------	1.15
Nitrogen Content (% N, w/w):	----------	7.94

Heat of Combustion & Physical Properties (by ASTM D 3588-91)

I. @ ASTM Base Conditions; 14.696 psia, 60°F, dry gas format		Result
Net Heat of Combustion	(Lower Heating Value, Btu/ft^3):	860
Gross Heat of Combustion	(Higher Heating Value, Btu/ft^3):	956
Gross Heat of Combustion	(Water Saturated Gas Format, Btu/ft^3):	939
Net Heat of Combustion	(Lower Heating Value, Btu/lb):	19,486
Gross Heat of Combustion	(Higher Heating Value, Btu/lb):	21,643
Molecular Weight:		16.76
Density (lb/ft^3):		0.0442
Specific Gravity (vs. dry/normal air):		0.5786
Compressibility Factor (z):		0.9981

II. @ ASME Base Conditions; 14.73 psia, 60°F, dry gas format		Result
Net Heat of Combustion	(Lower Heating Value, Btu/ft^3):	862
Gross Heat of Combustion	(Higher Heating Value, Btu/ft^3):	958
Gross Heat of Combustion	(Water Saturated Gas Format, Btu/ft^3):	941
Net Heat of Combustion	(Lower Heating Value, Btu/lb):	19,486
Gross Heat of Combustion	(Higher Heating Value, Btu/lb):	21,643

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

High BTU Gas

Volatile Sulfur Compounds (VSC, ppm v/v)	Result ppm v/v	DL ppm v/v
Hydrogen Sulfide:	0.1	0.1
Carbonyl Sulfide:	0.2	0.1
Sulfur Dioxide:	nd	0.1
Methyl Mercaptan:	nd	0.1
Ethyl Mercaptan:	nd	0.1
Dimethyl Sulfide:	nd	0.1
Carbon Disulfide:	nd	0.1
Isopropyl Mercaptan:	nd	0.1
t-Butyl Mercaptan:	nd	0.1
n-Propyl Mercaptan:	nd	0.1
Methyl Ethyl Sulfide	nd	0.1
sec-Butyl Mercaptan:	nd	0.1
Thiophene	nd	0.1
Isobutyl Mercaptan:	nd	0.1
Diethyl Sulfide:	nd	0.1
n-Butyl Mercaptan:	nd	0.1
Dimethyl Disulfide:	nd	0.1
3-Methylthiophene:	nd	0.1
Tetrahydrothiophene	nd	0.1
2-Ethylthiophene:	nd	0.1
2,5-Dimethylthiophene:	nd	0.1
Diethyl Disulfide:	nd	0.1
Unknown Sulfur Compounds:	nd	0.1

Comments: Total Sulfur (as H_2S) = 0.3 ppm v/v

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

High BTU Gas

GC/MS Result

TO-14 Target List

Target Analyte	Pk ID/Cat Scan No.	Amt. ppm v/v
Freon-12	--/157	nd 0.5
Methyl Chloride	--/171	nd 0.5
Freon-114	--/166	nd 0.5
Vinyl Chloride	--/172	nd 0.5
Methyl Bromide	--/197	nd 0.5
Ethyl Chloride	--/204	nd 0.5
Freon-11	--/222	nd 0.2
Vinylidene Chloride	--/256	nd 0.2
Freon-113	--/310	nd 0.2
Dichloromethane	--/271	nd 0.2
1,1-Dichloroethane	--/376	nd 0.2
cis-1,2-Dichloroethyle	--/406	nd 0.2
Chloroform	--/448	nd 0.2
1,1,1-Trichloroethane	--/503	nd 0.2
1,2-Dichlorethane	--/512	nd 0.2
Benzene	--/547	nd 0.2
Carbon Tetrachloride	--/568	nd 0.2
1,2-Dichloropropane	--/669	nd 0.2
Trichloroethylene	--/655	nd 0.2
cis-1,3-Dichloropropylene	--/793	nd 0.2
trans-1,3-Dichloropropylene	--/870	nd 0.2
Toluene	--/858	nd 0.1
1,1,2-Trichloroethane	--/890	nd 0.1
1, 2-Dibromoethane	--/988	nd 0.1
Tetrachloroethylene	--/984	nd 0.1
Chlorobenzene	--/1101	nd 0.1
Ethylbenzene	--/1128	nd 0.1
m+p-Xylenes	--/1149	nd 0.1
Styrene	--/1209	nd 0.1
o-Xylene	--/1214	nd 0.1
1,1,2,2-Tetrachloroethane	--/1258	nd 0.1
4-Ethyltoluene	--/1388	nd 0.1
1,3,5-Trimethylbenzene	--/1404	nd 0.1
1,2,4-Trimethylbenzene	--/1468	nd 0.1
1,3-Dichlorobenzene	--/1516	nd 0.2
1,4-Dichlorobenzene	--/1530	nd 0.2
Benzylchloride	--/1534	nd 0.2
1,2-Dichlorobenzene	--/1587	nd 0.2
1,2,4-Trichlorobenzene	--/1903	nd 0.2
Hexachlorobutadiene	--/1979	nd 0.2

Comments:

NOTES: **DL** = test detection limit. **nd** = less than the test detection limit. **na** = value is non-applicable. **--** = test not performed. **v/v** = volume analyte / volume sample. **w/w** = weight analyte / weight sample. **µL** = microliter. **µg** = microgram. **LT** = less than amount specified. **GT** = greater than amount specified. **%** = parts per hundred. **ppm** = parts per million. **ppb** = parts per billion.
Unit Conversions: 0.0001% = 1 ppm = 1,000 ppb = 1µL/L (v/v) or 1µg/g (w/w)

High BTU Gas

Toxic Substances Sub-17 Extended List

Compound	Cat/Scan No.	Amt. ppb v/v	DL ppb v/v
Chloroform	--/446	nd	10
1,2-Dichloroethane	--/527	nd	10
Benzene	--/561	nd	10
Carbon Tetrachloride	--/560	nd	10
Trichloroethylene	--/665	nd	10
1,4-Dioxane	--/698	nd	10
1,1,2-Trichloroethane	--/878	nd	10
1,2-Dibromoethane	--/930	nd	10
Tetrachloroethylene	--/990	nd	10
1,1,2,2 Tetrachloroethane	--/1267	nd	10
Methylene Chloride	--/286	nd	10
1,1,1-Trichloroethane	--/516	nd	10

Siloxanes (by GC/MS)

Target Analyte	Pk. ID. Cat./ Scan	Amt. ppb v/v	DL ppb v/v
Hexamethyldisiloxane (MM)	--/371	nd	20
Hexamethylcyclotrisiloxane (D3)	--/625	nd	20
Octamethyltrisiloxane	--/706	nd	20
Octamethylcyclotetrasiloxane (D4)	--/849	nd	20
Decamethyltetrasiloxane	--/914	nd	20
Decamethylcyclopentasiloxane (D5)	--/1024	nd	20
Dodecamethylpentasiloxane	--/1086	nd	20
Other Siloxanes	--/Various	nd	50

Peak ID Category:
A = computer library match **GT 900** and **retention time (t_r) match** with calibration standard.
B = computer library match **GT 900** but **not** confirmed by calibration standard.
C = computer library match **between 800 and 900** but **not** confirmed by calibration standard.
D = computer library match **LT 800**, potential structure and functional group information only.

Reviewed By,

Richard F. Frisch

Attachments: None
Chromatograms on file; Notebook data on file

EXHIBIT B

SWACO Green Energy Center
Final Scientific Report

Sample Production Reports

Gas Made

Run time start	2010/04/19 13:07
Run duration	336ms
Date range	2010/04/15 10:29 to 2010/04/15 12:00
Records	158

Statistics

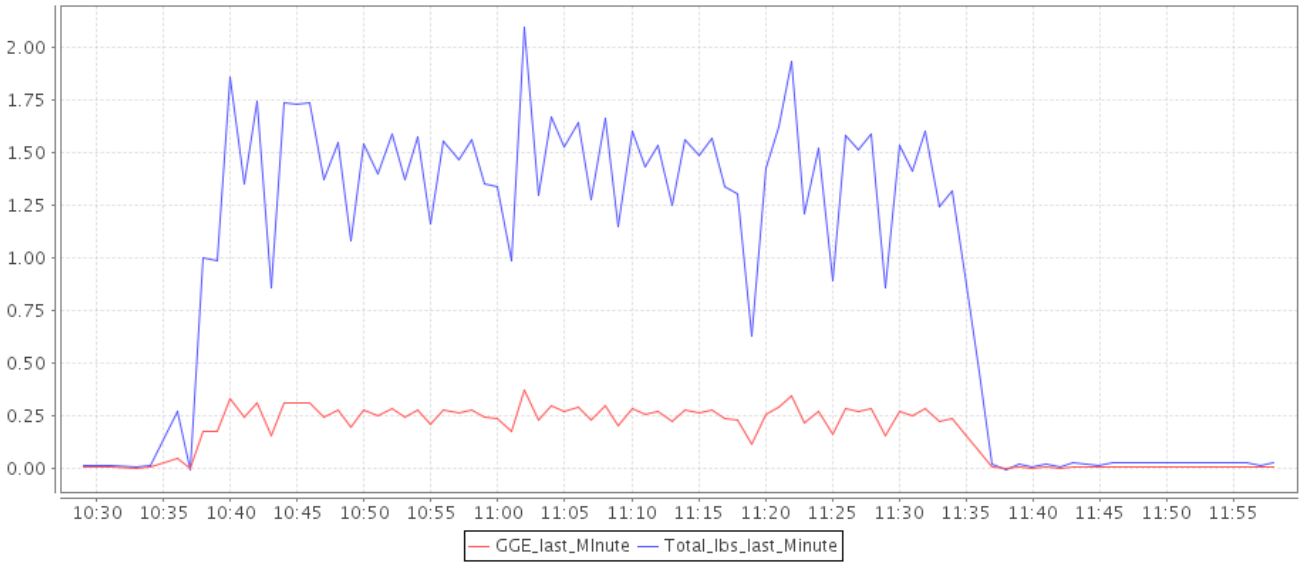
GGE_last_MInute

Data type	Numeric
Start	-0.0752
Minimum	-0.0752 @ 2010/04/15 10:29
Maximum	0.3698 @ 2010/04/15 11:02
Average	0.1617
Sum	14.6667
Count	79

Total_lbs_last_Minute

Data type	Numeric
Start	-0.42541708052158356
Minimum	-0.42541708052158356 @ 2010/04/15 10:29
Maximum	2.093228578567505 @ 2010/04/15 11:02
Average	0.9150695598993005
Sum	83.01373937900644
Count	79

Consolidated chart



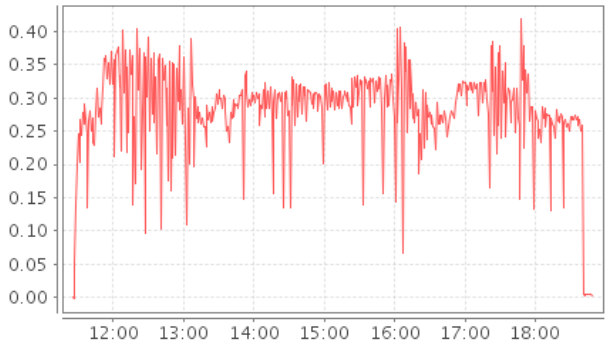
Gas Made

Run time start	2010/04/22 08:04
Run duration	1.1s
Date range	2010/04/21 11:25 to 2010/04/21 18:50
Records	886

Statistics

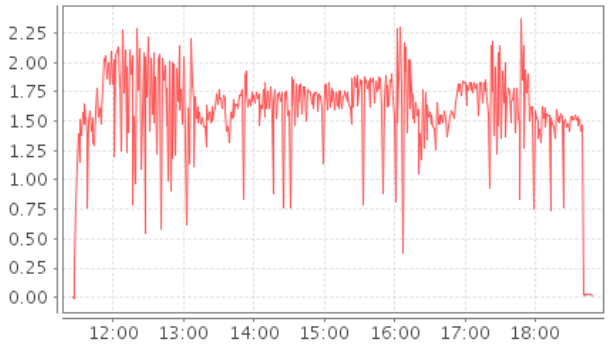
GGE_last_MInute

Data type	Numeric
Start	0.0010
Minimum	-0.0010 @ 2010/04/21 11:26
Maximum	0.4182 @ 2010/04/21 17:48
Average	0.2800
Sum	124.5911
Count	443

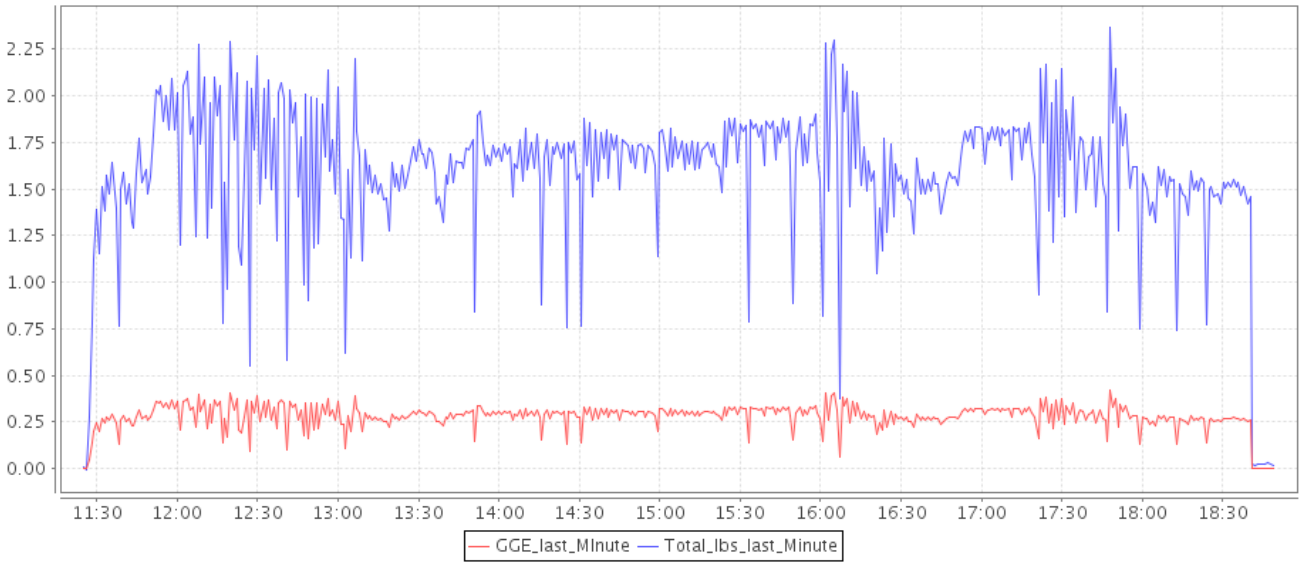


Total_lbs_last_Minute

Data type	Numeric
Start	0.005888125393539667
Minimum	-0.005888125626370311 @ 2010/04/21 11:26
Maximum	2.367026448249817 @ 2010/04/21 17:48
Average	1.5848120361500497
Sum	705.1854755666573
Count	443



Consolidated chart



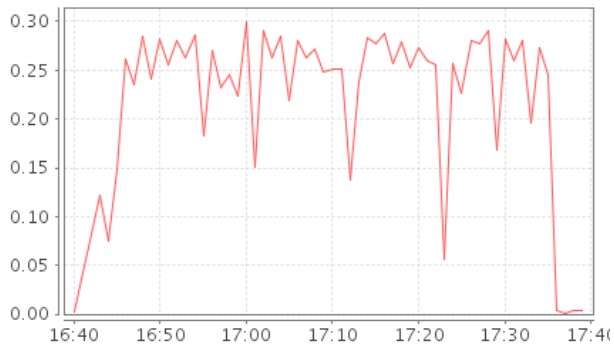
Gas Made

Run time start	2010/04/23 22:08
Run duration	542ms
Date range	2010/04/23 16:40 to 2010/04/23 17:40
Records	116

Statistics

GGE_last_MInute

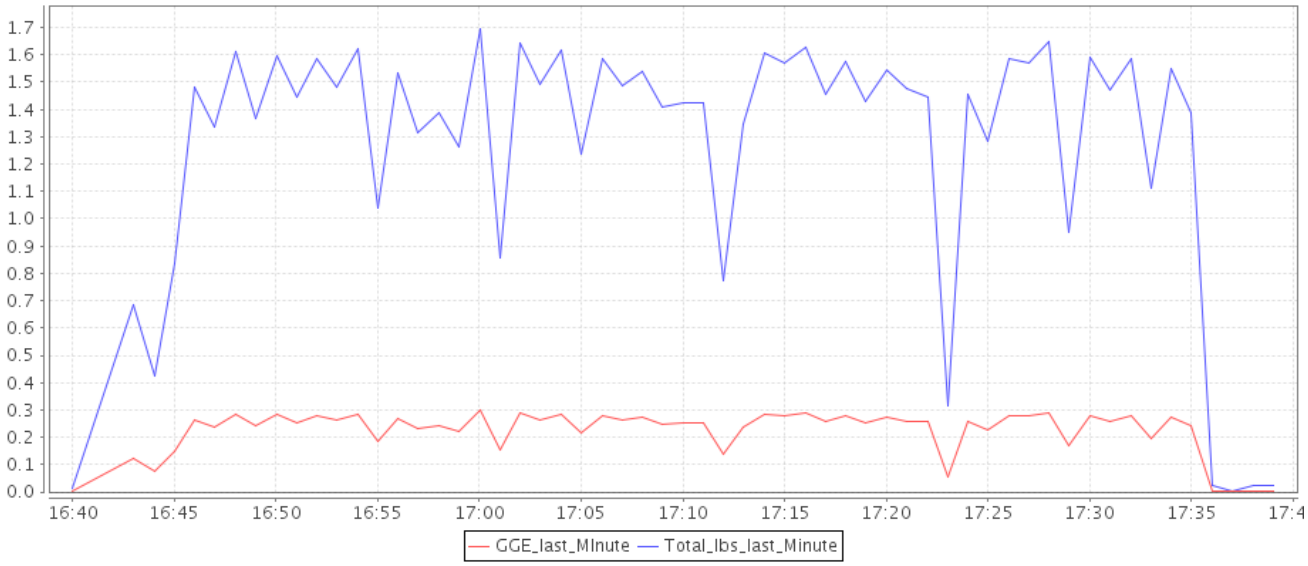
Data type	Numeric
Start	0.0029
Minimum	0.0008 @ 2010/04/23 17:37
Maximum	0.2996 @ 2010/04/23 17:00
Average	0.2146
Sum	12.8714
Count	58



Total_lbs_last_Minute

Data type	Numeric
Start	0.016192345414310694
Minimum	0.00441609404515475 @ 2010/04/23 17:37
Maximum	1.6957802176475525 @ 2010/04/23 17:00
Average	1.2146957487343337
Sum	72.85230635653716
Count	58

Consolidated chart



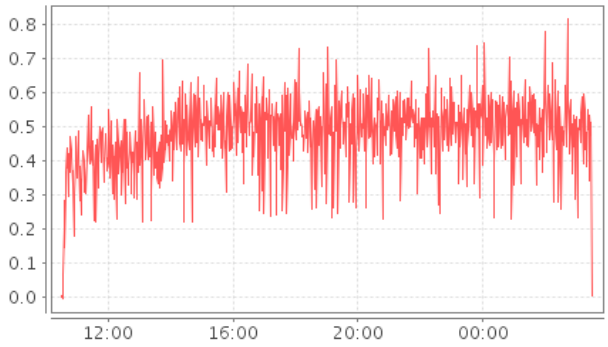
Gas Made

Run time start	2010/04/27 14:39
Run duration	677ms
Date range	2010/04/26 10:30 to 2010/04/27 03:30
Records	2040

Statistics

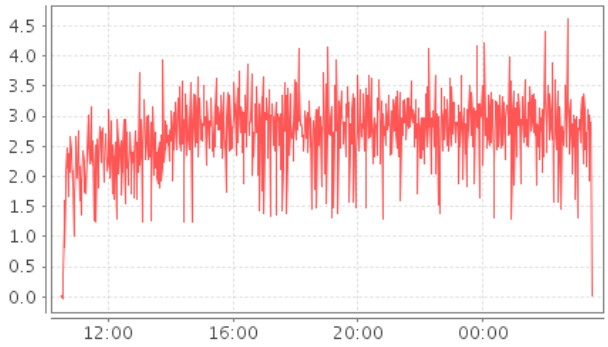
GGE_last_MInute

Data type	Numeric
Start	0.0010
Minimum	-0.0042 @ 2010/04/26 10:33
Maximum	0.8146 @ 2010/04/27 02:42
Average	0.4776
Sum	487.1730
Count	1020

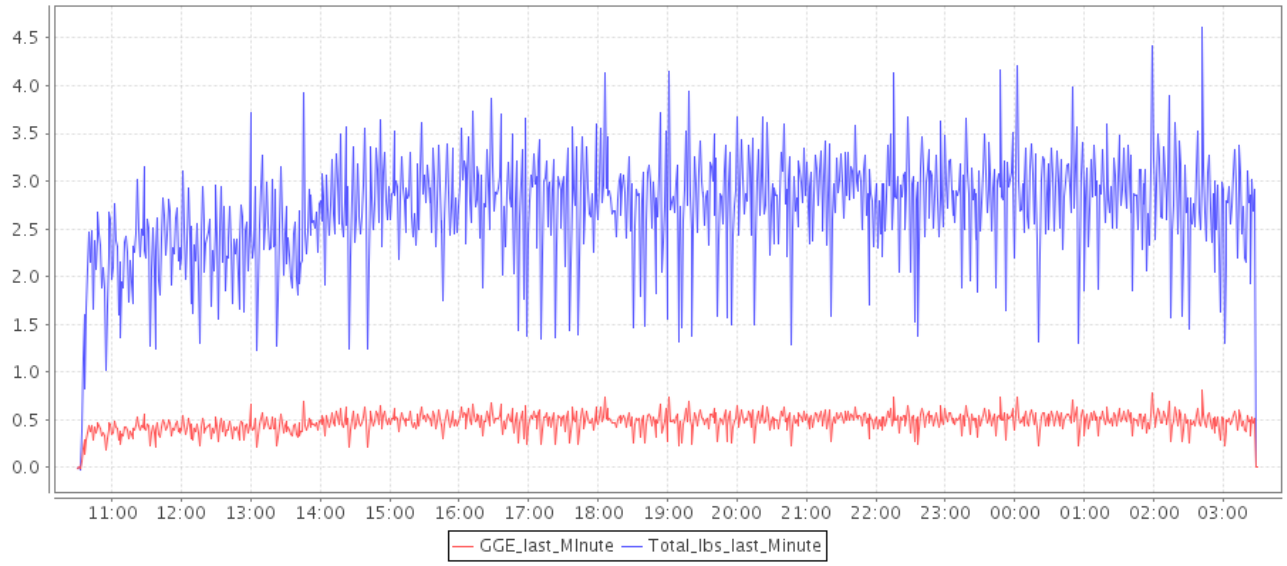


Total_lbs_last_Minute

Data type	Numeric
Start	0.005888125393539667
Minimum	-0.02355250157415867 @ 2010/04/26 10:33
Maximum	4.610402584075928 @ 2010/04/27 02:42
Average	2.7033319799020927
Sum	2757.398922427868
Count	1020



Consolidated chart



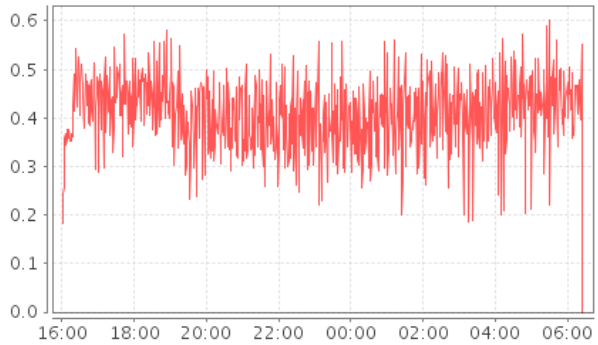
Gas Made

Run time start	2010/04/09 09:38
Run duration	458ms
Date range	2010/04/08 16:00 to 2010/04/09 06:26
Records	1728

Statistics

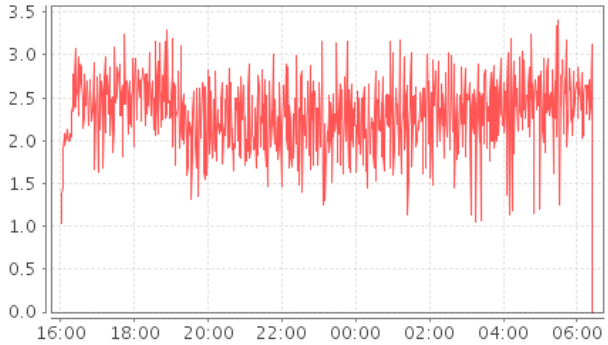
GGE_last_MInute

Data type	Numeric
Start	0.0021
Minimum	0.0000 @ 2010/04/09 06:25
Maximum	0.6021 @ 2010/04/09 05:30
Average	0.4076
Sum	352.6329
Count	864

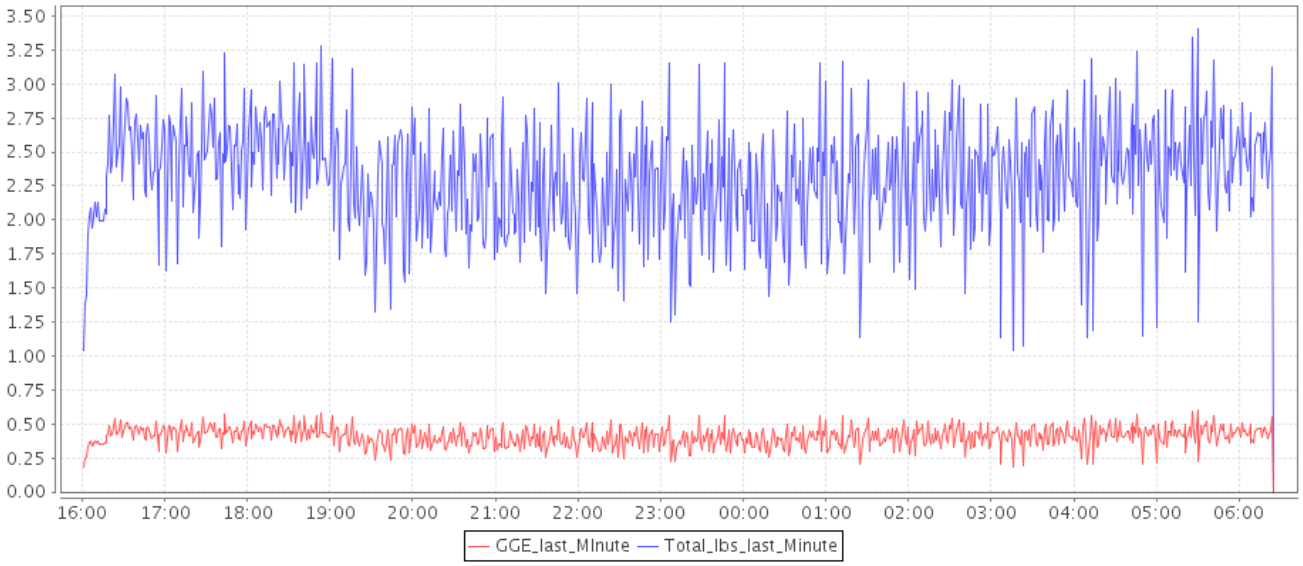


Total_lbs_last_Minute

Data type	Numeric
Start	0.011776250787079334
Minimum	0.0 @ 2010/04/09 06:25
Maximum	3.4077526330947876 @ 2010/04/09 05:30
Average	2.3069404766070605
Sum	1995.9023531088606
Count	864



