Appendix D:
White Paper: Pyrolysis Overview/Background

Oneida Seven Generations Corporation Energy Recovery Project, Green Bay, Wisconsin

White Paper: Pyrolysis Overview/Background

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On April 12, 2011, DOE conducted a scoping meeting on the proposed project to solicit comments and get input on the Draft Environmental Assessment (EA) from the public. DOE received a mix of comments, many including public concerns about the viability of pyrolysis technology, those facilities in operation, and its disguise as an incineration project. This paper was prepared to address those comments.

Based on the scoping comments received, DOE conducted research on pyrolysis and gasification technology and those plants around the world that have been in operation, are in operation, or are proposed for operation using the technology. The research included the International Environmental Solutions (IES) Romoland Facility (Romoland), a small-scale pilot pyrolysis project in Romoland, California. The Romoland Facility was a demonstration facility, processing approximately 30 tons of waste per day, experimenting with different types of wastes prior to selecting the pyrolysis of post-recycled municipal solid waste (MSW). Romoland was one of the few pyrolysis plants in the nation that processed MSW under jurisdiction of one of the most stringent air quality regulations in the nation, the South Coast Air Quality Management District (SCAQMD). The plant was fined on December 8, 2009, for "operating equipment which puts contaminants in the air without having a permit to operate."[1] The public scoping comments DOE received during the EA process indicated that Romoland violated its air permits by exceeding SCAQMD regulatory thresholds for pollutants. However, DOE contacted SCAQMD for clarification and learned that IES violated SCAQMD regulations by operating its facility during demonstrations without an air permit. Romoland was fined for this violation during a SCAQMD visit. For reasons unknown to SCAQMD, IES did not submit final permit applications and subsequently decommissioned the facility. SCAQMD speculates that the facility may have moved to a location outside SCAQMD's jurisdiction.[2] Based on further research, DOE learned that the IES equipment once operated in Romoland was moved to Menifee, California, where it was contracted to a private company. The operation subsequently relocated to Mecca, California, where it was set up for commercial scale processing of tires.[3]

IES currently is in the process of demonstrating pyrolysis technology on a larger scale for the Los Angeles County Department of Public Works (DPW). On April 20, 2010, Los Angeles County approved a Memorandum of Understanding for three conversion technology demonstration projects that included the award of a contract to IES for the purpose of developing

1. South Coast Air Quality Management District, Facility Information Detail Database, Facility ID: 122334, International Environmental Solutions Corporation, Notices of Violation, Notice Number P49741.
2. Phone Communication with Richard Tambura and Amir Dahjbad Dejbakhsh (Senior Engineer), Permitting Department, South Coast Air Quality management District.
3. County of Los Angeles Department of Public Works, Board Motion April 20, 2010, Item No. 44 Conversion Technologies in Los Angeles County Six Month status Update: October 2010 through April 2011 Update, April 21, 2011; Available online at: http://file.lacounty.gov/bc/q2_2011/cms1_159240.pdf.

solid waste handling alternatives in Los Angeles. IES has been contracted to demonstrate its low-temperature advanced pyrolysis technology to convert solid waste feedstock into a synthesis gas (syngas) that would be used to generate electric power. DOE contacted the Los Angeles County DPW, and inferred that the IES research and demonstration facility would be of commercial scale with an initial capacity of 184 tons per day, for a process using one module. At this time, the County and IES are "jointly exploring other potential options to conduct the test phase of this project."[4]

