ZEROS Frequently Asked Questions

DRAFT

System Characteristics

What is ZEROS?
ZEROS (Zero-emission Energy Recycling Oxidation System) is an "oxy-fuel" technology developed in the late 1980s and early 1990s to clean up oil field waste without producing atmospheric emissions or water pollution. Using pure oxygen rather than air, ZEROS creates the high temperatures needed to completely oxidize hazardous organic wastes, producing electricity, liquid motor fuels, oxygen, pure carbon dioxide, distilled water and ash.

ZEROS is currently being commercialized to produce electrical energy, liquid fuels, pure carbon dioxide and distilled water with a complete sequestration or destruction of carbon dioxide, nitrous oxide, sulfur, mercury, hydrocarbon particulates and other contaminants. A variety of organic materials, including coal, lignite, municipal solid waste (MSW), wood materials and agricultural biomass and manure, can be used to power the system.

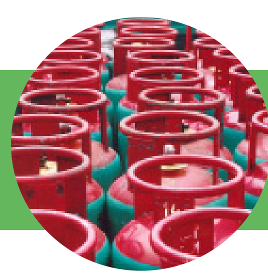
What are the component technologies of ZEROS?
The major components of ZEROS were first combined into an operational unit in 1992 to clean up a 200,000-barrel oil spill in California. Throughout the 1990s, the system was used as a proprietary technology to dispose of a variety of organic and hazardous wastes in cleanup projects throughout the United States.

The major components of the ZEROS technology are fully operational in many locations around the world.

- Rotary kiln (RK)s have been operating since the early 1900s and are currently operating in Europe, the United States and many other countries. Hundreds of RKs are operating as incinerators and in the cement manufacturing industry. While those units are not configured exactly like the proposed ZEROS units, many of those facilities are extremely similar in operational characteristics.
- The steam turbine technology is 1950s era in size, working pressures and temperatures.
- The heat recovery steam generator (HRSG) is essentially the same as those used with combustion turbines in combined-cycle configuration.
- CO_2 recovery technology is consistent with CO_2 production and capture units in service for the last 40 years.
- Air separation unit (ASU)s, steam turbines and generators, baghouses, precipitators and acid scrubbers are in widespread use by many industries worldwide.

Are there any currently operational ZEROS units?
No ZEROS units are currently in service; however a number are in the early stages of project development in Mexico, Pennsylvania, Italy and Texas. Several locations are under study in Texas, Connecticut, Florida and the Southwestern United States.

There are significant numbers of "open cycle" RKs worldwide—with no effort to capture the CO_2 or other stack gases made—ranging from as small as 2.2 MW combined heat and power to 45 MW in size. A number of waste remediation and power generation systems are used worldwide. While none combine all the characteristics of ZEROS, some are worth mentioning. The European units are generally all air-blown versus oxygen-blown units. They were built during the 1980s when CO_2 capture was not an issue. A number of Japanese oxygen-blown units are currently in service.



While not a ZEROS unit, the Great Plains Synfuels plant in North Dakota is an excellent example of a gasification facility using CO_2 capture for enhanced oil recovery. There are also many other examples of CO_2 capture from coal-fired boilers, refineries and other processes, some in operation for more than 20 years.

Why aren't these power plants being built in large numbers in the United States?

- Most utilities are interested in 250–600 MW size units for capacity additions.
- Little impetus to build closed-cycle units existed prior to emerging clean air regulations and the Kyoto Accord.
- Most power plants take seven to 10 years to permit and build. The effort to convert ZEROS from a waste disposal to an energy production technology began less than five years ago. Design and financing of several units are well advanced, and the first commercial units are expected to be operational by 2010–2011.

What is the scalability of the technology?

Existing RKs in the cement industry are capable of handling in excess of 3,000 tons per day of fuel source materials. That level of fuel volume capability would equate to a 150–500 MW single unit thermal capability, depending on fuel sources. Smaller plants (50 MW or less) are being designed for fuel loads of 1,000 tons per day or less. Even smaller plants (20 MW) may be feasible in some circumstances.

What are the major issues with facility-size scaling?

- Adequate volumes of selected fuels may not be available, depending on the source and type of fuel.
- Each location has its own specific site conditions, market, infrastructure and transmission access capabilities. Each project will need to be evaluated for best-fit criteria in facility-sizing. This decision cannot be based on an electrical requirement alone.
- Site development, engineering design costs and system interconnect costs are only marginally affected by scaling.

What are the operational challenges of ZEROS?

