APPLYING LANDFILL GAS TO COMMERCIAL GREENHOUSE OPERATIONS

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ABSTRACT

Sanitary landfills can have beneficial post closure end-uses after being filled to capacity with waste and appropriately covered. Federal and state landfill regulations require control of landfill gas and post closure monitoring. These additional long-term responsibilities for the owners and operators can be supported financially by appropriate commercial development of the closed landfill.

One innovative solution to using both the land and landfill gas is to construct combined greenhouse and gas recovery facilities at completed solid waste landfills. Greenhouses have been constructed on the surface of a capped landfill or adjacent to landfill sites at three locations in the Midwestern United States. Landfill gas is used to heat and power greenhouses through gas recovery technology.

This paper describes energy requirements and gas recovery equipment needed. Average construction costs and profitability of the addition of such equipment to greenhouses are examined.

NOMENCLATURE

Btu = British thermal unit
Btu/hr = British thermal unit per hour
°F = Fahrenheit
HVAC = Heating, Ventilation, and Air Conditioning
kW = Kilowatt
kW/hr = Kilowatt per hour
kWh = Kilowatt hours
PE = Polyethylene
PVC = Polyvinylchloride
SCF = Standard Cubic Foot
SCFH = Standard Cubic Foot per Hour
SCFM = Standard Cubic Foot per Minute
$/year = Dollars per year

OBJECTIVE

The objective of this paper is to report guidelines for use in researching gas recovery projects to complement greenhouse operations using actual information from a 1-acre facility to approximate requirements for multiple acre operations.

Average fuel consumption and power usage rates were then determined for a 2-acre greenhouse operation. Beginning with these factors and other standard landfill gas parameters, landfill area, wellfield requirements, and cogeneration equipment requirements can be approximated.

The major areas of concern for a gas recovery application will be addressed by applying the required energy loads to common landfill gas and power generation parameters.

ENERGY REQUIREMENTS OF MODERN GREENHOUSES

The energy requirements of a commercial greenhouse must be broken into three main parts. They are the heating demand, the cooling demand, and the electric power demand.

Heating Load

The actual energy requirements to heat a given greenhouse is usually influenced by a combination of local phenomenon and operational requirements. These factors can vary considerably. Some items to consider when establishing a heating load include the following:

(a) Type of crops being grown.
(b) Required temperature and seasons for the crops.
(c) Average ambient high temperature during heating season.
(d) Average ambient low temperature during heating season.
(e) Average high and low wind velocities.
(f) Weather patterns.
(g) Greenhouse construction and materials.

Each greenhouse, grower, and location combination should be evaluated independently to determine a site specific heating load.

Local heating and ventilation engineers will be able to provide assistance towards determining a heating load from information provided by growers and manufacturers.

The operation on the landfill in Belleville, Michigan [1] resulted in the following heating load factors to maintain a minimum 65°F temperature in the greenhouses during the winter months.

8 million Btu/hr for a 2-acre greenhouse

Cooling Load

The cooling load is generally a ventilation concern. Depending on the nature of the operation additional cooling may be necessary. In either case, the energy demand will be part of the total electric power demand.

Power Demand

The total electric power demand will usually consist of the basic power requirements for packing workspace and offices plus power for pumps, fans, storage refrigerators, artificial growing lights.

Components from the above three areas will add up to a maximum electric power consumption amount. The total will vary considerably between winter and summer because the grow lights are used less in the summer time.

Power consumption at the greenhouse operation in Belleville, Michigan revealed the following average power consumption rates for winter and summer operations [2].

220 kW/hr per 2-acre greenhouse (winter)

45 kW/hr per 2-acre greenhouse (summer)

It is critical to establish the amount of energy required for a greenhouse in your area. I suggest engineers, growers, manufacturers, and agriculture extension agents for information. I believe that the best estimate will be obtained through a combination of all four.

APPLICATION OF LANDFILL GAS AS AN ENERGY SOURCE

Once the actual heat and power loads have been determined they can be applied with gas extraction and power generation factors to approximate landfill gas quantities required.

Quantity Required

Landfill gas typically contains approximately 400–600 Btu of heating capacity per SCF [3]. This factor allows us to estimate the quantity of gas needed to heat a 2-acre greenhouse, assuming 500 Btu/SCF.

$$8 \text{ MM Btu/hr} / 500 \text{ Btu/SCF} = 16{,}000 \text{ SCF/hr or } 266 \text{ SCFM}$$

The heating load can be satisfied with 266 SCFM of landfill gas.

