FastOx® Gasification: An Integrated Solution to Zero Waste

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ABSTRACT

Sierra Energy has developed and demonstrated a technology that makes it possible to eliminate the need for waste disposal while generating new, salable resources and energy. To make this waste gasification technology globally accessible, Sierra Energy developed the FastOx® gasification system, which is capable of converting nearly any waste into a medium BTU synthesis gas (syngas), ideal for compressing, cleaning, and reformation (using off-the-shelf technologies) into alternative fuels, electricity, hydrogen. In addition, the process generates molen metals (ideal for recovery and re-processing) and inert stone (slag) suitable for use in road base, cement, and other construction-related applications. Coupled with other waste recycling, reuse, conversion, and avoidance technologies, FastOx systems can assist any organization in creating useful resources from all waste stream, thereby eliminating waste disposal.

Keywords: Gasification, Waste Diversion, Net Carbon Negative Fuel, Hazardous Waste Conversion, Distributed Renewable Energy, Molecular Recycling

1 INTRODUCTION

FastOx® gasifiers efficiently produce a synthesis gas (syngas) suitable for use in manufacturing low-carbon-intensity fuels from virtually any waste. The FastOx system generates useful resources without byproducts to be landfilled, while eliminating emissions to atmospere from the FastOx process itself. The FastOx gasifier breaks down waste at the molecular level by subjecting the waste to extreme temperatures of up to 4,000°F, and then using its proprietray process to inject high concentrations of oxygen and steam at the base of the process vessel. At this point, the oxygen reacts with the carbon in the waste to create syngas and the remaining organics are melted and recovered as saleable resources of non-leaching, inert stone and molten metals.

The FastOx system is ideal as an add-on to existing recycling and waste diversion sites, as the final phase solution for energy and product recovery from remnant and non-recyclable waste. The combined emissions elimination from 100 percent waste diversion, in addition to the production of energy with a low emissions profile, achieves a net carbon intensity below that of landfill gas.

2 SYSTEM OVERVIEW

Sierra Energy's FastOx gasifier is an advanced derivative of the centuries-old blast furnace, redesigned to convert waste into renewable energy. Sierra Energy has successfully tested its FastOx® gasification system in a complete pilot-scale, with the first full commercial-scale system set for commissioning in mid-2017 at Fort Hunter Liggett, Monterey County, CA, USA.

2.1 FastOx Gasification

FastOx gasification involves several processes including waste preparation, gasification, syngas cooling and conditioning, and end-product conversion (Fig. 1). Waste is received and sorted to remove valuable recyclables. The waste is then shredded, dried (to below 50% moisture by weight), and fed into the top of the gasifier via a conveyor and airlock charging system. The waste devolatilizes as it drops to the bottom of the gasifier. Oxygen and steam are injected at supersonic speeds at the base of the gasifier using patented nozzles. The resulting thermochemical reaction converts the waste into syngas at temperatures of up to 4,000°F.

The injection of concentrated oxygen increases process temperatures, and avoids side-reactions that emit NOx, dioxin, and furan emissions. Oxygen injection also leads to the production of hydrogen, which both speeds the conversion process and produces a higher-quality syngas. This process converts the organic components in the waste into a clean and energy-dense syngas.

Syngas exits the gasifier and flows into the polisher to reform volatile compunds into additional syngas. The stream then travels to the gas cleaning isle, where it is cleaned and conditioned to meet the chemical requirements of the end product. Excess heat is captured during this process and can be used for waste drying.

The remaining inorganic waste melts into a vitrified mixture of stone and metals that is collected and sold for reuse. The chemical reactions facilitated by the gasifier's high temperature ensures that the stone and metal are non-leaching and safe for reuse.

2.2 Syngas Production

Syngas volume production is dependent on the carbon content available in the feedstock, with higher organic content yeilding more gas, and increased production of fuels.

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The FastOx syngas is primarily composed of hydrogen (H_2) and carbon monoxide (CO). As a flexible, low cost fuel source, FastOx syngas:

- Displaces natural gas and conventional fossil fuels.
- Is overall 'carbon negative' or 'carbon neutral' due to avoidance of the emissions from transportation and waste off-gasing from decomposition.
- Converts into a variety of fuels (Table 1).