Only the handling of alternative fuels and multiple byproducts poses a new paradigm for an operating company. None of the energy delivery technology is new or high tech. The major components are off-the-shelf/commercially available equipment. Any operator proficient in operating an existing generating unit should be able to quickly adapt to the differences in equipment configuration and operating procedures.

What wastes have been previously remediated or test burned?

In the 1990s, commercial ZEROS units were used to dispose of car tires, explosive materials, raw oil, oil spills, solvent-contaminated soils, benzene, toluene, ethyl-benzene, xylenes, fiberglass-reinforced plastics, asbestos, organic cyanides, halogenated and non-halogenated volatiles and semi-volatiles, PCB-contaminated soils, polyethylene, polystyrene, polypropylene, mustard gas and chlorinated volatile compounds.

What are the general system electrical power requirements?

Depending on fuel source, the oxygen requirements for a 50–125 MW facility would require approximately 6.5–19 MW of auxiliary load to support a cryogenic, electrically driven ASU. Other ASU configurations may require less auxiliary power. The plant will consume approximately 2.5–5 MW of auxiliary equipment loads. Fuel handling could require an additional 1–2 MW, depending on the fuel source(s) chosen.

How is the plant cooled?

Steam turbine exhaust is water- or air-cooled depending on cooling tower design and river or lake availability.

- Generator has an air-to-glycol cooling system.

- Auxiliary steam plant equipment uses a service water cooling system.
- RK uses water jacket cooling-to-waste heat recovery system.

Why is a dry cooling tower proposed instead of a wet cooling tower?
We will use a dry cooling tower because a dry cooling tower condenses the steam from the turbine exhausts in piping in the cooling tower. The dry cooling tower is a closed system like a car radiator. There is no water/mist release from this type of cooling tower and there is no special chemical treatment required. The condensed steam is returned to the plant condensate water system for reuse as boiler water to make steam. There is no cooling tower blowdown to a disposal pond.

What are the electrical characteristics of the unit?
A nominal 50 MW generator typically has a 12.8 kV output voltage to the transformer and a 5,000–6,000 amp capability. Power factor on the generator should be .85.

At what temperature does the ZEROS process operate, and how is the process temperature controlled?
The ZEROS operating temperature is approximately 1450 F. The hot gases' temperature out of the secondary chamber is controlled by excess oxygen to about 2100–2300 F. Output of the HRSG/OTSG (once through steam generator) will be nominally 900–1000 F and 1000–1,800 psig for a given unit size. The furnace-side process operates like a negative pressure boiler at a slightly subatmospheric pressure. Total mass flow is less than for an air-fired process (about 75%–80% less) based on the ratio of the volume of air to oxygen.

What is the system operating pressure?
The ZEROS operation is slightly subatmospheric. The steam system would be a function of design criteria to support the design steam turbine operation (900–1,800 psig).

How much oxygen does the process use?
Oxygen requirements are highly fuel source dependent, but could be up to approximately double the requirements of other gasification processes. The actual range will vary from approximately 1–2 pounds of oxygen for every (organic) pound of fuel. Ash and moisture content must be subtracted from the total volume of fuel to calculate the approximate oxygen requirements.

How much water is consumed by the process?
The basic system requires no external water sources. The chemical process involved is a net generator of water from oxygen and the various fuel sources. The internal volumes of water generated provide for the condensate makeup requirements of the heat recovery steam generator and any other internal system uses. A dry cooling tower (fin-fan type) can be used for turbine exhaust steam condensation. This cooling tower eliminates any water losses due to evaporation and cooling tower drift. The dry cooling tower also eliminates chlorine and other chemical usage that could evaporate with the cooling tower drift and pose downwind equipment corrosion problems.

Approximately 20 tons of flash distilled water can be produced per ton of (organic) fuel consumed. If production of distilled water is desired, then an external raw water source will be necessary for the volumes of flash distilled water desired.

How is the energy converted to steam in the secondary cycle?
The mass flow (CO_2 and H_2O, as steam) from the secondary chamber is sent directly to an HRSG for heat transfer to the secondary cycle (main steam cycle) for use in a steam turbine. The HRSG does not have a stack, which

minimizes "boiler" heat losses. Boiler manufacturers have confirmed their ability to deliver an OTSG or a more traditional HRSG (drum type) with the desired output ratings. Exiting the steam generator at less than 400 F, the gases are directed to a baghouse for ash particulate removal, a wet scrubber for acid gas removal, and ultimately to a precipitator to remove any remaining ionized particles. Trace gases and particulates are recirculated for ultimate removal by capture in the volcanic glass/slag.

