Technology Assessment Report

Energy Transition Technology, Inc.

North Andover, MA

Prepared for
The Massachusetts Strategic
Envirotechnology Partnership
STEP

December 11, 1996

Prepared by

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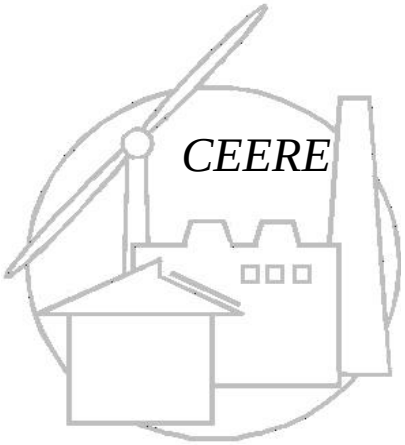

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University of Massachusetts Amherst
UMASS

PROJECT FUNDING

The Step Technology Assessment Project was Funded by
The University Of Massachusetts and The Massachusetts Division of Energy Resources

PREFACE

The STEP technology assessment process is designed to identify those technologies that will support the economic and environmental/energy goals of the Commonwealth of Massachusetts and may benefit from STEP assistance. The process is meant to be one of screening, in which technologies are evaluated by independent technical specialists. Recommendation from this process does not constitute an endorsement of the technology or of the absolute validity of the technology. Rather, STEP technical assessments attest only that, through the screening process, the reviewers feel there may be benefit to the Commonwealth of Massachusetts.

Background

Applicant: Energy Transition Technology, Inc.

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Energy Transition Technology, Inc. (ETTI) is a Massachusetts-based company established in 1996 to design and market a Turbo Charger Gas Turbine (TCGT) engine. TCGT are low pressure, ultra-lean burn, highly recuperated gas turbine engines designed to burn gas from solid waste landfills and generate electricity.

The system is designed so that it can be assembled from mostly commercially available components and from components developed by ETTI, and operate profitably on medium Lower Heating Value (LHV) landfill gas.

Technology/Mode of Operation

Overview - ETTI has developed a low-cost gas turbine engine that should operate profitably using landfill gas. In addition to landfills, there are other biomass fuel sources, such as gasification of coal, waste water treatment plants, industrial digesters, etc., for which TCGT could be used. The engine design combines commercially available turbocharger parts, controls and other components with a proprietary combustor and recuperator design. The resulting turbocharger gas turbine engine generator set is expected to operate efficiently on LHV landfill gas and at the same time have much lower emissions than conventional engines. The costs of producing electricity and operating this engine are projected to be below the cost of conventional engines.

The TCGT is expected to produce electricity for less than $0.03/kWh, allowing the company to stay solvent even in the deregulated utility market, without tax credits or other price supports commonly needed by renewable energy devices.

ETTI's plan is to operate on landfill sites as a non-utility generator, providing power as a qualified source under PURPA provisions. Production development is in the pilot stage with signed contracts for three landfills capable of supporting six or seven 750 kW units. If the 750 kW unit attains a satisfactory market acceptance, subsequent development of 250 kW and 500 kW generating units will follow.

Operation - The TCGT engine design includes a simple, single stage compressor and turbine with an optimized ultra-lean burn reverse flow can combustor, integrated into a system with a high efficiency recuperator (folded-plate type) of modular construction and a low loss fuel pressure boosting system.

A low pressure ratio (3.8:1) is developed by a single stage centrifugal compressor and is utilized in a single stage gas turbine. The system design, with ultra lean combustion and low gas turbine inlet temperature, should facilitate high efficiency combustion, and together with the recuperator, provide competitive efficiency at a very low emission rate. Because of the system's low pressure ratio, the fuel system is simplified and conventional positive displacement pressure boosting pumps are replaced with a centrifugal compressor system, driven from a separate high speed electric drive. The results are lower costs and lower energy consumption, as well as a more reliable fuel system. Typical performance and cost of the TCGT system are projected to be:

Capital Cost		< $1000/kW
Operation & Maintenance		< $0.003/kWh
Heat Rate		11,000 Btu/kWh
Emission	NO_x	0.1 g/kWh
	CO	< 0.3 g/kWh
	UHC	negligible

The estimated installation cost for the TCGT system is expected to range from $50,000 to $150,000 depending on the site characteristics and the difficulty of utility interface and interconnection.

Competing Technologies

The search for technology that could offer economically favorable energy production from landfill gas has been an area of interest for the past three decades. Depending on the site size and the amount of landfill gas production, several conventional technologies have been implemented with satisfactory results. They include thermal oxidation, reciprocating engines, boilers and steam turbines and gas turbines. Several other new technologies are emerging as possible sources for the destruction of landfill gas. They differ by the amount of landfill gas they can process and the level of emissions they release to the atmosphere, but they are all competing to set the standards as the Best Available Control Technology (BACT).

