

Final Scientific Report

Planet Fuels, Inc.
Trenton Biogas Plant Re-Construction

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| Prime Recipient: | Peter A. Joseph |
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Introduction and Background to Program and Findings

During the total period of funding, the project objectives changed. The initial objective of the project was to research the health and efficacy of two commercial derivative products of levulinic acid extracted from food waste and to optimize conversion methods for manufacturing. Unfortunately, and prior to any final conclusions, the scientist performing the studies passed away leaving much of the work incomplete. Analysis of the initial work product suggested that the process for commercializing levulinic acid from the food waste product was cost prohibitive mostly due to the market readiness for the levulinic acid product.

The second phase of funding research period focused on utilizing the food waste (which had already been researched from phase 1) for other sources of energy. The focus and objectives of this phase were more focused on the technology transfer necessary to commercialize anaerobic digestion of food waste in a somewhat urban environment. During this transition, the project name changed from Trenton Fuel Works to Trenton Biogas.

The Trenton Biogas Project involves the engineering design of a renewable energy facility that will introduce a European technology to United States markets that captures the green energy value of organic materials while also producing recycled compost and fertilizer. Research related to this design addresses the goals of the Bioenergy Technologies Office by being aligned with each of the office's three main goals: Promoting national security through developing domestic

sources of energy, growing a sustainable future with renewable biomass resources and generating green jobs by stimulating a bioenergy economy. The engineering design will generate green, renewable energy and produce a range of recycled products to support local and regional agriculture and is therefore, beneficial to the public.

The proposed project will include the engineering design of an anaerobic digestion process that will convert organic waste to energy and fertilizer. The engineering design effort will involve information gathering and document preparation. The initial phase of the project involves data analysis and computer modeling to generate comprehensive technical and financial models along with a business plan.

Period 1 (Initial Hypothesis, Approaches and Objectives)

The early phase of the program goals consistent with the Biofuels and Biorefinery Development Program focused on deriving a fuel product from food waste. Levulinic acid is a molecule with multiple functional groups and therefore possesses the potential to be transformed into new families of useful molecules, as concluded in a recent DOE report.¹ In particular, levulinic acid, according to the report, *“is one of the more recognized building blocks available from carbohydrates (and has attracted interest from a number of large chemical industry firms), and for that reason, has frequently been suggested as a starting material for a wide number of compounds.”*

The report also stated that *“[t]he family of compounds available from [levulinic acid] is quite broad, and addresses a number of large volume chemical markets. Conversion of [levulinic acid] to methyltetrahydrofuran and various levulinate esters addresses fuel markets as gasoline and biodiesel additives, respectively.”*

The report recommended that a *“greater impact could be realized by focusing effort on conversion of levulinic acid to various derivatives.”* This CDP addresses this recommendation by completing essential R&D activities necessary for manufacturing levulinic acid using unrecyclable or food-contaminated paper products, as well as lignocellulosic waste from food processing, as the feedstock. Specifically, these R&D activities address optimizing the conversion of levulinic acid into two products:

1. Levulinate esters to be used as a “cellulosic diesel” to replace or supplement petroleum diesel in vehicle engine and heating oil applications, primarily in the form of levulinate ester *butyl levulinate* (BL).
2. Levulinic acid-based bio-solvents, principally gamma valero lactone (GVL) and ethyl levulinate (EL)

¹ “Top Value Added Chemicals from Biomass”, edited by T. Werpy and G. Petersen and produced by the staff at PNNL, NREL and EERE in August 2004 (Report No. DOE/GO-102004-1992).

Period 2 Objectives

The objectives of this phase focused primarily on technology transfer of European technology to the United States markets to effectively convert Food waste to Energy using anaerobic digestion technology in urban markets. The specific objectives identified below were obtained resulting in basic engineering, license agreements and material handling designs that were used to prepare financial models to be used for project finance requests. Following is the detail of each area.

STATEMENT OF PROJECT OBJECTIVES

A. PROJECT OBJECTIVES

The overall objective of this project is to design an anaerobic digestion system that generates renewable electricity, biogas and agricultural amendments using pre and post- consumer organics as the feedstock to operate at a specific property. The specific intended tasks relating to the project objectives of the Grant are listed as follows:

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| Task N. | Digester Unit: FEL-3/4 Engineering and Technology Transfer- | Completed |
| Task O. | Water Separation Unit: FEL-3/4 Engineering and Technology Transfer - | Completed |
| Task P. | Materials Handling: Design and Site Plan- | Completed |
| Task Q. | Process Integration and Costing- | Completed |
| Task R. | Lease Payments, Utilities and Insurance Costs Related to Maintenance of the Site during Design and Detailed Engineering- | Completed |
| Task S. | Application for Environmental Permits- | Completed |
| Task T. | External Review and Financial Modeling- | Completed |
| Task U. | Facility Detailed Engineering- | Completed |
| Task V. | Project Management and Reporting- | Completed |

1) All providers of professional services relating to the project have appropriate professional qualifications. Credentials include Professional Engineers, Civil Engineers, Electrical Engineers, Mechanical Engineers, Chemical Engineers, PHD, CPA, LLP.