How much energy can a ZEROS unit oxidizing approximately 400–800 tons of (organic) fuel per day deliver?
Depending on the fuel source (Btu content) and the moisture content of the fuel, the same ZEROS unit with an appropriately sized OTSG/HRSG will develop between 50 and 125 MW of energy in the form of steam turbine output (gross).

What is the possibility of the plant not being a "zero emissions" facility, such as if any of the individual unit operations doesn't work as planned?
A very small probability exists that the plant will not be a "zero emissions" facility. Zero emissions really means that there are no pollutant emissions. There will be heat given off by the equipment, water, slag, ash and salts and the CO_2 will be captured.

On the nonpollutant side, nitrogen gas may be released from the various processes where the nitrogen will be in use: inerting gas, pneumatic systems, tire processing and chillers.

On the pollutant side, if the CO_2 recovery unit suffers an outage, some small amount of CO_2 may be released prior to unit shutdown. The ZEROS unit will be operated in a zero-release mode, with a system shutdown in the procedures for any inadvertent release or emissions-related subcomponent failure. The ZEROS system has a vacuum bottle to capture any gases in the system during a shutdown event. All the other gases are removed by a packed bed wet scrubber or precipitator or are recirculated back to the RK for concentration and capture in the slag.

How is emissions control and monitoring achieved?
The Texas Commission for Environmental Quality (TCEQ) recommended that area continuous emission monitors be installed to detect any fugitive emissions since no stack exists to monitor for traditional atmospheric emissions. The Italian Environmental Protection Agency has also concurred with the area emissions monitoring recommendations made by Triencon Services Group for the unit that will be constructed near Eboli, Italy.

How has the technology been received by environmental groups?
TCEQ is very interested in the development of a zero atmospheric emissions facility. The air permitting, municipal solid waste and storm water management divisions have been highly receptive and extremely proactive in assistance. Briefings have been conducted with the U.S. Environmental Protection Agency, Department of Energy, Department of Agriculture, Department of Defense and Congress. Responses have been uniformly positive.

Why are there no atmospheric emissions from the plant?
All possible atmospheric pollutants are captured in some part of the plant's equipment.

The gasification-oxidation process is a two stage process that, using limited oxygen and high temperature, gasifies the fuel source to produce primarily carbon monoxide and hydrogen. After exiting the gasifier, the gases pass through a dual-stage high-efficiency cyclone separator to remove any fine particulates (fly ash). Additional oxygen is introduced into the secondary combustion chamber to produce CO_2 and water (steam) from the primary combustion chamber gases. Any trace gases (impurities) produced from the fuel constituents are conveyed through the secondary combustion chamber to the HRSG, then on to a baghouse to remove larger particulates, and ultimately are removed in either a packed bed wet scrubber as an acid-gas salt or an electrostatic precipitator as fine particulates. All ash and particulates are ultimately recirculated back to the RK where they combine with a lime additive to be fused into a glassy slag. There will be trace gas amounts of SOx, NO, CL or any heavy metals removed by a combination of processes (primarily as constituents of the slag or as an acid-gas salt).

The CO_2 produced is removed by the cryogenic process to ease separation from water and any other minute amounts of remaining contaminants. The remaining constituents of the gas entering the cryogenic removal process will consist of 5% oxygen, 1% nitrogen, 70–75% CO_2 and 20–25% water. The CO_2 produced is at least 99.995% pure and is sold as a byproduct, ideally for use in enhanced oil recovery (EOR).

The water vapor is condensed during the CO_2 recovery as distilled water. This internally produced water is then further purified by H–OH mixed bed demineralization or other water purification technology to produce demineralized water for condensate makeup and for potential ceramic membrane separation into oxygen and hydrogen. If used for hydrogen separation, the oxygen will be consumed internally and the hydrogen will be sold as a byproduct. The oxygen produced can reduce the need for ASU production of oxygen by up to approximately 30%.

What happens if there is a system leak/equipment failure or upset?
The system is designed to automatically shut down if any subsystem fails. The control system uses a combination of fuel, oxygen, temperature and recirculated gas flow loops to provide for system control. Monitoring points for temperature, oxygen content and air in-leakage provide safety measurements and automated shutdowns.

The RK and secondary combustion chamber operate in an auto-thermal mode as long as there is oxygen and a sufficient fuel source, and the operating temperature is maintained. Elimination of the oxygen-feed source will immediately shut down the system. The RK, HRSG and baghouse operate at a slightly sub-atmospheric pressure, so any leakage will be into the system. Air in-leakage is monitored and used as a control set point to prevent the internal formation of NOx. The wet scrubber and precipitator also operate at very low pressures (inches of water) above atmospheric conditions and the possibility of leakage is almost non-existent.