ETTI has set a goal to manufacture systems that are smaller than currently available gas turbines used in landfill gas applications. In this way, they will compete with other conventional technologies over which gas turbines can have a competitive advantage. A certain number of gas turbine manufacturers have the

knowledge and resources to develop competing service, but they are currently not doing so. The landfill gas market is, at this point, too small and provides to low rate of return on investment for these companies to find it attractive. ETTI's goal is to develop their product and thereby gain a competitive advantage before these companies enter the market.

STEP Support Requested

ETTI has three sites suitable for pilot operation under contract, and is looking for support in:

1. Pilot program Financing - MDFA Emerging Technology Fund loan guarantee for TCGT units.
2. Utility deregulation pilot program - Such as participation in the Massachusetts High Technology Council program or the Massachusetts Municipal Wholesale Electric Contracts for Worcester.
3. Detailed information on landfills and location of potential pilot sites for a cogeneration unit.
4. Assistance in obtaining permits for the pilot site
5. Technical Assistance- computer modeling of landfill gas generation and TCGT emissions, grants for on-site testing and conducting pilot site tests.

ASSESSMENT FINDINGS

The data presented by the ETTI indicate that the TCGT system should perform as claimed. The EADC recommendation is that the STEP program provide further assistance to ETTI and help with any regulatory and permitting needs. At least one landfill site should be identified for a TCGT demonstration of landfill gas use.

Technical Assessment

Introduction

Municipal solid waste landfills are large repositories of biomass which emit substantial quantities of methane, a gas which contributes to the formation of smog and poses an explosion hazard if uncontrolled. Because landfill gas is about 50% methane, it is both a potent greenhouse gas and a valuable source of energy. For this reason, the Environmental Protection Agency (EPA) created a Landfill Methane Outreach Program to recover energy from the gas and reduce methane emissions.

Under the program, landfills which have a capacity of at least 2.5 million metric tons and annual emissions greater than 50 tons of non-methane organic compounds (NMOC) must be capped, and a methane collection system must be installed. Additionally, the landfill must be an existing landfill that received waste after 1987, or a new landfill constructed after May 1991. The collection system, which collects the gas under a vacuum through a system of valved wells connected to a header (collection pipe) system and blower, recovers the gas and prevents its off-site migration. The system must also be controlled to minimize air intrusion, which will affect the useful quality of the gas and can contribute to underground fires.

The composition of municipal landfill gas depends on the age of the site and the content of the buried waste. The volume of the landfill gas resource depends on the age of the landfill site, the volume of material in the site, and the water content of the waste. Initially the breakdown of waste occurs both in the presence of air (aerobic decomposition) and in its absence (anaerobic decomposition). During the aerobic phase, landfill gases are composed primarily of methane, carbon dioxide, and hydrogen, with relative amounts varying widely with time and from site to site. The gas may include small amounts of oxygen, nitrogen and trace gases. Waste buried for some time undergoes only anaerobic decomposition, resulting primarily in methane and carbon dioxide with trace gases [Brosseau and Heitz]. Depending on the site composition, the trace gases may be VOCs, hydrogen sulfide, halogenated compounds or other hydrocarbons. The total trace gas volume may be as great as 5% of the gas or as little as 0.1% or less. The available energy depends on the gas flow and the gas composition.

Trace gases may cause a number of problems, including toxic pollution from incineration, corrosion of gas collection and combustion systems, subsurface migration to residences and unwelcome odors. The first two issues are of concern here. The primary methods of incineration of landfill gases in North America are in flares and in internal combustion engines. In the presence of an available source of chlorine, internal combustion engines will emit polychlorinated dibenzodioxins and dibenzofurans [Brosseau and Heitz]. Additionally, if toxic gases enter the engine, some may emerge as unburned contaminants. The combustion of gases including sulfur or chlorine also forms corrosive acids which may harm the combustion system.

Attempts to profitably exploit landfill gas have met with difficulty due to the cost of installing and maintaining the equipment which generates electricity from the gas. Since its development as a primary

mover, the gas turbine has established itself as the engine of choice for many industrial applications. It is compact and light weight, resulting in low installation costs. Improvements in material and cycle performance plus exceptional reliability and maintainability have resulted in the establishment of gas turbines in markets previously reserved for reciprocating internal combustion engines and steam power plants. Since TCGT is a low pressure gas turbine it should have a low parasitic loss fuel system that should be less costly to install, operate and maintain.

