Aide-Mémoire
ZEROS-Related Activities
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August 2015

This summarizes our efforts since 2001, primarily while we were Directors of the Texas Water Resources Institute (TWRI) from 2000 to 2008 and Senior Research Scientist at the Spatial Science Laboratory at Texas A&M University, to verify the technical feasibility and encourage use of the Zero-Emission Energy Recycling Oxidation System (ZEROS).

In 2001 Mr. Steve Clark, inventor of ZEROS, and his business partner Mr. William McKenzie, former Chair of the Texas A&M University System Board of Regents, approached Texas A&M University to determine its interest in evaluating the ZEROS system. After meeting with university leaders, Mr. Clark approached TWRI for assistance in developing a ZEROS system to oxidize dairy and/or feedlot manure to produce both electricity, distilled water, and (possibly) steam power and cooling capacity for dairies, feed lots, and/or slaughter houses. We were initially interested because of the great potential to reduce the amount and environmental impacts of animal wastes applied to crop fields.

Because ZEROS had initially been developed by Mr. Clark to remediate oil field wastes, and we were not familiar with the technology, we felt it necessary to do "due diligence" on the engineering and economic feasibility of using the system to oxidize animal manure. Therefore, in 2003 TWRI hosted two meetings between Mr. Clark and six senior Texas A&M University System engineers and economists. The consensus of the faculty was that ZEROS is technically feasible to oxidize animal wastes like dairy manure, and its economic feasibility would depend on the tipping fees for accepting the manure and the prices of the commodities produced (electricity, carbon dioxide, nitrogen, argon, distilled water, etc.).

Unfortunately, in January 2004 Mr. Clark was involved in an auto accident, and our cooperation had to be delayed until he had recovered. After resuming cooperation in late 2004, We consulted with Mr. Tom Boyd of Triencon Services, Inc. on the technical and economic feasibility of using ZEROS technology to power both electrical generation and produce liquid fuels. Mr. Boyd, an early skeptic of the technology, had developed sophisticated engineering and economic models of ZEROS and, as a result, become a strong proponent of and advocate for the system. We have examined and discussed with him his analyses and trust his conclusions regarding both the technical and economic feasibility of the ZEROS process.

The due diligence described above convinced us of the technical feasibility of ZEROS to address many of society's energy and environmental problems. For example, one of the most unique and noteworthy features of the ZEROS oxy-fuel biorefinery process is that it produces useable electrical energy and/or transportation fuel with no air or water emissions. Because pure oxygen from an onsite air separation unit (rather than ambient air) is used as the oxidant, no atmospheric nitrogen enters the primary or secondary oxidation chambers, and all carbon dioxide produced can be cooled, pressurized, condensed and sequestered for sale as liquid carbon dioxide or dry ice, providing an important additional source of revenue. In addition, if the sequestered carbon

dioxide is sold to the oil industry for injection to enhance crude oil recovery, the entire process would be a net sink for atmospheric carbon dioxide.

Because partial initial oxidation (gasification) of the fuel occurs in a rotary kiln at high temperature and controlled atmosphere, the process can use a diverse mix of fuels of varying composition and moisture content. In fact, water is normally added to the rotary kiln chamber to maintain appropriate chamber temperatures. Mr. Clark has demonstrated that ZEROS effectively oxidizes diverse sources of fuel from agricultural, forestry, municipal, and industrial wastes, including municipal solid waste, oil soaked soil, agricultural crop residues, forestry residues, animal manure, and coal waste contaminated with soil.

A standard size ZEROS plants can produce 50 MW of continuous electrical power and 40 million gallons per year of diesel fuel. Commercial products other than electricity and/or liquid fuel that can be produced by a ZEROS plant include pure liquid or solid carbon dioxide, pure nitrogen and argon gases. It can also distill several million gallons of waste water per day, though such modifications could reduce the production of liquid fuel. Finally, the plant could oxidize and delist large quantities of solid and liquid wastes, including organic hazardous wastes like dioxin and medical grade nuclear wastes. The facility would also be available to denature and render harmless asbestos-containing demolition wastes and oxidize animal carcasses.