Fuels

What are the fuel requirements?
The ZEROS technology is capable of handling solid, liquid or gaseous fuel sources singularly or interchangeably as a mixed blend. The fuel quality is limited to approximately 30–35% moisture by weight. While this is not a maximum moisture content limitation, energy loses in the RK are directly proportional to the moisture content of the fuel. Limiting the fuel moisture content to more manageable levels helps to ensure full unit electrical output.

The following is a partial list of potential fuel sources:

- Coal/lignite/pet coke
- Wood pulp/waste tree liquor
- Sewer sludge (when blended with other fuel sources)
- Animal wastes
- Car tires
- MSW, plastics
- Waste oils, tar, oil, emulsions, tank bottoms, flared gases (H_2S, etc.)
- Cooking oils/grease

- Roofing shingles
- Construction/demolition material
- Bio-hazardous waste

These fuels may be burned interchangeably, but should be blended to prevent significant fluctuations in moisture contents.

How is the energy released, and what is the expected heat rate of the process?
The energy released from the traditional combustion of coal is approximately 8400 Btu/lb. (western coal). The oxidation of the coal produces CO and H_2 gas in the primary chamber. In the secondary combustion chamber (sometimes called an afterburner), additional oxygen is added and the CO and H_2 form CO_2 and H_2O respectively. Both of these reactions are exothermic and release (by molar ratio) the heat of oxidation for the formation of CO_2 and H_2O. The additional heat released in the secondary chamber, as a function of these heats of oxidation, is calculated to theoretically approach about 7496 Btu/lb., depending on fuel, and does not include any process losses (conversion efficiency, piping losses, etc). The total energy delivered per pound of coal is enhanced by thermal oxidation as compared to combustion. Preliminary calculations of heat rate projections based on energy requirements and typical component efficiencies have been undertaken allowing for CO_2 cryogenic removal and the purchase of the oxygen, the equivalent gross heat rate appears to approach 7,900 Btu/kWh. Net heat rates appear closer to 8,500–12,000 Btu/kWh depending on plant specific configuration. A typical pulverized coal plant has a net heat rate of about 10,000 Btu/kWh.

What about fuels containing high sulfur content?
High sulfur content fuel does not pose a problem for the ZEROS process. Based on the Department of Energy values, there is an energy loss of 4% for every 1% of sulfur. If high sulfur fuels consumption is planned, the fuel's sulfur content may be removed as either sulfur cake or sulfuric acid, depending on the configuration desired by the client. Sulfur cake is quite valuable to the fertilizer industry.

Trace amounts of sulfur in most fuels will form H_2S or COS in the RK and be broken down to a species of SOx in the secondary combustion chamber. These SOx compounds will form an acid gas as the temperatures in the gas stream drop to below the acid gas dew point, which occurs between the baghouse and the wet scrubber. The wet packed bed scrubber will remove these acid gases as salts.

Can car tires be used as a fuel source?
Yes, but the car tires must be processed/shredded to reduce the tire rubber to appropriate size criteria.

Isn't crumb rubber subject to spontaneous combustion?
Yes. However, once the tire rubber is separated from the steel belts, the rubber is sent immediately into a nitrogen-inerted silo for storage. A typical large silo will hold approximately 1,000 tons of chopped car tires or about a 1.5-day supply of fuel for a 50 MW unit. Alternatively, tire rubber will be consumed in parallel with the storage process. It will be prudent to construct a number of inerted fuel silos to have a 7–10 day fuel storage capability.

If dairy waste is to be used as a fuel source, how will it be handled?
The dairy waste needs to be processed to reduce the slurry to a "dry cake" with a moisture content of less than 35%. Drying dairy waste using steam heat will give off methane and hydrogen sulfide, which is corrosive. Both of these gases will have to be collected by a vapor recovery system. The vapor/liquids given off will potentially contain various organic compounds that will have to be removed from the water by some other means than distillation. Distillation alone will not remove all organic compounds.

How are fuels handled and stored at a ZEROS facility?
Fuel storage should consist of at least 10 grain-type silos approximately 24 feet in diameter and 55 feet tall. This type of storage will handle biomass, MSW or other solid fuel sources. Allowing for approximate fuel densities, 10 silos will allow for approximately seven days of fuel storage in the silos.

Fuel silos either will be of lined steel-concrete fabrication or coated-concrete fabrication, depending on final engineering design package criteria. Silos will be filled from inerted barrel shredders via an inerted auger system. Fuel handling will be by inerted, covered/sealed auger systems to prevent loose material from escaping into the plant.

