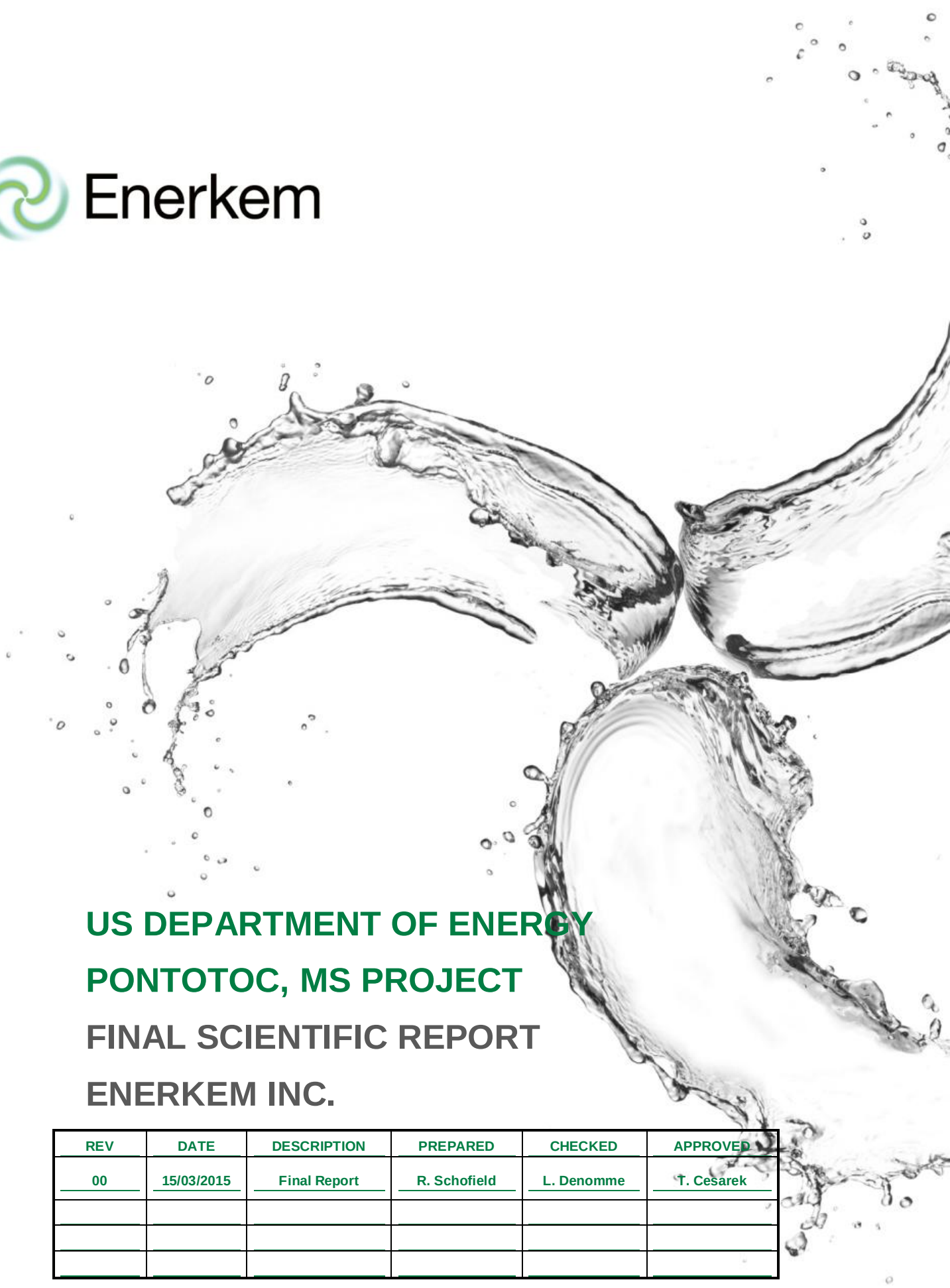
Enerkem



US DEPARTMENT OF ENERGY

PONTOTOC, MS PROJECT

FINAL SCIENTIFIC REPORT

ENERKEM INC.