Most industrial gas turbines were originally designed to burn natural gas, #2 fuel oil, or both. Legislative, environmental and economic factors in recent decades have necessitated the development of gas turbines capable of operating on alternative fuels. Expanding gaseous fuel-burning capabilities to alternate gaseous fuels without cumbersome changes in controls or combustion systems requires adequate analysis, design, development and testing. The operational experience of landfill gas turbines at many locations in the United States confirmed that this is a mature technology that can achieve high on-line time and maintain NOx and carbon monoxide at low levels.

Performance Claims and Performance Data

ETTI claims that their TCGT system has the ability to destroy UHC to negligible levels and generate carbon monoxide and NOx at a much lower level than competing technologies. Typical performance and cost characteristics of the TCGT system with the recuperator are projected to be:

Capital Cost		< $1000/kW
Operation & Maintenance		< $0.003/kWh
Heat Rate		11,000 Btu/kWh
Emission:	NO_x	0.1 g/kWh
	CO	< 0.3 g/kWh
	UHC	negligible

As improvements are made, the ETTI staff expects the heat rate to be reduced to about 8,000 Btu/kWh. The TCGT is expected to produce electricity for less than $0.03/kWh, allowing the company to stay solvent even in the deregulated utility market, without tax credits or other price supports commonly needed by renewable energy devices.

The estimated installation cost for the TCGT system is expected to range from $50,000 to $150,000 depending on the site characteristics and the difficulty of utility interface and interconnection.

Capital Cost

ETTI is planning to produce the TCGT system mostly from components commercially available on the market. The components that still need development are the combustor and the recuperator, which are ETTI's proprietary technology. The system is expected to be installed at the first pilot site without a recuperator. An investigation into a variety of recuperator operating characteristics and manufacturing economics led ETTI to design their own folded-plate type recuperator. The system is expected to have good performance characteristics and to be cost-effective.

The first site will be used as a learning tool and is expected to have larger capital costs. The first unit is expected to cost about twice the production estimate, but the cost will be reduced at a rate of about 30% per system, allowing the cost to come down to the expected level by the time the fourth engine is installed.

The assumption that the company will be able to produce the TCGT system for less than $1,000/kW installed is realistic.

Operation & Maintenance

The landfill gas will be cleaned of liquids or solid particles before entering the TCGT system. Liquid fractions will be removed by liquid separators and the fuel temperature will be held above any liquid dew-point temperatures throughout the fuel-handling system to ensure reliable and stable operation. Solid particles will also be filtered from the fuel.

The fuel delivery system must include all components necessary to maintain proper fuel supply during startup and operation from idle or no load to the full load. The ETTI's fuel system is expected to handle landfill gas under all weather conditions and quality changes.

The possible presence of corrosive compounds (organic chlorine) in the landfill gas could cause problems for the fuel control system, combustor system, fuel injection system and turbine components, and should be monitored during operation. The field experience of other manufacturers have shown that these components were free of corrosion despite the fact that the fuel was not treated before injection into the turbine.

Two components of the TCGT system, the combustor and the recuperator, still need some development, and have never been tested in the landfill gas application. The combustor must ensure satisfactory and reliable operation and long life under a wide range of ambient temperatures, environmental conditions and fuel quality variations.

The recuperator with a thin, high aspect ratio folded fin is designed to overcome problems of possible silica deposits experienced by other types of recuperators in landfill gas applications. When gas turbine

heat recovery is implemented, the recuperator should be carefully monitored for problems related to the possible presence of corrosive compounds.

The performance characteristics of the system and its maintenance costs can only be determined through prolonged operation**.** The company plans to address maintenance through partnering with one or more of the potential providers of components and labor. Among others, the candidates are Elliott, Ewing Power Systems, Cannon, Marathon and Westech, that have international sales and service organizations.

Heat Rate

The first system, which will be installed without a recuperator, is expected to have an efficiency of about 15% (Heat Rate of about 22,750 Btu/kWh). After the completion of the recuperator and its installation, the overall efficiency will rise to about 31% (Heat Rate of 11,000 Btu/kWh). Based on existing data for gas turbine performance these numbers are realistic and the system should operate as claimed. However, since no system has been installed and tested, the numbers have to be verified through tests.

Over a period of time and after improvements are made, ETTI expects the heat rate to be reduced to 8,000 Btu/kW (overall efficiency of about 43%).

Emission

The behavior of gas turbines operated on landfill gas has been tested at many locations in the United States [Maxwell, 1989]. It has been determined that nitrogen oxide (NOx) emissions from landfill gas turbines is significantly lower then that from natural gas turbines due to the quenching effect of the CO_2. Natural gas-fired turbines typically require water or steam injection to reduce NOx when required by local permitting agencies, while turbines operating on landfill gas require no supplemental treatment to reduce NOx. The expected NOx emission of 0.7 g/kW for the test site is expected to be reduced to below 0.1 g/kW for subsequent installations with the recuperator. The company believes that the TCGT engine should have NOx emission below existing flares and other existing generating equipment.