Fuel unloading should be conducted in a slightly negative pressure enclosure with concrete floors and a dust suppression/washdown system to prevent odors, dust or materials from escaping onto the plant property. All fuel-related systems should be redundant, consisting of two 120% capacity lines of equipment. This allows preventive maintenance and repairs to equipment to proceed while online and minimizes unit downtime. Fuel delivery can be by truck or rail. Unloading facilities for both can be in a negative pressure enclosure with rail siding access. Final design should allow for the unloading of five to six trucks and up to four rail cars simultaneously.

If MSW is used as a fuel source, what is the danger of producing dioxins (PCDD—polychlorinated-dibenzo-dioxins), furans (PCDF—polychlorinated-dibenzo furans) or cyanides (CN compounds)?
Dioxins and furans are formed under a combination of the following conditions:

- *Temperature:* The optimum temperature for dioxin/furan formation is between 300°C–400°C. Process temperatures in the ZEROS unit will be much greater at 1450°F (~788°C) and dioxins and furans should not be formed.
- *Oxygen*: In the RK, the sub-stoichiometric conditions (low oxygen levels) limit the formation of any dioxins and furans.
- *Fly ash*: Since dioxin/furan formation is catalyzed by fly ash content (and the presence of molecular chlorine) at temperatures between 200°C and 500°C, any fly ash produced in the RK is immediately captured by cyclone separation prior to the syngas being sent to the secondary combustion chamber, removing the potential catalyst for dioxin/furan formation.
- *Residence-time*: Formation of dioxin/furan increases with increased residence times, in the presence of excess oxygen, fly ash particles and lower operating temperatures. These factors do not exist simultaneously in the ZEROS process.
- *Chlorine*: Free chlorine is limited to the presence of chlorine in the fuel sources. Average chlorine contents of most biomass, MSW and nonpetroleum-based fuels is typically quite low.

Dioxins that may be present in the fuel source are destroyed at temperatures above 2100°F. Thermal destruction of cyanides occurs at temperatures above 1800°F. The secondary combustion chamber operates at temperatures of approximately 2300°F.

To reduce the possibility that conditions in the economizer section of the HRSG could reach the point of formation of a dioxin compound, any potential dioxin particulates are captured in the HRSG by acoustic "blast" type soot blower operation. This particulate fly ash is recirculated back to the RK for concentration and capture (using the addition of lime) in the vitrified (glassy) slag, which will render them inert. The baghouse filter cake will also be handled in the same fashion to eliminate the possibility of dioxin formation.

ZEROS Products

What products can be produced?
Based on fuel source and design options, the primary products of ZEROS are:

- Electricity
- Process steam
- Carbon dioxide
- Transportation grade liquid fuels (optional)
- Distilled water
- Fly ash
- Volcanic glass (glassy slag)

Secondary products, depending on fuel source, could include:

- Demineralized water
- Sulfur cake/sulfuric acid
- Hydrochloric acid
- Hydrogen
- Oxygen
- Nitrogen
- Argon
- Ammonium nitrate
- Ammonium bicarbonate

What process gases are produced?
CO_2 is the principal process gas generated. Volumes of CO_2 generated will average between one to two times the oxygen volumes consumed by the oxidation process. Other gases are recirculated within the ZEROS process for ultimate removal via combination with other byproduct outputs by adding limited amounts of lime to help bind the trace elements into the solid products stream. Nitrogen will be produced by the ASU during the process of producing oxygen. Argon can also be produced. Both of these gases will be sold as byproducts where markets permit.

Isn't the CO_2 recovery process by cryogenic removal extremely expensive?
CO_2 capture and removal does add capital costs to the plant. It can be done either by cryogenic process or by other methods including ceramic or metallic membrane separation or PSA process, depending on the sales market purity requirements. The removal cost depends on the technology chosen. The cryogenic removal process will provide food/beverage/medical quality CO_2, (99.995% pure), whereas for enhanced oil recovery, a cryogenic CO_2 removal process may not necessarily be required. CO_2 removal can also be accomplished using the significant quantities of waste heat available from the rest of the processes. These processes need not necessarily be electrically driven. Significant quantities of steam are available for compression.

What solid byproducts are produced?
Residuals are all treated as byproducts with potential saleable values. The hazardous solids (mercury, selenium, other heavy metals) are captured in the slag (volcanic glass) also known as "frit." This crystalline structure is inert and non-leaching. A toxicity characteristic leaching procedure (TCLP) test will document the non-leachability of the slag. The slag, when tested in this manner, has been deemed non-hazardous by the EPA. The slag is sold as road-base material, concrete aggregate or sandblasting grit. Any fly ash produced will have no carbon content and is usable as a replacement for sand in concrete mix.