REV	DATE	DESCRIPTION	PREPARED	CHECKED	APPROVED
00	15/03/2015	Final Report	R. Schofield	L. Denomme	T. Cesarek

1. IDENTIFY THE DOE AWARD NUMBER; NAME OF RECIPIENT; PROJECT TITLE; NAME OF PROJECT DIRECTOR/PRINCIPAL INVESTIGATOR; AND CONSORTIUM/TEAMING MEMBERS.

- DOE Award Number: DE-EE0002882
- Recipient: Enerkem Mississippi Biofuels, LLC
- Project Title: Recovery Act : Heterogeneous Feed Biorefinery Project
- Current Team Members (EMB): Tim Cesarek, Ben Hoffman, Richard Schofield

2. DISPLAY PROMINENTLY ON THE COVER OF THE REPORT ANY AUTHORIZED DISTRIBUTION LIMITATION NOTICES, SUCH AS PATENTABLE MATERIAL OR PROTECTED DATA. REPORTS DELIVERED WITHOUT SUCH NOTICES MAY BE DEEMED TO HAVE BEEN FURNISHED WITH UNLIMITED RIGHTS, AND THE GOVERNMENT ASSUMES NO LIABILITY FOR THE DISCLOSURE, USE OR REPRODUCTION OF SUCH REPORTS.

N/A

3. PROVIDE AN EXECUTIVE SUMMARY, WHICH INCLUDES A DISCUSSION OF: (1) HOW THE RESEARCH ADDS TO THE UNDERSTANDING OF THE AREA INVESTIGATED; (2) THE TECHNICAL EFFECTIVENESS AND ECONOMIC FEASIBILITY OF THE METHODS OR TECHNIQUES INVESTIGATED OR DEMONSTRATED; OR (3) HOW THE PROJECT IS OTHERWISE OF BENEFIT TO THE PUBLIC. THE DISCUSSION SHOULD BE A MINIMUM OF ONE PARAGRAPH AND WRITTEN IN TERMS UNDERSTANDABLE BY AN EDUCATED LAYMAN.

To overcome the hurdles associated with introducing a new technology, Enerkem applied to the US DOE for grant assistance with its Pontotoc, Mississippi, biorefinery under the DOE's Demonstration of Integrated Biorefinery Operations FOA. Consistent with Enerkem's strategic approach, the project proposed uses post sorted municipal solid waste blended with other forest residue. The proposed biorefinery is to be located within the boundaries of a working landfill, thus simplifying many aspects of environmental permitting while also reducing feedstock acquisition and transportation costs.

An economic impact analysis was conducted using an adaptation of the US Department of Energy's JEDI (Jobs and Economic Development Impact) model for an ethanol-producing biorefinery. The JEDI model, which does not have a thermochemical processing option, had to be configured to reflect a biomass feedstock and was thus adapted by Enerkem to account for the unique feedstock requirements and operations of the Project. According to this model, development, construction, and 2

years of operation of the biorefinery require an investment of approximately $140 million. Also, a construction period of 18 months will create significant direct and indirect employment. Indirect employment includes steel manufacturers, construction materials manufacturers, material shipping, equipment manufacturers and fabrication, etc.

During the construction phase of the Project, 210 total jobs are expected to be created, including 145 direct jobs and 72 indirect or induced jobs. During the operating period, 131 jobs would be created, 95 of which are direct. It is anticipated that the project will create at least 10 new jobs (included in the above figures and in addition to the JEDI data) in the sorting and recycling sector, since the project will require operations in sorting MSW since valuable ferrous, nonferrous and recyclable plastic materials will be sorted from MSW as part of the process that isolates MSW-derived biomass.