The below product yield table estimates volume and output of energy product derived from for 20 metric tonnes of select feedstock. The data is based on minimal expected syngas production and quality, and standard conversion metrics from raw syngas to each product.

	Electricity (MWhe)	Diesel (gal)	Hydrogen (kg)	Ammonia (kg)
MSW*	19.1	680	1230	6960
Medical	18.9	660	1202	6820
Tires	25.7	920	1724	9780
Biomass	24.3	830	1490	8440
ASR**	14.5	520	978	5540

Table 1: Product Yield Table. *Post-recycled. **Auto shredder Residue.

3 OPERATING PLANTS

3.1 Early Design and Testing

Sierra Energy tested four separate prototypes between 2009 and 2012 at the Renewable Energy Testing Center, an independent laboratory established and funded by the Department of Defense. The primary goal was to validate heat and mass balance models for multiple feedstocks and emission profiles. Multiple simulated waste streams were introduced to the gasifier and the syngas produced and analysed to determine composition and purity.

By the end of 2012, the following technical objectives were met[i]:

- Verification of operability with numerous waste materials, all varying in ash and moisture content.
- Validation of increased syngas quality through real-time gas analysis, demonstrating a 118% increase in the dry syngas energy density when compared with conventional air-blown operations.
- Confirmation of the non-leaching character of produced slag material, in accordance with EPA TCLP and TTLC standards, qualifying the stone material to be sold as a construction material to replace cement clinker and road-base.
- Analysis of performance metrics, indicating a 116% increase in operational productivity and a 185% increase in oxidant productivity.

Based on these results, the US Army, California Energy Commission, and PG&E extended funding for a full commercial system. This series of funds are aimed at meeting specific zero waste and net-zero carbon goals of the funding agencies, and for development of a proven community scale system for converting on site waste to energy products.

3.2 First Commercial System

Based on the design from a complete pilot-scale demonstration, Sierra Energy's full-scale commercial system is being developed for the US Army and California Energy Commission at Fort Hunter Liggett in Monterey County, CA. It is designed to demonstrate conversion of up