The electric power demand can also be met by using landfill gas as a fuel for engine generator set. A reciprocating engine generator set will typically burn 10,000–15,000 Btu of fuel to produce 1 kW/hr of power ([2] and Caterpillar Engine Specifications). This ratio of fuel consumed to power produced allows us to estimate how much landfill gas is needed to produce the 220 kW/hr of power needed for a 2-acre greenhouse.

$$(10{,}000 \text{ Btu/kW} \times 220 \text{ kW/hr}) / 500 \text{ Btu/SCF}$$

$$= 4400 \text{ SCFH} = 73 \text{ SCFM}$$

The heating and power loads can be satisfied with approximately 339 SCFM of landfill gas (266 + 73).

Landfill Area and Gas Wells Required

The question of how much landfill area and gas wells are required to produce this much gas must be addressed. It must be remembered that each landfill will produce gas based upon a wide range of variables, and that not all of the gas produced can be collected (Methane Generation and Recovery From Landfills) [4].

These variables would include age of refuse, organic content of refuse, depth of landfill, moisture content of the refuse, thickness of the cap, well design, and any other site specific characteristics.

Mathematical computer models can be used to estimate the quantities of gas produced in a landfill. They require detailed information of the composition of the refuse making the gas. Engineering firms that specialize in this type of work are available for consultation.

Field operations of present gas extraction systems show that production quantities from well to well vary.

For the purposes of evaluating a greenhouse project a conservative figure of 4–10 SCFM per well [3] of landfill gas can be used to estimate the approximate number of wells required to supply a given amount of gas.

Assuming 10 SCFM/well from wells averaging 70 ft deep, a 2-acre greenhouse would require 34 wells to maintain 339 SCFM.

$$339 \text{ SCFM}/10 \text{ SCFM/well} = 33.9 \text{ wells}$$

It is good practice to space the wells so that there is approximately 1 well per acre [3, 5].

Therefore, a landfill approximately 34 acres in surface area with good gas production capability should be able to maintain enough gas to support a 2-acre greenhouse.

COGENERATION EQUIPMENT CONSIDERATIONS

Hardware to Extract the Gas

The major hardware required to extract the gas, clean it, and deliver it is listed as follows:

Wellfield Components

(a) PVC and PE pipe for wells and distribution pipe.
(b) Isolation valves.

The main considerations of the wellfield piping is that it must be sized correctly to prevent overloading the suction end of the compressor. It is usually sized by applying standard HVAC ducting calculations.

Isolation valves are the critical part of maintaining balance throughout the well field. It is important to select valves which will require the least amount of maintenance.

Gas Recovery Equipment

(a) Compressor.
(b) Gas cooling heat exchanger.
(c) Coalescing filters.

The compressor must be oversized to compensate for the volume of leachate removed from the gas during filtering. It must also be sized to provide the necessary amount of operating discharge pressure. It is usually best to consult manufacturers for specific performance curves.

Compressors for greenhouse use must be sized to compensate for seasonal load. (Maximum summer load will not include heating requirements but maximum winter loads will.) This case may require two smaller compressors rather than one large one especially if electric power production must be maintained.

Gas cooling heat exchangers and coalescent filters must be evaluated for volume capacities, pressure drop, and port sizes. The purpose of these components is to remove leachate from the gas. An environmentally sound means of disposing of this residual must be obtained.

Power Generation

(a) Gas drying equipment.
(b) Engine generator unit.
(c) Associated mechanical and electrical interfacing.

The gas drying unit is capable of removing even more moisture from the gas. It is necessary to maintain fuel quality for the engine/generator set. It must also be evaluated for volume, pressure drop, and port sizes, but most of all it must be able to lower the landfill gas temperature to its dew point. The dew point of the leachate in the gas can be determined by having a gas sample analyzed at a lab. The local gas company is usually equipped to provide assistance.

The engine generator must be selected based on the needs of the project. However, it may not be possible to select the exact size necessary. Because engine generator sets are only manufactured in a few sizes, a slightly oversized unit may be the closest unit available.

Feasibility of a contract to sell excess power to the local utility should be considered to accommodate oversizing and low summer power demands.

There are many additional items to consider when actually interfacing the mechanical and electrical components. These items are very much dependent on the exact nature of the project and can usually be addressed best during the later phases.

RELATIVE COSTS

Relevant conceptual costs for the installation of gas recovery wells and piping in conjunction with electrical power generation equipment are provided based on projects done in-house at Wayne Disposal Inc. and Wayne Energy Recovery.