4. PROVIDE A COMPARISON OF THE ACTUAL ACCOMPLISHMENTS WITH THE GOALS AND OBJECTIVES OF THE PROJECT.

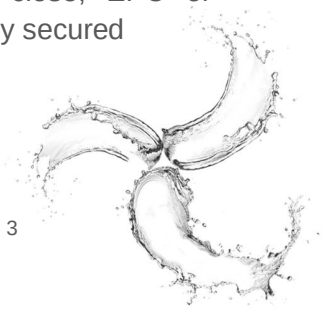
The main objective of the project was to build and operate a plant using Enerkem's patented technology in Pontotoc, Mississippi, which was to transform 300 dry metric tons a day into 10 million gallons per year of cellulosic ethanol. This plant was to start-up in 2013, operating for 2 years through DOE funding until March 2015.

There were a few delays in the project due to project financing issues. Therefore, only preliminary engineering and permitting activities were funded by the DOE. No detailed (FEL 3) design and no operational-related activities were accomplished as a part of the DOE funding.

In December 2009, Enerkem Corp. (a U.S. subsidiary of Enerkem Inc., a Montreal, Quebec, Canada based company) received initial award from DOE that covers the performance period of 10/1/2009 – 9/30/2013. Preliminary total project cost estimate = $124M; $74M Enerkem cost share; ARRA funds obligated by DOE = $50M.

The original project performance baseline was as follows:

- Budget period 1 (10/1/2009 – 12/31/2010): Project definition level (FEL2) design and design suitable for EPC bid (FEL3), NEPA, engineering, permitting, pilot test validation, value engineering, feedstock supply agreements, offtake agreements, financial close, EPC or construction contract in place, location secured, cost share secured, contingency secured



- Budget period 2 (1/11/2011– 12/1/2012): Final design, construction, commissioning, startup, shakedown

- Budget period 3 (12/1/2012 – 12/1/2014): Operations (2 years of operational data supplied to DOE)

The final project schedule proposed was:

- Budget period 1 (10/1/2009 – 1/1/2014)
- Budget period 2 (1/2/2014 – 1/1/2015)
- Budget period 3 (1/31/2015 – 9/30/2015)

The DOE provided an extension of Budget period 1 to address the project delays.

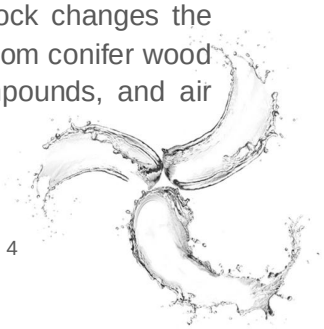
Because of continuing schedule slippage and the fact that the ARRA funds sunset on October 1, 2015, DOE and Enerkem met in June 2013 to discuss opportunities to recover the schedule. In that meeting, the strategy of phasing the construction of the EMB facility was examined, phase one would be to validate design elements (feedstock to Methanol Island to move forward in parallel with continued testing on those processes that were not yet fully validated (methanol-to-ethanol – Phase 2).

DOE conducted a CD-3 (Approve Start of Construction) for phase 1 of the project. The result was a conditional “Go” decision. The following summarizes the critical conditions that were required to move forward into Budget period 2:

- DOE’s approval to move forward with Phase 1 of BP2 (feedstock-to-methanol production) included a Go/No go decision point that links the release of additional BP2 funds to the successful completion of parallel testing of the methanol-to-ethanol gas separation tests at the Westbury facility.

- Enerkem was requested to acquire the services of a dedicated project manager with substantial experience managing the execution of major capital projects to successful completion.

- The switch to woody biomass (for the first years of operations) as a feedstock changes the characteristics of the potential emissions, which will include terpenes derived from conifer wood chips. This requires technology changes to handle the volatile organic compounds, and air quality permits.



- Enerkem was requested to provide DOE written confirmation that it will be able to meet its cost share and contingency requirements as required by the Terms and Conditions of the award.