How is Freon destroyed in the ZEROS process?
If a Freon compound is encountered in the fuel, the secondary combustion chamber operating temperature will destroy the Freon. The fluorine and chlorine contained in the Freon form acid gases that are removed in the wet scrubber system.

ZEROS-FT™ Bio-refinery

What is the ZEROS-FT™ Bio-refinery?
The ZEROS-Fischer-Tropsch™ (FT) Bio-refinery (ZEROS-FT™) is the adaptation of the ZEROS Remediation or ZEROS Power System to convert carbon-based organic matter to synthetic liquid fuels equal to any fuels produced from oil or hydrocarbon distillation. The Germans developed this process in the late 1920s to support their war effort. The South Africans used it in a joint venture with Chevron during the embargo years and continue to use it.

What is new and unique about ZEROS-FT™ that makes it competitive?
ZEROS-FT™ has the unique ability to make producer gas without the contamination of oxides of nitrogen, a major problem with other processes. ZEROS-FT™ has no smokestacks or other pollution-venting stacks. Without internal nitrogen, the system produces enough energy from the converted fuel stock to allow the plant to operate without having to use additional outside energy to produce the fuel. The high efficiency means lower operating costs and the feedstock diversity means that several feedstocks can be used to make motor fuels. With no emissions, the environmental impact statement need not be opened for public comment and the system can be placed in a non-attainment zone without regulatory problems.

What type of fuels can be produced using the ZEROS-FT™ as a conversion technology?
Any fuels produced by petroleum refining can be produced with ZEROS-FT™ without using crude oil as the feedstock.

- Diesel
- Gasoline
- Kerosene
- Naphtha
- Home heating oil
- Jet fuels (JP4, JP8 etc.)

Are the ZEROS-FT™ finished fuels ready for consumption or do they need further refining and processing as do fossil fuels?
The ZEROS-FT™-derived fuels are American Petroleum Institute-certified quality fuels rated by the U.S. Department of Energy as ready for consumption. The fuels exceed the U.S. Department of Transportation standards for fuels and fuel emissions and pollutants. No additional steps are necessary to market the fuels after they leave the ZEROS-FT™ system.

Is there any sulfur in ZEROS-FT™ fuels?
No sulfur is present in the biomass feedstock that feeds the ZEROS-FT™ process; therefore, no sulfur enters the final fuel product. Crude oil and fossil fuels, on the other hand, typically have some sulfur in their chemical structure, which ends up in the final product from crude distillation.

What makes ZEROS-FT™ work?

Up to 70% of the synthesis gas (also called producer gas) produced in the RK (composed primarily of hydrogen, carbon monoxide and methane) is routed through a steam reformer and catalyst to make hydrogen and carbon, which is then run through a catalytic cracking tower to produce hydrocarbon fuels. The process gives off no emissions and produces waste heat that can be used to distill water or produce electricity.

Is the ZEROS-FT™ suitable for rural areas?

The ZEROS-FT™ system is particularly suited for rural operations. The system can use the waste and agricultural biomass in rural areas to produce fuels and distilled water. With growing urban areas that are not friendly to energy production, rural areas offer a unique opportunity and abundant feedstock sources for the ZEROS-FT™ system. These feedstocks include dairy and feedlot waste, scrap tires and agricultural waste.

How does ZEROS-FT™ compare to the ethanol production process?

Ethanol is an alcohol-based compound that is corrosive and cannot be transported over long distances because of its instability. The ethanol process converts sugar in the plant matter into alcohol. Scientists have not yet perfected and commercialized techniques to convert cellulose and lignin into alcohol, which results in major waste from ethanol production. Also, ethanol requires almost as much energy to produce as it gives as a motor fuel. ZEROS-FT™ synthetic fuels, on the other hand, have none of these problems. The entire plant matter is converted to a syngas that is then processed through the system and recovered as sulfur-free motor fuels, such as diesel, gasoline, kerosene, naphtha, jet fuels and home heating oil.

It is said that ethanol consumes more energy to produce than it makes available for motor fuel. Is this the case with the ZEROS-FT™ process?

The ZEROS-FT™ system converts more raw feedstock to fuel than the ethanol process does and each pound of fuel produced by the ZEROS-FT™ system has substantially more energy per pound than ethanol. The ZEROS-FT™ system will give approximately four times as many miles per pound of feedstock as the ethanol process does. Additionally, the ZEROS-FT™ process can take the waste after the food has been consumed and still make the fuel. This means corn can be grown and fed to cattle and their manure converted to diesel.

Are there any emissions from the ZEROS-FT™ process like there is in refining crude oil?