The pyrolysis and gasification of MSW is used all over the world, particularly in Japan and parts of Europe and Scandinavia. Denmark, for example, has been converting waste to energy for over a century, primarily through incineration of waste, but including through the use of pyrolysis plants in the 60's.[5] Within the United States, refuse-derived fuel systems and pyrolysis units were introduced in the late 1970s. At that time, the U.S. Environmental Protection Agency had proposed several pyrolysis waste-to-energy demonstration projects, including the Baltimore Pyrolysis Plant powered by Monsanto, a $26 million demonstration project that was plagued with operational problems hindering it from operating successfully, and the El Cajon Plant, a $14 million project in Southern California that also experienced troubles during operations. It may be that the failure of these plants to materialize a successful operational plant has given the technology a negative reputation. However, it should be noted that the equipment utilized during pyrolysis is highly variable.[6] The equipment utilized in the 1970s was not as advanced as recent technology. Today, there are numerous successful plants in operation around the world and in the United States that utilize various forms of pyrolysis to process different resources to produce energy. Resources range from MSW to strict use of post-recycled waste, tires, auto shredder residues, sewage sludge, and others for conversion into different end-products including steam to power boilers or turbines to syngas for combustion into electricity, or into liquid biofuels.

At this time there is no single collective database that documents all of these pyrolysis facilities. DOE researched literature and found several databases for use; however, none were comprehensive databases that displayed consistent, similar information. The databases researched include the International Energy Agency website, which tracks conversion technology projects now in development or construction in the United States; the Zeus Global Gasification Database, which follows more than 300 facilities; the DOE National Energy Technology Laboratory Gasification Worldwide Database; and other literature that tracks pyrolysis/gasification technologies around the world.[7] Given the varying information obtained, and because the scope of research required to provide a comprehensive review of these facilities exceeds the scope of the analysis for this project, DOE research focused on literature review of the viability of the technology rather than those facilities that are in operation today or proposed

4. Ibid.; Phone communication with Coby Skye, LA County Department of Public Works, May 26, 2011.
5. In the 60's, experiments with pyrolysis (known then as the "Destrugas" system) of waste was used in Kolding, Denmark. Klies and Dalager, Babcock &Wilcox, Volund and Ramboll, "100 years of Waste Incineration in Denmark,p. 21, Reprinted 2007.
6. Haverland, Rick, and Sussman, David, USEPA, Baltimore, A Lesson in Resource Recovery (SW-712), Presentation at the American Society of Civil Engineers Environmental Engineering Division Specialty Conference, July 10- July 12, 1978; Garbe, Yvonne, USEPA, Technology Update from the US EPA Office of Solid Waste Management Programs, "Demonstration of Pyrolysis and Materials Recovery in San Diego, California," Reprinted from Waste Age, December 1976.
7. Pytlar, Jr., Theodore, Vice President- Solid Waste Group, Dvirka and Bartilucci Consulting Engineers, "Status of Biomass Gasification and Pyrolysis Facilities in North America,"~~,~~ NAWTEC 18-3521; Proceedings of the 18th Annual North American Waste to Energy Conference, 2010 ASME.

for operation in the future.[8] Further, as pyrolysis equipment and technology advance, the viability of a facility becomes dependent on more than one variable. The differing equipment heated to differing degrees to produce differing end products, the differing feedstock, and the different operators of these facilities are all variables that can affect successful operations.

What has been recognized, based on DOE's research, is that pyrolysis of MSW is a technology that has advanced to an adequate stage to result in MSW reduction benefits, energy generation benefits, and has subsequently produced greenhouse gas benefits over incineration technology and the continuous use of fossil fuel resources. According to a life-cycle assessment of MSW conversion to energy modeling of pyrolysis/gasification technologies, pyrolysis/gasification is environmentally favorable due to the lower emissions associated with the system.[9] Further, research conducted by the University of California at Riverside indicates that, "independently verified emissions tests results show that pyrolysis and gasification plants throughout the world with waste feedstocks meet each of their respective air quality emission limits." Advanced air pollution control strategies and equipment that were not available ten years ago "are no longer a barrier."[10]