Emission levels of CO and UHC are more difficult to correlate with fuel characteristics, but can be estimated for combustion system for which experimental data are available on high Btu fuel with and without water injection [Meier, 1986]. The natural trend of CO and UHC to increase as flame temperature decreases can be overcome by careful redesign of the combustor’s primary zone and the fuel injection system.

If landfill fuel contain significant amount of emissions-yielding compounds such as nitrogen-bearing compounds (ammonia and hydrogen cyanide) and sulfur-bearing compounds (hydrogen sulfide and sulfur dioxide), this could increase substantially the amount of NOx and SO_2/SO_3 emissions.

Potential Environmental and Energy Benefits

The potential environmental benefits of the use of ETTI's system for the destruction of methane are significant. The TCGT system should have NOx emissions below the existing conventional equipment for landfill gas applications. Also, since landfill gas is a significant contributor to the formation of smog and global warming, reducing its release to the air represents an environmental benefit. While burning methane produces carbon dioxide, it replaces every molecule of methane with one of carbon dioxide. As methane is 20 times more effective at inducing global warming than carbon dioxide, burning methane that would otherwise escape into the atmosphere reduces the potential for global warming [Williams, 1992].

By producing electricity, the TCGT system will also contribute to a reduction in overall emissions of NOx, CO and UHC, since this energy should have been produced by some other source with the larger emission of these components. This will also save the equivalent amount of fossil fuel that would have been used otherwise to produce this energy.

Competing Technologies

An increased number of municipal landfills are now required to control the emission of landfill gases. There are several existing or developing technologies that will compete with ETTI's TCGT system for the destruction of landfill VOCs. These technologies can be divided in two categories:

i) technologies for the landfill gas destruction without the energy recovery

ii) technologies for the landfill gas destruction with the energy recovery

The representatives of these technologies are:

- Thermal oxidation with flares. Flares are low cost systems but include no energy recovery and can emit some Products of Incomplete Combustion (PIC) and chemicals derived from the trace gases.

- Reciprocating engines. This type of landfill gas destruction and electric power generation is most commonly used today. These are conventional diesel engines redesigned for this application. They offer a heat rate of about 11,500 Btu/kWh and NO_x emissions of about 1 g/kWh.

- Boilers and steam turbines. Landfill gas is used in steam-generated electricity plants. Economics rarely favor the development of these plants unless the project exceeds 10 MW.

- Gas Turbines. The existing gas turbines in the size range suitable for landfill applications are industrialized versions of aircraft turboprop engines. The most widely used gas turbines operating on landfill gas have been Solar Saturn (750 kW) and Centaur (2.7 MW).

There are other technologies, like fuel cells that are emerging as a possible source of competition. These convert methane directly into electric energy by chemical means. The technology is available but is still too expensive for commercial applications. Still, research continues because fuel cells can produce as much as 40 percent more energy from the same amount of gas as competing technologies.

ETTI has set a goal to manufacture systems smaller in size than currently available gas turbines used in landfill gas applications. Their goal is to develop turbines from 250 kW to 750 kW, starting with the development of 750 kW engine. The major competitor in this range, Solar, has commercially available units of 750 kW and 2.7 MW. Competition will also come from other conventional technologies such as reciprocating engines, compared to which gas turbine has a competitive advantage. A certain number of gas turbine manufacturers, like Solar, Allison and Allied Signal, have the knowledge and resources to develop competing service, but they are currently not doing so. ETTI's goal is to develop their product and gain a competitive advantage, before these companies enter the market.

Several other technologies are emerging as possible sources for the destruction of landfill gas. They differ by the amount of landfill gas they can process and the level of emissions they release to the atmosphere, but they are all competing to set the standards as the Best Available Control Technology (BACT).

Summary of Technical Assessment and Recommendations

The data presented by the ETTI indicate that the TCGT system should perform as claimed. It is the recommendation of this report that the STEP program provide further assistance to and help select additional potential sites from among state landfills, and lay the groundwork for any regulatory and permitting needs. The landfill sites should be identified for a TCGT demonstration of landfill gas use. These tests should be designed to demonstrate that the TCGT system has low maintenance and operational costs and high reliability.

ETTI's combustor was originally designed to use natural gas, a high LHV fuel. The use of fuels with a different LHVs and molecular weights requires modification of the control system to ensure satisfactory combustion over the entire operating range. It is recommended that ETTI perform numerical calculations and verify the expected performance characteristics of the combustor before it is installed on the test site.