The ZEROS-FT™ system is a completely closed-cycle system that is 100% emissions free. All volatile organic compounds and other gasses are captured by and recycled through the system and produced as market products for sale. This fact means the system can be permitted without opening its environmental impact statement to public comment.

Does the ZEROS-FT™ process pollute the surrounding watershed?

The ZEROS-FT™ process has no air or water emissions. All water either produced or used by the system is purified by flash distillation from waste heat from the process and the purified water is sold into local markets.

Will the fuels from the ZEROS-FT™ Bio-refinery be competitively priced?

The fuels produced by the ZEROS-FT™ system will be very competitive with fossil fuel-based fuels. In most situations, the system will be paid a tipping fee to consume waste as opposed to a refinery having to buy crude oil to refine. The capture of all producer gasses from the oxidation to the waste biomass makes an economical fuel when converted through a steam reformer and catalytic column. Overall the "rack price" of the diesel out of the ZEROS-FT™ is about $1.25 per gallon compared to the $2.25 per gallon at any crude oil refinery today.

How much liquid fuel can be made per year for a ZEROS-FT™ system?

The ZEROS-FT™ system produces fuel at an approximate equivalent of the plant's capacity in MW. For every MW of capacity, the system will produce one million gallons of diesel per year. In other words, if a power plant was a 50 MW power plant that same plant could produce 50 million gallons of diesel if fuel was made instead. A 300 MW plant consuming 3,850 tons of raw feedstock per day can produce 300 million gallons of diesel per year. This is a production capacity equal to most midsize oil refineries.

Are there any advantages of ZEROS-FT™ over standard crude oil refining today?

With ZEROS-FT™, you never hit a dry hole! You never have to lease land or maintain nonproducing properties to have the right to gamble your money on hitting a pay zone.

- ZEROS-FT™ uses no new technology but applies proven existing technologies.
- The process is not dependant on wildly fluctuating crude or natural gas supplies and world market forces. ZEROS-FT™ takes advantage of what the world's major oil companies learned over two decades ago: the profit is in the downstream products, not in owning the crude oil reserves. That is why most major oil and refining companies sold their oil reserves to independent producers in favor of the higher profits from the downstream markets such as the final fuels.
- Since the market price of fuel includes a modifier for the current cost of crude oil, the product's price is high with a smaller profit margin. With the ZEROS-FT™ system, since most raw feedstock is waste from someone else's operation, the feedstock normally comes with a tipping fee (someone is paying you to take the waste). All the byproducts from the process (along with the fuel) are sold in the commodities markets for a profit. These products include nitrogen for oil well completion, argon for welding, carbon dioxide as a liquid for oil well completion or refrigeration and distilled water.
- ZEROS-FT™ can be configured to produce electricity as well as liquid fuels and can use a diversity of feedstock to produce its energy.

Performance and Costs

What is a reasonable/economical MW size range?

In the United States, based on comparably low purchase prices for electricity, a unit/facility of less than 20–25 MW generally borders on a non-economically viable size, due to relatively high capital costs plus relatively high (calculated) maintenance costs. Profitability requires some reasonable economies of scale and favorable byproduct market opportunities. Modeling efforts indicate that a 50 MW unit would be the preferred minimum desirable size in the United States for waste to energy packages with any MW multiplier of 2, 3, 4 etc. based on fuel availability. For coal or petroleum coke, 200–300 MW units would be a good planning size with any multiple of 2, 3 or 4 units at a facility. From a byproducts handling perspective, 600 MW would be a significant facility with regards to moving the projected byproduct volumes.

What are some of the factors affecting plant profitability?

- Location—The answer to the previous question is based on a Southern U.S. location and was made for the benefit of potential U.S. investors.
- Maintenance costs—depend to some degree on the fuel source(s)
- Fuel tipping fees—range from $0–$100/ton
- Price of electricity—range from $45–$100/MWh
- Markets, market prices and market volumes for byproducts:
  – CO_2 for enhanced oil recovery is worth $20–$25/ton.
  – CO_2 for food, beverage, dry ice is worth $60–$100/ton or more.

– Nitrogen (liquid) for cryogenic use is worth $40–$70/ton.
– Hydrogen for fuel cells, refinery desulphurization brings approximately $2,500–$3,200/ton of hydrogen.
– Argon for industrial processes, electronic chip manufacturing is worth approximately $400/ton.
– Distilled water is worth $5/thousand gallons or $0.40/gallons depending on bulk or bottled.