Consolidated chart



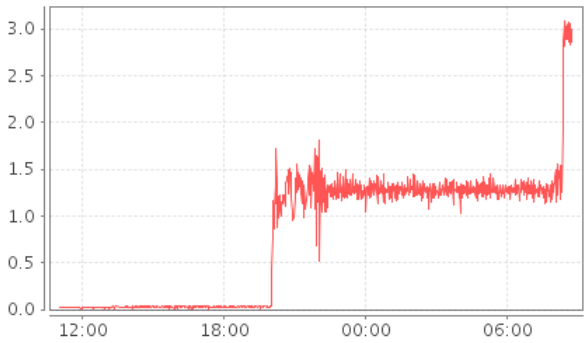
gasmade

Run time start 2010/06/25 08:44
Run duration 1.47s
Date range 2010/06/24 11:00 to 2010/06/25 08:44
Records 5489

Statistics

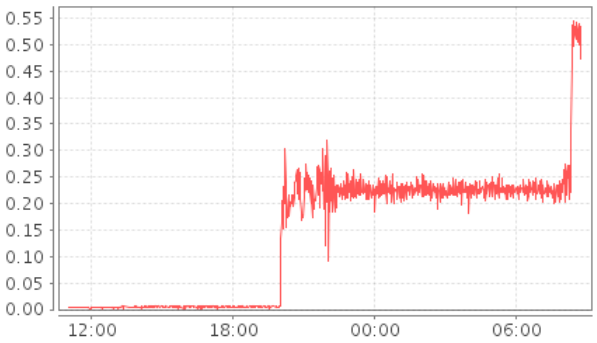
Total_lbs_last_Minute

Data type Numeric
Start 0.013248282833956182
Minimum 0.0 @ 2010/06/24 11:56
Maximum 3.1368988752365112 @ 2010/06/25 08:33
Average 0.7881691173730503
Sum 1024.8179571256042
Count 1162



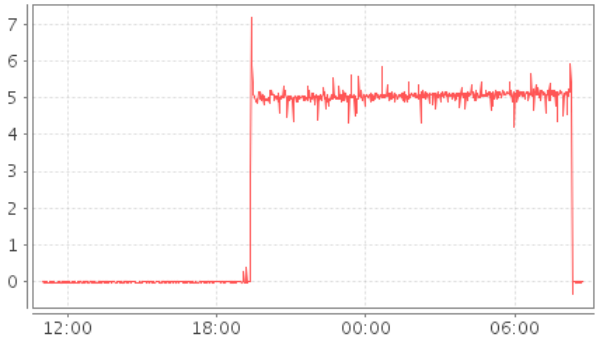
GGE_last_MInute

Data type Numeric
Start 0.0023
Minimum 0.0000 @ 2010/06/24 11:56
Maximum 0.5542 @ 2010/06/25 08:33
Average 0.1393
Sum 181.0632
Count 1162



FT-551

Data type Numeric
Start -0.0.#/m
Minimum -1.3.#/m @ 2010/06/25 08:19
Maximum 8.5.#/m @ 2010/06/25 08:13
Average 3.0.#/m
Sum 10373.5.#/m
Count 3165



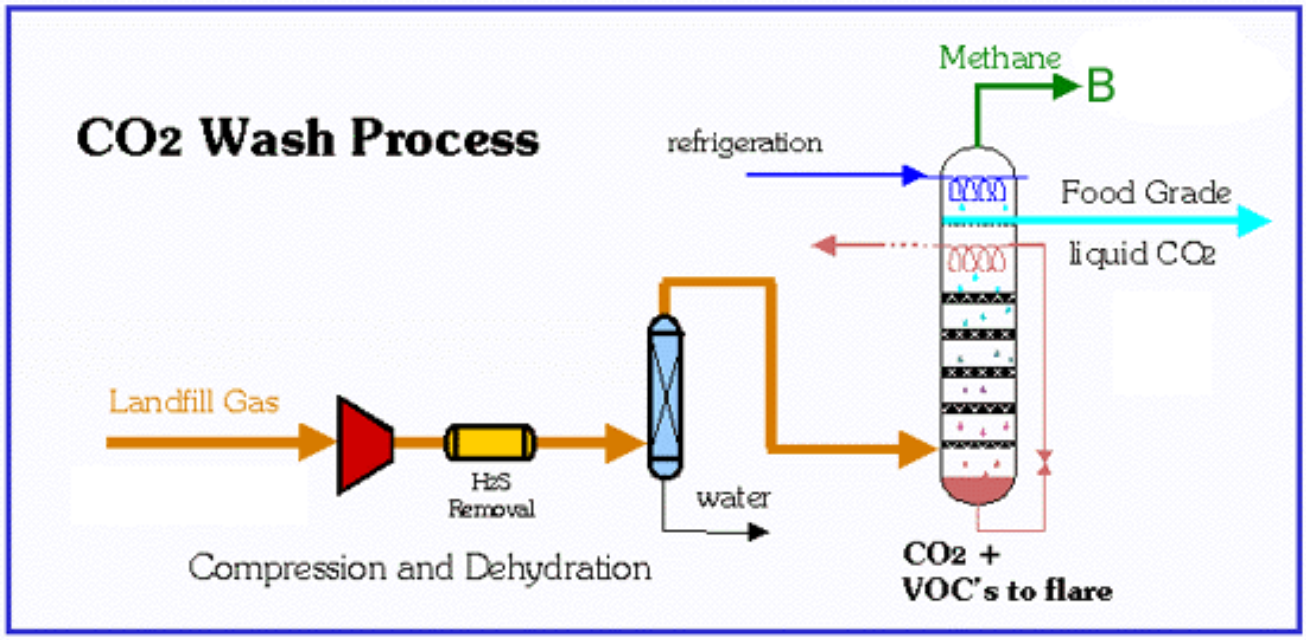
Consolidated chart

EXHIBIT C

SWACO Green Energy Center
Final Scientific Report

Process Flow Diagram

The CO2 Wash™ produces a primary methane stream consisting of approximately 60% methane, and 40% CO2, which is equivalent to medium-Btu pipeline gas (600 Btu/scf). The medium Btu fuel can be used in the MT 250 to power the facility of further polished into a high Btu product.



The primary methane stream is suitable for direct use as medium Btu fuel, or can be routed to a secondary processing stage for further CO2 removal. This secondary process is what generates the high Btu gas that can be used as a vehicle fuel.

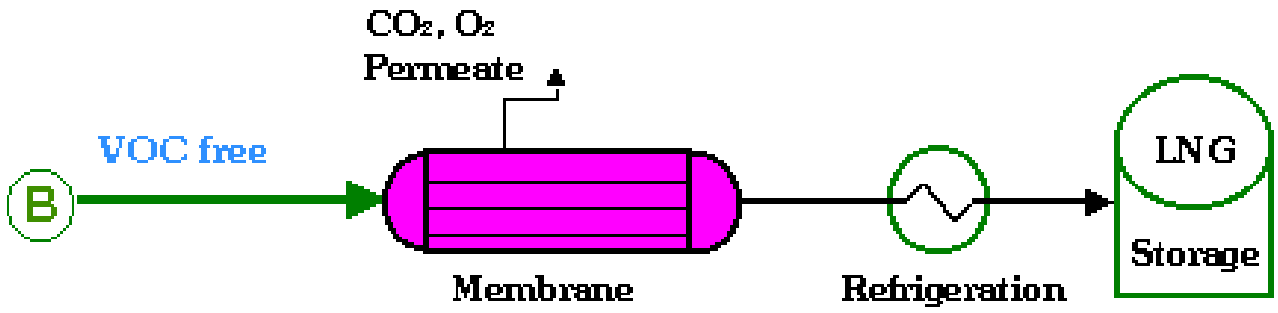


EXHIBIT D

SWACO Green Energy Center
Final Scientific Report

Publications

GREEN ENERGY CENTER

FUELING UP ON LANDFILL GAS

While the flare (at right above) is the Maximum Achievable Control Technology required for collected landfill gas, SWACO wanted to go beyond that level of compliance and recover energy and fuels.

Solid Waste Authority of Central Ohio launches into a multiphase public/private partnership to convert landfill gas into biofuels and other high-value end products.

Nora Goldstein

THE Solid Waste Authority of Central Ohio (SWACO) operates a 142-acre municipal solid waste landfill to service the Columbus, Ohio metro region. The Franklin County landfill, which opened in 1985 and receives about 3,500 tons/day of MSW, has another 221 acres of expansion capacity. Because of the size of its landfill, SWACO was required to install a landfill gas collection system and a flare, the Maximum Achievable Control Technology (MACT) as required by the U.S. Environmental Protection Agency. While the flare addressed the MACT requirement, it created an air quality concern.

"Like so many things we do, solving one environmental problem creates others," says Michael Long, SWACO's Executive Director. "When we burn the flare, we release carbon monoxide (CO) and NOX into the atmosphere, and there is no energy recovery. Upon analyzing the situation, we recognized that we were dealing with a couple of valuable resources — methane and carbon dioxide — and decided to explore options that would enable us to utilize those resources, send a minimum amount of BTUs to the flare to destroy the NMOC (non-methane organic compounds), and minimize the production of NOX and CO."

A traditional landfill gas to energy recovery system was a challenge because of access to the electric grid. "Just because the technology exists to produce electricity doesn't mean the landfill will always have easy access to the end user," adds Long. "We are in the service area of the electric utility, and we can't run a parallel wire to them to distribute power. There also were tariffs, and the issue of how much the utility would pay for the electricity."

That reality led SWACO to look around for other end uses for the landfill gas. Underlying the search was the mindset that the solution(s) had to offer flexibility in the end products generated to take advantage of market and regulatory fluctuations. "We didn't want to make a major commitment of capital to one technology that may be viewed now as a winner," he explains. "During the energy crisis of the 1970s, the City of Columbus built a waste-to-energy power plant. Every prediction was wrong at that time, from interest rates and electricity prices to construction costs and running out of landfill space. Everything that pointed toward that project being feasible was not correct. So when we are talking about significant capital investments today, we need to be smarter about our approach, especially with landfill gas. We were looking for a project that generated a variety of products, where we can shift from one end product to another, depending on the end markets."

SWACO learned about the landfill gas recovery initiatives at the Burlington County, New Jersey Resource Recovery Complex. The Resource Recovery Complex includes an active bioreactor landfill (and a closed landfill), a biosolids composting operation, a greenhouse heated and powered with landfill gas, and a wood recycling operation. Also colocated at the site is the Rutgers University EcoComplex, a business incubator for environmentally-based companies. (See "Landfill Gives Birth To Ecoindustrial Complex," December 2004 (Part I), and March 2005 (Part II)). One tenant of the incubator was Acrion Technologies, Inc. (based in Cleveland, Ohio), which developed a carbon dioxide wash system to clean up landfill gas for multiple uses, including food grade liquid CO_2, and methane that can be converted to vehicle fuel as liquid (LNG) or compressed natural gas (CNG), methanol or pipeline quality natural gas.

"We toured the EcoComplex in 2003, and met with Acrion, and what we saw was an opportunity to have multiple markets for our landfill gas," explains Long. "We also saw the advantage of working with a private partner who has the ability to change that mix of end products according to market demand and new opportunities. As a lo-

cal government agency, we do not have the expertise or the resources to do all of these things. We created a private sector partnership with Acrion and FirmGreen Energy (FirmGreen™), a California company that is a licensee of the patented Acrion CO_2 Wash® technology. Together, the public-private partnership has a mission to utilize more than 750 billion BTUs of thermal energy from our landfill in an environmentally responsible way."

Acrion's CO_2 Wash technology removes hydrogen sulfides, VOCs and siloxanes out of the raw landfill gas. Carbon dioxide, recovered from the landfill gas and converted to liquid form, is used to wash out the impurities. CO_2 Wash product, a contaminant-free mix of roughly 70 percent methane and 30 percent CO_2, can be used directly as fuel to generate electricity or as feedstock for synthetic chemicals such as methanol. Further separation of CO_2 produces methane suitable for pipeline injection or vehicle fuel. A second product, ultra pure CO_2, has many uses including food freezing, chemical reagent, inerting gas, greenhouse plant nutrient, and dry ice manufacture.

The Green Energy Center (artist rendering at left) will house several carbon dioxide wash systems (above) that remove contaminants from landfill gas and yield a mix of methane and CO_2.

GREEN ENERGY CENTER

SWACO's first stop on its renewable energy journey is the Green Energy Center, located next to the Franklin County landfill. A groundbreaking ceremony for the Green Energy Center, which is being developed in three phases, took place in June 2005. Components of the Center include: CO_2 Wash®; Carbon Dioxide Sequestration; Electrical Generation (via microturbine); Methanol Synthesis (reforming methane to synthesis gas for conversion to methanol, which then can be used to produce biodiesel): CNG and Biodiesel for Vehicle Fuel; Optional Gas to Pipeline; Optional IC (internal combustion) Engine Electrical Generation; Greenhouse Operation using the CO_2; and Hydrogen Fuel Research and Development.

Phase I, which is now under construction, is expected to be operational by this fall. SWACO will own and operate Phase I. "It involves taking a small amount of the landfill gas and running it through a 300 cfm CO_2 wash," says Long. "Some of the methane will be compressed into CNG and used to power our fleet of vehicles. The remainder of the natural gas will be run into a 250 kW Ingersoll Rand microturbine with waste heat recovery. We will use the outputs of the microturbine at our administration and maintenance buildings. We believe that we will save about 10 percent on our electric bill, 15 percent on our propane use, and produce the CNG necessary to eventually operate our truck fleet and potentially sell excess CNG to local governments. The current 300 cfm design is capable of producing up to 650 gallons of diesel equivalent energy content CNG per day. Our goal with Phase I is to demon-

SWACO had one of its fleet trucks retrofitted with a dual-fuel system powered by CNG and biodiesel. The 300 cfm CO2 wash system being installed in Phase I will produce up to 650 gallons/day of diesel equivalent energy content CNG.

strate that the technology works and we are going to get some immediate benefit."

Long adds that SWACO identified a company in Atlanta that can retrofit its fleet of trucks to run on CNG. Four tanks each hold the equivalent of 40 gallons of diesel. The tanks get placed behind the truck cab. Last year, SWACO took delivery of a 2005 Ford Sterling truck with a 12.7-Detroit series 60 diesel engine that was retrofitted to be a dual-fuel system powered by CNG and biodiesel. The current price of CNG is about $2/diesel gallon equivalent; SWACO expects its net costs will be about $1/diesel gallon equivalent. Between the buildings and the vehicles, he anticipates a direct savings in energy and fuel costs of over $150,000/year from this Phase I project.

METHANOL AND BIODIESEL PRODUCTION

Phase II, to be developed and owned by FirmGreen, will involve installation of two CO_2 Wash units for a total of 2,500 cfm of landfill gas processing capacity. The methane will be reformed into methanol; production capacity is up to 20 million gallons/year. A portion of the methanol has been presold to Mitsubishi Gas Chemical America, Inc. The remainder of the methanol will be converted into biodiesel. FirmGreen has a contract with a soybean farmers cooperative located south of Columbus. The co-op will crush the beans and bring the soybean oil to the landfill for reacting with the methanol to create biodiesel. The 100 percent biodiesel will be blended to produce an estimated 100 million gallons/year of B-20 fuel, according to FirmGreen. Construction of Phase II is scheduled for fall of 2007, with completion in the last quarter of 2008.

Phase III of the project involves installing IC engines (6.5 MW) and a greenhouse at the landfill to utilize pure CO_2 from the wash process. "At the Rutgers Eco-Complex greenhouse, we saw that injecting CO_2 into the greenhouse causes a significant increase in productivity of the crop, in this case tomatoes," says Long. "Another possible end product is dry ice, which is being used increasingly as a refrigerant in the trucking industry to reduce fuel use and the load on the truck." In Phase III, FirmGreen will also increase electricity production from the landfill gas for sale to the grid.

A traditional landfill gas to energy recovery system was a challenge because of access to the electric grid.

Permitting for Phase I has gone relatively smoothly, in part because the units being installed are small and are exempt from air quality regulations. Building and construction permits are in hand. Phase II permitting is more complicated due to the methanol plant, and Phase III will be equally complex because of the electricity generation and grid connections. The air permits for Phases I and II have been approved.

An anticipated overall benefit in terms of air quality is the reduction of hazardous air pollutants. The landfill is limited to 250 tons/year of carbon monoxide emissions. "We were pushing that limit last year, even with installation of an enclosed flare in 2005," says Rick Dodge, SWACO's Director of Environmental Compliance. "But with the installation of the CO_2 Wash system, we expect to reduce carbon monoxide emissions to the point where we will never exceed that limit." Long adds that SWACO, as the enforcement agency, will be overseeing air emissions compliance, so will know immediately if the wash system is effective at reducing CO in the flare.

ECOINDUSTRIAL PARK

With its $18 million Green Energy Center on its way to becoming a reality, SWACO has its sights on other environmentally sustainable initiatives. The former waste-to-energy plant site built by the City of Columbus is being transformed into an ecoindustrial complex. One of the first tenants will be Rastra Technologies Inc., a building products company that plans to locate a factory to manufacture building panels out of ground polystyrene and cement. The panels are used for home and commercial construction. Over 80 percent of the Rastra panels are made from recycled product. SWACO's Franklin County Landfill receives at least five tractor-trailer loads of polystyrene daily, which adds up to almost 87,000 cubic yards annually or 6 percent of the total yearly capacity at the landfill, according to SWACO.

Also on the site will be an expansion of The Grossman Group's paper recycling operation, currently located in the last remaining trash plant building. This expansion will add another 28,000 square feet to the 14,000 square feet already in use. Grossman Group's recycling operation diverts over 50 tons/day of paper from the landfill.

Energy to power the new businesses will also come from "green" sources. Kurtz Brothers plans to build an anaerobic digester on SWACO property next to the site. The digester will take organic materials, including biosolids, food residuals and yard waste, and turn the mix into energy.

"Everyone benefits from this initiative," says Long. "When we consider all possibilities, we can better our environment, help our economy, and provide new energy." ■

BioCycle energy

SWACO's Green Energy Center opened for business in mid-September, with its CNG fuel pumps (in foreground) ready to service fleets — at a price well under $3/gallon.

GREEN ENERGY CENTER

LANDFILL GAS TO FLEET FUEL IN OHIO

Solid waste authority in Ohio opens facility that converts landfill gas to compressed natural gas for use in fleet vehicles and medium duty trucks.

Nora Goldstein

IN mid-September, the Solid Waste Authority of Columbus, Ohio (SWACO) cut the ribbon on Phase I of its Green Energy Center that will convert landfill gas to compressed natural gas (CNG) for use in CNG-powered cars and medium duty trucks. The facility will produce enough CNG annually to replace almost 250,000 gallons of gasoline, plus additional natural gas sufficient to generate electricity for its own operations.

The first phase of the Green Energy Center is a public-private partnership between SWACO and FirmGreen Fuels, LLC. The facility collects and cleans raw landfill gas — primarily composed of methane and carbon dioxide, using CO_2 Wash®, a patented technology developed in Ohio by Acrion Technologies.

"What started four years ago as a vision has now become reality. By making use of waste gases generated from SWACO's landfill, we will produce renewable transportation fuels and skilled jobs for Ohio," says Steve Wilburn, founder and CEO of FirmGreen, Inc.

SWACO is working to establish a consortium of local governments, school districts and private companies that are interested in adding CNG vehicles to their fleets. The CNG is available at a gasoline gallon equivalent rate of less than $3.00 — and much less if pumped directly from the Green Energy Center. "We will have plenty of fuel beyond what we could ever realistically use ourselves," says Ron Mills, SWACO's Executive Director. "This is the very first application of the Acrion technology anywhere in the world. We felt confident enough that it would work that we were willing to invest in the installation of a modest sized facility to demonstrate that it would perform as advertised to produce the quality of fuel needed. We plan to convert many of our vehicles and light-duty pickups to run on CNG within the next 18 months, and hope to see it used in our heavy-duty trucks as soon as possible."

PROJECT BACKGROUND

SWACO operates a 142-acre municipal solid waste landfill to service the Columbus, Ohio metro region. The Franklin County landfill, which opened in 1985 and receives about 3,500 tons/day of MSW, has about 200 acres of expansion capacity. Because of the size of its landfill, SWACO was required to install a landfill gas collection system and a flare. Recognizing that the flare releases carbon monoxide

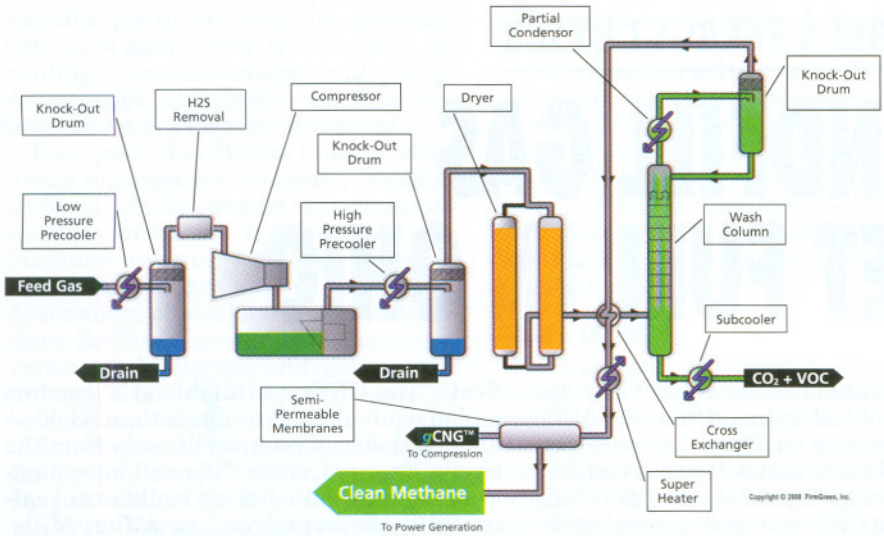
School districts getting hit with budget-breaking costs for diesel fuel are good candidates for CNG-powered buses.

and NOX into the atmosphere — and that the landfill gas itself contains methane and CO_2, which have resource value — SWACO decided to explore options available to utilize the resources.

The more traditional landfill gas to electric system was a challenge because of access to the grid, as well as the low price paid by the utility for the electricity. While researching alternatives, SWACO learned about the Acrion CO_2 wash system, which was operating on a pilot basis at the Burlington County (New Jersey) Resource Recovery Complex. SWACO's previous executive director, Mike Long, toured the installation in Burlington County and ultimately decided to create a partnership with FirmGreen to install a CO_2 wash system at the SWACO landfill (see "Fueling Up On Landfill Gas," May 2007).

Acrion's CO_2 Wash technology removes hydrogen sulfides, VOCs and siloxanes out of raw landfill gas. Carbon dioxide, recovered from the landfill gas and converted to liquid form, is used to wash out the impurities. The CO_2 Wash product, a contaminant-free mix of roughly 70 percent methane and 30 percent CO_2, can be used to generate electricity. Further separation of CO_2 produces methane suitable for pipeline injection or vehicle fuel.

Figure 1. Schematic of CO2 Wash® system and CNG production



Groundbreaking on the Green Energy Center was held in June 2005. Elements of the center are being developed in phases. Phase I was financed and developed by SWACO. Capital costs were about $4.5 million. Phase II is being developed (and will be owned) solely by FirmGreen. At full build-out of Phase II, FirmGreen will process 4,000 MMBtu/day of landfill gas using the CO_2 Wash technology. With CO_2 production, yields are expected to equal about 25,900 diesel gallons (DGE)/day as CNG and 132 tons/day of CO_2.

"This amount of CNG production can displace the use of 9.1 million gallons of diesel fuel or 10.3 million gallons of gasoline annually," notes Rhonda Howard, Communications Director of FirmGreen, which is based in Newport Beach, California. "Our ability to produce a fuel that meets natural gas pipeline specifications as well as vehicle and truck engine specifications (ASTM) provides us marketing flexibility."

There is currently a 30-year supply of gas in SWACO's Franklin County Landfill. Phase I of the Green Energy Center will tap approximately 8 percent of that supply. "We are relying on FirmGreen to take the balance of the gas — 92 percent — that is available," says Mills. "Groundbreaking and construction of Phase II of the Center could happen in a matter of months."

CNG VEHICLE AND TRUCK ENGINES

With the CNG production facility up and running at the Green Energy Center, the next step is supply fuel to vehicles and trucks equipped with CNG engines. At this point in time, however, the number of vehicles equipped with those engines is limited. "It is the proverbial chicken-and-egg situation," says Mills. "One reason we don't have more trucks and vehicles with CNG engines is the lack of access to CNG. There are light-duty passenger vehicles and pickup trucks, as well as light-duty construction equipment, being converted to run on CNG. I don't think it will be that long before we start seeing more production of CNG-powered vehicles as it is not a big challenge from an engine perspective. But right now, people committed to driving a CNG vehicle either have to purchase that vehicle in a state where dealerships are licensed by auto manufacturers to sell CNG light-duty vehicles, or buy a conventional vehicle and have it converted to a CNG engine. Either option means the consumer will be paying anywhere from 30 to 50 percent more to get it equipped. That is an important barrier in the marketplace right now and one that elected officials are paying attention to."

That cost may be a barrier for individual consumers, however the price differential when considering a higher cost pickup truck or a school bus becomes less significant, he adds. "Because the starting sticker price is higher, retrofitting those vehicles with a CNG engine is a smaller portion of the total cost. For example, a pickup truck with a gasoline engine may be $50,000; with a CNG engine, it could cost $70,000, which is a smaller differential when considering the lower cost fuel."

School districts that are getting hit with budget-breaking costs for diesel fuel this year also are good candidates for CNG-powered buses. "Again, there may be a 20 percent difference in the sticker price, but if a school district can realize significant savings by using a lower cost fuel, the payback on the investment becomes very practical," says Mills.

While school districts near the Green Energy Center have access to CNG, much

The solid waste authority's CNG-powered Honda Civic is parked next to a CNG fuel pump during the recent ribbon-cutting event.

wider infrastructure is needed to truly make this conversion to an alternative fuel feasible. "Our primary barrier remains infrastructure — how to deliver the fuel to fleets," says Rhonda Howard. The access issue makes waste collection trucks an ideal candidate for an engine conversion — if they are using a disposal facility that captures and converts landfill gas to CNG. "If a fueling station is at the landfill, haulers can drop off the trash, go to the fuel station, and go back out on their routes," she adds.

Howard notes that the CO_2 Wash technology can work with biogas produced by anaerobic digesters, but it may not be an ideal application. "The real advantages of the CO_2 wash is its ability to effectively screen out all kinds of contaminants, such as are found in landfill gas," she says. "Other technologies are designed to clean out one contaminant, but not another. In addition, the wash system uses CO_2 as the solvent. As trash decomposes, it continuously generates CO_2 with the methane, so our solvent is continuously available. And because we aren't bringing any solvents to the site, the permitting process is simplified, reducing the time it takes to get a project going."

Recently, Ron Mills spent two days in Washington, D.C., meeting Congressional representatives from Ohio to tell them about the Green Energy Center and discuss the role that the federal government can play in providing incentives to promote development of the infrastructure needed to make this kind of fuel practical nationwide. "If enough people are buying the vehicles that use this fuel, more cars will be produced that can run on the fuel and the price differential will keep going down," says Mills. "We also discussed how there need to be numerous outlets for this fuel around the country. The federal government can help get this jump started."