It is recommended that ETTI prepare plans for testing protocols for the TCGT system, and that STEP review the plans and provide third party monitoring of the demonstration. STEP will then incorporate the demonstration results into an enhanced study of the technology evaluation procedure.

If after the tests are completed and if it is determined that ETTI's technology does not meet the BACT standard, STEP should take into consideration the fact that the gas turbine produces electricity through cogeneration, thereby reducing an existing pollutant emission and the amount of fossil fuel needed to produce the same amount of electricity. The ETTI's technology will be referred to DEP for permitting and to DEP/DOER for assistance under the States Landfill Methane Outreach Program.

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Business Assessment

Company Background and Mission

Energy Transition Technology, Inc. (ETTI) is a new corporation formed in 1996 by the principals of B-E Holdings (BEH) which has been in existence since 1986 and was involved in the industrial machinery business. ETTI owns the intellectual property rights to a specialized gas turbine engine using commercially available turbochargers called the TCGT engine, and has developed additional enhancements enabling combustion of low energy content fuels.

ETTI's primary mission is to develop renewable energy technology with a focus on biomass-related technology. The TCGT engine development and application of the TCGT technology is the company's current effort. Past efforts of ETTI personnel have included hybrid vehicle propultion system design and wind power generator system design and development.

The Marketplace

The overall marketplace for the TCGT engine needs to be viewed from two perspectives. The technology is capable of converting the thermal energy from low BTU fuels into electrical energy as a saleable commodity into regional power grids. On this basis, one measure of market demand is that of electrical energy demand requirements at large.

At the domestic level, several regulatory drivers, the Energy Policy Act, New Source Review, and the Public Utility Regulatory Policy Act have required the opening of the electric power market to competitive suppliers other than base operated power plants. At the international level, developing nations without an electrical power infrastructure represent a marketplace which can accommodate thousands of units, provided appropriate strategic alliances can be developed.

Another marketplace perspective is that of the original customer, i.e. the landfill operator or industrial facility interested in making a capital investment in power production to offset operating expenses. The US EPA estimates that there are 7000 Municipal Solid Waste sites domestically, the only types of landfills potentially suitable for energy conversion purposes, which collectively create a feedstock gas production rate of an estimated 1.4 billion cubic feet of gas per day. EPA estimates 750 MSW sites could

install economically viable energy projects, and that this translates into the potential for the creation of 5000 megawatts of electrical power.

ETTI estimates that there is a market potential for upwards of 10,000 TCGT engines in the 250-750 kW size range for existing and new MSW sites over the next 20 years, plus thousands of sewerage treatment plants and industrial facilities that would be well suited for smaller sized TCGT engine units.

The ongoing deregulation of electric utilities in general, and the concurrent uncertainty in resultant pricing structures, lends a significant amount of uncertainty and risk to any pricing assumptions that might be made, which in the case of ETTI are offset to some degree with power purchase agreements with municipalities. There appears to be a viable and good-sized marketplace for this type of technology, which can create the combined benefits of revenues, jobs, and efficient utilization of combustible landfill and industrial process gases.

Competitive Strengths and Weaknesses

Competing uses of landfill gas are present and have been successfully utilized, including pipeline gas, vehicle gas, methanol production, and as incinerator and industrial process heat. They all have limitations that pose significant constraints on these applications, including cost effectiveness, emissions level compliance, and geographic locational requirements.

Other units exist which can convert landfill gases into electrical energy, but not with the alleged operational efficiencies of the TCGT engine concept. In the absence of this technology or a similar one that has not yet been commercially developed, the energy potential from landfills will not be developed until the economics of natural gas supplies from wellheads increases due to depletion of fossil fuel supplies, not projected by the Gas Research Institute for 3 to 5 decades.

Given the low emissions and maintenance costs associated with the operation of the TCGT engine, it has competitive advantages for industrial and commercial generation applications. The engine, unlike its competitors, incorporates heat exchanger designs which recover thermal energy from the engine exhaust coupled with new turbine designs that extract mechanical power from process heat, which otherwise would be lost. This combined cycle trait enables the engine to operate at higher efficiency levels.

Regardless of its technology and efficiency advantages, the TCGT engine and its competitors are all highly dependent upon their economic ROI justification on the prevailing pricing of electricity, which is a function of the price of prevailing fuels used to create the electric power supply. In many cases, the aspects of feeding electrical power into regional grids is a “push” market, instead of being “pulled” by fundamental economic demands. E.g. natural gas prices are off over 30% from 4-5 years ago, making this type of technology less competitive than otherwise would be the case. In the longer term, however, the finite supplies of fossil fuels and the fundamental supply demand aspects of resource economics will bode

favorably for the efficient recovery and utilization of otherwise wasted fuel feedstocks, such as those which can be obtained from landfills.