Public comments received during the scoping process include concern regarding the project as an "incineration project in disguise." However, this is a misconception, as the two technologies are similar but not comparable. Pyrolysis is a type of thermal conversion technology similar to gasification that differs from the direct combustion process of an incinerator. Pyrolysis technology decomposes waste at elevated temperatures in the absence of or near absence of oxygen. Pyrolysis typically occurs at temperatures between 400 and 800 degrees Celsius (C) [750 and 1,500 degrees Fahrenheit (F)]. As the temperature increases, the product distribution (or the form of the product) can be altered. Pyrolysis of products at lower temperatures typically produces more liquid products, whereas higher temperatures produce gas. The products can include syngas, oil, and fine particulate matter (char), which have a clear and more manageable air emission profile. The syngas that is produced can be cleaned using scrubbers and subsequently can be used for electricity generation purposes by various methods. The speed at which pyrolysis occurs is also a factor in determining the product distribution. Slow pyrolysis (carbonization) can be used to maximize the yield of solid char. This process requires slow decomposition at low temperatures.[11] Fast pyrolysis, in comparison, is often used to maximize the yield of liquid products, through condensation of gas molecules into liquid.

While related, pyrolysis and gasification are different. Gasification is more reactive than pyrolysis. Gasification involves the use of air, oxygen, hydrogen, or steam/water as a reactive agent. Gasification processes vary considerably; typical gasifiers operate at elevated

8. Pyrolysis is an expensive technology requiring ample financial backing. Due to the current financial environment the last several years, the market for funding of this technology is constantly evolving leading to facilities shutting down or acquisition by larger companies. As such, DOE has focused its research on the viability of the technology.
9. Zaman, AtiqUz, "Life Cycle Environmental Assessment of Municipal Solid Waste to Energy Technologies," Global Journal of Environmental Research 3 (3):155-163, EESI School of Architecture and the Built Environment , KTH- Royal Institute of Technology, Stockholm Sweden, IDOSI Publications, 2009.
10. University of California Riverside, Evaluation of Emissions from Thermal Conversion Technologies Processing Municipal Solid Waste and Biomass Final Report, Riverside CA, June 21, 2009.
11 . Yan, W., et al., "Experimental Studies on low-temperature pyrolysis of municipal household garbage- temperature influence on pyrolysis product distribution," Renewable Energy 30 (2005) 1133-1142, Received May 16, 2004; Accepted September 20, 2004.

temperatures between 700 and 800 degrees C (1,300 and 1,500 degrees F). The chemistry that takes place with gasification includes different reactions depending on the process input, thus providing a range of outputs for specific uses. Similar to pyrolysis, the syngas that is produced can be cleaned or scrubbed for electricity generation. General by-products associated with gasification include glassy slag and fine particulate matter (char).

In comparison, incineration processes require large quantities of oxygen, converting waste to carbon dioxide, water and non-combustible materials with solid residue. The solid residue consists of bottom ash and fly ash. To date, air pollution control strategies and equipment have made incinerator projects a practical technology for use around the world.

To date, regulatory agencies around the country are looking into thermal conversion processes to alleviate landfill shortage concerns. States across the nation, including Nevada, Oregon, California, New York, and Florida, are looking for alternatives to landfill disposal due to the shortage of land available for landfills. Combined with increasing fuel costs and increasing solid waste, these waste conversion technologies are viewed as an effective management tool to alleviate increasing landfill shortages.[12]

Based on its research, DOE has compiled information about vendors and waste-to-energy facilities using pyrolysis technology or a combination of pyrolysis and gasification technology either in construction, operation, those that operated, or are proposed for operation, as presented on the next page. This list is not meant to be comprehensive, but it provides a sample of the number and types of facilities that use this technology for processing of MSW. As shown in the table, it is evident that the use of pyrolysis technology for processing solid waste is global. There are multiple commercial plants either proposed or currently in operation. The processing of waste using pyrolysis has been around for generations and, similar to other technologies, is expected to continue to evolve and advance.

12. URS, Conversion Technology Evaluation Report Prepared for the County of Los Angeles Department of Public Works and the Los Angeles County Solid Waste Management Committee/Integrated Waste Management Task Force's Alternative Technology Advisory Subcommittee, August 18, 2005.