Mills estimates that there are at least 100 MSW landfills in the U.S. that are the size of SWACO's Franklin County landfill. "Our landfill alone has the potential to replace 3 million gasoline gallon equivalents per year," which he says is a conservative estimate. "If the other landfills of our size installed a system like ours, it could be significant in a national strategy for energy independence." ■

Sunday, October 26, 2008 at 5:38 p.m.

GROVE CITY, OH (AP) -- Trash is being turned into gas near a landfill outside Columbus, where officials hope the cheap fuel - made from the methane that's naturally given off by rotting garbage - will eventually be used in local buses and other government vehicles.

Solid Waste Authority of Central Ohio officials said the landfill's new gas-producing facility is capable of processing 300,000 gallons. That's enough to possibly fuel Franklin County's entire fleet of 400 vehicles, said Charlotte Ashcraft, director of fleet management for the county.

But it's just a fraction of how much fuel the landfill could produce, considering how much methane is given off by the dump's waste, according to the authority director Ron Mills. About 92 percent of the landfill's methane is allowed to escape through two large venting stacks, he said.

A California company, FirmGreen Fuels, plans to invest $14 million to boost capacity even further, officials said. The landfill could produce 10 times more fuel at a cost of about $2 a gallon, only a little cheaper than the $2.50 a gallon for regular gas that many consumers are paying today.

But prices could easily rise again toward $4 a gallon, making the landfill-produced fuel even more attractive.

"It's not going to be the bargain when gas prices are where they are today," Mills said. "But who expects gasoline prices to stay in that range?"

The agency has been using the fuel in several of its vehicles, but Mills' ambition is to also run it in garbage trucks, Central Ohio Transit Authority buses and other local government vehicles.

But some area cities are wary about investing in natural gas. Gahanna is considering building a fueling station for its vehicles, but wants to wait to see how other cities use natural gas, service director Terry Emery said.

Franklin County already has two Ford sedans that run on natural gas and four vans used for animal control that use a mix of gasoline and natural gas, Ashcraft said.

But access to filling stations is a major problem, she said. The landfill's new station nearby would be only the second natural gas station in the area.

"If you get clear up at the north side of town and you run out of gas, you're in trouble. You can't just stop at a BP," Ashcraft said. "I think a lot of people are in the wait-and-let-somebody-else-do-it-first stage."

10. NOV 14 2009 6:00AM ET **MotorWeek** **Nielsen Audience: 2,586**
WOSU-PBS COLUMBUS, OH **Run Time: 1:34**

[06:06:49**]** OUR SUCCESS STORY OF THE WEEK COMES FROM GROVE CITY, OHIO, HOME OF THE **SOLID WASTE AUTHORITY** OF CENTRAL OHIO, WHERE THEY'RE TURNING TRASH INTO A RENEWABLE FORM OF NATURAL GAS. AT THIS SPECIALLY-BUILT **GREEN ENERGY CENTER**, MORE THAN 3,000 TONS OF TRASH IS DUMPED INTO **SWACO'S LANDFILL** EACH DAY. AS THE TRASH DECOMPOSES, IT RELEASES METHANE GAS, WHICH IS COLLECTED THROUGH A NETWORK OF PIPES. THE RAW GAS IS PROCESSED AND CLEANED THROUGH A SERIES OF STACKS AND TUBES LOCATED INSIDE THE ENERGY CENTER. THE RESULTING COMPRESSED NATURAL GAS IS USED TO POWER **SWACO'S** FLEET OF BI-FUEL PICKUP TRUCKS AND DEDICATED CNG CARS. **JOHN REMY**: PHASE ONE OF THE **GREEN ENERGY CENTER** AT **SWACO** USES ABOUT 8% OF THE AVAILABLE **LANDFILL** METHANE. THAT HAS THE CAPACITY TO CREATE 250,000 GASOLINE GALLON EQUIVALENTS ANNUALLY. JOHN: THAT'S A QUARTER OF A MILLION GALLONS OF GASOLINE THAT WON'T BE NEEDED! **SWACO** IS ALSO EDUCATING CONSUMERS WITH **LANDFILL** TOURS SHOWING COMMON WASTE BEING USED TO CREATE RENEWABLE, CLEANER FUEL. NO ONE WORKS CAR MAGIC LIKE OUR OWN PAT GOSS! SO LET'S SEE WHAT TRICKS HE HAS UP HIS SLEEVE THIS WEEK. PAT: JOHN, AS YOU KNOW, WE GET A LOT OF QUESTIONS ABOUT PDR, AND HERE TO GIVE US SOME POINTERS IS MR. BOB MCCONKEY FROM DENTBUSTERS. BOB, WELCOME TO GOSS' GARAGE.

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NEWS BRIEFS

SWACO project earns EPA award

The Solid Waste Authority of Central Ohio's Green Energy Center has received a "Project of the Year" award from the U.S. Environmental Protection Agency.

The honor was presented Jan. 13 at the U.S. EPA Landfill Methane Outreach Program in Baltimore, Md.

The Green Energy Center transforms gas from SWACO's Franklin County Landfill into compressed natural gas for vehicle fuel as well as energy for a 250-kilowatt microturbine that provides electricity for the Grove City facility.

The center is a public-private partnership with FirmGreen Inc.

"The center shows American ingenuity is alive and well and that we can grow regional energy hubs to help meet our country's future needs," said Ron Mills, executive director of SWACO, in a press release.

The first phase of the center, which opened in September, is expected to produce enough compressed natural gas annually to replace almost 250,000 gallons of gasoline and reduce carbon emissions at an amount equal to more than 630,000 gallons of gasoline.

It is initially being used to fuel SWACO vehicles. In the next three years, SWACO plans to covert at least nine fleet vehicles to compressed natural gas. SWACO also is working with local governments, schools districts and businesses to establish a consortium to tap the gas supply.

Old electronics have home at zoo

Looking for a good place to dispose of an old computer or TV? Look no further than the Columbus Zoo and Aquarium.

On Saturday and Sunday, Jan. 24 and 25, the zoo, in conjunction with the Delaware-Knox-Marion-Morrow Solid Waste District and Tech Disposal, will hold a recycling drive for electronic equipment. It runs from 10 a.m. to 2 p.m. each day.

Television sets, computers, computer peripherals and cell phones are among the items that will be accepted. Workers will remove the items from vehicles; donors need not lug them out of the car.

A four-pass Family Fun Pack, valid through March 31, will be presented to the driver of each car that brings in items to recycle.

Projections show many older TVs are likely to be disposed of when the country switches over to digital-only broadcasts next month, and the recycling drive is intended to reduce the number of those TVs tossed in Central Ohio landfills, according to a zoo press release.

Those who bring in TVs to recycle are asked to donate $10 to help cover the cost of recycling.

The zoo cannot accept microwave ovens, appliances or other electronic items not listed above.

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Landfills turn rotting garbage into energy

Posted by John Funk/Plain Dealer Reporter December 07, 2008 06:56AM
Categories: Energy

Roadell Hickman/The Plain Dealer

Matt Abahazi "tunes" each of the 150 gas wells twice a month at Waste Management's American Landfill in Waynesburg, Ohio, to check for gas quality as well as to help figure out what's happening hundreds feet below as anaerobic bacteria digest anything organic.

The next time you take out the garbage, here's something to think about: You haven't seen the last of it.

There is a good chance the stuff will return -- morphed into methane in the bowels of a regional landfill, cleaned up, pressurized, injected into the rivers of natural gas flowing through utility pipelines -- and eventually back into your house.

It took nature millions of years to build the vast reservoirs of natural gas trapped thousands of feet underground. These days, it takes a landfill owner only a few months to begin generating a similar mixture of gases in pockets just a few hundred feet down.

Landfill gas is not as naturally potent as so-called natural gas, because it contains 40 percent to 50 percent carbon dioxide, along with chemical impurities. But it can be cleaned up.

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And, unless it is used as a fuel, it must by federal law be immediately flared (burned) on site because the U.S. Environmental Protection Agency has identified it as a greenhouse gas at least 20 times more potent than carbon dioxide. Of the nation's 1,000 or so large landfills, more than 400 in 43 states are today producing commercial gas instead of flaring, said the U.S. Environmental Protection Agency.

The gas is used in boilers, ovens, manufacturing processes, space heating, electricity generation and as a truck and bus fuel.

There are 11 Ohio landfills participating in the EPA's gas-to-energy program. And more will be added soon.

The Solid Waste Authority of Central Ohio, or SWACO, is preparing to jump into the vehicular fuel market with its landfill gas.

The publicly owned facility near Columbus is fueling a car and a truck with pure methane that it began to produce on-site in September from just 8 percent of its landfill gas. It plans to power its garbage transfer trucks with the gas and run a turbine to generate electricity for on-site use.

Click here to see how the process works. (PDF)

Small as it is, SWACO's purification system can generate the methane equivalent of 250,000 gasoline gallons per year, said spokesman John Remy. The authority is talking with school districts and transit systems about converting their buses to run on methane.

Landfill gas is definitely big business.

Houston-based Waste Management, the nation's largest investor-owned trash hauler, is producing fuel from landfill gas at more than 100 landfills, including four in Ohio -- Solon, Dayton, Toledo and Waynesburg, near Canton..

"It's resource recovery," said Paul Pabor, Waste Management's vice president for renewable energy. "The gas flow at a landfill will increase as long as it keeps receiving waste."

The company's new business focus is to use the gas to generate electricity with small gas-fired generators producing 3 to 6 megawatts, and shipping the power to local utilities. There is a federal tax credit for power produced with "biogas" - 1 cent credit for every kilowatt-hour generated.

"We directly own 43 power plants," said Pabor, "generating about 220 megawatts."

Add that to the power produced by outside companies at some of Waste Management's other landfills and you have enough electricity to power nearly one million homes, according to the company's Web site.

The company added six new gas production plants this year and hopes to add another nine next year, Pabor said.

Waste Management is looking to generate electricity at two additional Ohio sites in the future.

Waynesburg landfill supplies Dominion

Currently, its largest Ohio project is the American Landfill in Waynesburg, which has about 15 million tons of waste already buried and 3,000 tons to 4,000 tons of new trash arriving daily from all over Northeast Ohio. The 234-acre landfill ships 4 million cubic feet of gas every day to Dominion East Ohio Gas Co.'s underground storage reservoirs about nine miles away.

That's enough gas to heat 6,500 Midwestern homes, said Todd Brady, Waste Management's Ohio gas operations manager. He said the company began cleaning the gas in 2003 rather than burning it.

"We have 155 wells, which we tune on a pretty consistent basis," he said.

Tune?

"We have to make sure the methane gas is of the right quality," Brady said. "It varies based on the depth of the well, how much organic there is and how old the trash is."

Brady especially likes household garbage and trash.

"The higher your residential percentage, the higher the organics," he said. "Probably 95 percent of what you throw away is going to break down - old clothes, left over pizza boxes, anything like that."

Roadell Hickman/PD

Up to 4,000 tons of household garbage and trash from throughout Northeast Ohio arrive at Waste Management's American Landfill every day. The waste is buried in lined "cells" up to 300 feet deep. But it's just the beginning of a resource recovery process that converts the stuff into 4 million cubic feet of gas per day.

The trash typically has to be buried 18 to 24 months before it gets cooking. Then the wells, unless they were installed as the garbage was put in, have to be drilled.

Conventional rotary drilling rigs are used to bore into each self-contained landfill section, called a cell. But that's about all these wells have in common with a traditional natural gas well.

Landfill wells stop at about 150 feet, are interconnected near the surface and operate at negative pressure.

In other words, they are a kind of sprawling vacuum system, gently sucking the gas from the deeply buried, decomposing garbage and piping it to a pump station.

There is it either immediately burned -- or analyzed, cleaned up, pressurized and sent to a customer. The landfill at Waynesburg sends the gas to Dominion East Ohio gas company.

Filtering plant cleans up the gas

Getting the gas safely out of the ground is where Waste Management's role stops. The cleaning is done by Toro Energy of Ohio, a subsidiary of National Fuel Gas Co.

of Williamsville, N.Y.

Toro's automated filtering plant at the landfill is interfaced electronically with Dominion's pipeline and reservoir control center. And a Dominion employee watches over the system.

Because Toro's clean-up plant removes only the chemical contaminants -- not the carbon dioxide -- the gas cannot be mixed one-for-one with the utility's pipeline gas because its energy value is only about half that of pipeline-quality gas.

Instead, it is piped into Dominion's underground storage nine miles away, to await careful mixing with gas flowing in a nearby major Dominion pipeline.

"It's about a 20 percent blending rate," said Darrin Wiechman, Operations Manager with National Fuel Gas. In other words, the blend is one part landfill gas, five parts pipeline gas.

At that percentage, the lower-BTU landfill gas does not dilute the pipeline gas energy levels below the industry standard --one million BTUs per 1,000 cubic feet.

"It's all automatically controlled within the system" said Wiechman. "If the gas flow rate of Dominion's pipeline reduces, the system will automatically back down our flow rate. The gas is continuously monitored downstream of the blending."

Dominion spokesman Neil Durbin said the big transmission pipeline carries 80 million cubic feet of gas per day -- 20 times the 4 million cubic feet coming from the landfill.

He said the energy density of the gas is measured after the blending to make sure it meets industry specs.

And just for the record, Durbin said, Dominion does not actually own the gas -- but only stores it and ships it on behalf of gas marketers, who asked not to be identified for competitive reasons.

Integrys Energy, an independent gas supplier that now markets "biogas," does not buy from Waste Management, a spokeswoman. said

Other independents are evidently considering the move to "green," however. Durbin said Dominion is talking to a number of landfill operators about accepting landfill gas -- which if shed of its carbon dioxide has the same energy value as natural gas.

COMMENTS (6) **Post a comment**

Posted by **boatbum** on 12/07/08 at 8:09AM

Finally, a "green" energy program that is viable and not an unproven concept being pushed by radical environmentalists. Create a market and they will come.

Inappropriate? Alert us. Post a comment

Posted by **cleveland78** on 12/07/08 at 10:39AM

Ohio's renewable energy mandates for electricity will create one market for LFG. And if you live in a municipally-owned provider area (amp-Ohio.org), talk to your city leaders about this type of energy.

Inappropriate? Alert us. Post a comment

Posted by **Lapdog65** on 12/08/08 at 10:05AM

Great! Set this up at City View center, clean up the methane and offer free or discounted power to the tenants, it's a win win situation, the smell will be gone, and it will attract new tenants.

Inappropriate? Alert us. Post a comment

Posted by **Lapdog65** on 12/08/08 at 10:08AM

Set this up at City View Center in Garfield Hts. Offer free or discounted power to the tenants to attract new tenants. It's a win win if you can get rid of that smell, and attract new business.

Inappropriate? Alert us. Post a comment

Posted by **toko1** on 12/08/08 at 10:30AM

I think Lapdog65 is on to something

Inappropriate? Alert us. Post a comment

Posted by **Lapdog65** on 12/08/08 at 10:49AM

Sorry for the double post, but I've been thinking of this since seeing the burning of the gasses for the past 20 years in the dump on the North West corner of I-77 and rt 82 in Broadview Hts. , It's seems silly to burn off the gas when it can be used for energy.

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By Tim Norman/*ThisWeek*

John Remy, director of communications for the Solid Waste Authority of Central Ohio, talks about the machine behind him during a tour of the Green Energy Center at SWACO on London-Groveport Road on Feb. 11. Methane from the landfill is cleaned and prepared as compressed natural gas for use in vehicles and to power the micro turbine in the next room. The facility is part of phase one of the Green Energy Center, a partnership between SWACO and Firm Green Ltd.

Green Energy Center at SWACO

Trash being turned into fuel

By KEVIN PARKS
ThisWeek Staff Writer

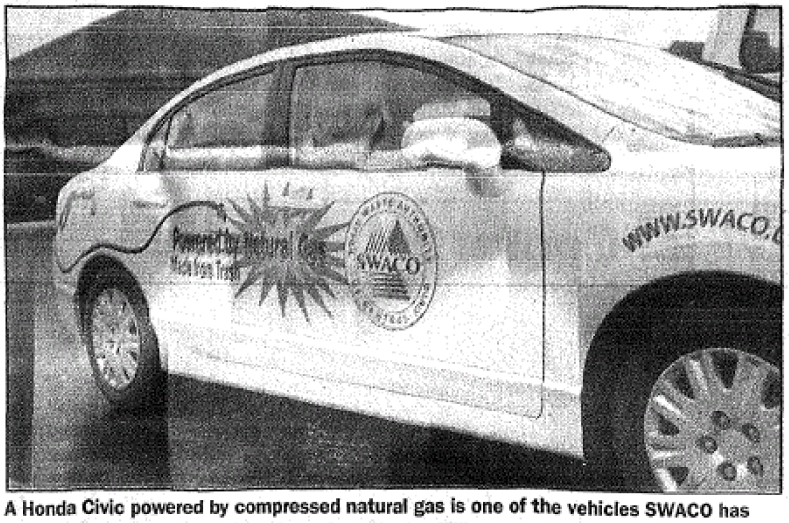
Turning what we most definitely don't want, trash, into what we most decidedly need, fuel, is no longer a pipedream.

It's a matter of piping.

What the residents of central Ohio throw away and have thrown away is being converted into fuel that allows a specially equipped fleet of vehicles to drive away from some fairly ordinary looking pumps at the Solid Waste Authority of Central Ohio's Green Energy Center on London-Groveport Road.

Organic garbage such as egg shells, chicken skin, grapefruit rinds and that crust of bread in the bottom of the bag that no one in the family will eat, as well as fibers such as paper and cardboard, decompose in a landfill setting. Part of that decomposition process creates gas.

See **FUEL**, *page A2*



A Honda Civic powered by compressed natural gas is one of the vehicles SWACO has outfitted to burn converted methane from the landfillll.

FUEL

Continued from page A1

Methane gas.

It's smelly stuff, and up until recently operators of landfills, waste water treatment plants and other facilities had to get rid of the gas by extraction through a network of pipes to be burned off at the surface.

Now at the Green Energy Center, the gas produced by all that rotting trash is being cleaned up, thanks to a process developed by William Brown, and converted into compressed natural gas that can power automobiles and pickup trucks that have undergone modifications.

Brown, one of the founders in 1989 of Cleveland-based Acrion Technologies Inc., developed the process by which the impure methane gas from landfills is cleaned with carbon dioxide and made ready for use as fuel.

The initial phase of the Green Energy Center was built and is being operated for SWACO by FirmGreen Inc., a privately held, integrated energy company with headquarters in Newport Beach, Calif.

"The facility collects and cleans raw landfill gas using Acrion's patented technology CO2 Wash," according to the firm's Web site. "The cleaned methane is then converted into 'green' compressed natural gas for use in CNG-powered cars and medium duty trucks."

During the groundbreaking ceremony for the facility in September, SWACO executive director Ron Mills said: "What once was an idea is now fuel to power America's future. What was once waste is now energy to drive our economy. What once was considered the end of the line is now a starting point for economic development."

FirmGreen Inc. founder and chief executive officer Steve Wilburn said at the time: "FirmGreen is very pleased and honored to have been selected to partner with SWACO to build the first Green Energy Center in the U.S. FirmGreen believes the successful completion of the ... concept positions Ohio at the forefront in the national effort to clean our air and lessen our dependence on foreign oil while providing the surrounding communities with clean affordable vehicle fuels and retraining Ohio's displaced industrial workers to find work in the emerging green energy marketplace."

Early in the 21st century some SWACO officials chanced to encounter William Brown at a convention or trade show, and he told them about his very 21st century technology for using landfill-produced methane, according to SWACO director communications John Remy.

"The idea hatched," Remy said last week during a tour of the Green Energy Center.

The incubation effort, with the help of the California firm, now taps 8 percent of the Franklin County Landfill's 30-year supply of gas that can be converted to CNG. This can create the equivalent of 250,000 gallons of gasoline annually. It is currently being used to run two Honda Civics and several pickup trucks in SWACO's fleet, but officials are working with commercial fleet operators, school districts and cities around central Ohio to create a consortium of users of this type of vehicle fuel, according to Remy.

The communications director, who often drives the 2006 Civic outfitted at Honda's Marysville plant to run on compressed natural gas, said it feels just like driving a standard vehicle.

"You can't tell the difference," Remy said. "It sounds like a car."

The second phase of the Green Energy Center, which would be owned entirely by FirmGreen, would have the capacity to produce the equivalent of 3 million gallons of gas a year, according to Remy. If this process were to be replicated at 100 landfills across the country, he pointed out, it would produce a heck of a lot of fuel.

"That's a pretty big dent in terms of our dependence on foreign oil," Remy said. "Is this the end-all to our energy needs? No. It is part of the answer? Yes."

Construction on phase two is to start sometime this year, the communications director added.

Landfill operators from through the United States have expressed interest in learning more about the Green Energy Center, and many have visited the SWACO facility, which received a "Project of the Year" award from the U.S. Environmental Protection Agency in January during the annual Landfill Methane Outreach Program conference in Baltimore.

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Recently-opened SWACO green energy center earns national award

By RICK ADAMCZAK
Daily Reporter Staff Writer

It's only been operational for less than five months, yet the Solid Waste Authority of Central Ohio's green energy center already is receiving accolades.

Last month the center, which converts gas from SWACO's landfill into compressed natural gas that fuels cars and trucks, was named project of the year by the U.S. Environmental Protection Agency. It was one of only seven projects in the country honored by the EPA.

"We're certainly pleased," said John Remy, director of communications for SWACO. "This is something that can help us promote the facility and maybe it can be duplicated across the country."

The green energy center, located in Grove City, is a public-private partnership with FirmGreen Fuels LLC. Phase one of the center can produce enough compressed natural gas annually to replace about 250,000 gallons of gasoline plus enough extra natural gas run the facility.

California-based FirmGreen built and operates the facility. Cleveland's Acrion Technologies created the technology used to convert methane gas collected from the landfill that is converted into methanol.

Currently six SWACO vehicles, four lightweight pick-up trucks and two Ohio-assembled Honda Civics, are operating on compressed natural gas, but that's expected to increase.

The cars are built with a CNG engine, but the trucks need to be converted to accommodate CNG.

(See SWACO, Page 12)

SWACO

(Continued from Page 1)

"We had a goal in the first few years to have 10 vehicles and we're already up to six," said Remy. "As we replace our fleet vehicles we'll be adding more."

But eventually SWACO wants to supply the compressed natural gas to vehicles outside the agency, including fleets for governments, school districts and companies.

The CNG will be available at a gasoline gallon equivalent rate of less than $3 or lower, if it's pumped from SWACO's fueling station.

"From the day the Green Energy Center was conceived, we believed it was a project with far-reaching benefits, says SWACO Executive Director Ron Mills. "This award from the U.S. EPA will help us tell the story. The center shows American ingenuity is alive and well and that we can grow regional energy hubs to help meet our country's future needs."

Planning for the center started four years ago and construction of the facility took two years; it opened in September.

"Everyone who sees it is thrilled, amazed. They ask why more people don't do it," said Remy.

Phase one of the center will produce enough compressed natural gas annually to replace

almost 250,000 gallons of gasoline. The center will reduce carbon emissions at an amount equal to more than 15,000 barrels of oil or 630,000 gallons of gasoline per year.

There currently is a 30-year supply of gas in SWACO's Franklin County landfill. Phase one of the center will tap approximately 8 percent of that supply.

"It's a novel thing, turning trash into energy," said Remy.

He said that so far the feedback from SWACO drivers using the CNG-powered vehicles has been positive.

"Really, you notice no difference," said Remy.

SWACO officials said that by utilizing waste gases generated from its landfill they can produce domestic, renewable transportation fuels, improve the environment and generate economic growth.

"We are proud of our ongoing partnership with SWACO as we work to clean our air, reduce our dependence on foreign oil, provide clean and affordable vehicle fuels and spur job creation," Mills said.

He also said there are approximately 100 landfills across the United States similar in size to SWACO's Franklin County Landfill. "Just think of how we could reduce our nation's reliance on foreign energy if we harness the power of those other landfills!"

SWACO serves Columbus and Franklin County, Ohio with innovative waste reduction and recycling projects.

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Short takes

● **TURNING CENTRAL** Ohio's trash gas into a cleaner-burning automotive fuel is an exciting prospect, but only time and the jockeying of competing technologies will prove whether the Solid Waste Authority of Central Ohio truly has a groundbreaking process, as backers claim.

The authority has teamed with a private company, FirmGreen Inc., to capture the methane pumped out of the Franklin County landfill, to remove its impurities and to turn it into compressed natural gas for use in vehicles.

Landfills around the country have similar projects, but SWACO officials say the FirmGreen process produces a purer product with a higher yield. So far, only a few vehicles are running on the gas, but SWACO, FirmGreen and Clean Fuels Ohio, a nonprofit organization that advocates for alternative fuels, this month will pitch the product to school districts, city refuse divisions and other potential customers.

Fleet users of medium- and heavy-duty trucks are seen as the likeliest market for this gas because they can accommodate the storage tanks and often get their fuel from central refueling stations. Spreading use beyond fleets would take more time and investment. The next few years should see many new energy technologies succeed or fail. Let's hope SWACO has a winner.

• • •

● **THE EXONERATIONS** of men wrongly convicted of rape and murder, their innocence established years later by advanced testing of DNA evidence, are often only one step on their path to re-entering society.

And in the cases of those who were convicted of rape and subsequently registered as sex offenders, their freedom is far from complete, as long as those labels linger. State laws often provide no means to remove the labels.

Among men profiled in the January 2008 *Dispatch* series "Test of Convictions" was Arthur Whitfield of Norfolk, Va., who was shown by DNA evidence in 2004 to be innocent of the rape with which he had been charged. He is free now, but Virginia law doesn't allow anyone who has been freed from prison to be declared innocent, and without a declaration of innocence, he didn't qualify for compensation for his 23 years of wrongful imprisonment.

Whitfield got a break Monday when Virginia Gov. Timothy M. Kaine abruptly pardoned him. But it shouldn't take such extraordinary intervention to clear the name of someone who has been so greatly wronged by the justice system.

The Ohio Senate is considering a bill that would remove some barriers to post-conviction DNA testing; it also should ensure that exoneration includes clearing one's name.

• • •

● **KUDOS TO** Walgreens for offering free care to current customers of its Take Care Clinics who lost their jobs on April 1 or after and are without health insurance. As unemployment rates continue to rise, more Ohioans find themselves without their employer-provided insurance or the means to acquire health care.

People with nowhere else to turn often end up in emergency rooms, which treat patients regardless of their ability to pay. But this is an expensive place to seek care and a drain on the system.

While the Take Care Clinics do not offer a full range of health care — they are staffed by nurse practitioners, not doctors — they can offer some assistance. So patients with the flu, strep infection or a rash have a place to go for treatment and advice.

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Landfill's methane powering vehicles

County's fuel-conversion project gets national interest

By Barbara Carmen
THE COLUMBUS DISPATCH

A project at central Ohio's landfill — garbage in, gas out — is being pitched in Washington, D.C., as a way to reduce America's dependence on foreign oil.

"We were the first in the country to use this technology" on a full-scale commercial basis, said Franklin County Commissioner Paula Brooks.

"It's environmentally cleaner. It reduces our dependency on foreign oil. And it works."

During the past few months, Brooks and Ron Mills, executive director of the Solid Waste Authority of Central Ohio, met with Sen. Sherrod Brown, key members of his staff and other policymakers in Washington.

They told them about a test project at the landfill that began eight years ago: Methane is plumbed from rotting garbage, scrubbed of pollutants and impurities using a process invented in Ohio, and stored in tanks.

An equivalent amount of compressed natural gas, or "CNG," offers the same mile-

See **LANDFILL** Page **A4**

LANDFILL

FROM PAGE A1

age as a gallon of gasoline but burns 75 percent cleaner. Its production also keeps the air cleaner. Landfills typically flare off the methane to prevent explosions, releasing a gas blamed for global warming.