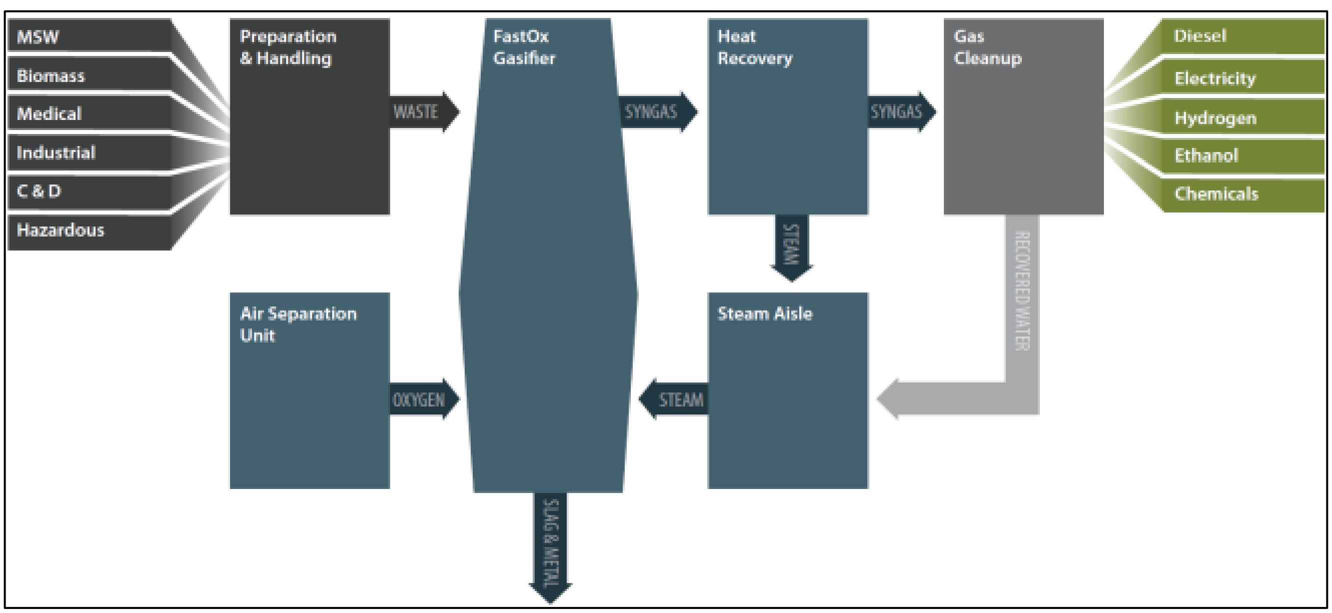

Figure 1: Schematic Diagram of FastOx Gasification

to 15 metric tonnes of biomass and post-recycled waste into renewable energy products daily, including up to 300 kW of electricity (DOD-funded study), up to 42 gallons of FT liquids (current CEC-funded study), and up to 50 kg of hydrogen per day (DOD Defense Logistics Agency SBIR, Phase II funding, pending). This system will further prove the value and applicability of FastOx as a community scale waste and power generation solution.

3.3 Advantages

Flexibility is a key advantage of FastOx gasification. The gasifier can convert multiple streams, even at high moisture levels (up to 50% by volume) with minimal pre-preprocessing. Feedstock mixtures can safely include municipal solid waste, biomass, construction and demolition waste, medical waste, hazardous waste, industrial waste, and auto shredder residue. The system is designed to produce electricity, or other options such as diesel, hydrogen, ammonia, or other valuable chemicals.

FastOx gasification is designed for continuous operation with few moving parts. This translates into low maintenance costs, efficient processing and high up-time. Each section is fabricated for easy transport and can be hauled on truck or in a container. The required space and resources to run a system are also minimal. A complete system has a maximum height of only 35 feet and requires less than a quarter acre of land.

3.4 Under Development

Sierra Energy is in the planning stage with community leaders to establish a Zero Waste Innovation Park in Yolo County, CA, USA. This $250 Million project would create a next generation waste R&D facility that will demonstrate cooperative technologies to the FastOx system, with the intent on actively demonstrating a full-suite of waste processing technologies to achieve true zero waste. This site will include larger scale FastOx gasification systems (100 and 250 tonnes per day) to process MSW, biomass, food scraps, and waste water effluent into biofuels, electricity, and hydrogen.

3.5 Future Projects

In addition to exploration of additonal projects with the US military for processing hazardous materials in the field and US-based projects for communities and landfill operators, Sierra Energy has also begun developmnet of several international opportunities.

Of specific note, Sierra Energy was awarded the inaugural Roddenberry Foundation Innovation Award for co-developing a project in Mexico City to address waste disposal in economically distressed neighborhoods.

Sierra Energy has also been actively working with island nations to develop FastOx systems that can assist with waste processing options due to the limited options for disposal and extreme costs for transportation and liability.

Each of these efforts are focused on improvement in communities without waste disposal services or reliable energy sources, with the added benefit of improved in air quality from displacement of trash-burning practices.

4 ECONOMICS

4.1 System Economics

FastOx gasification generates additional profits for companies in the waste or energy industries. Systems can recover cost within the first 2 years of operation, while reducing the burden of waste and associated pollution on the economy. The system is, most importantly, profitable without subsidies. There are several configurations which yield high recovery. One such model is destruction of hazardous waste. Below is the breakdown of profit for two scenarios at a scale of 20 metric tonnes per day.

Income Breakdown	**Hazmat to Electricity**	**MSW to Hydrogen**
Tipping Fees	$3,653,000	$447,000
Output Sales	$511,000	$2,583,000
Stone Sales	$107,000	$56,000
Carbon Credits	$20,000	$241,000
Payback (years)	**1.92**	**2.75**
Annual Income	$3,624,000	$2,532,000
Energy Output	558 kWh	1414 kgH2/day

Table 1: Typical income and rate of return, based on processing 20 tonnes per day of hazardous material.

The importance of reviewing the cost of infrastructure and the economics is that processing of all waste into useful products can be accomplished technologically, but also at a profit. The ability for profit without reliance on subsidies provides fiscal stability, with siginifacnt improvemant on rate of return over other technologies and greater acceptance to the financial markets.

5 MARKET APPLICATION

Waste gasification using FastOx technology can fill the gap in older or incomplete waste remediation programs. FastOx systems can cut costs in landfill management and extend the life of existing operations.