In the cogeneration market niches especially, the TCGT engine faces direct competition from more mature, but perhaps less efficient technologies consisting of reciprocating engines and the emerging technology of fuel cells. However, the ability of the TCGT engine to operate efficiently using low BTU nonconventional fuels coupled with its favorable emissions performance gives ETTI a specific niche advantage in the MSW landfill arena.

Patent Protection

Although ETTI owns the intellectual property rights to the TCGT combustor design and its associated recuperator design, there is no explicit patent protection, the patent search and application processes are yet in a very early stage, and there may be conflicts with other existing patents which already address key design attributes to the technology. ETTI does, however, expect to receive patentability on specific areas of the recuperator, fuel system and cumbustor design.

As such, ETTI is vulnerable to competitive forces and unprotected entry barriers from existing and prospective competitors. This should be viewed from an investment perspective as a risk factor. To the extent that ETTI and its TCGT technology becomes visibly successful and given the size and scope of the marketplace, there is little if anything that would stand in the way of much larger and established entities in the business, from entering the fray with some competitive advantages based on size, networks, and economies of scale. ETTI has wisely considered the option of partnering with some of its suppliers that have already established international sales and service organizations, which could give it some strategic advantages in a yet to be formed competitive milieu.

Financial Status and Income Performance

The company has no demonstrable income performance at this time, and is anticipating commercial loan guarantees from federal and state sources for up to $5 million in order for it to in order to get the operation up and running.

Current ETTI operational expenditures are in the $4 thousand per month range, and are supported by personal contributions of the principals to the corporation, which can be allegedly be maintained at this level more or less indefinitely, as long as the key contributing principals maintain their current level of enthusiasm about the prospects for the business and the TCGT engine technology.

In examining projected cashflow statements provided by the corporation even without evaluating their reasonableness, they are based on a successful scenario of obtaining anticipated loan guarantees. On this basis operational expenses will increase considerably at the point that anticipated grant acquisition occurs, with an anticipated "burn rate" of approximately two years, the window of opportunity for the company to become a viable business mirroring its projected P&L projections.

In the event commercial loan guarantees were not achieved from federal and state sources, ETTI would of necessity need to fall back to a much more modest and staged development timetable, and it would be some time before the operation would have the potential of commercial and environmental success. The principals have already explored opportunities within the venture capital community, but are of the temperament that they want own and direct the venture without v.c. constraints.

Management Team

ETTI's management group consists of six individuals with related product development and managerial experience which was formed by mutual consensus to pursue this business opportunity. As is understandable with a fledgling organization of this size and with its key product in the design development stage, there is no specific organizational structure, although various individuals contribute value based upon their own skills and expertise.

John Fitzgerald, Treasurer, has several decades of broadranging functional experience in various industrial companies, both established and startup, and has developed several patented technologies. His primary function is to steer and oversee the continued design development of the TCGT engine.

Robert Williams established Williams Energy Systems in 1990 to locate and develop existing landfills into alternative energy facilities. He's had over a decade of technical experience in the methane gas recovery field, with a corresponding network amongst both municipal and private landfill operators. His primary function is to discover and develop sales and utilization opportunities for the TCGT engine with his network of familiarity.

Regina Dumbrowski, President, has diversified operational experience in various small and mid-sized businesses, and is responsible for corporate liaison with domestic and international licensees, and legal counsel. Her principal function at this stage is to work with public sector financing and regulatory agencies to remove impediments from the development path, including loan guarantees, and pilot and demo opportunities.

Allan Chertok is a P.E. which has directed the development of various electronics and controls systems, and holds ten patents in electronics and wind generation mechanisms. He is currently providing technical input as a paid consultant, and anticipates joining the organization as its technical director once financing is in place.

Joseph Lynch and E. Roy Norster are both independent consultants who are closely involved with ETTI. Mr. Lynch's field of expertise includes finance and licensing, and he's worked with various businesses including those in energy related fields. Mr. Norster's expertise is in combustion design and engineering, with significant contributions in lean burn, low emission technologies.

Given its newfound status, ETTI's senior management team needs an extensive focus on the marketing and business development aspects of its identity, especially in the interface with landfill operators and municipal targets. In this age of tight budgets and public accountability, an essential component of this venture entails convincing these entities of the economic payback benefits that ETTI's TCGT engine can provide, in direct comparison with alternatives ranging from status quo to alternative technologies. Likewise, given its ambitious growth plans, the senior management teams needs to devote considerable attention to the coordination of in-company staffing and outside contracted services in support of its growth objectives.