The landfill's CNG should sell for about $2.50 per gasoline gallon equivalent, Mills said. Regular gas is selling for about $1.98 a gallon in central Ohio, after rocketing above $3 a gallon. A gallon of diesel fuel sells for $2.09 to $2.59.

Like imported oil, the cost of CNG will vary, but SWACO's CNG should go down. Production costs are steady. Supply is guaranteed: "We have 24 years' worth of garbage buried here," Mills said.

The more CNG sold, the lower the unit price.

"It's a reliable, indigenous fuel — an American resource we can use to replace foreign oil and clean our air. It's very cutting edge, but it's feasible," said Steve Wilburn, owner, founder and president of FirmGreen Inc.

His company bought the technology, developed near Cleveland, and teamed up with SWACO.

"It was clear that the board of trustees at SWACO wanted to do something different," Wilburn said. "They were ready to change the way we do things in this world."

The FirmGreen plant, built next to the landfill, already is supplying CNG to a handful of cars and trucks at SWACO and in Jackson Township, Grove City and Columbus.

A handful of other landfills across the country, notably in Texas and California, also are extracting gas and using it to power trucks or selling it via pipeline to utility companies.

But Mills said SWACO's plant uses a new technology and the product is so pure that it can be pumped directly into the tank of a vehicle adapted to use it.

Sam Spofforth, executive director of Clean Fuels Ohio, thinks SWACO is indeed using a different technology and producing more CNG from a landfill than anyone else in the country.

His nonprofit group sees

SWACO's project as "a great economic opportunity for Ohio. We have lots of landfills in Ohio."

"And this isn't just pie in the sky, incredibly expensive. You can make a business case for this."

But Spofforth cautions that the project still needs infrastructure. "We're going after stimulus dollars in a big way to build refueling stations," he said.

Clean Fuels Ohio, FirmGreen and SWACO will meet with potential customers — including school districts, city refuse divisions and businesses — on April 23 in Columbus.

CNG is viewed as a good fuel for medium- and heavy-duty vehicles, which can handle the storage tanks, and for those with fleets that report to a central refueling site.

FirmGreen has helped local governments pay to retrofit vehicles with CNG engines and tanks. Tax credits cover most of the expense, which can run $32,000 to convert a diesel-burning refuse truck.

Mills figures that if 700 of the 3,091 landfills in the U.S. produced CNG instead of burning off their methane, the U.S. could reduce foreign oil imports by 4 percent.

"That doesn't sound like much," Mills said. But he noted that fuel prices dropped more than $1 a gallon in the past year "and that was driven by a decline in demand of only 3 percent. So this is big."

bcarmen@dispatch.com

KELLIE MANIER | DISPATCH

For eight years, the Solid Waste Authority of Central Ohio has been using technology that removes methane from the landfill and converts it into compressed natural gas.

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Landfill breaks new ground with garbage-to-fuel process

SWACO's transformation of methane gas to vehicle fuel may be nationally influential.

By RACHEL BUCCICONE

Suburban News Publications

U.S. Sen. Sherrod Brown made a stop near SWACO's landfill in Grove City to announce new national legislation Thursday, May 28.

Brown spoke of the Rubbish to Renewables Act of 2009, which takes a cue from SWACO's efforts to transform methane gas into fuel.

SWACO, using technology developed in Cleveland and manufactured in Dublin, converts the methane gas naturally emitted by the landfill into fuel able to power advanced energy vehicles, said Ron Mills, executive director of SWACO.

Landfills give off methane gas as a natural byproduct. In order to eliminate that gas, most landfills burn it, releasing carbon dioxide, which is harmful to the environment. The technology used by SWACO cleans the methane instead, creating compressed natural gas.

"It will compress and clean the landfill gas to pipeline and natural gas standards," said Mike Mitariten of Guild Association, the Dublin-based company manufacturing the technology.

That natural gas is used to fuel several SWACO vehicles. When fully developed, the process will create enough fuel to power an entire urban refuse fleet for five metropolitan centers the size of Columbus, Mills said.

"We're renewing our nation's greatness right here at SWACO," said Franklin County Commissioner Paula Brooks. "It's recycling at its best and virtually inexhaustible."

This technology feasibly can be applied to 700 of the 7,000 landfills nationwide, Mills said. The resulting natural gas could reduce the nation's dependence on foreign oil by 4 percent each year, he said.

The technology was created by the Cleveland company Acrion and is manufactured by Dublin's Guild Associates.

Brown said his legislation would apply the technology SWACO utilizes on a national scale, calling Columbus the "Silicon Valley of alternative energy."

"One person's waste can be another's source of clean energy," Brown said.

The Rubbish to Renewable Act would create a $250 million competitive grant program through the Department of Energy to support the use of the technology. Projects similar to SWACO's would be eligible to receive $5 million in grant funding.

"We have a nice marriage between industry and government," Mitariten said.

It also will create jobs and increase the demand for clean energy, Brown said.

"It's about creating jobs," Brooks said.

Brown touts green energy bill

By EVAN BROOKS
ThisWeek Staff Writer

U.S. Sen. Sherrod Brown, D-Ohio, announced new legislation last week that would create funding to expand the use of municipal trash as a source of clean energy.

He made his announcement at the Solid Waste Authority of Central Ohio, 4239 London-Groveport Road, where equipment that processes methane gas produced from waste at the landfill into compressed natural gas was installed almost a year ago.

SWACO executive director Ron Mills said the solid waste authority and the city of Columbus can use compressed natural gas from the landfill to fuel fleet vehicles at a cost of $2.25 for the equivalent of a gallon of gasoline.

"This is another major step for Ohio to become the Silicon

See **GREEN**, *page A3*

By Lorrie Cecil/*ThisWeek*

Bill Brown, president of Acrion Technologies Inc., shows U.S. Sen. Sherrod Brown D-Ohio (left) the CO2 wash machine during a tour of SWACO's facilities on London-Groveport Road May 28.

GREEN

Continued from page A1

Valley of alternative energy," Brown said. "One person's waste can be another person's windfall."

Brown's bill, the Rubbish to Renewables Act of 2009, would create a $250-million competitive grant program at the U.S. Department of Energy to expand infrastructure and policies on the use of municipal solid waste as a clean energy source, the senator said.

The bill would create grants of up to $5-million to fund projects similar to the one at SWACO.

"We want to see other communities adopt this technology," Brown said.

Mills said the SWACO operation is in its first phase.

The operation now produces the equivalent of 250,000 gallons of gasoline. When the second phase of the project takes off, Mills estimates SWACO will be able to produce the equivalent of nearly seven-million gallons of gasoline a year.

He added that according to Environmental Protection Agency information, 700 landfills in the nation could produce the same amount of compressed natural gas as SWACO.

If those 700 landfills operate as SWACO's conversion process does, they could have the capacity to produce 4.5-billion gasoline-gallon equivalents of compressed natural gas in a year, which represents 4 percent of all imported crude oil to the United States, Mills said.

"These landfills will continue to produce gas for the next 50 to 100 years," the SWACO director said. "And this technology goes beyond renewable energy and energy independence."

Processing methane gas for fuel rather than burning it will reduce SWACO's carbon dioxide emissions by 95 percent, Mills said.

Officials credited Bill Brown, president of Acrion Technologies of Cleveland, for devising the technology for the purification and conversion of methane gas to compressed natural gas.

Bill Brown was on hand for the senator's announcement last week.

"Investors don't look at energy in versus energy out," Bill Brown said. "They look at the cost of the raw material versus the energy it produces. Raw energy in landfill gas is relatively inexpensive."

Guild Associates, a research and design firm in Dublin, manufactured the equipment for processing landfill gas at SWACO.

Mills said $2.25 a gallon cost for compressed natural gas won't fluctuate like gasoline or diesel fuels.

"That'll be a stable price, because the gas is coming from our landfill and not some foreign country," he said.

Compressed natural gas can be an alternative to using gasoline or diesel fuels for school districts, municipalities in other entities that use a central location to fuel fleet vehicles, Mills said.

Brown said he hopes his bill will expand use of the natural gas all over the country.

The senator said Ohio already has made developments in the global alternative energy market. He cited examples of the largest manufacturer of solar energy cells in Toledo, fuel cell technology breakthroughs in Canton and ideas to operate a wind turbine farm in Lake Erie.

"Ohio really does lead the nation in this kind of new energy," Brown said.

"From start to finish in Ohio, we're really taking off in alternative energy."

Operating on waste

Landfill gas project fuels own vehicles

By Jim Johnson

A new $5 million landfill gas project in Central Ohio already is fueling a couple of solid waste-related vehicles. But that's just for starters as there are plans to greatly expand use of the technology at both the landfill and up and down the state.

The Solid Waste Authority of Central Ohio is using gas from its 363-acre landfill in Grove City, near Columbus, to create compressed natural gas that's already running two SWACO vehicles.

Plans are to increase the authority's natural gas fleet in the months and years ahead as well as provide a publicly available location for local municipalities and consumers to fill up their alternative-energy vehicles.

And there will be a second phase, owned by project developer Firm Green Inc., which will ultimately produce the equivalent of 10 million gallons of gasoline equivalent fuel each year.

"Here at SWACO, with the support of our board, we look at the waste stream as a potential resource," said Ron Mills, executive director of the authority. "What can we do with that resource?"

Make vehicle fuel.

"Energy independence, I take that very seriously. We need to change, fundamentally, the way we do business," said Steve Wilburn, founder and CEO of Newport Beach, Calif.-based FirmGreen.

FirmGreen plans to construct phase two of the project, which is approximately 10 times larger than SWACO's current fueling operation, during the next couple of years. That project will be part of what Wilburn sees as a corridor of natural gas vehicle fueling facilities eventually stretching from Cincinnati to Cleveland in Ohio.

"The marketplace, we're just now starting to see significant numbers of these automobiles being produced in the United States," Mills said. "We're now starting to see commitments being made by the auto makers."

While the case can be made for the future of natural gas-powered vehicles these days, that wasn't always the case.

Mills remembered starting the project years ago without a guarantee that the effort would be successful. That's why SWACO started with the smaller phase one, which it owns. "We didn't want to get the cart before the horse because there was a distinct possibility that this wouldn't work the way we thought it would work," he said.

But Mills and Wilburn and a few dozen other folks weren't milling around the fueling station recently because the project doesn't work. And there weren't speeches and thank-yous and a ribbon to cut because of failure.

"By going in this direction, we knew we were taking a risk. But we also knew that there would be a substantial revenue back to the community," Mills said.

GAS AND GO: Ron Mills, executive director of the Solid Waste Authority of Central Ohio, stands at the 363-acre landfill in Grove City, near Columbus, that is used to create compressed natural gas to fuel SWACO vehicles.

SWACO will receive about $50 million from FirmGreen over 20 years for the landfill gas it provides that company.

Both FirmGreen and SWACO talk about the rather large potential for the project at the landfill and at other disposal sites throughout the country. With about 100 other landfills that are about the same size as the SWACO site in the United States, Mills said there is the potential to create enough fuel to become a significant source of vehicle fuel.

Vehicles fueled at SWACO pay the equivalent of less than $2 per gallon of gasoline. ■

Contact Waste News senior reporter Jim Johnson at (937) 964-1289 or jpjohnson@crain.com

INNOVATIVE LANDFILL GAS UTILIZATION
THE SWACO/FIRMGREEN™ ENERGY, INC.
GREEN ENERGY CENTER©
FRANKLIN COUNTY SANITARY LANDFILL
GROVE CITY, OHIO

Ralph Hirshberg, P.E.
Project Manager
Civil & Environmental Consultants, Inc.
Cincinnati, Ohio 45241

ABSTRACT

The **Green Energy Center©** located at the Franklin County Sanitary Landfill is a fully integrated renewable energy project developed in a cooperative effort between **FirmGreen™ Energy**, **Inc.,** (FirmGreen™) and the **Solid Waste Authority of Central Ohio** (SWACO). SWACO owns and operates the **Franklin County Sanitary Landfill** (FCSL) which serves as the host facility.

The Green Energy Center concept focuses on utilization of a host landfill as a renewable energy "fuel cell". A specific emphasis is placed on a maximum utilization of available energy as well as carbon sequestration. Unlike conventional gas-to-electric or gas-to-pipeline projects, the Green Energy Center includes a rather unique business model that facilitates production of a wide variety of energy sources from landfill gas that may include compressed natural gas (CNG), ethanol, methanol and biodiesel fuel. These products are in addition to the conventional gas-to-electric and pipeline gas commodities. This unique aspect of the Green Energy Center's business strategy was developed to achieve an optimal synergy between the environmentally responsible energy development, and a viable business model.

Unlike typical gas-to-energy projects, the Green Energy Center utilizes a hub-and-spoke project model, with the patented CO_2 Wash™ technology serving as the hub for a variety of energy development possibilities. The CO_2 Wash™ technology is a landfill gas separation and purification process, which separates the methane and carbon dioxide (CO_2) components of raw landfill gas, and purifies each gas stream using a low emission, cold distillation process. The levels of product purity achieved facilitates direct use of processed methane for a wide variety of uses including vehicle fuel, process feedstock (e.g. methanol and hydrogen production), and low, medium or high-Btu fuel. Likewise, the ultra-pure carbon dioxide is suitable for direct sale as an industrial commodity. Sequestered carbon dioxide can also be used directly as "plant-fuel" for greenhouse crop production.

The hub-and-spoke model provides diversification critical to success of landfill gas-to-energy projects which rely on variable energy market price points. In today's volatile energy market, such diversification can determine the success or failure of typical landfill gas projects which rely on single commodity price points. More importantly, this model also provides the host site with a multitude of opportunities for unique energy projects and interaction with host communities, local school districts or governmental entities through supply or price support of renewable energy resources.

The Green Energy Center at FCSL includes the following components:

- A modular methane/CO_2 purification plant, capable of scale-up to approximately 5,000 MM Btu per day;
- A compressed natural gas station used to support an on-road CNG-diesel conversion study of refuse transfer trucks operated by SWACO;
- A 250 kW microturbine used to power all SWACO infrastructure:
- An IC-engine electrical generating station with a maximum capacity of approximately 6.5 MW;
- An 80-acre greenhouse complex which will utilize purified CO_2 as well as waste heat from both the IC-engine unit and microturbine facilities;
- A methanol synthesis plant; and
- A biodiesel production facility.

Expansion (or contraction) of each component will be dictated by prevailing market price points, or needs of the host facility. As previously indicated, the diverse range of end-uses for landfill sourced energy also offers the landfill operator/owner unique opportunities for interaction with the host community; a factor which can assist in promoting expansion of the "fuel cell" concept, thereby securing long-term disposal as well as "energy" capacity.

COMPANY PROFILE AND TECHNOLOGY
FirmGreen™ Energy, Inc.

General Company Profile

Headquartered in Newport Beach, CA, **FirmGreen™ Energy, Inc.,** (FirmGreen™) is a privately held, integrated energy company participating in virtually all aspects of the global green energy business. It is involved with identifying, developing and commercializing new and emerging technologies and energy systems that promise to play an increasingly important role in the world's energy mix.

President and CEO - Steven Wilburn

Mr. Wilburn has over thirty years of experience in the development and implementation of energy production technologies and alternative energy projects. Previously Mr. Wilburn served as Vice President of Business Development for the Allied Signal Corporation. In this capacity, he personally managed the successful development of over three hundred (300) million dollars of alternative-fuel energy generation projects.

He founded FirmGreen™ Energy, Inc. in 2001. In his present capacity, he successfully acquired the world wide patent rights to the CO_2 Wash™ technology. The CO_2 Wash™ technology cleans landfill gas into pipeline quality methane and industrial grade CO_2. The company is currently developing green energy projects in excess of $750 million dollars worldwide.

Patented Gas Purification Technologies

FirmGreen™'s patented and proprietary CO_2 Wash™ technology includes methods of converting solid, liquid and gaseous hydrocarbons from readily available renewable resources including landfill gas, forest residues, and biomass, into clean bio-fuels to power vehicles, electrical power generating stations and fuel cells. Purified hydrocarbons, in the form of methane can also be used as feedstock for industrial chemical production, replacing conventional non-renewable feedstock (e.g. natural gas).

The CO_2 Wash™ process may be simply described as a cold distillation process which utilizes the solvent properties of carbon dioxide to remove non-methane hydrocarbons and similar "impurities" from raw landfill gas. This technology also removes organosilicates (siloxanes) which pose risk to internal combustion engines and turbines often used for power generation at municipal solid waste landfills. Non-methane contaminant removal efficiency easily satisfies requirements for pipeline and compressed natural gas applications.

Developed through years of research sponsored by the United States Department of Energy (DOE), the CO_2 Wash™ process achieves high levels of methane and carbon dioxide purity through a series of compression and refrigeration cycles, with the these primary gas fractions separated within a distillation column. Process residuals, referred to as a "slipstream" are concentrated in the lower end of the distillation column. The slipstream and concentrated gas impurities are typically routed to the host landfill's control device (typically a flare) for thermal oxidation.

The CO_2 Wash™ process was demonstrated on a field scale from September through November 2001 at the Rutgers University Ecocomplex as a component of their "*Environmental Incubator*" technology program. The *Environmental Incubator* is a high-tech research center for start-up businesses, focusing on industries that market and develop environmental cleanup technologies.

In November, 2001, following one-hundred hours of continuous operation, the pilot scale facility recovered high purity methane fuel and food grade liquid CO_2 from raw landfill gas. Composition of the methane and CO_2 process streams were confirmed through independent analysis, by Atlantic Analytical Laboratory, Whitehouse, NJ. Results of the analysis are provided as Attachment I. Contaminant removal was achieved for non-methane hydrocarbons and organosilicates to laboratory detection levels (10 ppb or less).

For landfill based projects, the CO_2 Wash™ technology facilitates production of a wide variety of renewable energy products, which may include compressed natural gas (CNG), ethanol, methanol, biodiesel, and ultra-pure hydrogen. The capacity for hydrogen production is of immediate interest with respect to the burgeoning fuel cell research industry.

As a greenhouse gas-friendly technology, the CO_2 Wash™ process also partitions and purifies the CO_2 fraction of landfill gas. This offers enormous benefits relative to the sequestration of CO_2, and diversion from

the atmosphere to marketable commodities. For the Green Energy Center, ultra-pure CO_2 partitioned from the landfill gas stream is proposed to be used to support development of a high-tech 80-acre greenhouse complex which utilize the CO_2 as a renewable source of plant fertilizer. The CO_2 can also be marketed for a wide variety of industrial applications including dry ice, coolants and non-toxic cleaning agents.

GREEN ENERGY CENTER COMPONENTS

CO_2 Wash™ Methane Purification Plant

The methane purification plant being constructed at the Green Energy Center consists of a modular CO_2 Wash™ facility. This plant is a scaleable module that is currently designed to process up to 5,500 cfm of raw landfill gas daily. Operating ranges for CO_2 Wash™ modules typically range from 300 cfm to 7,000 cfm. The process, in general, is easily scaled. This allows for expansion of processing capacity with increasing landfill gas yield.

The CO_2 Wash™ produces a primary methane stream consisting of approximately 80% methane, and 20% CO_2, which is equivalent to medium-Btu pipeline gas (800 Btu/scf) (Figure 1).

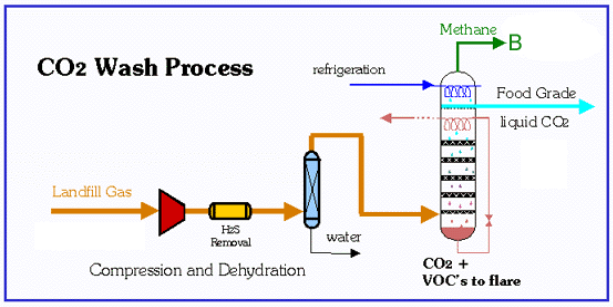

Figure 1
CO^2 Wash™ Process Schematic

The primary methane stream is suitable for direct use as medium Btu fuel, or can be routed to a secondary processing stage for further CO_2 removal (Figure 2).

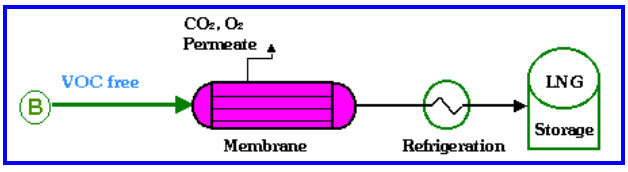

Figure 2
CO^2 Wash™ Methane Enrichment

Secondary processing assumes the form of membrane separation, resulting in CO_2 concentrations of 50 ppm or less and elevation of the methane stream to high-Btu grade.

Removal of sulfur from the raw landfill gas is accomplished via an iron-bed reactor (Figure 1). Removal efficiencies for sulfur allow categorization of secondary processed high-Btu methane as "*natural gas*" or the more stringent "*pipeline natural gas*" pursuant to 40 CFR §72.2 (U.S. EPA Acid Rain Program).

Initial operation of the CO_2 Wash™ technology at the Green Energy Center will occur in two primary phases. Phase I will include processing of a low-Btu methane stream used to fire a 250kW microturbine. Feed rates are projected in the range of 100 cfm. A second process stream of approximately 120 cfm will be converted to high-Btu methane, suitable for compression and use as CNG for vehicle fuel. This process stream will produce approximately 1,200 Diesel Gallon Equivalents (DGE) per day which will be used for the SWACO vehicle fuel conversion program.

Phase II will include scale-up of the CO_2 Wash™ to process 90% or more of available gas yield. Expected production rates are in the range of 5,500 to 6,000 cfm. This second phase of gas processing will be used primarily to support methanol production and additional electrical generating capacity.

Compressed Natural Gas Fueling Station

As a portion of long-range planning for the Green Energy Center, SWACO has initiated a renewable vehicle fuel study involving conversion of a 2005 Ford Sterling truck with a 12.7 liter Detroit series 60 diesel engine. The conversion allows operation on a combination of CNG and diesel fuel. A second study will be initiated using a combination of CNG and biodiesel fuel. The converted vehicle was placed in service in June 2006 and is currently being evaluated for the following performance criteria utilizing a combination of CNG and petroleum diesel over a 3-month study period:

- Fuel mileage
- Usable power and acceleration
- Engine wear (evaluated via oil analysis)
- Operator satisfaction

A subsequent 3-month evaluation will be performed with a combination of CNG and B20 biodiesel blend. Results of the conversion study will be used to assess the viability of long-term use of renewable fuels for SWACO's waste transfer truck fleet. Results of initial

testing are not available at the time of this publication, but will be provided as a supplement to this paper at WasteCon 2006. Future studies are also planned for heavy equipment (landfill operations) conversions.

250 kW Microturbine Generating Station

The Green Energy Center includes two electrical generating stations. Phase I will include installation of an Ingersoll Rand MT-250 kW microturbine (Figure 3).

Figure 3
Ingersoll-Rand MT-250 Microturbine (250kW)

The MT-250 will produce sufficient power to support all SWACO infrastructure and landfill operations. This will allow SWACO to become independent of the local electrical grid, and become "self-powered" from on-site renewable fuel resources.

At a consumption rate of approximately 100 cfm, the MT-250 represents a fuel and emissions efficient mode of small scale generating capacity. Initial operations will be fueled via a low-Btu (600 Btu/scf) process stream from the CO_2 Wash^{TM} facility. Relative to air pollutants produced, the emissions profile of the MT-250 compares very favorably to comparable emission rates for regional electrical utility power plants.

TABLE 1
EMISSION PROFILE – MT-250 MICROTURBINE
COMPARISON TO REGIONAL ELECTRIC
GENERATING FACILITIES
(lbs/MWh)

Pollutant	MT-250 (1)	Picway (2)	Conesville (3)	Avoided Emissions (tpy) (4)
NOx	0.48	5.3	4.0	3.6
CO	0.56	-	-	-
CO_2	2,080	2,400	1,911	78
Mercury	Negligible	0.0002	0.0001	0.0001
SO_2	Trace (5)	49.3	20.3	21

1. Ingersoll-Rand Co. Ltd. Estimated MT-250 emissions, May 2005
2. U.S. EPA Clean Air Markets Database (CY 2005). Columbus Southern Power Company, Picway Generating Station, Pickaway County, Ohio
3. U.S. EPA Clean Air Markets Database (CY 2005). Columbus Southern Power Company, Conesville Generating Station, Coshocton County, Ohio
4. Theoretical avoided emissions based on 250kW base load at 8,300 hours per year vs. average power plant rate (60% methane/40% CO_2 fuel mix at 90F°). Assumes avoided electrical generation.
5. Assumes sulfur removal prior to combustion.

As shown significant reductions in NOx, CO_2, Mercury and SO_2 will be realized as compared to comparable generating station emission rates.

6.5 Megawatt Internal Combustion Engine Generating Station

In an effort to further the energy independence of the Green Energy Center, Phase II of proposed electrical generating capacity includes installation of a series of GE-Jenbacher reciprocating internal combustion generator sets (Figure 4).

Figure 4
GE-Jenbacher Type 420 IC Engine Generator Set
(1.428 MW per unit)

Power generated from these units will be used primarily to satisfy parasitic power loads from the CO_2 Wash^{TM}, CNG and methanol synthesis plants. Excess power will either be fed back to the local grid, or used to support a local industrial/commercial business center located adjacent to FCSL. Waste heat from the engines will be used to support SWACO infrastructure (facilities heating/cooling) or diverted to the adjacent greenhouse complex for heating purposes.

As with the MT-250 microturbine, comparisons to electrical grid emission rates are very favorable. Although the specific number of engines and engine model mix has not been determined at the time of this publication, emission rates for various GE-Jenbacher models are sufficiently similar to provide the following general comparison:

TABLE 2
EMISSION PROFILE – GE JENBACHER TYPE 4 IC GENERATOR SETS (6.5 MW TOTAL) COMPARISON TO REGIONAL ELECTRIC GENERATING FACILITIES
(lbs/MWh)

Pollutant	Type 420 (1)	Picway (2)	Conesville (3)	Avoided Emissions (tpy) (4)
NOx	1.8	5.3	4.0	59
CO	9.1	-	-	-
CO_2	343	2,400	1,911	48,900
Mercury	Negligible	0.0002	0.0001	0.003
SO_2	Trace (5)	49.3	20.3	548

1. Northeast Energy Systems, Inc. Estimated emissions, Jenbacher type 420, July 2006
2. U.S. EPA Clean Air Markets Database (CY 2005). Columbus Southern Power Company, Picway Generating Station, Pickaway County, Ohio
3. U.S. EPA Clean Air Markets Database (CY 2005). Columbus Southern Power Company, Conesville Generating Station, Coshocton County, Ohio
4. Theoretical avoided emissions based on 6.5 MW base load at 8,300 hours per year vs. average power plant rate (60% methane/40% CO_2 fuel mix at 90F°). Assumes avoided electrical generation.
5. Assumes sulfur removal prior to combustion.

Methanol Synthesis Plant

The primary long-term use for purified methane generated from the CO_2 Wash^{TM} facility will be feedstock for the production of methanol. Methanol will be produced via a conventional steam reforming/catalytic unit. Maximum permitted production capacity is currently 20 million gallons per year.

The steam reforming process involves catalytic oxidation of methane via injection of steam into methane in the presence of a metal based catalyst. This process produces hydrogen and carbon dioxide gas which are then reacted under pressure in a separate catalytic process to form liquid methanol.

Methanol production represents a critical component of the Green Energy Center business model. As the vast majority of domestic and imported methanol used in the United States is manufactured from non-renewable energy sources, the production of "*Green Methanol*" from renewable fuel sources allows the Green Energy Center to assume a unique position in the domestic methanol market.