5.1 Current Energy Recovery and Waste Conversion Technologies

Various thermo-chemical technologies have been developed to recover energy from waste, include incineration, pyrolysis, low temperature gasification, and plasma gasification.

Incinerators operate at relatively low temperatures in an oxygen-rich environment that only allows feedstock to burn. Burning produces ash, both as a solid that collects at the bottom of the incinerator and as particulates in the flue gas. This ash must be collected and disposed of in hazardous waste landfills as it contains leachable heavy metals. Burning also produces smoke, which contains dioxins, furans, and nitrogen oxides, among other harmful byproducts. Pyrolysis also produces toxic ash needing further disposal, in addition to oils and tars. Pyrolysis is limited to organic feedstocks, and performs poorly on mixed wastes.

Low temperature gasifiers have feedstock limitations and create toxic ash, and therefore face the same issues as pyrolysis. Plasma arc gasifiers, while they operate at ultra-high temperatures, are expensive to build and operate and energy intensive, making them unfeasible for most waste types.

FastOx gasification differentiates from other gasifiers in its simple design and pure oxygen injection. The patented injection of pure oxygen and steam allows FastOx gasifiers to reach high temperatures necessary to handle virtually any waste stream, without emissions. Nozzles specific to the system are designed to withstand the extreme temperature and pressure of injecting oxygen and steam in a concentrated stream. There is no toxic ash to landfill, or emissions from the gasifier vessel. The system is productive due to high system up-time and has a comparatively low maintenance burden.

5.2 Additional Applications

Besides processing of hazardous materials, tires, and other hard to handle waste, Sierra Energy is exploring applicablity of the FastOx technology to areas like:

- Medical waste elimination, including in resiliency applications for pandemic events.
- Communities that have significant quantities of biomass or agricultural waste.
- Waste and hazardous materials elimination in active conlfict scenarios, eliminating logistics and liability.

5.3 Profitability

FastOx gasification also has major implications in currently small markets that are primed to grow. For example, the hydrogen market in the US contributed only approximately $2.2 billion to the economy in 2014 but it grew from $1.3 billion in 2013[ii]. As mass production of hydrogen-fueled vehicles ramps up to accommodate rising transportation costs, this market share is expected to continue to grow at similar rates. Further, a 2008 NRC report estimated that approximately 5 years after commercialization of hydrogen fueled vehicles, 2 million vehicles could be on the road.[iii]

6 CONCLUSION

The global waste management industry handles approximately 1.3 billion tonnes of waste per year. That number is expected to grow to approximately 2.2 billion tonnes per year by 2025.[iv] The market to handle this waste encompassed an estimated $863.8 billion in 2014 and is forecasted to grow to $1,442.0 billion by 2019 with a compound annual growth rate during that period of 8.9%.[v]

Given the diminishing returns on recycling technology implementation, it is not economically or physically feasible to handle all landfilled waste through current recycling and composting programs alone. Gasification is the next step for the waste management industry. It can extend the life of a landfill, eliminate hazardous materials, and operate at a profit in areas with greatest supply of waste and demand for energy product.

In addition, compliance and liability costs are crippling this low margin industry and have led to widespread closures and consolidation in the waste industry. Each landfill must economically plan for future closure. In the US, the EPA estimates that preparing compliant landfill infrastructure requires approximately $1 million per acre with additional permitting fees averaging $1.2 million. The estimated testing, monitoring, and control costs sum to approximately $24,000,000 in control costs over the lifetime of an average landfill and $66,000 in testing and monitoring costs. The EPA further estimates that the ratio of compliance costs to revenue will be approximately 12% with new policies coming online.[vi]

Waste conversion promotes energy independence, avoidance of fossil fuel use, and reduces greenhouse gas emissions, while diverting trash from landfills.

[i] Technikon Report #1604-111, “Sierra Energy Technology Test Technical Report” (2012).

[ii] http://energy.gov/sites/prod/files/2015/10/f27/fcto_2014_market_report.pdf

[iii] http://www.nap.edu/catalog/12222/transitions-to-alternative-transportation-technologies-a-focus-on-hydrogen#toc

[iv] http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/Chap3.pdf

[v] http://www.marketsandmarkets.com/PressReleases/industrial-waste-management.asp

[vi] https://www3.epa.gov/ttnecas1/regdata/EIAs/LandfillsNSPSProposalEIA.pdf