5. SUMMARIZE PROJECT ACTIVITIES FOR THE ENTIRE PERIOD OF FUNDING, INCLUDING ORIGINAL HYPOTHESES, APPROACHES USED, PROBLEMS ENCOUNTERED AND DEPARTURE FROM PLANNED METHODOLOGY, AND AN ASSESSMENT OF THEIR IMPACT ON THE PROJECT RESULTS. INCLUDE, IF APPLICABLE, FACTS, FIGURES, ANALYSES, AND ASSUMPTIONS USED DURING THE LIFE OF THE PROJECT TO SUPPORT THE CONCLUSIONS.

The statement of project objectives indicated the following objectives, scope, tasks and deliverables:

PROJECT OBJECTIVES

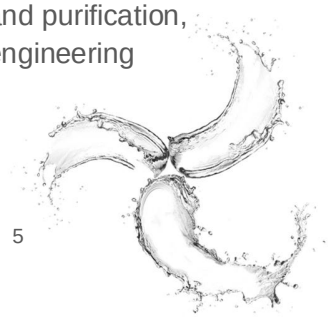
The objective of the project is to demonstrate and produce at a 10 million gallons-per year scale, Enerkem's gasification waste-to-ethanol technology using post sorted municipal solid waste as primary feedstock. The validation of Enerkem's technology at this scale was removing remaining hurdles to broad commercial deployment in the U.S. The project is located in Pontotoc, Mississippi in Pontotoc County. In the course of the project Enerkem plans to build and operate a biorefinery, producing ethanol from heterogeneous, low-cost waste feedstock and gaining detailed data from each step of the process that will support and facilitate further commercial deployment of the technology. The resulting physical plant would become the basis model for expanding business opportunities that will utilize the 10MM gallon production unit footprint.

PROJECT SCOPE

The project entails the engineering, construction, start-up and operation of an integrated biorefinery that will use low-cost MSW and other waste biomass feedstock materials in an advanced gasification and gas clean-up and conditioning system to produce a synthesis gas of sufficient purity and composition stability to be transformed via catalysis into transportation fuels. The Biorefinery will be commissioned and then operated for two years during the data collection and analysis phase of the project.

TASKS TO BE PERFORMED

Task A. Engineering Services (Budget Period 1) – This task (previously called "Basic Engineering") involves the completion of basic engineering on storage and feed systems, the gasification and gas conditioning unit, methanol synthesis, ethanol production and purification, utilities and buildings. This task will be completed through Enerkem's internal engineering division and by working with specialized external engineering firms.



Task B. Permitting (Budget Period 1) – This task involves working with the State of Mississippi to assure a timely and complete filing and issuance of all necessary project environmental permits, including air, solid waste handling, water, storm water (construction related), etc. In addition, this task involves completing the necessary environmental questionnaires for the project activities.

Task C. Project Management (Budget Period 1) – In this task Enerkem and its consultants will complete an array of pre-construction project management and project administration tasks including completion of a detailed project budget and schedule, completion of a land survey and independent engineer's review, and completion of all project agreements and financial arrangements, including project financing arrangements.

Task D. Detailed Engineering (Budget Period 1 and 2):

Task D.1 HAZOPS Activities (Budget Period 1 and 2) – Enerkem engineering will undertake the Hazardous Operations Review (HAZOPS) on all process designs to optimize safe operational practices and mitigate any associated risk.

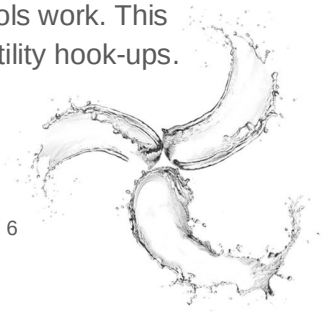
Task D.2 Control and Automation Design (Budget Period 1 and 2) – Enerkem, along with a specialty consultant, will provide control system architecture design and configuration for the plant.