Methanol is widely used as a chemical production feedstock (e.g. for production of formaldehyde through catalytic oxidation). Methanol is also used as feedstock for the production of biodiesel fuel. The ability to produce biodiesel fuel represents an additional means of enhancing the environmental benefit of the Green Energy Center through reduction of mobile air pollutant emissions.

Biodiesel Production Facility

Biodiesel fuel production at the Green Energy Center will be produced using a conventional transesterfication process. Transesterfication is a chemical catalysis process whereby glycerin is separated from animal fats or vegetable oil. The process produces two product streams; methyl esters (the chemical name for biodiesel) and crude glycerin.

Mixing of methanol with animal fats or vegetable oils in the presence of a catalyst drives the transesterfication process. For the Green Energy Center, methanol produced from purified landfill gas will be mixed with soy oil to produce the methyl ester (biodiesel) and crude glycerin.

For each gallon of biodiesel produced, 0.2 gallons of methanol and 0.8 gallons of soy oil are required. These feedstock ratios establish a maximum production rate of approximately 100 MM gallons of pure biodiesel (B100). At conventional blending rates of 20% with petroleum diesel (B20), maximum production capacity is increased to 500 MM gallons of B20 blend which may be distributed to local dispensing facilities.

Biodiesel fuels and emissions from their combustion have been extensively studied, and a comprehensive examination of emissions from biodiesel fueled engines was published in draft form by the U.S. EPA in 2002 (5).

The results of this study indicate that significant reduction in CO, particulate matter (PM) and hydrocarbon (HC) emissions may result from biodiesel use in conventional compression ignition engines (Figure 5).

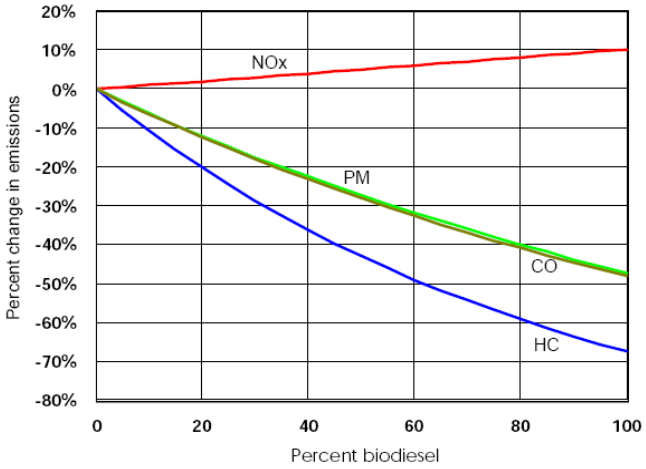

Figure 5
Biodiesel vs. Petroleum Diesel Emission Profile
(U.S. EPA, 2003)

This draft study also concluded that an increase in NOx may result from biodiesel combustion (U.S. EPA, 2003). This NOx increase has been the subject of considerable debate, and additional studies on the combustion by-products of biodiesel fueled engines have been undertaken to further study the biodiesel-NOx relationship (McCormick et al., 2003).

While maximum production rates for biodiesel fuel are optimistic, and will likely be limited by the amount of landfill gas produced, they nonetheless represent a tremendous opportunity to expand the environmental benefit of the Green Energy Center beyond the immediate landfill area.

Facility Air Permits

Application for air emission permits for each Green Energy Center facility was undertaken on a component-by-component basis.

For the CNG dispensing and MT-250 microturbine, detailed evaluation of emissions and coordination with vendors facilitated a determination by the Ohio Environmental Protection Agency (OEPA) that each unit was exempt from Permit to Install (PTI) application requirements and could be installed without construction and operating permits. This determination was based on evaluation of emission levels for regulated pollutants. For each unit, emission levels of less than 10 pounds per day per pollutant were calculated, satisfying the exemption criteria.

The CO_2 Wash™ facility was amended to FCSL's Gas Collection and Control System (GCCS) Design Plan (40 CFR §60.752(b)(2)(i)) as a gas treatment system (40 CFR §60.752(b)(iii)(C)). For permitting purposes, the facility was considered as a zero emission unit as it neither alters nor adds to regulated pollutants contained within the raw landfill gas it processes. As the slipstream discharged from the facility is routed to the landfill's control device (enclosed flare), it is considered a closed loop treatment system utilizing an existing permitted control device. Slipstream rates and residual landfill gas that will be fed to the flare were deemed sufficient to maintain the required destruction efficiency of 98% as well as compliance with NESHAP related control device operating requirements (40 CFR §63.11).

For the methanol synthesis facility and IC Engine generating station, permitting was significantly more complex.

As methanol is a listed hazardous air pollutant (HAP), National Emission Standards for Hazardous Air Pollutants (NESHAP) are applicable. The host landfill (FCSL) and methanol plant each meet numerical standards for classification as NESHAP *area sources*. However, each was considered as a NESHAP *major source* for air permitting purposes.

FCSL, by virtue of its permitted capacity is considered by definition as a NESHAP *major source*. Thus although FCSL has a potential to emit less than 10 tons of any single hazardous air pollutant (HAP) or 25 tons per year of any combination of HAPs, OEPA considered it a *major source* by definition for permitting purposes.

Location of the methanol plant on property contiguous to a NESHAP *major source* (FCSL) resulted in classification of the plant as a *major source* as well. Thus while the methanol plant also met numeric criteria for classification as an *area source* (and less stringent regulatory obligations) *major source* obligations were included in permit requirements

The methanol plant is generically grouped in the Synthetic Organic Chemical Manufacturing Industry (SOCMI) class, and thus is subject to the provisions of the Hazardous Organic NESHAP (HON) subset of air regulations (40 CFR §63, Subparts F, G and H). Requirements for Industrial, Commercial, and Institutional Boilers and Process Heaters at MACT *major*

sources are also applicable (40 CFR 63, Subpart DDDDD).

Various New Source Performance Standards (NSPS) also apply to the methanol plant. While significant overlap with associated NESHAP Subparts significantly reduces NSPS obligations, various recordkeeping and testing requirements nonetheless apply. Applicable NSPS regulations include 40 CFR §60 Subparts Db, Kb, VV, NNN and RRR.

Permit requirements for the IC Engine generating station focused on the Prevention of Significant Deterioration (PSD) program. FCSL operates as a PSD synthetic minor, and maintains voluntary restrictions on control device (flare) flow rates such that CO emissions remain below the 250 ton PSD *major source* threshold. In a similar fashion, the proposed IC Engine PTI application (developed by FirmGreen™) set forth voluntary restrictions limiting CO emissions to less than the 250 ton threshold (under the assumption that it would be permitted separately and distinctly from the landfill).

However, the OEPA expressed specific concerns regarding apparent interdependence of the facilities, and the appearance of PSD circumvention due to the fact that the proposed FirmGreen™ IC Engine facility was essentially dependent on the landfill as a fuel source. No alternative fuel source was proposed in preliminary PTI discussions. Therefore, in a manner consistent with the "*interdependence doctrine*" OEPA would aggregate emissions from each facility for the purpose of determining PSD applicability despite separate ownership and control, and dissimilar Standard Industrial Classification (SIC). In the absence of a contractual agreement clearly indicating the ability of the each facility to operate independently (e.g. from pipeline natural gas), OEPA's preliminary determination regarding PSD applicability included aggregation of each facility's emissions.

At the time of this publication, FirmGreen™ is in the process of evaluating various PTI options, as well as extension of a natural gas pipeline to provide alternate fueling options. Each may facilitate resolution of the PSD applicability issue. OEPA's assessment of proposed options is anticipated to be complete by September 2006.

Project Team

On June 21, 2005, a formal groundbreaking ceremony for the Green Energy Center was held at the FCSL Landfill Facility. In attendance were approximately 250 local government leaders, State of Ohio legislators, industry representatives, and SWACO personnel. The FirmGreen™ project team, CO_2 Wash™ research and development team, and local government officials are pictured at this ceremony (Figure 6).

Figure 6
The FirmGreen™ and CO_2 Wash™ Green Energy Center Project Development Team

Finally, this Green Energy Center would not have been possible without the enthusiastic support and vision of the Solid Waste Authority of Central Ohio, and Executive Director Mike Long. Pictured here (left) with FirmGreen™ president Steve Wilburn, Mr. Long's persistent efforts to develop economically viable, innovative and environmentally responsible landfill gas utilization projects provided the entire project team with strong leadership, innovative thinking, and the drive necessary to bring this vision to reality.

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McCormick, R.L., Alvarez, J.R., and Graboski, M.L., 2003, “NOx Solutions for Biodiesel”, Final Report NREL/SR-510-31465, National Renewable Energy Laboratory, Golden, Colorado.

GAS ANALYSIS REPORT
by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)
ACRION'S CO2 WASH PROCESS DEMONSTRATION UNIT
NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / September 2001

	Raw Landfill Gas AAL 6061-1		Methane Product AAL 6061-3	
Non-Condensable Gases	**vol%**	**DL vol%**	**vol%**	**DL vol%**
Nitrogen	6.7	0.01	9.6	0.01
Oxygen	--	0.10	--	0.10
Hydrogen	--	0.10	--	0.10
Carbon Dioxide	35.0	0.01	25.7	0.01
Volatile Hydrocarbons	**ppm volume**	**DL ppm**	**ppm volume**	**DL ppm**
Methane	(49.6%)	1	(62.6%)	1
Ethylene	3	1	3	1
Acetylene	nd	10	nd	10
Ethane	2	1	2	1
Propylene	nd	1	nd	1
Propane	41	1	14	1
Isobutane	13	1	nd	1
n-Butane	8	1	nd	1
Butenes	nd	1	nd	1
Isopentane	2	1	nd	1
n-Pentane	2	1	nd	1
Hexanes +	200	1	nd	1
Volatile Sulfur Compounds	**ppm volume**	**DL ppm**	**ppm volume**	**DL ppm**
Hydrogen Sulfide	nd		nd	0.05
Carbonyl Sulfide	1.10		0.1	0.05
Sulfur Dioxide	nd		nd	0.05
Methyl Mercaptan	nd		nd	0.05
Ethyl Mercaptan	nd		nd	0.05
Dimethyl Sulfide	4.00		nd	0.05
Carbon Disulfide	0.46		nd	0.05
Isopropyl Mercaptan	nd		nd	0.05
Methyl Ethyl Sulfide	0.06		nd	0.05
n-Propyl Mercaptan	nd		nd	0.05
t-Butyl Mercaptan	0.26		nd	0.05
Dimethyl Disulfide	1.00		nd	0.05
sec-Butyl Mercaptan	0.16		nd	0.05
Isobutyl Mercaptan	0.26		nd	0.05
Diethyl Sulfide	nd		nd	0.05
n-Butyl Mercaptan	0.12		nd	0.05

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by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)
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NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / September 2001

	Raw Landfill Gas AAL 6061-1		Methane Product AAL 6061-3	
GC/MS Results ***TO-14 Target List***	**ppm volume**	**DL ppm**	**ppm volume**	**DL ppm**
Freon-12	2.8		nd	0.5
Methyl Chloride	nd	0.5	nd	0.5
Freon-114	0.5		nd	0.5
Vinyl Chloride	0.5		nd	0.5
Methyl Bromide	nd	0.5	nd	0.5
Ethyl Chloride	nd	0.5	nd	0.5
Freon-11	nd	0.5	nd	0.5
Vinylidene Chloride	nd	0.5	nd	0.5
Freon-113	nd	0.5	nd	0.5
Dechloromethane	nd	0.5	nd	0.5
1,1-Dichlorethane	nd	0.5	nd	0.5
cis-1,2-Dichloroethylene	1.2		nd	0.5
Chloroform	nd	0.5	nd	0.5
1,1,1-Trichloroethane	nd	0.5	nd	0.5
1,2-Dichlorethane	nd	0.5	nd	0.5
Benzene	0.8		nd	0.2
Carbon Tetrachloride	nd	0.5	nd	0.5
1,2-Dichloropropane	5.1		nd	0.5
Trichloroethylene	0.7		nd	0.2
cis-1,3-/Dichloropropylene	nd	0.5	nd	0.5
trans-1,3-Dichloropropylene	nd	0.5	nd	0.5
Toluene	38.0		nd	0.2
1,1,2-Trichloroethane	nd	0.2	nd	0.2
1,2-Dibromoethane	nd	0.5	nd	0.5
Tetrachloroethylene	1.5		nd	0.2
Chlorobenzene	nd	0.2	nd	0.2
Ethyl Benzene	14.0		nd	0.2
m+p-Xylenes	15.0		nd	0.2
Styrene	4.4		nd	0.2
o-Xylene	4.2		nd	0.2
1,1,2,2-Tetrachloroethane	nd	0.2	nd	0.2
4-Ethyltoluene	6.2		nd	0.2
1,3,5-Trimethylbenzene	1.2		nd	0.2
1,2,4-Trimethylbenzene	1.2		nd	0.2
1,3-Dichlorobenzene	nd	0.2	nd	0.2
1,4-Dichlorobenzene	nd	0.2	nd	0.2
Benzylchloride	nd	0.2	nd	0.2
1,2-Dichlorobenzene	nd	0.2	nd	0.2
1,2,4-Trichlorobenzene	nd	0.2	nd	0.2
Hexachlorobutadiene	nd	0.2	nd	0.2

GAS ANALYSIS REPORT
by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)

ACRION'S CO2 WASH PROCESS DEMONSTRATION UNIT
NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / September 2001

	Raw Landfill Gas AAL 6061-1			Methane Product AAL 6061-3	
GC/MS Results	**ppm**	**DL**		**ppm**	**DL**
Non-TO-14 Target List	**volume**	**ppm**		**volume**	**ppm**
Propane	41			14	
Isobutane	13			nd	0.5
Acetone	21			nd	0.5
Methylethyl Ketone	40			nd	0.5
2-butanol	38			nd	0.5
C6H12O2	28			nd	0.5
C9 Aliphatic Hydrocarbon	32			nd	0.5
Alpha-Pinene	38			nd	0.5
C11 Aliphatic Hydrocarbon	16			nd	0.5
D-Limonene	15			nd	0.5
GC/MS Results	**ppb**	**DL**		**ppb**	**DL**
Toxic Substances Sub-17	**volume**	**ppb**		**volume**	**ppb**
Freon-12				nd	10
Vinyl Chloride				nd	10
Chloroform				nd	10
1,2-Dichloroethane				nd	10
Benzene				nd	10
Carbon Tetrachloride				nd	10
Trichloroethylene				nd	10
1,4-Dioxane				nd	10
1,1,2-Trichloroethane				nd	10
1,2-Dibromoethane				nd	10
Tetrachloroethylene				nd	10
1,1,2,2 Tetrachloroethane				nd	10
Methylene Chloride				nd	10
1,1,1-Trichloroethane				nd	10

Compounds detected with other test methods

Analysis at ppb level not performed.

NOTES:

AAL 6061-1: raw landfill gas after compression to 400 psig and water knockout
AAL-6061-3: product gas from CO2 wash
DL = Detection Limit, if not shown, reported result is greater than DL
nd = concentration is less than stated DL
-- = test not performed
ppm = parts per million
ppb = parts per billion

GAS ANALYSIS REPORT
by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)
ACRION'S CO2 WASH PROCESS DEMONSTRATION UNIT
NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / November 2001

	Raw Landfill Gas AAL 6696		CO2 Product AAL 6695	
Non-Condensable Gases	**vol%**	**DL vol%**	**ppm v/v**	**DL ppm v/v**
Nitrogen	7.5	0.01	--	10
Oxygen	--	0.10	--	4
Argon	--		--	4
Hydrogen	--	0.10	--	10
Carbon Dioxide	38.3	0.01	--	4
Volatile Hydrocarbons	**ppm volume**	**DL ppm**	**ppm volume**	**DL ppm**
Methane	54.3%	1	nd	1
Ethylene	4	1	nd	1
Acetylene	nd	10	--	
Ethane	3	1	nd	1
Propylene	nd	1	nd	1
Propane	47	1	67	1
Isobutane	13	1	nd	1
n-Butane	9	1	nd	1
Butenes	nd	1	nd	1
Isopentane	2	1	nd	1
n-Pentane	2	1	nd	1
Hexanes +	370	1	nd	1
Volatile Sulfur Compounds	**ppm volume**	**DL ppm**	**ppm volume**	**DL ppm**
Hydrogen Sulfide	nd	0.05	nd	0.05
Carbonyl Sulfide	1.00	0.05	0.25	0.05
Sulfur Dioxide	nd	0.05	nd	0.05
Methyl Mercaptan	nd	0.05	nd	0.05
Ethyl Mercaptan	nd	0.05	nd	0.05
Dimethyl Sulfide	5.00	0.05	nd	0.05
Carbon Disulfide	1.20	0.05	nd	0.05
Isopropyl Mercaptan	nd	0.05	nd	0.05
Methyl Ethyl Sulfide	0.06	0.05	nd	0.05
n-Propyl Mercaptan	nd	0.05	nd	0.05
t-Butyl Mercaptan	nd	0.05	nd	0.05
Dimethyl Disulfide	0.13	0.05	nd	0.05
sec-Butyl Mercaptan	0.21	0.05	nd	0.05
Isobutyl Mercaptan	0.19	0.05	nd	0.05
Diethyl Sulfide	nd	0.05	nd	0.05
n-Butyl Mercaptan	0.05	0.05	nd	0.05

GAS ANALYSIS REPORT
by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)
ACRION'S CO2 WASH PROCESS DEMONSTRATION UNIT
NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / November 2001

	Raw Landfill Gas AAL 6696		CO2 Product AAL 6695	
GC/MS Results ***TO-14 Target List***	**ppm volume**	**DL ppm**	**ppm volume**	**DL ppm**
Freon-12	1.6		--	
Methyl Chloride	nd	0.5	--	
Freon-114	0.5		--	
Vinyl Chloride	0.7		nd	0.5
Methyl Bromide	nd	0.5	--	
Ethyl Chloride	nd	0.5	--	
Freon-11	nd	0.5	--	
Vinylidene Chloride	nd	0.5	--	
Freon-113	nd	0.5	--	
Dichloromethane	nd	0.5	--	
1,1-Dichlorethane	nd	0.5	--	
cis-1,2-Dichloroethylene	0.9		--	
Chloroform	nd	0.5	--	
1,1,1-Trichloroethane	nd	0.5	--	
1,2-Dichlorethane	nd	0.5	--	
Benzene	0.6		nd	5 ppb
Carbon Tetrachloride	nd	0.5	--	
1,2-Dichloropropane	3.1		--	
Trichloroethylene	0.5		--	
cis-1,3-/Dichloropropylene	nd	0.5	--	
trans-1,3-Dichloropropylene	nd	0.5	--	
Toluene	26.0		nd	0.2
1,1,2-Trichloroethane	nd	0.2	--	
1,2-Dibromoethane	nd	0.5	--	
Tetrachloroethylene	0.8		--	
Chlorobenzene	nd	0.2	--	
Ethyl Benzene	9.3		nd	0.2
m+p-Xylenes	13.0		nd	0.2
Styrene	3.1		--	
o-Xylene	3.6		nd	0.2
1,1,2,2-Tetrachloroethane	nd	0.2	--	
4-Ethyltoluene	3.5		--	
1,3,5-Trimethylbenzene	0.8		--	
1,2,4-Trimethylbenzene	0.8		--	
1,3-Dichlorobenzene	nd	0.2	--	
1,4-Dichlorobenzene	nd	0.2	--	
Benzylchloride	nd	0.2	--	
1,2-Dichlorobenzene	nd	0.2	--	
1,2,4-Trichlorobenzene	nd	0.2	--	
Hexachlorobutadiene	nd	0.2	--	
Other Organics	--		nd	1

GAS ANALYSIS REPORT
by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)

ACRION'S CO2 WASH PROCESS DEMONSTRATION UNIT
NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / November 2001

	Raw Landfill Gas AAL 6696		CO2 Product AAL 6695	
GC/MS Results	**ppm**	**DL**	**ppm**	**DL**
Non-TO-14 Target List	**volume**	**ppm**	**volume**	**ppm**
Methanol	--		nd	2
Ethanol	--		nd	2
Propane	47		67	
Isobutane	13		nd	1
Acetone	19		--	
Methylethyl Ketone	9.1		--	
2-butanol	26		--	
Iso-Butanol	--		nd	0.5
C6H12O2	19		--	
C8 Aliphatic Hydrocarbon	--		nd	0.5
C9 Aliphatic Hydrocarbon	3.6		--	
Alpha-Pinene	9.5		--	
C11 Aliphatic Hydrocarbon	15		--	
D-Limonene	7.3		nd	0.5
GC/MS Results	**ppb**	**DL**	**ppb**	**DL**
Toxic Substances Sub-17	**volume**	**ppb**	**volume**	**ppb**
Freon-12	Analysis not performed on raw landfill gas		--	
Vinyl Chloride			nd	500
Chloroform			--	
1,2-Dichloroethane			--	
Benzene			nd	5
Carbon Tetrachloride			--	
Trichloroethylene			--	
1,4-Dioxane			--	
1,1,2-Trichloroethane			--	
1,2-Dibromoethane			--	
Tetrachloroethylene			--	
1,1,2,2 Tetrachloroethane			--	
Methylene Chloride			--	
1,1,1-Trichloroethane			--	

NOTES:
AAL 6696: raw landfill gas after compression to 200 psig and water knockout
AAL-695: product CO2 bottom of stripper
DL = Detection Limit, if not shown, reported result is greater than DL
nd = concentration is less than stated DL
-- = test not performed
ppm = parts per million
ppb = parts per billion

GAS ANALYSIS REPORT
by ATLANTIC ANALYTICAL LABORATORY (AAL, Whitehouse, NJ)

ACRION'S CO2 WASH PROCESS DEMONSTRATION UNIT
NJ ECOCOMPLEX / BURLINGTON COUNTY LANDFILL / September 2001

	Raw Landfill Gas AAL 6014-1		Methane Product AAL 6014-2	
Target Analyte	ppb volume	DL ppb	ppb volume	DL ppb
Hexamethyldisiloxane (MM)	130	5	nd	5
Hexamethylcyclotrisiloxane (D3)	480	5	nd	5
Octamethyltrisiloxane	20	5	nd	5
Octamethylcyclotetrasiloxane (D4)	1,190	5	nd	5
Decamethyltetrasiloxane	nd	5	nd	5
Decamethylcyclopentasiloxane (D5)	500	5	nd	5
Dodecamethylpentasiloxane	nd	5	nd	5
Other Siloxanes	nd	10	nd	10

NOTES:
AAL 6014-1: raw landfill gas at blower outlet (before compression)
AAL-6014-2: methane (fuel) product gas from CO2 wash
DL = Detection Limit, if not shown, reported result is greater than DL
nd = concentration is less than stated DL
ppm = parts per million
ppb = parts per billion

Acrion Technologies, Inc
9099 Bank Street
Cleveland, Ohio 44125
216 573 1187

EXHIBIT E

SWACO Green Energy Center
Final Scientific Report

Know-How Sublicense and Licensing Agreement

Patent Sublicensing Agreement

Trademark License

KNOW-HOW SUBLICENSE AND LICENSE AGREEMENT

THIS KNOW-HOW SUBLICENSE AND LICENSE AGREEMENT (this "Sublicense"), dated as of November 19th, 2009, is made by and between FirmGreen, Inc., a Delaware corporation having offices at 2901 West Coast Highway, Suite 200, Newport Beach, California 92663 (hereinafter "FGI"), and Solid Waste Authority of Central Ohio, a regional solid waste authority established pursuant to Ohio Revised Code Section 343.11, having offices at 4239 London Groveport Road, Grove City, Ohio 43123 (the "Sublicensee").

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RECITALS

WHEREAS, pursuant to that certain Know-How License Agreement, by and between Acrion Technologies, Inc. ("Acrion") and FGI, dated April 4, 2008 (the "Prime License Agreement"), FGI is the exclusive worldwide licensee of rights relating to the Licensed Subject Matter (as defined below) and has the authority to enter into sublicense agreements consistent with the Prime License Agreement;

WHEREAS, in addition to its rights under the Prime License Agreement, FGI has developed and owns, or expects to develop and own valuable know-how relating to the Licensed Subject Matter; and

WHEREAS, Sublicensee wishes to acquire rights to use the Licensed Subject Matter, and FGI wishes to grant Sublicensee a sublicense and license to use the Licensed Subject Matter, on the terms and subject to the conditions set forth herein.

NOW, THEREFORE, in consideration of the mutual covenants and agreements herein contained and for other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged and accepted, the parties hereto intending to be mutually bound do hereby covenant and agree as follows:

1. EFFECTIVE DATE

This Sublicense is effective as of the date set forth in the preamble of this Sublicense (such date, the "Effective Date").

2. DEFINITIONS

As used in this Sublicense, the following terms have the meanings indicated:

2.1 "Acrion Know-How" means know-how and expertise, including proprietary and nonproprietary technical information, processes, procedures, compositions, devices, methods, formulas, protocols, techniques, software, designs, drawings or data created by Acrion before and after the Effective Date relating to Biogas clean-up, subject to and limited by third party license rights under the Mack License as described in paragraph 5.3 hereof. Acrion Know-How includes, without limitation, the subject matter described in Exhibit A1 attached hereto and certain data, files and materials that have been or during the Term will be transferred to Sublicensee.

2.2 "Affiliate" means, with respect to a party, any business entity more than fifty percent (50%) owned by such party, any business entity which owns more than fifty percent (50%) of such party, or any business entity that is more than fifty percent (50%) owned by a business entity that owns more than fifty percent (50%) of such party.

2.3 "Biogas" means LFG or anaerobic digester gas.

2.4 "Commercialize" means having sales of Licensed Product in any applicable jurisdiction or country.

2.5 "FGI Equipment" means any and all equipment and machinery obtained by Sublicensee from FGI, its Affiliates, or their respective designees, for use in the production of Biogas, including such equipment and machinery as may embody or use the Licensed Subject Matter.

2.6 "FGI Know-How" means know-how and expertise, including proprietary and nonproprietary technical information, processes, procedures, compositions, devices, methods, formulas, protocols, techniques, software, designs, drawings or data created by FGI before and after the Effective Date relating to Biogas. FGI Know-How includes, without limitation, the subject matter described in Exhibit A2 attached hereto and certain data, files and materials that have been or during the Term will be transferred to Sublicensee.

2.7 "Field-of-Use" means Biogas for other than producing a liquid methane product.

2.8 "LFG" means landfill gas.

2.9 "LFG Rights" means the legal right and authority to extract LFG at the Licensed Territory.

2.10 "Licensed Product" means Biogas (i) processed using Acrion Know-How, (ii) processed using a Proprietary Gas Processing Module, or (iii) processed using FGI Know-How.

2.11 "Licensed Subject Matter" means Acrion Know-How and FGI Know-How within the Field of Use.

2.12 "Licensed Territory" means the site more particularly described in Exhibit C attached hereto at which Sublicensee will develop a Biogas recovery project using, at least in part, the Licensed Subject Matter.

2.13 "Proprietary Gas Processing Module" means any combination of Acrion Know-How or FGI Know-How and third party technology used to process Biogas which does not alter the molecular structure of methane or carbon dioxide contained therein.

2.14 "Sale" or "Sold" means the transfer or disposition of Licensed Product for value by Sublicensee.

2.15 "Term" is defined in paragraph 9.1 hereof.

3. REPRESENTATIONS AND WARRANTIES BY FGI

FGI hereby represents and warrants to Sublicensee that:

3.1 FGI is a corporation duly organized, validly existing and in good standing under the laws of the State of Delaware and has all requisite corporate power and authority to carry on its business as now conducted.