In addition to our independent assessment of ZEROS's oxy-fuel technology, the 2005 Intergovernmental Panel on Climate Change's (IPCC) "Special Report on Carbon Dioxide Capture and Storage" describes several advantages of oxy-fuel combustion. Oxy- fuel technology "uses oxygen instead of air for combustion, producing a flue gas that is mainly H_2O and CO_2 and which is readily captured." The IPCC report states that "oxy-fuel combustion applied to furnaces, process heaters, boilers and power generation systems is feasible since no technical barriers for its implementation have been identified." In addition, the report predicts that "future oxy-fuel capture systems based on coal firing…could potentially match the best efficiencies realizable today for pulverized coal-fired plants without CO_2 capture." It also predicts future "plant efficiencies for natural gas-fired oxy-fuel cycles with CO_2 capture above 50%." The IPCC report points out that it should be possible to retrofit oxy-fuel combustion systems "to existing equipment such as process heaters and boilers, in order to minimize development costs and achieve early market entry."

Additional information about ZEROS is available at (zerosinc.com/Due-Diligence.pdf). This web site contains details of the theory, engineering, operations, and economics of ZEROS facilities; risk assessments; environmental impacts; patents; Florida and Texas environmental agency permit exemptions; legal opinions; actual test results from waste remediation applications; and EPA verification that ZEROS can be used to "delist" hazardous wastes.

Convinced by our due diligence that ZEROS merited full scale implementation to demonstrate its capabilities, we began to work with Mr. Clark to inform key state and federal officials of its potential to solve multiple energy and environmental problems facing Texas and the United States.

In 2007, Mr. Clark and Dr. Jones met with a number of senior engineers working with Federal and State agencies in Washington, D.C., Dallas and Austin. These included: Robert C. Marlay, Director of the EPA Office of Science and Technology Policy; David Schanbacher, Chief Engineer of TCEQ; Vic Der, Deputy Assistant Secretary for Clean Coal – DOE; and Carl Edlund, Multi-Media Planning and Permitting Division Director of EPA Region 6. In fact, Mr. Edlund indicated that he was aware of the use of ZEROS as an oil field waste remediation technology in California. Dr. Jones concluded after speaking with these and other experts in alternative energy production is that the ZEROS technology is the only oxy-fuel technology that has operated successfully for an extended period at a commercial scale producing electric power from a variety of "low quality" fuels while capturing and sequestering 100% of the carbon dioxide produced.

Also, in 2007 Dr. Kalyan Annamalai, Paul Pepper, Professor of Mechanical Engineering, and Dr. Kenneth Hall, Jack E. and Frances Brown, Chair Professor of Chemical Engineering at Texas A&M University evaluated the technical feasibility of ZEROS for TXU Power Generation Company. They reported to TXU, TWRI, and Mr. Clark that their analyses indicated that the ZEROS process is technically feasible using several possible fuels, though their calculations of the amount of fuel required to produce 50 MW of electricity were somewhat higher than those proposed by Mr. Clark. This was not a serious concern since the ZEROS waste-to-energy facility would receive a tipping fee for disposing of the waste. The additional income from greater fuel tipping fees, as well as the sale of additional CO_2, nitrogen, argon, and distilled water byproducts would more than offset the cost of additional O_2 required to produce 50 MW of electricity. As a result of this study, TXU planned to construct a ZEROS facility at one of its Central Texas lignite mines to generate electrical energy needed by its mining operations from low-quality lignite. However, before negotiations were concluded, TXU was purchased by venture capitalists and split into three units. This ended discussions of constructing a ZEROS facility.

The Texas State Energy Conservation Office (SECO) published "Energy Efficiency: Texas' Newest Energy Resource," reviewing research on renewable energy production in Texas through 2008. The study described many sources of organic waste materials that could be processed by ZEROS, and it was clear that many sources of municipal, livestock, and forestry wastes could be available for conversion by ZEROS to transportation fuel and/or electricity.

As a result of these positive analyses of ZEROS thermodynamics, in 2008 TWRI worked with Mr. Clark to develop short documents describing the ZEROS processes, answering frequently asked questions, and developing "rules of thumb" for typical ZEROS facilities. In addition, in April 2008 Mr. Clark and I testified before the Texas House of Representatives Energy Resources Committee concerning initial discussions with a number of federal, state, and local officials about the ZEROS process.

By May 2008 eleven ZEROS waste-to-energy projects were in varying stages of development in the United States, Mexico, and Italy. Pro forma proposals had been produced and project developers were in discussions with several venture capital funds. For example, in 2008 Arrendondo, Zepeda & Brunz, LLC (AZ&B) reviewed a proposal to build a ZEROS municipal solid-to-energy facility at a proposed regional land fill in Grimes County. AZ&B concluded,

based on their analyses, as well as discussions with Drs. Annamalai and Hall, that the project is technically feasible, though they questioned the economic benefits to the land fill operator.