Pyrolysis/Gasification Technology Around the World

Facility/Supplier Name	Location	Country	Capacity	Primary Feedstock	Syngas/Waste Heat Utilization
Cleveland Public Power- MSWE Plant/ Princeton Environmental Group	Cleveland, OH (Preconstruction stages)	USA	900-1,500 TPD	MSW	Boiler- 20 MW
Conrad Industries	Chehalis, WA	USA		Plastics	
Graveson Energy Management	Summit, NJ	USA		MSW	
North American Power Company	Las Vegas, NV			MSW, industrial, medical, plastic	Boiler
Pan American Resources, Inc.	Pleasanton, CA			MSW	
LACDPW/ International Environmental Solutions	Riverside, CA (Preconstruction stages)	USA	180 TPD (pilot)	MSW	
Waste Gen UK Ltd	Gloucester	UK	110,000 TPY	MSW	Boiler
Utility Savings & Refund, LLC	Newport Beach, CA	USA	150 TPD	carbon-based material	BioOil
Global Energy Solutions, Inc. Sarasota, FL	Claims 4 plants in operation around the world			MSW	Boiler
Interstate Waste Technologies Malvern, PA	3 Plants: Italy- 100 TPD, Japan- 330 TPD, Germany- 792 TPD		289,000 TPY	MSW	Boiler/IC
Compact Power Holdings PLC/Compact Power Ltd.	Avonmouth	UK	8,000 TPY	MSW- Special wastes, mainly clinical medical waste	Boiler
Mitsui Babcock - R-21	Toyohashi City	Japan	400 TPD	MSW	8.7 MW
	Koga Seibu		260 TPD	MSW; Sewage Sludge	4.5 MW
	Yame Seibu		220 TPD	MSW	2.0 MW
	Nishiiburi		210 TPD	MSW	2.0 MW
	Ebetsui City		140 TPD	MSW	2.0 MW
	Kyoboku Regional		160 TPD	MSW	1.5 MW
WasteGen/Techtrade	Hamm	Germany	353 TPD	MSW; Sewage Sludge	power generation
	Burgau	Germany	154 TPD	MSW, Sewage Sludge	power generation

Facility/Supplier Name	Location	Country	Capacity	Primary Feedstock	Syngas/Waste Heat Utilization
Thide Environment	Arras	France	40,000 TPY	Household Wastes	Industrial Stream
	Dreux	Paris	6,400 TPY (pilot)	MSW, Industrial Waste, & sludge	
	Izumo	Japan	70,000 TPY		
	Itoigawa	Japan	25,000 TPY		
	Nakaminato	Japan	8,000 TPY		
IET Energy/ Entech Renewable Energy System		Singapore	72 TPD	Food Processing Wastes	4.0 MWt (Steam)
		Korea	60 TPD	MSW	power generation
		Korea	30 TPD	MSW	power generation
		Hong, Kong	58 TPD	MSW	power generation
	Genting/Sri Layang	Malaysia	60 TPD	MSW (WDF)	6.9 MWt
	P.N.G.		40 TPD	MSW	syngas
	Chung Gung Municipality	Taiwan	30 TPD	MSW	2.3 MWt (steam)
		Australia	15 TPD	MSW (WDF)	power generation
		Indonesia	15 TPD	MSW (WDF)	power generation
Pyral AG (Formerly PKA)	Freiberg	Germany		Waste w/ high aluminum/plastic content	Aluminum briquettes, inert glass granulates, syngas
Compact Power Holdings PLC/Compact Power Ltd.	Bristol	UK	9,000 TPY	Clinical & Special Waste	Heat for Autoclave
Ensyn	Renfrew	Ontario, Canada		Residual Wood	Fuel oil replacement
Siemens (Formerly Future Energy GmbH and Noell)	Freiberg	Germany		Coal/low-grade fuels (facility can also take waste)	Power generation (3-5 MWth), chemicals, synthetic fuels
Thermoselect	Chiba	Japan	100,000 TPY	Industrial Waste	
	Mutsu	Japan	50,000 TPY	MSW	

Compiled by DOE Golden Field Office during work conducted on the Draft Environmental Assessment for Oneida Seven Generations Corporation: Energy Recovery Project, Green Bay, Wisconsin (DOE/EA-1862).

MSW= municipal solid waste.
tpd= tons per day.
tpy= tons per year.