3.2 The execution and delivery of this Sublicense by FGI have been duly authorized by all necessary corporate action and (assuming the due execution and delivery hereof by the Sublicensee) this Sublicense constitutes a legal, valid and binding obligation of FGI, enforceable in accordance with its terms, subject to applicable bankruptcy, insolvency, reorganization,

moratorium or other similar laws affecting creditors rights generally and subject to general principles of equity, whether considered in a proceeding in equity or at law.

3.3 Except for limitations and rights reserved to publish research relating to the Acrion Know-How, (i) pursuant to the Prime License Agreement, Acrion has granted FGI a royalty-bearing, exclusive worldwide license to use the Acrion Know-How within the Field of Use and has authorized FGI to grant sublicenses consistent therewith; and (ii) FGI has not knowingly granted any license or sublicense with respect thereto to any other person or entity that would restrict rights granted to Sublicensee hereunder.

3.4 FGI grants this Sublicense, and Sublicensee accepts same on a strictly "as-is" basis without warranty or condition of any kind whether express, implied or statutory, and FGI makes no representations, warranties, conditions, covenants, guarantees or obligations of any kind in relation to the Licensed Subject Matter, whether as to title, the uses, merchantable quality or merchantability, suitability, performance, fitness for a particular purpose, capabilities, non-infringement of third party intellectual property or other proprietary rights, reliability or accuracy thereof, or concerning any defects or deficiencies or the lack thereof of any nature in same.

4. REPRESENTATIONS AND WARRANTIES BY SUBLICENSEE

Sublicensee hereby represents and warrants to FGI that:

4.1 Sublicensee is a regional solid waste authority duly organized, validly existing and in good standing under the laws of the State of Ohio and has all requisite power and authority to carry on its business as now conducted.

4.2 The execution and delivery of this Sublicense by Sublicensee have been duly authorized and (assuming the due execution and delivery hereof by FGI) this Sublicense constitutes a legal, valid and binding obligation of Sublicensee, enforceable in accordance with its terms, subject to applicable bankruptcy, insolvency, reorganization, moratorium or other similar laws affecting creditors rights generally and subject to general principles of equity, whether considered in a proceeding in equity or at law.

4.3 Sublicensee, by execution hereof, acknowledges, covenants and agrees that it has not been induced in any way by Acrion, FGI, or their respective directors, officers, employees or agents to enter into this Sublicense, and further warrants and represents that (i) it has conducted sufficient due diligence with respect to all items and issues pertaining to this Sublicense; and (ii) Sublicensee has adequate knowledge and expertise, or has utilized knowledgeable and expert consultants, to adequately conduct such due diligence, and agrees to accept all risks inherent in the transactions contemplated hereby.

4.4 Sublicensee has all LFG Rights necessary to the use of the Licensed Subject Matter and the FGI Equipment and, upon request, shall provide FGI with written proof thereof.

4.5 Sublicensee acknowledges that FGI Equipment is proprietary and that it would cause serious and irreparable damage to FGI if FGI Equipment were used by Sublicensee or any third party outside of the Licensed Territory. Sublicensee further acknowledges that the restrictions

on use or disposition of FGI Equipment provided in paragraph 5.2 hereof are reasonable and necessary and do not materially impair Sublicensee's business or property interests.

4.6 Sublicensee acknowledges that no rights, express or implied, including rights under the patent exhaustion doctrine, are granted hereunder, or by the sale or transfer of FGI Equipment, to any issued, pending or future patents or patent applications or to any know-how, trade secret or any other technology owned, licensable, or controlled by Acrion, FGI or any of their Affiliates, other than the Licensed Subject Matter.

5. SUBLICENSE OF ACRION KNOW-HOW; RESTRICTIONS

5.1 FGI hereby grants to Sublicensee a royalty-bearing, non-exclusive, non-sublicensable (i) sublicense of Acrion Know-How, which is further detailed in Exhibit A1 and herein and (ii) license of FGI Know-How, which is further detailed in Exhibit A2 and herein, to facilitate the design, installation, and operation of FGI Equipment and plant, equipment, and machinery incorporating Licensed Subject Matter and developed by Sublicensee or any Affiliate and to manufacture or have manufactured only within the Licensed Territory, and to use and/or sell, Licensed Product only in the Field-of-Use, subject to the limitations set forth in this Sublicense. In furtherance of this Sublicense, at the request of Sublicensee, to the extent permitted by the Prime License Agreement and subject to the needs of FGI, Acrion and other sublicensees, as determined by FGI in its sole discretion, FGI may, at its option, request Acrion to provide Sublicensee periodic technical assistance and deliverables as specified in Exhibit B attached hereto.

5.2 Sublicensee may not extend this Sublicense to any Affiliate or any other person or entity without the prior written consent of FGI, which may be granted or withheld in FGI's sole discretion. During the Term of this Sublicense and for ten (10) years thereafter, Sublicensee may not utilize FGI Equipment outside of the Licensed Territory, or sell, loan, or otherwise transfer possession of the FGI Equipment for use outside of the Licensed Territory.

5.3 Notwithstanding anything to the contrary in this Sublicense, Sublicensee shall take this Sublicense subject to the rights granted by Acrion pursuant to an agreement dated September 2, 2002 (the "Mack License"), whereby Acrion granted an exclusive worldwide license to Mack Trucks, Inc. and Mack's parent company, AB Volvo, to commercially develop and make full use of certain Acrion technology for the express and sole purpose of preparing Biogas to produce liquid methane, and carbon dioxide coincident with the preparation of Biogas for that purpose.

6. INTELLECTUAL PROPERTY OWNERSHIP

6.1 All right, title and interest in and to any intellectual property created by either FGI or Sublicensee during the Term in the course of either party's performance under this Sublicense, including but not limited to any inventions and improvements (whether patentable or not patentable) discovered, developed or reduced to practice, in each case related to the Licensed Subject Matter, shall be the sole and exclusive property of FGI and FGI hereby grants a non-exclusive license to Sublicensee to use such intellectual property solely in the ordinary course of Sublicensee's operations in connection with Sublicensee's operation of the CO_2 Wash™ Unit and appurtenant equipment and software purchased by Sublicensee from FirmGreen Fuels of

Ohio, L.L.C. at the Franklin County Sanitary Landfill, during the term of the patent or patents or renewal thereof.

6.2 At FGI's sole cost and expense, Sublicensee shall fully cooperate with FGI and its Affiliates and assist FGI and its Affiliates in respect of the preparation, filing or prosecution of any domestic or foreign applications, claims, notices, forms, filings with governmental authorities or any other person or entity, or other documents or actions deemed reasonably necessary or advisable by FGI to register, protect or enforce the rights of FGI under this Sublicense.

7. USE OF FIRMGREEN AND ACRION NAMES AND MARKS

Sublicensee acknowledges that any trademarks, trade names, design marks, service marks, symbols, and/or logos adopted by FGI, FirmGreen, or Acrion to identify the Licensed Subject Matter and related products and services (collectively, "Licensor Marks") belong to FirmGreen or Acrion, as applicable, and that Sublicensee acquires no rights therein under this Sublicense. No Licensor Marks may be used by Sublicensee without the express written consent of FirmGreen or Acrion, as applicable, and then only in accordance with such party's trademark usage guidelines. For purposes hereof, "FirmGreen" includes FGI and/or any of its Affiliates.

8. PAYMENTS

8.1 In consideration of rights granted by FGI to Sublicensee pursuant to this Sublicense, Sublicensee shall pay during the Term of this Sublicense a site-specific annual Sublicense Fee in the amount of $20,000, payable on the first, second, and third anniversary of the date hereof. The total of this Sublicense Fee shall not exceed $60,000.

8.2 All amounts payable hereunder by Sublicensee shall be paid in United States funds without deductions for taxes, assessments, fees, or charges of any kind. Checks shall be payable to FirmGreen, Inc., or to such other person as FGI may designate in writing from time to time. Such amounts may also be paid by wire transfer of immediately available funds to an account designated by FGI in writing.

8.3 Sublicensee shall reimburse FGI for, or pay directly, all reasonable and documented out-of-pocket business expenses incurred by FGI in performing its obligations under this Sublicense; provided, that any such expenses to be reimbursed hereunder shall be approved in advance by Sublicensee.

9. TERM AND TERMINATION

9.1 The term of this Sublicense ("Term") is from the Effective Date through the 20th anniversary of the date hereof, unless earlier terminated pursuant to the terms of paragraph 9.2 hereof. Upon any termination of this Sublicense, the Sublicensee shall have no further license to any Acrion Know-How or FGI Know-How.

9.2 This Sublicense will earlier terminate:

(a) with respect to Acrion Know-How only, automatically upon any termination of the Prime License Agreement; or

(b) automatically, at FGI's option, if Sublicensee becomes bankrupt and/or if the business of Sublicensee is placed in the hands of a receiver, assignee, or trustee, whether by voluntary act of Sublicensee or otherwise; or

(c) at FGI's option, upon thirty (30) days written notice from FGI if Sublicensee breaches or defaults on its obligation to make payments (if any are due) or reports, in accordance with the terms of Article 8 hereof, unless, before the end of the thirty (30) day period, Sublicensee shall have cured the default or breach and so notifies FGI, stating the manner of the cure; or

(d) at the non-breaching party's option, upon ninety (90) days written notice by such non-breaching party if the other party breaches or defaults on any other obligation under this Sublicense, unless, before the end of the ninety (90) day period, such breaching party shall have cured the default or breach and so notifies such non-breaching party, stating the manner of the cure; or

(e) at any time by mutual written agreement between Sublicensee and FGI, upon one hundred eighty (180) days written notice to all parties and subject to any terms herein which survive termination;

(f) upon expiration or termination of Sublicensee's LFG Rights, unless FGI consents to transfer of this Sublicense to a new site, which consent shall not be unreasonably withheld; or

(g) upon termination or abandonment of the Green Energy Refueling Center by Sublicensee.

9.3 At any time SWACO shall have the right to terminate this agreement at any time upon ninety (90) days written notice to FGI. Upon such termination, FGI shall have no obligation to refund fees paid by SWACO and all other obligations of the parties to each other shall expire upon the effective date of such termination, *provided, however*, SWACO shall continue to be bound by the provisions of Articles 7 (Use of FirmGreen and Acrion Names and Marks) and 11 (Confidential Information).

9.4 Notwithstanding anything to the contrary in this Sublicense, no right reserved by Acrion, referred to in Article 3 or Article 5 hereof, nor the continuation, validity or termination of such right, nor any act or omission of Acrion with respect to the Licensed Subject Matter shall, directly or indirectly, be a ground or cause for termination of this Sublicense (except as provided in paragraph 9.2(a) hereof).

9.5 If this Sublicense is terminated for cause (other than expiration of the Term of this Sublicense in accordance with paragraph 9.1 hereof):

(a) nothing herein will be construed to release any party of any obligation matured prior to the effective date of termination;

(b) after the effective date of termination, Sublicensee may sell all Licensed Product it then has on hand at the date of termination but shall make pro-rated payments thereon as set forth in Article 8 hereof; and

(c) notwithstanding such termination, Sublicensee shall continue to be bound by the provisions of Articles 7 ("Use of FirmGreen and Acrion Names and Marks"), 10 ("Limitation of Liability"), and 11 ("Confidential Information") of this Sublicense.

10. LIMITATION OF LIABILITY

10.1 EXCEPT FOR VIOLATION OF ARTICLES 5 ("SUBLICENSE OF ACRION KNOW-HOW; RESTRICTIONS"), 6 ("INTELLECTUAL PROPERTY OWNERSHIP"), 10 ("LIMITATION OF LIABILITY"), AND 11 ("CONFIDENTIAL INFORMATION") OF THIS SUBLICENSE, IN NO EVENT WILL EITHER PARTY BE LIABLE TOWARD THE OTHER PARTY FOR ANY INCIDENTAL, SPECIAL, OR CONSEQUENTIAL DAMAGES, HOWEVER CAUSED AND UNDER ANY THEORY OF LIABILITY, WHETHER FOR BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE) OR OTHERWISE, ARISING OUT OF THIS SUBLICENSE, INCLUDING BUT NOT LIMITED TO LOSS OF PROFITS, EVEN IF SUCH PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION WILL BE EFFECTIVE EVEN IF ANY REMEDY FAILS OF ITS ESSENTIAL PURPOSE.

10.2 EXCEPT FOR VIOLATION OF ARTICLES 5 ("SUBLICENSE OF ACRION KNOW-HOW; RESTRICTIONS"), 6 ("INTELLECTUAL PROPERTY OWNERSHIP"), 10 ("LIMITATION OF LIABILITY"), AND 11 ("CONFIDENTIAL INFORMATION") OF THIS SUBLICENSE, FGI'S TOTAL LIABILITY FOR DAMAGES OF ANY KIND ARISING OUT OF OR IN RELATION TO THIS SUBLICENSE IS LIMITED TO THE AMOUNT PAID BY SUBLICENSEE TO FGI DURING THE TWELVE (12) MONTHS PRIOR TO THE OCCURRENCE OF SUCH DAMAGES.

11. CONFIDENTIAL INFORMATION

11.1 FGI and Sublicensee each agree that the Licensed Subject Matter, the FGI Equipment and all information and documentation related to the Licensed Subject Matter or the FGI Equipment, including information identified as confidential or that should be recognized as confidential under the circumstances (collectively, "Confidential Information"), provided by FGI to Sublicensee hereunder, constitutes the confidential and proprietary information of FGI, and that Sublicensee's protection thereof is an essential condition to Sublicensee's use of the Licensed Subject Matter and the FGI Equipment. Prior to any disclosure by FGI to SWACO contended by FGI to be confidential, FGI shall conspicuously mark any material as CONFIDENTIAL in a format corresponding to the following: "CONFIDENTIAL; FGI; {DATE OF DISCLOSURE}." Confidential Information shall (i) be received in strict confidence, (ii) be used only for the purposes of this Sublicense, and (iii) not be disclosed by the recipient except to its employees and agents pre-approved by FGI in writing who have a need to know to perform their work pursuant to this Sublicense, have signed a confidentiality agreement permissible in content and form, approved by Sublicensee, containing terms at least as strict as the confidentiality terms in this

Sublicense, and have been informed that the Licensed Subject Matter and the FGI Equipment is confidential, contains trade secrets of FGI and Acrion, and is sublicensed to Sublicensee as such. Sublicensee shall ensure and be responsible for its employees' and agents' compliance with this Sublicense. Information shall not be considered Confidential Information if and to the extent such information:

(a) was in the public domain at the time of disclosure;

(b) later became part of the public domain through no act or omission of the recipient, its employees, agents, successors, or assigns;

(c) was lawfully disclosed to the recipient by a third party having the right to disclose it;

(d) was already known by the recipient at the time of disclosure;

(e) was independently developed by the recipient; or

(f) is required by law or regulation to be disclosed.

11.2 No information shall be regarded as CONFIDENTIAL if at any time, including any time after disclosure by FGI, the information (a) is or becomes a part of the public domain; (b) or is otherwise released to third parties without restrictions of confidentiality by FGI; (c) is disclosed to the public by a third party that has received the information from FGI; or (d) is published by FGI.

11.3 Each party's obligation of confidentiality hereunder shall be fulfilled by using at least the same degree of care with respect to the other party's confidential information as it uses to protect its own most valuable confidential information, but in no event less than reasonable diligence. This obligation shall continue during the Term and for a period of three (3) years thereafter.

11.4 Sublicensee shall promptly return to FGI all Confidential Information, together with all copies, reproductions, recordings, summaries, notes, memoranda, reports, compilations, derivatives, and other works prepared or based thereon which are in the possession of Sublicensee and, at FGI's option, certify in writing that all such materials have been returned and/or destroyed, upon written request by FGI or upon any termination of this Sublicense.

12. DISPUTE RESOLUTION

All disputes pursuant to this Sublicense shall take place in a court of competent jurisdiction in Franklin County, Ohio.

13. ASSIGNMENT

This Sublicense, including any part hereof, may not be assigned (by operation of law or otherwise) by Sublicensee without the prior written consent of FGI.

14. GENERAL

14.1 This Sublicense constitutes the entire and only agreement between the parties for Licensed Subject Matter and all other prior negotiations, representations, agreements, arrangements, course of conduct or dealings, and understandings between the parties, including any Affiliates, related parties, agents, officers, managers or directors thereof, in each case whether oral or written, are superseded hereby. No agreements altering or supplementing the terms hereof may be made except by a written document signed by both parties and expressly stating that it is intended to alter or supplement this Sublicense. To the extent, if any, that any agreement, current or future, regarding the FGI Equipment contains terms inconsistent with or less restrictive than the terms hereof, the terms of this Sublicense shall control and to that extent, any such other agreement shall have no force or effect.

14.2 Any notice or payment required by this Sublicense must be given by prepaid, first class, certified mail, return receipt requested, addressed as follows:

If to FGI	If to Sublicensee
FirmGreen, Inc. 2901 West Coast Highway, Suite 200 Newport Beach, California 92663 ATTENTION: Steven P. Wilburn	Solid Waste Authority of Central Ohio 4239 London Groveport Road Grove City, Ohio 43123 ATTENTION: Ronald J. Mills

or other addresses as may be given from time to time under the terms of this paragraph 14.2.

14.3 The parties are independent contractors, and nothing contained in this Sublicense will be construed as making either party or its employees the agent, employee, joint venturer or partner of the other party or granting to either party the authority to bind or contract any obligations in the name of or on the account of the other party or to make any representations, guarantees or warranties on behalf of the other parties.

14.4 Sublicensee shall comply with all applicable federal, state, and local laws and regulations in connection with its activities pursuant to this Sublicense.

14.5 This Sublicense shall be construed and enforced in accordance with the laws of the United States of America and of the State of Ohio applicable to contracts solely performed in that state.

14.6 The failure of either party to insist, in any instance, upon strict performance by the other party of any term or provision of this Sublicense or to enforce any of its rights under this Sublicense shall not be deemed to be a modification of any term hereof or a waiver or relinquishment of the future performance of any such term or provision by such party, nor shall such failure or omission constitute a waiver of the right of such party to insist upon future performance by the other party of any such term or provision. No waiver will be valid unless in writing and signed by the party against which enforcement of such waiver is sought.

14.7 Headings are included herein for convenience only and shall not be used to construe this Sublicense.

14.8 If any part of this Sublicense is for any reason found to be unenforceable, illegal, or invalid, all other parts nevertheless remain enforceable, legal, and valid in accordance with their terms.

14.9 This Sublicense may be executed in two or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument. Any signature page delivered by facsimile or electronic mail shall be binding to the same extent as an original signature page.

[Signature Page Follows]

IN WITNESS WHEREOF, parties hereto have caused their duly authorized representatives to execute this Sublicense as of the Effective Date.

FIRMGREEN, INC.

By: _____
Name: Steven P. Wilburn
Title: President

SOLID WASTE AUTHORITY OF CENTRAL OHIO

By: _____
Name: Ronald J. Mills
Title: Executive Director

APPROVED AS TO FORM:

_____
Leo V. Garvin, Jr.
Garvin & Maloney

per T/A authorization 19 November 2009

_____
Harold J. Anderson III
Chief Counsel
Solid Waste Authority of Central Ohio

EXHIBIT A1

ACRION KNOW-HOW

WHEREAS, in order to convert LFG into a commercially viable fuel or feedstock, high-purity methane must be separated from other components commonly found in LFG, including carbon dioxide ("CO2") and various volatile organic compounds ("VOC's"). Acrion's proprietary absorption process, implemented by a CO2 Wash® system using liquid CO2 produced *in situ* as a cleansing agent, can recover up to 99% of the methane found in LFG, while recovering up to sixty percent (60%) of the liquid CO2 as a secondary product. The purified methane produced by CO2 Wash® is free of LFG VOC's and water, and has diminished CO2 content with respect to the raw biogas feedstock. All nitrogen present in the raw LFG feedstock is present in the purified CO2 Wash® product gas. Acrion's proprietary absorption process has proven successful in several demonstration projects and is readily scalable for larger applications.

NOW THEREFORE, "ACRION KNOW-HOW" includes, but is not limited to, the following:

- Acrion's expertise acquired over more than thirty (30) years, independently and in parallel with Consolidated Natural Gas Co. and the U.S. Department of Energy, in the design of CO2 Wash® systems to accommodate the specific characteristics of unique Biogas, syngas, and natural gas feed streams.

- Acrion's experience and related proprietary data base that reflect extensive theoretical and experimental work undertaken with respect to systems containing gaseous, liquid, and solid carbon dioxide, especially near the triple-point of carbon dioxide.

- Acrion's experience and related proprietary data base that reflect work performed in connection with the design, construction, and operation of experimental apparatus for measurement of equilibrium parameters describing the behavior of binary systems comprised of selected contaminants and carbon dioxide, such equilibrium parameters being essential for specification and design of CO2 Wash® systems and comprising proprietary information.

- Acrion's experience, proprietary data base acquired in connection with the design, construction, maintenance, and successful operation of pilot plant projects in Ohio, New York. and New Jersey employing the CO2 Wash® process.

- Acrion's ability, based on such experience and proprietary data, to recognize and prioritize worthwhile and workable Biogas projects.

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EXHIBIT A2

FGI KNOW-HOW

FGI Know-How (BioGas Processing)

FGI has developed proprietary business and technical know-how in relation to processing Biogas into commercially viable, branded alternative fuel products and services. FGI has developed a manufacturing technique for its licensed Biogas cleaning technology CO2 Wash® by which standard processing modules sizes an configurations are fabricated and skid mounted for easy installation and field maintenance. The skid designs allow for substantially lower cost installation versus custom one off "stick built" field erected techniques.

FGI has developed proprietary control logic for the Biogas processing unit whereby FGI can detect variations in the gas feedstock and product gases and make process control adjustments automatically. FGI has developed a proprietary remote monitoring and reporting software and electronic communication interface to allow complete offsite unattended operation of the Biogas processing skids. The FGI remote management reporting system allows managers to access data in real time as well as receive customized operational reports from the Biogas processing skids and attendant CNG fueling systems operations.

FGI has developed a seamless interface technique to pre-treat raw Biogas prior to entering the CO2 Wash® process, thereby ensuring a more effective and economical conversion of the biogas into finished commercially viable products. In addition, FGI has developed and designed a seamless interface technique with standard gas polishing equipment to ensure the highest quality of alternative fuel products derived from the CO2 Wash® product gases.

11/19/09

11-19-2009

EXHIBIT B

ACRION TECHNICAL ASSISTANCE AND DELIVERABLES

"ACRION TECHNICAL ASSISTANCE AND DELIVERABLES" includes, but is not limited to, the following, but only to the extent permitted by the Prime License Agreement and subject to FGI's needs and needs of other sublicensees, as determined by FGI in its sole discretion:

1. At the request of the FGI during the Term, Acrion shall support the technical development of CO2 Wash® systems, including but not limited to, consulting with Sublicensee and interpret data in connection therewith. Such consultation shall be made available to Sublicensee throughout the Term. Requests for consultation shall be made at reasonable working hours, and such consultation shall be provided within reasonable industry-standard time frames.

2. Acrion shall provide Sublicensee access to its proprietary data base developed in extensive theoretical and experimental work with systems containing gaseous, liquid and solid carbon dioxide, especially near the triple-point of CO2 ("Gas Database"). In addition to providing access to the Gas Database, Acrion shall offer its expertise with regard to how best to access, search and retrieve information from the Gas Database, and facilitate interaction with the Gas Database upon request of the FGI. Requests for access to the Gas Database shall be made at reasonable working hours, and results from the Gas Database shall be provided within reasonable industry-standard time frames.

3. Acrion shall provide Sublicensee access to its proprietary data base developed in the design, construction and operation of experimental apparatus for measurement of equilibrium parameters describing the behavior of binary systems comprised of selected contaminants and carbon dioxide – these and other equilibrium parameters being useful for specification and design of CO2 Wash® systems and comprising proprietary information ("Equilibrium Database"). In addition to providing access to the Equilibrium Database, Acrion shall offer its expertise with regard to how best to access, search and retrieve information from the Equilibrium Database, and facilitate interaction with the Equilibrium Database upon request of the FGI. Requests for access to the Equilibrium Database shall be made at reasonable working hours, and results from the Equilibrium Database shall be provided within reasonable industry-standard time frames.

4. Acrion shall provide Sublicensee access to its proprietary data base developed in the design, construction, maintenance and successful operation of CO2 Wash® pilot plants in Ohio, New York and New Jersey ("Construction Database"). In addition to providing access to the Construction Database, Acrion shall offer its expertise with regard to how best to access, search and retrieve information from the Equilibrium Database, and facilitate interaction with the Construction Database upon request of the FGI. Requests for access to the Construction Database shall be made at reasonable working hours, and results from the Construction Database shall be provided within reasonable industry-standard time frames.

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5. Acrion's ability, based on such experience and proprietary data, to recognize and prioritize worthwhile and workable Biogas projects.

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SPW
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EXHIBIT C

LICENSED TERRITORY

[See attached]

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SWACO Parcel

DESCRIPTION OF A 3.962 ACRE PARCEL
SOUTH OF S.R. 665(London-Groveport Road)
EAST OF YOUNG ROAD

Situate in the State of Ohio, County of Franklin, Township of Jackson, and being a part of Survey No. 1371 and Survey No. 1365, Virginia Military District, being 3.962 acres out of that 17.834 acre tract as described in a Quit Claim Deed to The Solid Waste Authority of Central Ohio (formerly The Franklin County Regional Solid Waste Management Authority), filed on August 29, 2006, of record in Instrument Number 200608290171037, all records referenced are on file in the Recorder's Office, Franklin County, Ohio, said 3.962 acre tract being more particularly bounded and described as follows:

Commencing for reference at a railroad spike found at the intersection of the centerline of State Route 665 (London-Groveport Road) and the centerline of Young Road, being also in the V.M.S. line between surveys 1371 and 6178, being the northwesterly corner of a 4.319 acre tract as described in a Limited Warranty Deed to The Solid Waste Authority of Central Ohio, as recorded in Instrument Number 200105080101031;

Thence South 82°46'28" East, along the centerline of State Route 665, a distance of 1446.08 feet to a railroad spike set at the northwesterly corner of said 17.834 acre tract, and being the **True Place of Beginning** of the herein described parcel;

Thence South 82°46'28" East, continuing along the centerline of State Route 665, along the northerly line of said 17.834 acre tract, a distance of 119.75 feet to a rail road spike found;

Thence South 82°57'39" East, continuing along the centerline of State Route 665, along the northerly line of said 17.834 acre tract, a distance of 54.25 feet to a railroad spike to be set;

Thence into and through said 17.834 acre tract the following seven (7) courses and distances:

1. South 07°13'32" West, passing an iron pin set in the southerly right-of-way line of S.R. 665 at a distance 30.00 feet, a total distance of 286.55 feet to an iron pin set;
2. South 82°46'28" East, a distance of 97.00 feet to an iron pin set;
3. South 07°13'32" West, a distance of 127.43 feet to an iron pin set;
4. South 87°02'01" East, a distance of 33.23 feet to an iron pin set;
5. South 07°02'21" West, a distance of 101.46 feet to an iron pin set;
6. North 82°57'39" West, a distance of 95.16 feet to an iron pin set;
7. South 07°02'21" West, a distance of 172.68 feet to an iron pin set in the southerly line of said 17.834 acre tract;

Thence North 82°57'39" West, along the southerly line of said 17.834 acre tract, through an original 109.723 acre tract, Tract 11, and into an original 5 acre tract, Tract 8, as described in a deed to The Franklin County Regional Solid Waste Management Authority, of record in Official Record Volume 17757 D15, a distance of 178.00 feet to an iron pin set;

Thence North 29°14'04" East, along a westerly line of said 17.834 acre tract, continuing through said original 5 acre tract, Tract 8, a distance of 100.00 feet to an iron pin set;

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Thence North 60°45'56" West, along a southerly line of said 17.834 acre tract, continuing through said original 5 acre tract, Tract 8, into that original 5.004 acre tract, Tract 9, as described in said deed to The Franklin County Regional Solid Waste Management Authority, of record in Official Record Volume 17757 D15, a distance of 194.17 feet to an iron pin set;

Thence South 29°14'04" West, along an easterly line of said 17.834 acre tract, continuing through said original 5.004 acre tract, Tract 9, a distance of 100.00 feet to an iron pin set;

Thence North 07°13'32" East, crossing through said 17.834 acre tract, continuing through said original 5.004 acre tract, Tract 9, a distance of 249.21 feet to an iron pin set in a northerly line of said 17.834 acre tract;

Thence South 82°46'28" East, along a northerly line of said 17.834 acre tract, continuing through said original 5.004 acre tract, Tract 9, into said original 5 acre tract, Tract 8, a distance of 148.14 feet to an iron pin set;

Thence North 07°13'32" East, along a westerly line of said 17.834 acre tract, continuing through said original 5 acre tract, (passing an iron pin set in the existing southerly right-of-way line of State Route 665 at a distance of 334.39 feet) a total distance of 364.39 feet to the **True Place of Beginning** and containing an area of 3.962 acres, of which 0.170 acre is located within the existing right-of-way of State Route 665 and being located in Auditor's Parcel No. 160-000089.