By the end of 2009, Mr. Clark and Dr. Jones had personally briefed key staff in the White House Office of Economic Development (2), Congressmen (2), Congressional staff (9), US Department of Energy (5 individuals), US Environmental Protection Agency (19), US Army at Fort Hood (7), US Department of Agriculture (16), US Department of Interior (2), World Bank and its contractors (7), Office of the Governor of Texas (4), Texas Senators and House members and staff (6), Texas Commission on Environmental Quality (5), Texas Comptroller of Public Accounts and staff (2), Texas General Land Office (2), Lower Colorado River Authority (2), Texas Railroad Commission Commissioners (2), and Texas Agriculture Commissioner and Chief of Staff. We had also briefed staff involved in solid waste management for the cities of Arlington, Austin, Bryan-College Station, Houston, Killeen-Copperas Cove, McAllen, San Antonio, Temple, and Waco.

However, the financial crisis of 2008-2009 made venture capital funding of large energy projects very difficult if not impossible, and discussions of most ZEROS projects were put on hold. Despite this serious setback in potential funding, Mr. Clark and I continued to develop materials supporting the engineering and economic feasibility and benefits of ZEROS.

From our discussions with government officials and potential investor groups, it was clear that most of these individuals lacked sufficient understanding of the thermodynamic processes in ZEROS. In addition, an independent, third-party assessment of the economics of proposed ZEROS systems was needed. Therefore, in 2009 and 2010 I developed a non-engineer's technical description of the ZEROS system and worked with three respected Texas A&M applied economists to develop (with funding from the Texas State Energy Conservation Office) an economic risk assessment of a typical ZEROS project. The resulting publications are available on the Texas Water Resources Institute website:
http://twri.tamu.edu/publications/reports/2011/

TR-398, *ZEROS: The Zero-emission Energy Recycling Oxidation System, A Description for Non-Engineers*, C. Allan Jones

TR-402, *Economic and Financial Implications of the ZEROS Technology*, M. Rister, R. Lacewell, A. Sturdivant

In 2010 and 2011 Mr. Clark developed a proposal for a ZEROS zero-emission oxy-fuel-bioenergy refinery in Chambers County, Texas. We understand that Advanced Design Projects was to provide the architectural engineering design, with full scale operation within 3 years. The Chambers County Project was to use patented ZEROS oxy-fuel oxidation and producer gas reformation technology to produce 100 million gallons of synthetic, zero-sulfur diesel fuel per year plus sufficient electricity (13 MW) for internal plant needs. The plant was to produce zero air and water emissions due to its unique ability to sequester for sale all carbon dioxide produced. Firm agreements for approximately 1,500 tons per day of mixed municipal and industrial wastes were concluded with the Gulf Coast Waste Disposal Authority. I understand that agreements were also concluded with Maxim Energy and Glander International for sale of

the diesel fuel, which was to supply end users in the maritime industry. Substantial additional revenue was to be derived from sale of pure liquid carbon dioxide as well as nitrogen and argon from an associated air separation plant. However, it has not been possible to insure the project, and it is currently on hold until this issue is resolved.

In 2012 Mr. Clark was approached by officials representing the Kingdom of Kuwait to discuss the possible use of ZEROS to remediate soil contaminated by oil during the Gulf War of 2001. The most massive oil spill in history, it has taken over 20 years for the Kuwait, the World Bank, and other Gulf States to begin major remediation activities. Following initial technical failures of more conventional remediation technologies, ZEROS may be chosen to implement the project, which could require over ten ZEROS Bio-Dynamics units operating for over a decade.

ZEROS Bio-Dynamics is a zero-emission non-thermal process for cleaning hydrocarbon from soils (US Patent 6137026 A). For this application, high levels of petroleum hydrocarbons in contaminated soils would be oxidized with ZEROS to generate large amounts of carbon dioxide, which would be recovered in pure form and used as a solvent to clean other soils of petroleum hydrocarbons. In the solvent process, contaminated soils would be run through a soil separator where the soils would be washed with carbon dioxide. The carbon dioxide would then be recovered from the soil and reused while the remaining hydrocarbon would be processed by existing refineries.

Our conclusion based on the studies and other information cited above, as well as many discussions with experts in the field, is that in the early 1990s ZEROS operated effectively in California at a commercial-scale to remediate oil-soaked soil. It was then demonstrated to effectively and completely oxidize a variety of agricultural, municipal, and construction wastes. We believe that it is a technically and economically feasible zero-emission waste-to-energy technology that can be configured to generate commercial quantities of electricity; liquid transportation fuel; pure gases such as carbon dioxide, nitrogen, and argon; and distilled water..