- Renewable energy credits—varies by state on whether MSW is considered renewable or not
- Land costs—purchase or lease. The statement prior assumes a lease arrangement for land.
- Tax structure—assumes 35% (U.S.) rate

Other factors include fuel sources, infrastructure (roads and railroad access), labor rates and total tax loading. Each proposed project must be evaluated to determine the financial "Go/No-Go" criteria before proceeding.

How can a single ZEROS unit configuration be rated at a range spanning 55 to 100 MW (gross) of electrical output?

- ZEROS energy output is based primarily on a combination of fuel mass and fuel Btu content.
- Oxidation energy gained from the oxidation of CO and H_2 in the secondary combustion chamber is not linear with fuel source Btu content.
- Fuel source moisture content plays a significant role in process energy delivery.
- Even though the RK may be the same size for different fuels, the steam generator and steam turbine have to be sized based on the expected/anticipated fuel source(s), related Btu contents and energy delivery capabilities.

Auxiliary load requirements are not linear with higher energy fuels and larger facility sizes. This is especially true when considering an ASU as the process oxygen source. As an example, the projected oxygen requirements for a 165 MW pet coke plant are approximately two times the oxygen requirements of a 55 MW municipal solid waste-fueled plant despite being three times larger in generating capability.

How much does oxygen cost?
We have received quotes from Air Products, Praxair, BOC and Air Liquide for oxygen at prices ranging from $15–$25/ton (location dependent). Process oxygen purity minimum requirements are 87–90%. This lower purity standard may not require an ASU cryogenic unit for production and does lower the potential cost of the oxygen. Oxygen delivery costs at specific locations may lead to the decision to install an ASU for onsite oxygen production.

What fire-fighting capabilities are needed at a ZEROS facility?
The plant will have an internal fire main and firewater supply with installed fire pumps. Fuel handling equipment will have nitrogen inerting systems, vapor recovery, fire detection and fire deluge systems. In selected areas of the plant, PKP (dry chemical) and CO_2 fire extinguishers will be available for small fires.

What are the general storage requirements?
Depending on the production options chosen:

- CO_2 storage will be in large insulated steel tanks in liquid form and will provide approximately seven to 10 days of storage (10,000–15,000 tons).
- Hydrogen storage will be in large cylindrical tanks in gaseous form and will provide approximately seven to 10 days of storage (600–800 tons).
- Nitrogen storage will be in large steel tanks in gaseous form and will provide approximately seven to 10 days of storage (10,000–15,000 tons).
- Oxygen storage will be in large insulated steel tanks in gaseous or liquid form and will provide approximately seven days of operating supply (10,000–15,000 tons).

- Storm water/rain water storage will be in a large steel 240,000 barrel tanks for use as firefighting water and for watering trees and lawns.
- Demineralized water produced from the distilled water resulting from the biomass or MSW consumption will be stored in lined steel 250,000-gallon tanks. This water is used to make hydrogen and oxygen, and for boiler water makeup.
- Inert material, such as slag and sand/ash will be stored in covered metal bins for loading onto trucks or railcars and will have the capacity of approximately seven days storage.

All volumes above are approximate and are a function of the chemical characteristics of the fuel supply.

What is the projected overhaul inspection frequency for major components?

- RK—annual inspection
- HRSG—annual inspection
- Turbine valves—3–4 years
- Steam turbine generator—6–8 years
- ASU—annual inspection
- Balance of plant—annual inspection

We plan to monitor all components' performance on a real-time basis using OSISoft-PI; including equipment and systems diagnostics and performance measurement to support both predictive and planned maintenance activities. The base analysis provides for an annual assumed output factor of 85% based on 8,760 hours each year. This allows for an annual 21-day planned maintenance, a 2.5% forced outage rate and a 2.5% maintenance outage rate. Potential output factors using these values could be closer to 89%.

What kind of personnel training is required?

All plant operations, maintenance and management personnel are required to participate in annual training classes on the following subjects:

- Regulatory/environmental monitoring and reporting requirements
- Plant operating and maintenance procedures
- Emergency operating procedures and emergency response
- Plant safety, material safety data sheets, hazardous materials handling, testing and cleanup
- Laboratory testing and water chemistry

Personnel must pass annual examinations on each of these topics in order to maintain job classifications.

DRAFT

ZEROS, inc.

Steve Clark
ZEROS, Inc. • P.O. Box 888
Highlands, TX 77562 • sc@zerosinc.com
Tel: (281) 424-2511 • Fax: (281) 424-2512 • http://www.zerosinc.com

C. Allan Jones
Texas Water Resources Institute • 1500 Research Parkway, Suite A240
2118 TAMU • College Station, TX 77843 • cajones@tamu.edu
Tel: (979) 845-1851 • Fax: (979) 845-8554 • http://twri.tamu.edu