Sales and Business Development Strategies

ETTI intends to rely on successfully attaining commercial loan guarantees to use as a bridge in closing landfill contracts. They have made the assumption that they will be successful in obtaining financing assistance through the Massachusetts Development Finance Agency, especially on the three pending landfill demo contracts at the Glendale Landfill, Northampton, at the Greenwood Street Landfill, Worcester, and at the Main Avenue Landfill in Acushnet. Rapid turnaround in financing assistance will be essential if tax credit preservations (important cost savings elements in ETTI's financial projections) are to be achieved).

ETTI has some barriers that they will need to surmount in order to generate sales and profitability. The technology is still at the alpha stage of development, and while conceptually attractive, lacks the degree of performance related information to make it a competitive player in a marketplace currently using other and more established technologies than the TCGT engine. ETTI needs to successfully demonstrate the TCGT engine's benefits in a pilot / beta testing mode, within a timeframe that still allows it to capitalize on tax credit availability.

With only the capitalization in the form of the tax credits available from the aforementioned sites under contract,, the company must generate commercial loan guarantees quickly, prior to the end of 1st quarter, 1997. Even with the optimistic assumptions that these challenges can be overcome in the short term, the profitability of the technology is to some degree influenced by the evolution of current government regulations concerning energy pricing.

In summary, ETTI has an incompletely developed and demonstrated technology, is undercapitalized from the standpoint of being able to generate cashflow for further development and installation, and is positioned in a marketplace which is currently somewhat depressed given prevailing energy costs.

ETTI's sales and marketing strategy is incomplete in its conceptualization and development. Most efforts seem to be placed on an overly dependent reliance on the public sector to identify and support financing and market target identification of specific eligible landfills.

The company needs to demonstrate that is has developed compelling incentives, a pricing strategy, and selling strategies necessary to achieve deal closures with its key market targets, and it needs to spend much if effort doing so at this stage. They should not merely rely on the success of demos at several state landfill sites to provide market acceptability (with STEP resource utilization) and state financing support via loan guarantees (with state risk absorption).

ETTI's understanding of the importance of the development of comprehensive marketing and sales strategies are in need of ETTI's primary attention at this stage of their development. The company's projected cashflow statement for 1996 through 2000 allots marketing expenses as a percentage of total expenses with amounts in the area of 5 percent may be insufficient.

Summary of Business Viability Consideration

ETTI has an innovative technological concept which is incompletely developed, and the company is in need of considerable additional capitalization and/or loan guarantees to bring the technology to completion and to develop sufficient performance data to demonstrate marketplace credibility. The TCGT engine, is positioned against established competition in the sanitary landfill and industrial cogeneration markets, and in theory has competitive advantages in installation costs, operations & maintenance costs, and emissions performance relative to current regulatory requirements. The TCGT engine does not have patent protection, and their are some but limited entry barriers to established producers of combined cycle / gas turbine engines for other applications. The company needs to re-examine and readjust their market success expectations and the extent to which resources are invested in marketing and sales, and revise their P&L and growth projections and financing needs accordingly.

Regulatory Assessment

Potential Market for Landfill Gas Recovery Technologies

Landfill gas is a mixture of methane and CO2 (about 50% each) and other trace elements including non-methane organic compounds (NMOCs - many of these are also VOCs). Methane itself is not a VOC, and not a criteria pollutant under the Clean Air Act; however, landfill gas is a significant contributor to the formation of smog and to global warming.

EPA has promulgated new regulations - New Source Performance Standards - which require landfills above a certain size to control landfill gas emissions. The criteria for inclusion are capacity of 2.5 million metric tons, annual emissions > 50T of NMOCs, and operational status (existing landfills that received waste after 1987, or new landfills constructed after May 1991. DEP has been delegated authority to administer the regulations.

Landfills which will be required to treat landfill gas represent the strongest market for energy recovery. About 10 Massachusetts landfills are expected to be covered by the New Source Performance Standard (NSPS) regulations. In addition, ETTI has identified 25 communities in the state with existing landfills with partial or complete gas collection systems in place (attached).

In the early 1990s, EPA established the Landfill Methane Outreach Program, to encourage states, utilities, and landfill operators to recover the energy value of landfill gas. See EPA Handout for summary of program. Extensive information is also available from the National Landfill Gas Committee of SWANA (Solid Waste Association of North America) and private organizations such as Governmental Advisory Associates (yearbook that lists all landfill gas recovery projects in the US - cover page attached). EPA estimates that over 700 US landfills have economic potential for installation of energy recovery facilities.

EPA, DEP and DOER signed an MOU in 1994 to promote energy recovery of landfill gas. In 1994, there were 109 open landfills in the state, of which 95 were slated to close in the near term. However, the market for energy recovery from landfill gas is driven by the economics of electricity production, and to date only the largest landfills have been considered viable candidates. The Mass. Outreach Program estimates that 17 Massachusetts landfills are economically viable for energy recovery. However, the ETTI technology targets smaller flows of landfill gas, and may make recovery projects cost effective at additional sites.