The bearings described herein are based on the bearing North 82°46'28" West between two railroad spikes found for the centerline of London-Groveport Road, as described in a Limited Warranty Deed to The Solid Waste Authority of Central Ohio, as recorded in Instrument Number 200105080101031. Iron pins referenced to be set are 5/8 inch rebar, 30 inches long, with a yellow plastic cap stamped "7159-ms consultants".

The above description was prepared by **ms consultants, inc.** for the Solid Waste Authority of Central Ohio under the direct supervision of John L. Price, Registered Professional Surveyor No. 7159 from an actual field survey of the premises performed in September of 2005 and from records on File at the Recorder's Office, Franklin County, Ohio.

ms consultants, inc.

John L. Price 07/24/2008
Registered Professional Surveyor No. 7159

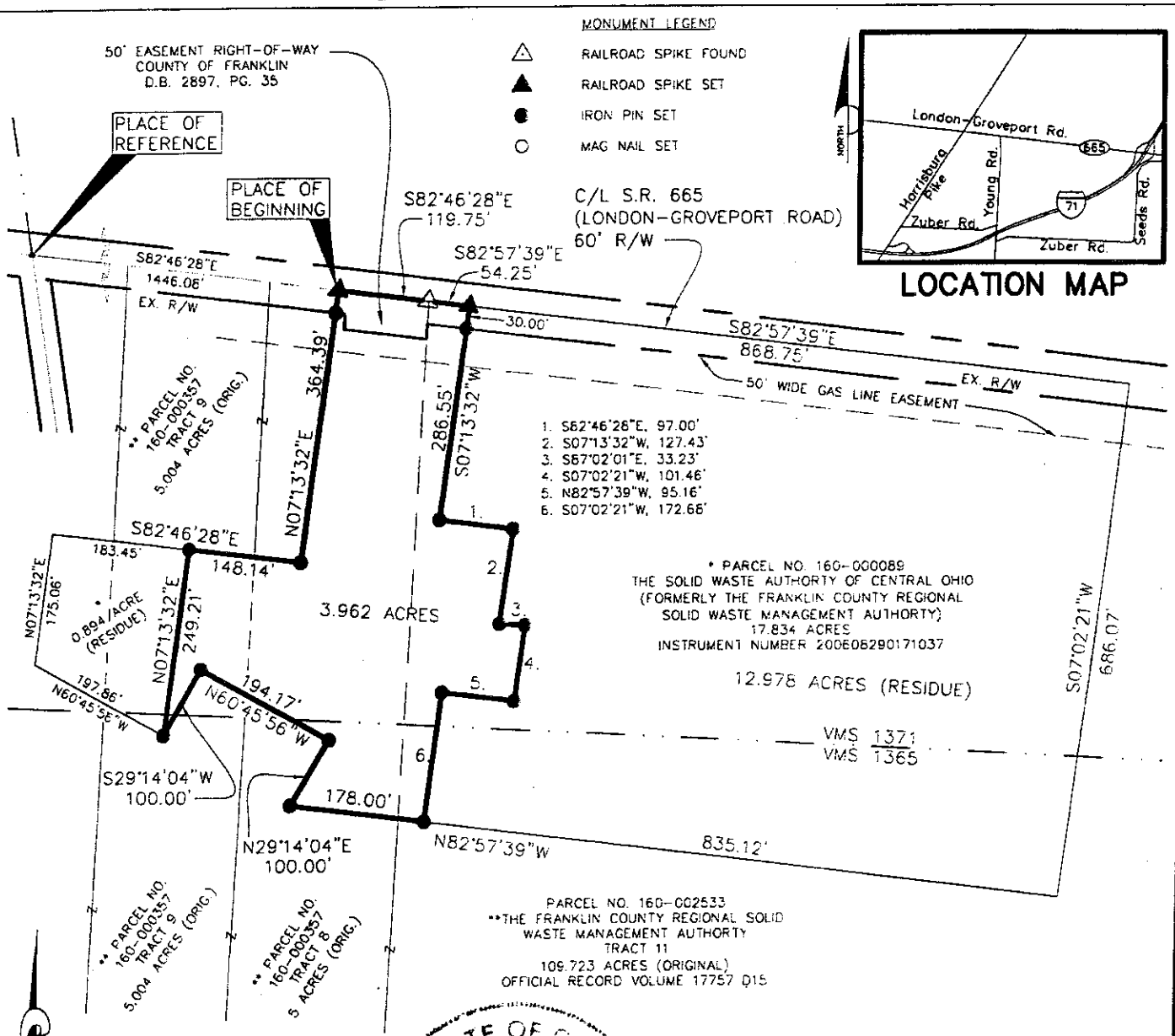
Jlp: 61-04917-00
T:\drawing\24\04467\survey\2005\3.962 desc.doc

11/19/09 11-19-2009

ms consultants, inc.
2221 SCHROCK ROAD, COLUMBUS, OHIO 43229
PHONE (614) 898-7100 FAX (614) 898-7570

Situate in the State of Ohio, County of Franklin, Township of Jackson, and being a part of Survey No. 1371 and Survey No. 1365, Virginia Military Lands, and being a 3.962 acre tract all out of that 17.834 acre tract as described in a Quit Claim Deed to The Solid Waste Authority of Central Ohio (formerly The Franklin County Regional Solid Waste Management Authority), of record in Instrument Number 200608290171037, on file in the Recorder's Office, Franklin County, Ohio.

PLAT OF 3.962 ACRE BOUNDARY



The bearings described herein are based on the bearing North 82°46'28" West for the centerline of State Route 665 (London-Groveport Road), as described in a Limited Warranty Deed to The Solid Waste Authority of Central Ohio, as recorded in Instrument Number 200105080101031, Recorder's Office, Franklin County, Ohio.

GRAPHIC SCALE

0 100 200 400

1 inch = 200 feet

STATE OF OHIO
JOHN L. PRICE
7159
REGISTERED
PROFESSIONAL SURVEYOR

We hereby certify that the foregoing boundary survey was prepared from an actual field survey of the premises by ms consultants, inc. under the direct supervision of John L. Price, Registered Professional Surveyor No. 7159, iron pins referenced as being set are 5/8" rebar, 30" long, with a yellow plastic cap stamped "7159-ms consultants".

ms consultants, inc.

John L. Price 07/25/08

John L. Price
Registered Professional Surveyor No. 7159

11/19/09 11-19-2009

PATENT SUBLICENSE AGREEMENT

THIS PATENT SUBLICENSE AGREEMENT (this "Sublicense"), dated as of November 9th, 2009, is made by and between FirmGreen, Inc., a Delaware corporation having offices at 2901 West Coast Highway, Suite 200, Newport Beach, California 92663 (hereinafter "FGI"), and Solid Waste Authority of Central Ohio, a regional solid waste authority established pursuant to Ohio Revised Code Section 343.11, having offices at 4239 London Groveport Road, Grove City, Ohio 43123 (the "Sublicensee").

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RECITALS

WHEREAS, pursuant to that certain Technology License Agreement, by and between Acrion Technologies, Inc. ("Acrion") and FGI, dated April 4, 2008 (the "Prime License Agreement"), FGI is the exclusive worldwide licensee of rights relating to the Licensed Subject Matter (as defined below) and has the authority to enter into sublicense agreements consistent with the Prime License Agreement; and

WHEREAS, Sublicensee wishes to acquire rights to use the Licensed Subject Matter, and FGI wishes to grant Sublicensee a sublicense and license to use the Licensed Subject Matter, on the terms and subject to the conditions set forth herein.

NOW, THEREFORE, in consideration of the mutual covenants and agreements herein contained and for other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged and accepted, the parties hereto intending to be mutually bound do hereby covenant and agree as follows:

1. EFFECTIVE DATE

This Sublicense is effective as of the date set forth in the preamble of this Sublicense (such date, the "Effective Date").

2. DEFINITIONS

As used in this Sublicense, the following terms have the meanings indicated:

2.1 "Acrion-Owned Technology" means Acrion's remaining Patent Rights, subject to third party license rights as set forth in paragraphs 3.3, 3.4 and 5.3 hereof.

2.2 "Affiliate" means, with respect to a party, any business entity more than fifty percent (50%) owned by such party, any business entity which owns more than fifty percent (50%) of such party, or any business entity that is more than fifty percent (50%) owned by a business entity that owns more than fifty percent (50%) of such party.

2.3 "Biogas" means LFG or anaerobic digester gas.

2.4 "FGI Equipment" means any and all equipment and machinery obtained by Sublicensee from FGI, or its designees, for use in the production of Biogas, including such equipment and machinery as may embody or use the Licensed Subject Matter.

2.5 "Field-of-Use" means Biogas for other than producing a liquid methane product.

2.6 "LFG" means landfill gas.

2.7 "LFG Rights" means the legal right and authority to extract LFG at the Licensed Territory.

2.8 "Licensed Product" means Biogas (i) processed using Acrion-Owned Technology, or (ii) processed in a manner that, but for the License granted herein, would infringe or contribute to the infringement of the Patent Rights.

2.9 "Licensed Subject Matter" means Acrion-Owned Technology within the Field of Use.

2.10 "Licensed Territory" means the site more particularly described in Exhibit A attached hereto at which Sublicensee will develop a Biogas recovery project using, at least in part, the Licensed Subject Matter.

2.11 "Patent Application Rights" means and includes rights to:

(a) any and all pending and/or later filed (within two (2) years of the Effective Date) U.S. patent applications controlled and/or otherwise owned by Acrion which have a claim that, if issued, would, but for the License granted herein, be infringed, directly or indirectly, contributorily or by inducement, by Sublicensee when operating in the Field-of-Use ("Applications"), including:

(b) any and all continuations, divisions, and continuations-in-part of such Applications, whether related to such Applications directly or through one or more intervening applications;

(c) any foreign applications for patents or utility models claiming priority in whole or in part from any of the applications identified in subparagraphs (a) and (b) above; and

(d) any and all continuations, divisions, and continuations-in-part of any of the applications identified in subparagraph (c) above, whether related to such applications directly or through one or more intervening applications.

2.12 "Patent Sublicense" is defined in paragraph 5.1 hereof.

2.13 "Patent Rights" means and includes rights to:

(a) US Patent Nos. 5,681,360, or 5,842,357;

(b) any and all patents and utility models issuing on or registered from any of the Applications described in paragraph 2.11 hereof; and

(c) any and all reexaminations, reissues, additions or extensions of any of the patents or utility models identified in subparagraphs (a) or (b) above.

2.14 "Term" is defined in paragraph 9.1 hereof.

3. REPRESENTATIONS AND WARRANTIES BY FGI

FGI hereby represents and warrants to Sublicensee that:

3.1 FGI is a corporation duly organized, validly existing and in good standing under the laws of the State of Delaware and has all requisite corporate power and authority to carry on its business as now conducted.

3.2 The execution and delivery of this Sublicense by FGI have been duly authorized by all necessary corporate action and (assuming the due execution and delivery hereof by the Sublicensee) this Sublicense constitutes a legal, valid and binding obligation of FGI, enforceable in accordance with its terms, subject to applicable bankruptcy, insolvency, reorganization, moratorium or other similar laws affecting creditors rights generally and subject to general principles of equity, whether considered in a proceeding in equity or at law.

3.3 Except for certain license rights granted by Acrion to Mack Trucks, Inc. and Mack's parent company AB Volvo (a) pursuant to the Prime License Agreement, Acrion has granted FGI a royalty-bearing exclusive worldwide license to use the Licensed Subject Matter and has authorized FGI to grant sublicenses consistent therewith; (b) FGI has not knowingly granted any license or sublicense with respect thereto to any other person or entity that would restrict rights granted to Sublicensee except Acrion has granted certain rights as stated in paragraphs 3.4 below.

3.4 Pursuant to an agreement dated September 2, 2002, Acrion granted an exclusive worldwide license to Mack Trucks, Inc., and Mack's parent company AB Volvo, to commercially develop and make full use of the Acrion-Owned Technology for the express and sole purpose of preparing Biogas to produce liquid methane, and carbon dioxide coincident with the preparation of Biogas for that purpose.

3.5 FGI grants this Sublicense, and Sublicensee accepts same on a strictly "as-is" basis without warranty or condition of any kind whether express, implied or statutory, and FGI makes no representations, warranties, conditions, covenants, guarantees or obligations of any kind in relation to the Licensed Subject Matter, whether as to title, the uses, merchantable quality or merchantability, suitability, performance, fitness for a particular purpose, capabilities, non-infringement of third party intellectual property or other proprietary rights, reliability or accuracy thereof, or concerning any defects or deficiencies or the lack thereof of any nature in same.

4. REPRESENTATIONS AND WARRANTIES BY SUBLICENSEE

Sublicensee hereby represents and warrants to FGI that:

4.1 Sublicensee is a regional solid waste authority duly organized, validly existing and in good standing under the laws of the State of Ohio and has all requisite power and authority to carry on its business as now conducted.

4.2 The execution and delivery of this Sublicense by Sublicensee have been duly authorized and (assuming the due execution and delivery hereof by FGI) this Sublicense constitutes a legal, valid and binding obligation of Sublicensee, enforceable in accordance with its terms, subject to applicable bankruptcy, insolvency, reorganization, moratorium or other similar laws affecting creditors rights generally and subject to general principles of equity, whether considered in a proceeding in equity or at law.

4.3 Sublicensee, by execution hereof, acknowledges, covenants and agrees that it has not been induced in any way by Acrion, FGI, or their respective directors, officers, employees or agents to enter into this Sublicense, and further warrants and represents that (i) it has conducted sufficient due diligence with respect to all items and issues pertaining to this Sublicense; and (ii) Sublicensee has adequate knowledge and expertise, or has utilized knowledgeable and expert consultants, to adequately conduct such due diligence, and agrees to accept all risks inherent in the transactions contemplated hereby.

4.4 Sublicensee has all LFG Rights necessary to the use of the Licensed Subject Matter and the FGI Equipment and, upon request, shall provide FGI with written proof thereof.

4.5 Sublicensee acknowledges that FGI Equipment is proprietary and that it would cause serious and irreparable damage to FGI if FGI Equipment were used by Sublicensee or any third party outside of the Licensed Territory. Sublicensee further acknowledges that the restrictions on use or disposition of FGI Equipment provided in paragraph 5.2 hereof are reasonable and necessary and do not materially impair Sublicensee's business or property interests.

4.6 Sublicensee acknowledges that no rights, express or implied, including rights under the patent exhaustion doctrine, are granted hereunder, or by the sale or transfer of FGI Equipment, to any know-how, trade secret or any other technology or to any issued, pending or future patents or patent applications owned, licensable, or controlled by Acrion, FGI or any of their Affiliates, other than the Acrion-Owned Technology.

5. SUBLICENSE OF ACRION KNOW-HOW; RESTRICTIONS

5.1 FGI hereby grants to Sublicensee a royalty-bearing, sublicense under the Acrion-Owned Technology to facilitate the design, installation, and operation of FGI Equipment and plant, equipment, and machinery incorporating Licensed Subject Matter and developed by Sublicensee or any Affiliate and to manufacture or have manufactured only within the Licensed Territory, and to use and/or sell, Licensed Product only in the Field-of-Use, subject to the limitations set forth in this Sublicense (the "Patent Sublicense"). The grant of the Patent Sublicense during the Term is subject to the payment by or on behalf of Sublicensee by Sublicensee of the lump-sum royalty required by paragraph 8.1 hereof and is subject, however, to further rights retained by Acrion to:

(a) publish the general scientific findings from research related to Licensed Subject Matter subject to the terms of Article 11 hereof ("Confidential Information"), and

(b) use the Licensed Subject Matter for research, teaching and other educationally-related purposes.

5.2 Sublicensee may not extend this Sublicense to any Affiliate or any other person or entity without the prior written consent of FGI, which may be granted or withheld in FGI's sole discretion. During the Term of this Sublicense, Sublicensee may not utilize FGI Equipment outside of the Licensed Territory, or sell, loan, or otherwise transfer possession of the FGI Equipment for use outside of the Licensed Territory.

5.3 Notwithstanding anything to the contrary in this Sublicense, Sublicensee shall take this Sublicense subject to the rights granted by Acrion pursuant to an agreement dated September 2, 2002 (the "Mack License"), whereby Acrion granted an exclusive worldwide license to Mack Trucks, Inc. and Mack's parent company, AB Volvo, to commercially develop and make full use of the Acrion-Owned Technology for the express and sole purpose of preparing Biogas to produce liquid methane, and carbon dioxide coincident with the preparation of Biogas for that purpose.

6. INTELLECTUAL PROPERTY OWNERSHIP

6.1 All right, title and interest in and to any intellectual property created by either FGI or Sublicensee during the Term in the course of either party's performance under this Sublicense, including but not limited to any inventions and improvements (whether patentable or not patentable) discovered, developed or reduced to practice, in each case related to the Licensed Subject Matter, shall be the sole and exclusive property of FGI and FGI hereby grants a non-exclusive license to Sublicensee to use such intellectual property solely in the ordinary course of Sublicensee's operations in connection with Sublicensee's operation of the CO_2 Wash™ Unit and appurtenant equipment and software purchased by Sublicensee from FirmGreen Fuels of Ohio, L.L.C. at the Franklin County Sanitary Landfill, during the term of the patent or patents or renewal thereof.

6.2 At FGI's sole cost and expense, Sublicensee shall fully cooperate with FGI and its Affiliates and assist FGI and its Affiliates in respect of the preparation, filing or prosecution of any domestic or foreign applications, claims, notices, forms, filings with governmental authorities or any other person or entity, or other documents or actions deemed reasonably necessary or advisable by FGI to register, protect or enforce the rights of FGI under this Sublicense.

7. USE OF FIRMGREEN AND ACRION NAMES AND MARKS

Sublicensee acknowledges that any trademarks, trade names, design marks, service marks, symbols, and/or logos adopted by FGI, FirmGreen, or Acrion to identify the Licensed Subject Matter and related products and services (collectively, "Licensor Marks") belong to FirmGreen or Acrion, as applicable, and that Sublicensee acquires no rights therein under this Sublicense. No Licensor Marks may be used by Sublicensee without the express written consent of FirmGreen or Acrion, as applicable, and then only in accordance with such party's trademark usage guidelines. For purposes hereof, "FirmGreen" includes FGI and/or any of its Affiliates.

8. PAYMENTS

8.1 In consideration of rights granted by FGI to Sublicensee pursuant to this Sublicense, Sublicensee shall pay a one-time license fee of $25,000 upon the execution of this Sublicense.

8.2 All amounts payable hereunder by Sublicensee shall be paid in United States funds without deductions for taxes, assessments, fees, or charges of any kind. Such amounts shall be paid by wire transfer of immediately available funds to an account designated by FGI in writing.

9. TERM AND TERMINATION

9.1 The "Term" means the period from the Effective Date through the earlier of (i) January 11, 2015 and (ii) the date upon which the last issued patent arising from the licensed Patent Right expires, unless earlier terminated pursuant to the terms of paragraph 9.2. Upon any termination of this Sublicense, the Sublicensee shall have no further license to any Acrion-Owned Technology.

9.2 This Sublicense will earlier terminate:

(a) automatically upon any termination of the Prime License Agreement between Acrion and FGI; or

(b) automatically, at FGI's option, if Sublicensee becomes bankrupt and/or if the business of Sublicensee is placed in the hands of a receiver, assignee, or trustee, whether by voluntary act of Sublicensee or otherwise; or

(c) at FGI's option, upon thirty (30) days written notice from FGI if Sublicensee breaches or defaults on its obligation to make payments (if any are due) in accordance with the terms of Article 8 hereof, unless, before the end of the thirty (30) day period, Sublicensee shall have cured the default or breach and so notifies FGI, stating the manner of the cure; or

(d) at the non-breaching party's option, upon ninety (90) days written notice by such non-breaching party if the other party breaches or defaults on any other obligation under this Sublicense, unless, before the end of the ninety (90) day period, such breaching party shall have cured the default or breach and so notifies such non-breaching party, stating the manner of the cure; or

(e) at any time by mutual written agreement between Sublicensee and FGI, upon one hundred eighty (180) days written notice to all parties and subject to any terms herein which survive termination; or

(f) Upon expiration or termination of Sublicensee's LFG Rights, unless FGI consents to transfer of this Sublicense to a new site, which consent shall not be unreasonably withheld.

9.3 At any time SWACO shall have the right to terminate this agreement at any time upon ninety (90) days written notice to FGI. Upon such termination, FGI shall have no obligation to refund fees paid by SWACO and all other obligations of the parties to each other shall expire upon the effective date of such termination, *provided, however*, SWACO shall continue to be bound by the provisions of Articles 7 (Use of FirmGreen and Acrion Names and Marks) and 11 (Confidential Information).

9.4 Notwithstanding anything to the contrary in this Sublicense, no right reserved by Acrion, referred to in Article 3 or Article 5 hereof, nor the continuation, validity or termination of such right, nor any act or omission of Acrion with respect to the Licensed Subject Matter shall,

directly or indirectly, be a ground or cause for termination of this Sublicense (except as provided in paragraph 9.2(a) hereof).

9.5 If this Sublicense is terminated for cause (other than expiration of the Term of this Sublicense in accordance with paragraph 9.1 hereof):

(a) nothing herein will be construed to release any party of any obligation matured prior to the effective date of termination;

(b) after the effective date of termination, Sublicensee may sell all Licensed Product it then has on hand at the date of termination but shall pay royalties thereon as set forth in Article 8 hereof; and

(c) notwithstanding such termination, Sublicensee shall continue to be bound by the provisions of Articles 7 ("Use of FirmGreen and Acrion Names and Marks"), 10 ("Limitation of Liability"), and 11 ("Confidential Information") of this Sublicense.

10. LIMITATION OF LIABILITY

10.1 EXCEPT FOR VIOLATION OF ARTICLES 5 ("SUBLICENSE OF ACRION KNOW-HOW; RESTRICTIONS"), 6 ("INTELLECTUAL PROPERTY OWNERSHIP"), 10 ("LIMITATION OF LIABILITY"), AND 11 ("CONFIDENTIAL INFORMATION") OF THIS SUBLICENSE, IN NO EVENT WILL EITHER PARTY BE LIABLE TOWARD THE OTHER PARTY FOR ANY INCIDENTAL, SPECIAL, OR CONSEQUENTIAL DAMAGES, HOWEVER CAUSED AND UNDER ANY THEORY OF LIABILITY, WHETHER FOR BREACH OF CONTRACT, TORT (INCLUDING NEGLIGENCE) OR OTHERWISE, ARISING OUT OF THIS SUBLICENSE, INCLUDING BUT NOT LIMITED TO LOSS OF PROFITS, EVEN IF SUCH PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. THIS LIMITATION WILL BE EFFECTIVE EVEN IF ANY REMEDY FAILS OF ITS ESSENTIAL PURPOSE.

10.2 EXCEPT FOR VIOLATION OF ARTICLES 5 ("SUBLICENSE OF ACRION KNOW-HOW; RESTRICTIONS"), 6 ("INTELLECTUAL PROPERTY OWNERSHIP"), 10 ("LIMITATION OF LIABILITY") AND 11 ("CONFIDENTIAL INFORMATION") OF THIS SUBLICENSE, FGI'S TOTAL LIABILITY FOR DAMAGES OF ANY KIND ARISING OUT OF OR IN RELATION TO THIS SUBLICENSE IS LIMITED TO THE AMOUNT PAID BY SUBLICENSEE TO FGI DURING THE TWELVE (12) MONTHS PRIOR TO THE OCCURRENCE OF SUCH DAMAGES.

11. CONFIDENTIAL INFORMATION

11.1 FGI and Sublicensee each agree that the FGI Equipment and all information and documentation related to the FGI Equipment, including information identified as confidential or that should be recognized as confidential under the circumstances (collectively, "Confidential Information"), provided by FGI to Sublicensee hereunder, constitutes the confidential and proprietary information of FGI, and that Sublicensee's protection thereof is an essential condition to Sublicensee's use of the FGI Equipment. Prior to any disclosure by FGI to SWACO

contended by FGI to be confidential, FGI shall conspicuously mark any material as CONFIDENTIAL in a format corresponding to the following: "CONFIDENTIAL; FGI; {DATE OF DISCLOSURE}." Confidential Information shall (i) be received in strict confidence, (ii) be used only for the purposes of this Sublicense, and (iii) not be disclosed by the recipient except to its employees and agents pre-approved by FGI in writing who have a need to know to perform their work pursuant to this Sublicense, have signed a confidentiality agreement permissible in content and form, approved by Sublicensee, containing terms at least as strict as the confidentiality terms in this Sublicense, and have been informed that the FGI Equipment is confidential, contains trade secrets of FGI and Acrion. Sublicensee shall ensure and be responsible for its employees' and agents' compliance with this Sublicense. Information shall not be considered Confidential Information if and to the extent that such information:

(a) Is or becomes in the public domain at any time ;

(b) later became part of the public domain through no act or omission of the recipient, its employees, agents, successors, or assigns;

(c) was lawfully disclosed to the recipient by a third party having the right to disclose it;

(d) was already known by the recipient at the time of disclosure;

(e) was independently developed by the recipient; or

(f) is required by law or regulation to be disclosed.

11.2 No information shall be regarded as CONFIDENTIAL if at any time, including any time after disclosure by FGI, the information (a) is or becomes a part of the public domain; (b) or is otherwise released to third parties without restrictions of confidentiality by FGI; (c) is disclosed to the public by a third party that has received the information from FGI; or (d) is published by FGI.

11.3 Each party's obligation of confidentiality hereunder shall be fulfilled by using at least the same degree of care with respect to the other party's confidential information as it uses to protect its own most valuable confidential information, but in no event less than reasonable diligence. This obligation shall continue during the Term and for a period of three (3) years thereafter.

11.4 Sublicensee shall promptly return to FGI all Confidential Information, together with all copies, reproductions, recordings, summaries, notes, memoranda, reports, compilations, derivatives, and other works prepared or based thereon which are in the possession of Sublicensee and, at FGI's option, certify in writing that all such materials have been returned and/or destroyed, upon written request by FGI or upon any termination of this Sublicense.

12. DISPUTE RESOLUTION

All disputes pursuant to this Sublicense shall take place in a court of competent jurisdiction in Franklin County, Ohio.

13. ASSIGNMENT

This Sublicense, including any part hereof, may not be assigned (by operation of law or otherwise) by Sublicensee without the prior written consent of FGI.