Installation of Wellfield and Extraction Piping [3]

Drilling, trenching, and pipe installation
$$6000 \text{ \$/well} \times 34 \text{ wells} = \$204{,}000$$

BASIC HARDWARE TO EXTRACT AND DELIVER GAS [2]

A 450 SCFM Compressor	$ 15,000
Gas Cooling Heat Exchanger	$ 2,500
Pipe and Fittings	$ 1,500
Coalescent Filters	$ 3,400
TOTAL	$ 22,900

ADDITION OF ENGINE GENERATOR SET [2]

Engine Generator Set (350 KWH)	$150,000
Refrigerated Gas Dryer	$ 25,000
Mechanical and Electrical Interfacing	$ 50,000
TOTAL	$225,000

**Note-Does not include costs to connect to utility grid.

SAVINGS, COSTS, AND EARNINGS

Combining gas mitigation operations at capped landfills and greenhouse facilities presents a mutually beneficial opportunity for the owners of completed landfills and produce growers using greenhouses.

A basic requirement for a project would be that the owner of the capped landfill is already obligated to provide a means of recovering and mitigating gas produced in the landfill and has budgeted funds to do so as required to meet post closure requirements. This owner could then gain a sizable yearly tax credit (0.86 $/million Btu energy) by providing gas to the greenhouse instead of flaring it for 6 months.

$$266 \text{ SCF/min} \times 262{,}800 \text{ min/year} \times 500 \text{ Btu/SCF}$$

$$\times\ 0.86 \text{ \$/MMBtu} = 30{,}059 \text{ \$/year}$$

Another requirement would be that the grower would provide funding to construct and set up greenhouse operations based on his desire to expand an existing operation or start new products. The use of landfill gas provides a further incentive to save on heating fuel costs.

A typical Great Lakes greenhouse will earn 6.54 $/sq ft and will profit 2 $/sq ft [6]. Therefore, a typical 2-acre greenhouse operation will earn and profit:

$$6.54 \text{ \$/sq ft} \times 43{,}560 \text{ sq ft/acre} \times 2 = \$569{,}764$$

$$2 \text{ \$/sq ft} \times 43{,}560 \text{ sq ft/acre} \times 2 = \$174{,}240$$

An average Great Lakes greenhouse without landfill gas will spend 5.8% of its earnings on heating fuel and 2.8% on other utilities [6]. Applying these percentages to the above earnings shows that a 2-acre greenhouse heating and utility costs are as follows for 1 year.

$$0.058 \times \$569{,}765 = \$33{,}046 \text{ — heating}$$

$$0.028 \times \$569{,}765 = \$15{,}953 \text{ — utilities}$$

Referring to our previous example of determining gas quantities, landfill area, and relative costs of recovery equipment required to supply a greenhouse operation we can consider the economic benefits of a landfill gas heating application in a project evaluation study or budget estimate.

Basically the grower would add in the cost of the equipment needed to remove the gas from the landfill owner's existing pipeline and the landfill owner would get back his initial cost of the recovery wells through tax credits.

ADDITION OF GAS RECOVERY EQUIPMENT

LANDFILL	EXPENSES	GROWER
$ 204,000	RECOVERY WELLS ETC	$ 0
$ 0	RECOVERY HARDWARE TO GROWER	$ 22,900
	YEARLY REVENUE, SAVINGS, or COSTS	
30,059 $/yr	TAX CREDIT	0
0 $/yr	HEATING COST	33,046 $/yr
	PAYBACK PERIOD	
204,000 $ / 30,059 $/yr		$22,900 / 33,046 $/yr
6.78 years		0.69 years

This example is intended to show only the costs and benefits of adding landfill gas heating capability to a business plan developed and funded by the grower and landfill operator individual requirements. Maintenance costs and interest payments on loans are shown and are best evaluated by individual project participants.

CONCLUSIONS

The combination of the greenhouse business and owners of capped and completed landfills is a very attractive option in locations where the landfills and markets coexist (any large city in the United States).

This is a good way to provide an end use for landfill space, provide revenue for landfill operators, provide jobs in communities, utilize landfill gas, and help curb heating costs for growers.

An extra investment of approximately $23,000 for gas recovery equipment to a greenhouse operation can pay for itself within 2 years and directly reduce heating costs for the remainder of the greenhouse operational life.

Considering that the landfill has already committed a significant sum of money for the long term mitigation of gas, the option of recovering it in less than 6 years through tax credits and gas sales is most attractive.

Larger gas recovery and power production operations are more economical than small ones. Greenhouses give operators a good way to increase capacities for small additional costs.

REFERENCES

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[4] "Methane Generation and Recovery From Landfills," EMCON Associates. San Jose, California.

[5] Knox, Tom. "Design of Gas Extraction Systems, Headers, and Related Facilities," Kansas City, Missouri: Black & Veatch.

[6] "1990 Greenhouse Operating Report," Lansing, Michigan: Professional Plant Growers Association.