Economics are a crucial factor for landfill gas energy recovery projects. DEP staff estimate that production of energy from landfill gas costs on average 5.5 cents per kWh. Current prices for the energy is about 2.5 cents, with an additional 1.2-1.5 cents supported by tax credits. The price paid by utilities for the energy may be further reduced by the pending deregulation of the utility industry.

Another important factor in the economic viability for an energy recovery project is whether the landfill already has in place (or will have to put in place for regulatory reasons) a system of pipes to control landfill gas. Installing this system solely as part of an energy recovery project adds a considerable cost to a project.

The Massachusetts Landfill Methane Outreach Task Force established by the 1994 MOU works with utilities and technology developers to encourage and promote energy recovery projects. The Task Force is preparing a primer on the requirements for landfill gas to energy programs, which will be available this winter.

Regulatory Framework

There are several permitting requirements for landfill gas energy recovery systems. Several permitting categories apply to landfill gas energy recovery projects. Specific permit requirements are case-specific, but each category is evaluated for its applicability to individual projects. The categories of requirements are summarized in this review, and the primer will contain detailed information on specific permit requirements summarized here. Permit review timeframes would range from a minimum of 3 to a maximum of 12 months after receipt of a complete application. The maximum timeline indicates a major permit with extensive public comment and review periods.

Regulatory Issues:

Air Quality regulations prohibit the use of a facility with an energy input capacity under 3 million Btu/h for the combustion of landfill gas, because of the variability in amount and characteristics of flow and concerns about proper management in the past of small facilities. The turbine now being developed by ETTI is well above this threshold, but the company foresees developing within the next few years a smaller turbine that will operate below the 3 million Btu/h level. As the company develops this size turbine, these underlying environmental and public health concerns will need to be considered, with adequate demonstration that a smaller turbine can address them. DEP would participate in the discussions needed to address these concerns, and if warranted, work toward the necessary regulatory changes.

In the process of permitting one of its turbines, ETTI has asked for clarification on requirements for enclosed vs. open flares as backups or joint combustion devices with its turbine. The costs and operational characteristics of the two are quite different, with the enclosed flare typically having lower costs but also a lower destruction rate. The enclosed flare generally has been considered the BACT technology in Massachusetts. However, open flares have also been declared BACT in certain circumstances. The BACT determination is made on a site-by-site basis during the permitting process. Many factors are considered,

including cost, operating efficiency and destruction rates, expected usage of the flare, and special site conditions.

Solid Waste Permits

Landfill permit modification.

Air Quality Permits

While landfill gas recovery projects produce energy and reduce landfill gas emissions, the engines typically used for electricity production also have the potential for creating additional NOx, a criteria pollutant regulated by DEP. If landfill gas air emissions exceed one ton per year or the engine burns more than 3 million Btu's of landfill gas per hour air permits are required. It will be important to verify the technology's performance on landfill gas, which is particularly dirty and variable. It often has a high level of nitrogen, which correlates to high levels of NOx emissions.

It appears from its application that the ETTI technology has not been put into operation anywhere. This is consistent with the company's statement in its application that it is looking to test 4 of its engines for 10,000 hours each.

Handling of Condensate

Landfills are responsible for proper treatment of landfill leachate and the condensate from energy recovery facilities. If the combined condensate/leachate is not classified as hazardous waste and meets discharge limits set by the local POTW, regulations allow the condensate from energy recovery projects to be returned to the leachate collection system and combined with it for disposed to the local sewer system. If not, it must be handled as hazardous waste. If only the condensate exceeds hazardous waste thresholds, it could be handled separately under hazardous waste regulations.

Massachusetts Environmental Policy Act (MEPA)

Rreview thresholds for an Environmental Notification Form may be triggered by a landfill energy recovery project (for example, a publicly-funded project over $1 million). MEPA should be contacted as part of a approval process.

LIST OF 25 LANDFILLS IN MASSACHUSETTS OF SUITABLE SIZETO ACCOMMODATE TCGT UNITS IDENTIFIED BY ETTI WITH PARTIAL OR COMPLETED GAS SYSTEM IN PLACE.

Amesbury	Lowell
Attleboro	Marion
Barre	Mashpee
Blackstone	New Bedford
Chicopee	Newton
Concord	Palmer
East Bridgewater (private)	Plainville
East Bridgewater (municipal)	Randolph
Fall River	Rockland
Falmouth	Scituate
Foxboro	Taunton
Gardner	Worcester
Haverhill	