Task D.3 Detailed Engineering (Budget Period 1 and 2) - In this task, Enerkem and its engineering contractors will carry out detailed engineering for all aspects of the project, including completion of the process engineering, site work design, civil engineering, the biorefinery equipment and buildings, and utilities to allow for the preparation of bid packages for all disciplines.

Task D.4 Procurement (Budget Period 1 and 2) – Enerkem and its engineering and fabrication contractors will continue and complete the procurement activity, which was started in Budget Period 1 (previously Task E), including supplier identification and contract negotiations. Enerkem and the fabrication contractors will procure all items and services necessary for the fabrication and installation of the facility. Enerkem will support the activities surrounding the procurement of key process vessels and other major equipment concentrating initially on long lead equipment and equipment with special material, fabrication or delivery requirements.

Task D.5 Temporary Power (Budget Period 1 and 2) – Enerkem will initiate the design and installation of temporary electrical power to allow the availability of power necessary during construction.

Task D.6 Construction Preparation and Site Works – (Budget Period 1 and 2) - This task involves general work such as civil work, site preparation, as well as shop fabrication of the facility's modules, including all mechanical, electrical, instrumentation and controls work. This task also includes other aspects of the project such as minor outbuildings and utility hook-ups. This task will be completed upon Mechanical Completion.



Task D.7 Construction Engineering Support (Budget Period 1 and 2) – Enerkem's engineering staff will provide technical support for the construction work from the home office as well as on-site during all phases of the work.

Task D.8 Mechanical Completion (Budget Period 2) – Enerkem will manage and support the Mechanical Completion of the plant construction in support of the Commissioning and Start-up of Operations. This activity will involve procurement of necessary parts, supplies and materials and assignment of plant operations personnel to assist.

Task E. – Commissioning and Start-up (Budget Period 2) - This task includes testing and commissioning of all components of the project, from core processes to buildings and utilities. This task also includes sequential start-up of the facility and ramp-up of operation to design capacity.

Task F. – Operations Training (Budget Period 2) - This task includes operations training, which will follow on program development and personnel hiring.

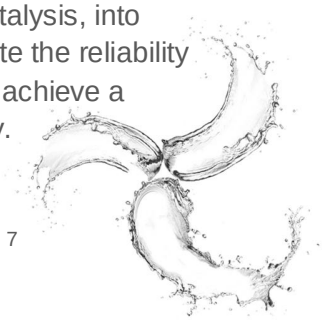
Task G. – Independent Engineer Test (Budget Period 2) - This task includes the hiring and support of an independent engineer to confirm that project performance is in line with the plant design (i.e. plant capacity, production through-put and quality, and confirmation of all OPEX).

Task H. – Operations (Budget Period 2) - This task includes the steady-state operation of the biorefinery for two years, with a performance review of the complete system and an evaluation of operating cost.

Deliverables

Periodic reports will be submitted in accordance with the requirements of DOE. Operating reports, including cost and technical analysis, will be submitted including a final report that will include a techno-economic analysis of the steady-state operation of the biorefinery in the final year of the project. All project activities will be monitored and managed to ensure successful completion. Earned value will be measured monthly and will include projections of incurred-to-date costs that are routinely and necessarily delayed as a result of subcontractor billing cycles. The PM will review risks monthly and report any significant changes, including risk as retired or other change in status.

The original hypothesis was that Enerkem would build and operate a 300 metric dry tonne-per-day biorefinery in Pontotoc, Mississippi that uses post sorted municipal solid waste as feedstock. The Enerkem technology platform is based on a state-of-the-art gasification system coupled with a proprietary gas cleaning and conditioning process. The product of Enerkem's thermo chemical process is a synthesis gas of sufficient purity and composition stability to be transformed, via catalysis, into transportation fuels and biochemicals. The objectives of the project were to demonstrate the reliability of the Enerkem biorefinery module through 8,000 hours of continuous operation and to achieve a production rate of 10 million gallons of ethanol per year from the operation of the facility.