14. GENERAL

14.1 This Sublicense constitutes the entire and only agreement between the parties for Licensed Subject Matter and all other prior negotiations, representations, agreements, arrangements, course of conduct or dealings, and understandings between the parties, including any Affiliates, related parties, agents, officers, managers or directors thereof, in each case whether oral or written, are superseded hereby. No agreements altering or supplementing the terms hereof may be made except by a written document signed by both parties and expressly stating that it is intended to alter or supplement this Sublicense. To the extent, if any, that any agreement, current or future, regarding the FGI Equipment contains terms inconsistent with or less restrictive than the terms hereof, the terms of this Sublicense shall control and to that extent, any such other agreement shall have no force or effect.

14.2 Any notice or payment required by this Sublicense must be given by prepaid, first class, certified mail, return receipt requested, addressed as follows:

If to FGI	If to Sublicensee
FirmGreen, Inc. 2901 West Coast Highway, Suite 200 Newport Beach, California 92663 ATTENTION: Steven P. Wilburn	Solid Waste Authority of Central Ohio 4239 London Groveport Road Grove City, Ohio 43123 ATTENTION: Ronald J. Mills

or other addresses as may be given from time to time under the terms of this paragraph 14.2.

14.3 The parties are independent contractors, and nothing contained in this Sublicense will be construed as making either party or its employees the agent, employee, joint venturer or partner of the other party or granting to either party the authority to bind or contract any obligations in the name of or on the account of the other party or to make any representations, guarantees or warranties on behalf of the other parties.

14.4 Sublicensee shall comply with all applicable federal, state, and local laws and regulations in connection with its activities pursuant to this Sublicense.

14.5 This Sublicense shall be construed and enforced in accordance with the laws of the United States of America and of the State of Ohio applicable to contracts solely performed in that state.

14.6 The failure of either party to insist, in any instance, upon strict performance by the other party of any term or provision of this Sublicense or to enforce any of its rights under this Sublicense shall not be deemed to be a modification of any term hereof or a waiver or relinquishment of the future performance of any such term or provision by such party, nor shall

such failure or omission constitute a waiver of the right of such party to insist upon future performance by the other party of any such term or provision. No waiver will be valid unless in writing and signed by the party against which enforcement of such waiver is sought.

14.7 Headings are included herein for convenience only and shall not be used to construe this Sublicense.

14.8 If any part of this Sublicense is for any reason found to be unenforceable, illegal, or invalid, all other parts nevertheless remain enforceable, legal, and valid in accordance with their terms.

14.9 This Sublicense may be executed in two or more counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument. Any signature page delivered by facsimile or electronic mail shall be binding to the same extent as an original signature page.

[*Signature Page Follows*]

IN WITNESS WHEREOF, parties hereto have caused their duly authorized representatives to execute this Sublicense.

FIRMGREEN, INC.

By: _____
Name: Steven P. Wilburn
Title: President and Chief Executive Officer

SOLID WASTE AUTHORITY OF CENTRAL OHIO

By: _____
Name: Ronald J. Mills
Title: Executive Director

APPROVED AS TO FORM:

_____
Leo V. Garvin, Jr.
Garvin & Maloney

Per P/A authorization 19 November 2009

_____
Harold J. Anderson III
Chief Counsel
Solid Waste Authority of Central Ohio

EXHIBIT A
LICENSED TERRITORY

[See attached]

SDW
11-19-2009

11/19/09

SWACO Parcel

DESCRIPTION OF A 3.962 ACRE PARCEL
SOUTH OF S.R. 665(London-Groveport Road)
EAST OF YOUNG ROAD

Situate in the State of Ohio, County of Franklin, Township of Jackson, and being a part of Survey No. 1371 and Survey No. 1365, Virginia Military District, being 3.962 acres out of that 17.834 acre tract as described in a Quit Claim Deed to The Solid Waste Authority of Central Ohio (formerly The Franklin County Regional Solid Waste Management Authority), filed on August 29, 2006, of record in Instrument Number 200608290171037, all records referenced are on file in the Recorder's Office, Franklin County, Ohio, said 3.962 acre tract being more particularly bounded and described as follows:

Commencing for reference at a railroad spike found at the intersection of the centerline of State Route 665 (London-Groveport Road) and the centerline of Young Road, being also in the V.M.S. line between surveys 1371 and 6178, being the northwesterly corner of a 4.319 acre tract as described in a Limited Warranty Deed to The Solid Waste Authority of Central Ohio, as recorded in Instrument Number 200105080101031;

Thence South 82°46'28" East, along the centerline of State Route 665, a distance of 1446.08 feet to a railroad spike set at the northwesterly corner of said 17.834 acre tract, and being the **True Place of Beginning** of the herein described parcel;

Thence South 82°46'28" East, continuing along the centerline of State Route 665, along the northerly line of said 17.834 acre tract, a distance of 119.75 feet to a rail road spike found;

Thence South 82°57'39" East, continuing along the centerline of State Route 665, along the northerly line of said 17.834 acre tract, a distance of 54.25 feet to a railroad spike to be set;

Thence into and through said 17.834 acre tract the following seven (7) courses and distances:

1. South 07°13'32" West, passing an iron pin set in the southerly right-of-way line of S.R. 665 at a distance 30.00 feet, a total distance of 286.55 feet to an iron pin set;
2. South 82°46'28" East, a distance of 97.00 feet to an iron pin set;
3. South 07°13'32" West, a distance of 127.43 feet to an iron pin set;
4. South 87°02'01" East, a distance of 33.23 feet to an iron pin set;
5. South 07°02'21" West, a distance of 101.46 feet to an iron pin set;
6. North 82°57'39" West, a distance of 95.16 feet to an iron pin set;
7. South 07°02'21" West, a distance of 172.68 feet to an iron pin set in the southerly line of said 17.834 acre tract;

Thence North 82°57'39" West, along the southerly line of said 17.834 acre tract, through an original 109.723 acre tract, Tract 11, and into an original 5 acre tract, Tract 8, as described in a deed to The Franklin County Regional Solid Waste Management Authority, of record in Official Record Volume 17757 D15, a distance of 178.00 feet to an iron pin set;

Thence North 29°14'04" East, along a westerly line of said 17.834 acre tract, continuing through said original 5 acre tract, Tract 8, a distance of 100.00 feet to an iron pin set;

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Thence North 60°45'56" West, along a southerly line of said 17.834 acre tract, continuing through said original 5 acre tract, Tract 8, into that original 5.004 acre tract, Tract 9, as described in said deed to The Franklin County Regional Solid Waste Management Authority, of record in Official Record Volume 17757 D15, a distance of 194.17 feet to an iron pin set;

Thence South 29°14'04" West, along an easterly line of said 17.834 acre tract, continuing through said original 5.004 acre tract, Tract 9, a distance of 100.00 feet to an iron pin set;

Thence North 07°13'32" East, crossing through said 17.834 acre tract, continuing through said original 5.004 acre tract, Tract 9, a distance of 249.21 feet to an iron pin set in a northerly line of said 17.834 acre tract;

Thence South 82°46'28" East, along a northerly line of said 17.834 acre tract, continuing through said original 5.004 acre tract, Tract 9, into said original 5 acre tract, Tract 8, a distance of 148.14 feet to an iron pin set;

Thence North 07°13'32" East, along a westerly line of said 17.834 acre tract, continuing through said original 5 acre tract, (passing an iron pin set in the existing southerly right-of-way line of State Route 665 at a distance of 334.39 feet) a total distance of 364.39 feet to the **True Place of Beginning** and containing an area of 3.962 acres, of which 0.170 acre is located within the existing right-of-way of State Route 665 and being located in Auditor's Parcel No. 160-000089.

The bearings described herein are based on the bearing North 82°46'28" West between two railroad spikes found for the centerline of London-Groveport Road, as described in a Limited Warranty Deed to The Solid Waste Authority of Central Ohio, as recorded in Instrument Number 200105080101031. Iron pins referenced to be set are 5/8 inch rebar, 30 inches long, with a yellow plastic cap stamped "7159-ms consultants".

The above description was prepared by **ms consultants, inc.** for the Solid Waste Authority of Central Ohio under the direct supervision of John L. Price, Registered Professional Surveyor No. 7159 from an actual field survey of the premises performed in September of 2005 and from records on File at the Recorder's Office, Franklin County, Ohio.

ms consultants, inc.

John L. Price 07/24/2008
Registered Professional Surveyor No. 7159

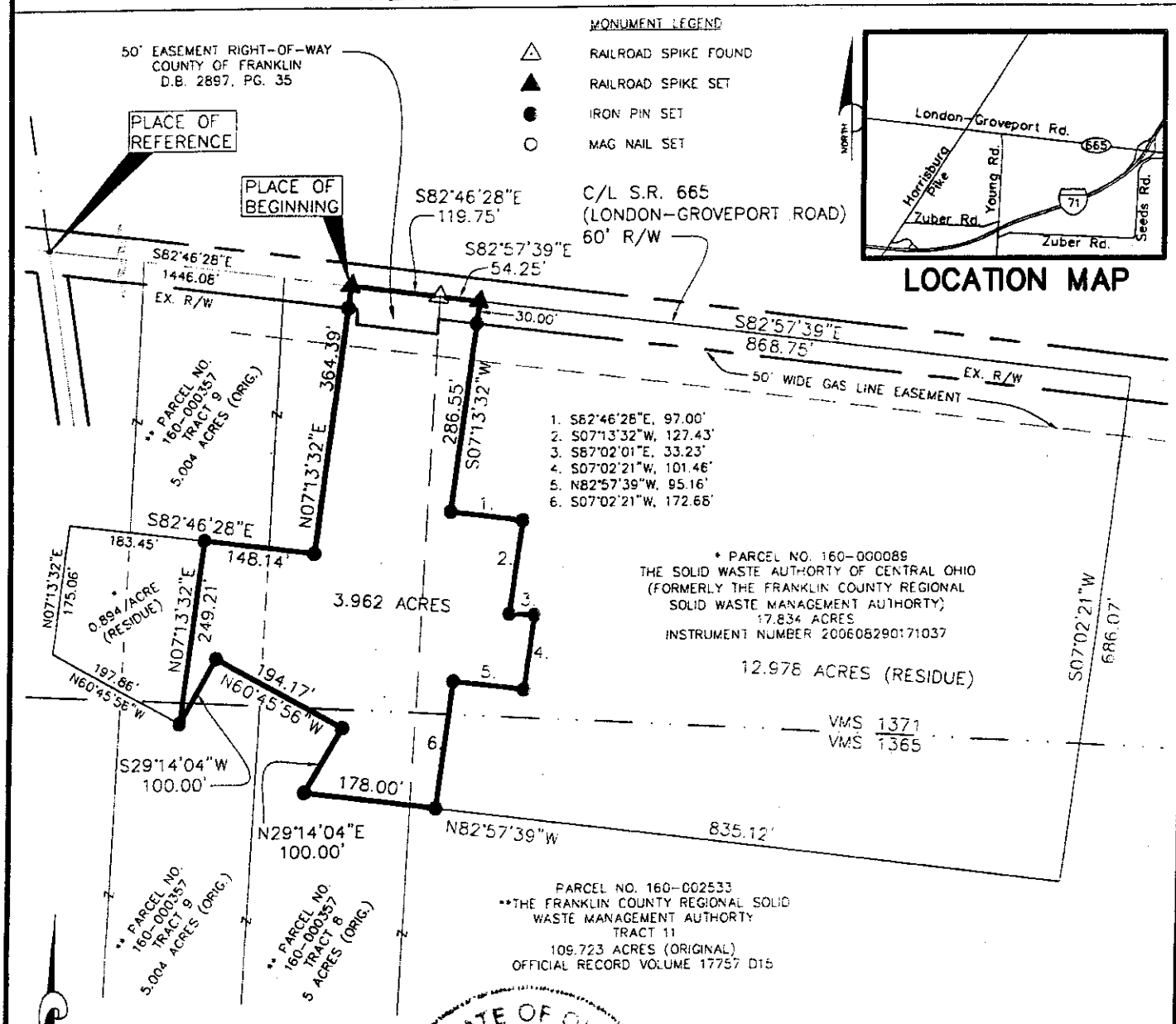
Jlp: 61-04917-00
T:\drawing\24004467\survey\2005\3.962 desc.doc

11/19/09 11-19-2009 SPW

ms consultants, inc.
2221 SCHROCK ROAD, COLUMBUS, OHIO 43229
PHONE (614) 898-7100 FAX (614) 898-7570

Situate in the State of Ohio, County of Franklin, Township of Jackson, and being a part of Survey No. 1371 and Survey No. 1365, Virginia Military Lands, and being a 3.962 acre tract all out of that 17.834 acre tract as described in a Quit Claim Deed to The Solid Waste Authority of Central Ohio (formerly The Franklin County Regional Solid Waste Management Authority), of record in Instrument Number 200608290171037, on file in the Recorder's Office, Franklin County, Ohio.

PLAT OF 3.962 ACRE BOUNDARY



The bearings described herein are based on the bearing North 82°46'28" West for the centerline of State Route 665 (London-Groveport Road), as described in a Limited Warranty Deed to The Solid Waste Authority of Central Ohio, as recorded in Instrument Number 200105080101031, Recorder's Office, Franklin County, Ohio.

GRAPHIC SCALE

0 100 200 400

1 inch = 200 feet

STATE OF OHIO
JOHN L PRICE 7159
REGISTERED PROFESSIONAL SURVEYOR

We hereby certify that the foregoing boundary survey was prepared from an actual field survey of the premises by ms consultants, inc. under the direct supervision of John L. Price, Registered Professional Surveyor No. 7159. Iron pins referenced as being set are 5/8" rebar, 30" long, with a yellow plastic cap stamped "7159-ms consultants".

ms consultants, inc.

John L. Price 07/25/08

John L. Price
Registered Professional Surveyor No. 7159

11/19/09

11-19-2009

TRADEMARK LICENSE

THIS TRADEMARK LICENSE (the "License") is made and entered into as of this 19th day of November, 2009 (the "Effective Date"), by and between FirmGreen, Inc., a Delaware corporation ("Licensor"), and Solid Waste Authority of Central Ohio, a regional solid waste authority established pursuant to Ohio Revised Code Section 343.11, having offices at 4239 London Groveport Road, Grove City, Ohio 43123 ("Licensee"). Licensor and Licensee are sometimes referred to herein collectively as the "Parties", and individually as a "Party".

RECITALS

A. Licensor owns the trademarks set forth on Exhibit A attached hereto (the "Trademarks").

B. Licensee desires to secure from Licensor the right to use the Trademarks in connection with the Green Energy Center at the Licensee's facility in Franklin County, Ohio commonly referred to as the "SWACO Phase I Project."

1. GRANT OF LICENSE

1.1 License. In consideration for a one-time payment of TEN Dollars ($10.00) and other good and valuable consideration, the receipt and sufficiency of which are hereby acknowledged, Licensor hereby grants to Licensee a royalty-free, non-exclusive license to use the Trademarks during the Term throughout the world in commerce in connection only with promotional purposes of the SWACO Phase I Project.

1.2 Reservation of Rights. Licensor reserves the right to use the Trademarks.

1.3 Quality Control. In order to protect the goodwill associated with the Trademarks, Licensee shall use the Trademarks only in connection with the promotion of goods or services rendered directly by Licensor or its designees in accordance with such guidance and directions furnished by Licensor from time to time to ensure that always the quality of the goods shall be satisfactory to Licensor and that the Trademarks are used in an appropriate manner. Licensor shall be the sole judge of whether or not Licensee has met or is meeting the standards of quality or usage so established. Licensee will permit duly authorized representatives of Licensor to inspect and sample the good bearing the Trademarks and all forms of use of the Trademarks by Licensee at all reasonable times, for the purpose of ascertaining or determining compliance with these quality control measures.

2. TERM AND TERMINATION

2.1 Term. The term of this License shall commence on the Effective Date and shall continue until the termination or expiration of that certain Know–How Sublicense and License Agreement, of even date herewith, between Licensor and Licensee, unless earlier terminated in accordance with paragraph 2.2 hereof.

2.2 Termination. This License may be terminated by Licensor upon fifteen (15) days written notice from Licensor if Licensee breaches or defaults on its obligations pursuant to

paragraphs 1.1 or 1.3 hereof, unless within such period Licensee shall have cured such breach or default and so notifies Licensor in writing, stating the nature or manner of the cure undertaken, which shall be acceptable to Licensor at its sole discretion.

3. PROPRIETARY RIGHTS

3.1 Ownership. Licensee acknowledges Licensor's exclusive right, title and interest in and to the Trademarks, and any registrations that have issued or may issue thereon. The Parties acknowledge that any and all goodwill arising from Licensee's use of the Trademarks shall inure to the benefit of Licensor. Licensee agrees to cooperate and assist Licensor in preserving Licensor's interest in the Trademarks. Licensee agrees not to challenge Licensor's ownership or validity of the Trademarks.

4. MISCELLANEOUS

4.1 Right of Enforcement. If the parties believe that a third party has violated or infringed, or threatens to violate or infringe the Trademarks, the parties shall confer with Licensor as to appropriate steps necessary to police such infringement.

4.2 Limitation of Liability. NEITHER PARTY SHALL, UNDER ANY CIRCUMSTANCES, BE LIABLE TO THE OTHER PARTY OR ANY OTHER PARTY FOR ANY INCIDENTAL, CONSEQUENTIAL, INDIRECT, SPECIAL, EXEMPLARY, PUNITIVE, OR TREBLE DAMAGE, OR FOR ANY LOST PROFITS OR SAVINGS, ARISING FROM ANY BREACH OF ANY PROVISION OF THIS LICENSE OR ANY CLAIMS ARISING IN TORT, PERSONAL INJURY, OR PRODUCT LIABILITY, EVEN IF SUCH PARTY HAS BEEN ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL LICENSOR'S TOTAL LIABILITY UNDER THIS LICENSE EXCEED THE TOTAL AMOUNT OF FEES COLLECTED FROM LICENSEE UNDER THIS LICENSE.

4.3 Further Assurances/Cooperation. Each Party agrees to execute, acknowledge and deliver such further instructions, and to do all such other acts, as may be necessary or appropriate in order to carry out the purposes and intent of this License.

4.4 Assignment. Licensee may not assign, delegate, or sublicense any of its rights or obligations hereunder, whether through a merger, acquisition, or otherwise, except with the prior written consent of Licensor, which consent may be withheld in Licensor's sole discretion. Subject to the restraints on assignment set forth above, this License shall be binding upon and shall inure to the benefit of all successors and permitted assigns of the Parties.

4.5 Applicable Law and Dispute Resolution Forum. This License and its validity, construction, and effect shall be governed by the laws of the United States of America and the State of Ohio. All disputes pursuant to this Trademark License shall take place in a court of competent jurisdiction in Franklin County, Ohio.

4.6 No Partnership. Nothing contained in this License shall create or be deemed to create any agency, fiduciary, partnership, franchise or joint venture relation between Licensor

and Licensee. No party hereto shall have the power to obligate or bind the other party in any manner whatsoever.

4.7 Entire Agreement. As of the effective date hereof, this License contains the full and complete understanding of the Parties and replaces any prior understanding or arrangement between the Parties, whether oral or written. The provisions of this License may only be amended by a subsequent instrument in writing clearly purporting to effect such amendment and signed by both Parties.

4.8 Waiver. The failure of a Party hereto to enforce, or the delay by a Party hereto to enforce, any of its rights under this License shall not be deemed a continuing waiver or a modification by such Party of any of its rights under this License. Any Party may, within the time provided by applicable law, commence appropriate proceedings to enforce any or all of its rights under this License, and any prior failure to enforce or delay in enforcement shall not constitute a defense.

4.9 Severability. Whenever possible, each paragraph of this License shall be interpreted in such a manner as to be effective and valid under applicable law. However, if a paragraph of this License shall be unenforceable or invalid under such law, such paragraph shall be ineffective only to the extent and duration of such unenforceability or invalidity. The remaining substance of such paragraph and the remaining paragraphs of this License shall in such event continue to be binding and in full force and effect.

4.10 Counterparts. This License may be executed in any number of identical counterparts, any or all of which may contain signatures of less than all of the Parties, and all of which shall be construed together as a binding instrument.

[*Signature Page Follows*]

IN WITNESS WHEREOF, the Parties hereto have each caused this License to be duly executed as of the date first above written.

FIRMGREEN, INC.

By: _____
Name: Steven P. Wilburn
Title: President and Chief Executive Officer

SOLID WASTE AUTHORITY OF CENTRAL OHIO

By: _____
Name: Ronald J. Mills
Title: Executive Director

APPROVED AS TO FORM:

_____
Leo V. Garvin, Jr.
Garvin & Maloney

Per T/C authorization 19 December 2019

_____
Harold J. Anderson III
Chief Counsel
Solid Waste Authority of Central Ohio

EXHIBIT A

TRADEMARKS

FIRMGREEN® (Classes 4 and 11)
U.S. Serial No. 78/408,504
U.S. Registration No. 3,308,174
Issued on October 9, 2007

Class 4: Biodiesel and alcohol fuels
Class 11: Gas decontamination units in the nature of machines for removing contaminants from landfill gas and converting it into methane for use as fuel

gCNG™ (Class 4)
U.S. Serial No., 77/227,938
Date of Application: July 12, 2007
Status: pending

Class 4: Fuels; Natural gas

FGE ® (Classes 4 and 11)
U.S. Serial No. 78/408,514
U.S. Registration No. 3,308,175
Issued on October 9, 2007

Class 4: Biodiesel and alcohol fuels
Class 11: Gas decontamination units in the nature of machines for removing contaminants from landfill gas and converting it into methane for use as fuel

THE WORLD OF RENEWABLE ENERGY™ (Class 4)
U.S. Serial No. 77/031,039
Date of Application: October 27, 2006
Status: pending

11/19/09 11-17-2009

(a) Appropriate Use of FirmGreen® Mark:

General Specifications

FirmGreen (Classes 4 and 11)
U.S. Serial No. 78/408,504
U.S. Registration No. 3,308,174
Issued on October 9, 2007

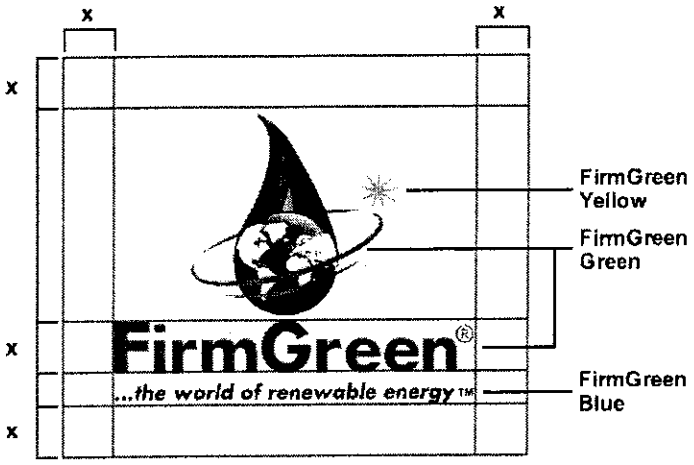
Class 4: Biodiesel and alcohol fuels
Class 11: Gas decontamination units in the nature of machines for removing contaminants from landfill gas and converting it into methane for use as fuel

Colors and Positional Guidance for Use of Logo

FirmGreen Blue - Pantone Matching System 286 (PMS 286)
C100 / M66 / Y0 / B2
R0 / G93 / B170

FirmGreen Green - Pantone Matching System 361 (OMS 361)
C69 / M0 / Y100 / B0
R84 / G185 / B72

FirmGreen Yellow - Pantone Matching System 109 (PMS 109)
C0 / M10 / Y100 / B0
R255 / G221 / B0



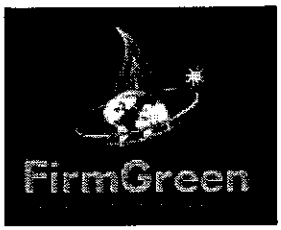
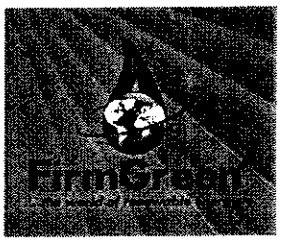
The FirmGreen name and tagline logo should be used on a white or very pale background only. The specified PMS or 4-color process colors should be used; an .eps file of the artwork may be requested by contacting info@firmgreen.com

11/19/09 11-19-2009

The RGB colors should be used for PowerPoint presentations, for web design, and for electronic communications

There is an area of isolation – or blank space – required around the logo for all uses, as shown above. The "x" dimension is the height of the company name; no text or other graphical elements should be inside the x-height dimension

For signage and all other uses, any resizing of the artwork must be proportional to the original artwork – i.e., if the height dimension is reduced/enlarged by 20%, the width dimension must also be reduced/enlarged by 20%

What To Do	What **Not** To Do
	
Logo, on white background	DO NOT use logo on black background
	
Logo, on light background	DO NOT use logo on dark background
	
Grayscale; please request artwork	DO NOT use logo on a photo or pattern

11/19/09 11-19-2009

(b) Appropriate Use of gCNG™ Mark:

General Specifications

gCNG (Class 4)
Status: pending
filed on July 12, 2007

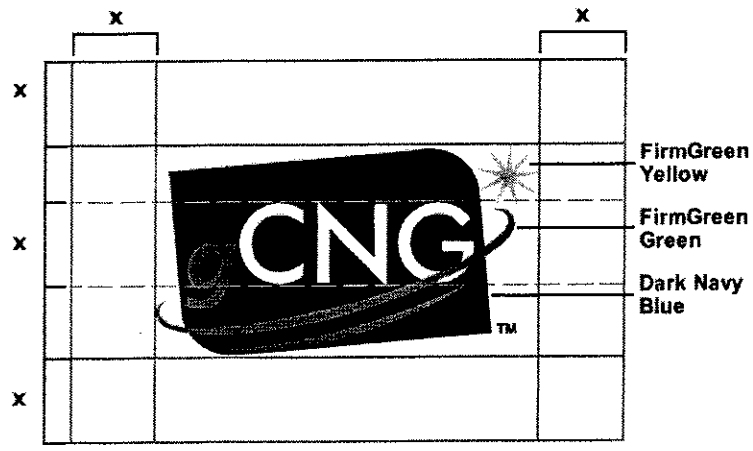
Class 4: Biodiesel and alcohol fuels

Colors and Positional Guidance for Use of Logo

Dark Navy Blue - Pantone Matching System 281 (PMS 281)
C100 / M72 / Y0 / B32
R0 / G61 / B125

FirmGreen Green - Pantone Matching System 361 (OMS 361)
C69 / M0 / Y100 / B0
R84 / G185 / B72

FirmGreen Yellow - Pantone Matching System 109 (PMS 109)
C0 / M10 / Y100 / B0
R255 / G221 / B0



The gCNG product name should be used on a white or very pale background only. The specified PMS or 4-color process colors should be used; an .eps file of the artwork may be requested by contacting info@firmgreen.com

The RGB colors should be used for PowerPoint presentations, for web design, and for electronic communications

There is an area of isolation – or blank space – required around the logo for all uses, as shown above. The "x" dimension is the height of the company name; no text or other graphical elements

11/19/09 11/19/2009

should be inside the x-height dimension

For signage and all other uses, any resizing of the artwork must be proportional to the original artwork – i.e., if the height dimension is reduced/enlarged by 20%, the width dimension must also be reduced/enlarged by 20%

What To Do	What **Not** To Do
	
Logo, on white background	DO NOT use logo on black background
	
Logo, on light background	DO NOT use logo on dark background
	
Grayscale; please request artwork	DO NOT use logo on a photo or pattern

11/19/09 SPW 11-19-2009