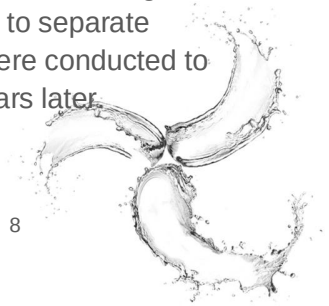
When Enerkem and the DOE agreed on the project funding, it was understood that Enerkem was developing the final validation phases of its technology at its demonstration plant in Westbury while simultaneously beginning the design of its commercial plants in Edmonton, Alberta, and Pontotoc, Mississippi. The preliminary design of its first commercial scale plant was thus partially financed through the DOE funding, as it went towards the project design of Pontotoc. Preliminary engineering work, required in the budget period 1 deliverables, was issued to the DOE as a result of this funding. This includes documents such as: process flow diagrams (PFDs), piping and instrumentation diagrams (P&IDs), Mass and Energy balances, Utility consumption lists, equipment lists, major equipment datasheets, electrical load lists, etc.

Also, site specific elements to the Pontotoc project were funded by the DOE. All required permitting was completed (Construction, Storm water, Air, solid waste processing, baseline stormwater, etc). Geotechnical work had also been done in order to estimate the civil and structural work that would be necessary for the project. As part of the permitting process, Enerkem received a FONSI (finding of no significant impact) from the EPA for its project in Pontotoc. Discussions were also underway with the FAA because of the Pontotoc airport that was located near the plant. Initial discussions indicated that there should not be an issue with the plant interfering with flight paths.

Engineering work specific to Pontotoc has also been completed and funded. The strategy around using the city's grey water (the outlet of their waste water treatment plant) as process water for Enerkem was completed, which arrived to the conclusion that in spite of using this grey water, a new well would also have to be built in coordination with the city to accommodate Enerkem's water needs, as well as an on-site water storage tank to handle inlet fluctuations caused by dry periods. The preliminary engineering of a secondary waste water treatment was also done as the city's WWTP was not able to handle the oxygen demand from Enerkem's process waste water. An aeration ditch was deemed necessary in order to reach the city's waste water standards.

A four season feedstock characterization had been done around Pontotoc's MSW and various other sources around the project site. A Memorandum of understanding was signed with Three Rivers Waste Authority (TRWA) for the MSW feedstock supply and Enerkem was participating on TRWA's quarterly board meetings. Memoranda of understanding were also signed with wood waste suppliers for the project. Air separation unit vendors were also contacted to participate with Enerkem in the project (pure oxygen being required for Enerkem's process). The Pontotoc Electrical Power Authority (PEPA), with the Tennessee Valley authority (TVA) also agreed to install an electrical substation for Enerkem's electricity requirements.

After initially proposing to be co-located on the Three Rivers Waste Authority site, it was decided that Enerkem's plant was to be located across the street from the landfill. Therefore a second round of site surveying and geotechnical reports were done to ensure that proper civil and site work may be estimated. Also at this time, it was unclear if the project would have been able to secure a final feedstock agreement with the waste authority on time to meet the DOE's ARRA related deadlines given that the Authority also required the construction of a Material Recovery Facility in order to separate recyclables (instead of implementing source separation activities). Therefore studies were conducted to use wood waste as an initial feedstock and transition to municipal solid waste a few years later.



6. IDENTIFY PRODUCTS DEVELOPED UNDER THE AWARD AND TECHNOLOGY TRANSFER ACTIVITIES, SUCH AS:

Not applicable as the DOE funded engineering and not R&D nor technology development.

7. FOR PROJECTS INVOLVING COMPUTER MODELING, PROVIDE THE FOLLOWING INFORMATION WITH THE FINAL REPORT:

Not applicable.