2) The project from conception required state, county and local approvals. These approvals included requirements for inclusion into the Mercer County Solid Waste Management Plan , the approval of the Trenton Sewer Authority, concurrence from the Trenton land use boards, a determination from the county planning board and the district soil conservation office will be required. On the state level, the following permits and approvals were identified as required for this particular technology at a particular location: a 3 part air permit, NJPDES Significant Industrial User Permit, Stormwater General Permits for Construction Dewatering and

storm water runoff, Water Allocation Permit during construction for dewatering, land use approvals, and Class C Recycling Permit.

In general, the September 2014 completion of project objectives identified in the SOPO document resulted in deliverables that when combined and analyzed resulted in a positive case to further pursue development of the technology via additional investment in detailed engineering, feedstock market analysis, pricing activities, research and development, contract design, energy market studies, interconnect agreements and over 20 modifications to the original financial model created from this review.

Task N. Digester Unit: FEL-3/4 Engineering and Technology Transfer

Specific Outcome Targeted: (as per SOPO)

The outcome of Task N will be a design package for the digester unit providing detailed design information at level FEL-3/4. This information will be suitable for integration at a site-specific, commercial-scale facility. The completed engineering work will emphasize the unit's process integration with adjacent components in an integrated waste-to-energy/fertilizer facility.

Deliverables: (1) Technology transfer package. (2) Consulting activities from the vendor pertaining to engineering, set-up and integration (3) License Agreement.

Stage-gate reviews: (1) The consulting component of Task N will be conditioned on successful completion of the technology transfer package component of Task N.

Specific Results Obtained:

- 1) Fully Executed Technical Services (Technology) agreement (TSA).
- 2) Consulting activities described and delivered as per TSA.
- 3) Fully Executed License Agreement

Task O. Water Separation Unit: FEL-3/4 Engineering and Technology Transfer

Specific Outcome Targeted: (as per SOPO)

The outcome of Task O will be a design package providing detailed design information pertaining to the components required for the production of both compost and liquid fertilizers at level FEL-3/4. This information will be suitable for integration at a site-specific, commercial-scale facility. The completed engineering work will emphasize the unit's process integration with adjacent components in an integrated waste-to-energy/fertilizer setting.

Deliverables: (1) Technology transfer package. (2) Consulting activities from the vendor pertaining to engineering, set-up and integration (3) License Agreement.

Stage-gate reviews: (1) The consulting component of Task O will be conditioned on successful completion of the technology transfer package component of Task O.

Specific Results Obtained:

- 1) Fully Executed Technical Services (Technology) agreement (TSA).
- 2) Engineering drawings received with pricing for integration
- 3) Fully Executed License Agreement allowed for tech transfer to Engineer

Task P. Materials Handling: Design and Site Plan

Specific Outcome Targeted: (as per SOPO)

The outcome of Task P will be a design package containing a conceptual design, a site plan, conceptual engineering, and detailed engineering surrounding the materials-handling component of the integrated biorefinery under development at Trenton, NJ. Materials handling will be critical to the plant's success; the plant is designed to process solid and slurry waste materials requiring special handling. The final design will include a waste shed capable of receiving at least two garbage trucks simultaneously, a tipping floor, and appropriate conveyors. Emphasis will be placed on appropriate grading and tipping-floor engineering to minimize required labor.

Deliverable: Conceptual design, site plan, conceptual engineering.

Stage-gate reviews: Ongoing review of vendor deliverables.

Specific Results Obtained:

- 1) Engineering drawings received as PFD's and GA's

Task Q. Process Integration and Costing

Specific Outcome Targeted: (as per SOPO)

The outcome of Task Q will be the complete conceptual design for the proposed integrated waste-to-energy/fertilizer facility at Trenton, NJ. This deliverable will be based on the individual engineering deliverables developed under Tasks N and O. A

guaranteed maximum price estimate will be provided which is expected to lead to a fully-bonded, performance guaranteed construction contract.

This activity follows Tasks N and O, which will have provided FEL-3/4 level engineering of the digester unit and water separation unit.

Deliverables: (1) Complete set of process flow diagrams, piping and instrumentation diagrams, equipment lists for all plant components. (2) Guaranteed maximum price estimate, including capital and operating costs.

Stage-gate review: Commencement of Task Q will be conditioned on the completion of Tasks N and O.

Specific Results Obtained:

- 1) A conceptual design for the proposed facility was received in the form of PFDs.
- 2) A GMP was proposed based on the design.
- 3) Engineering firm that provided the information quit the project
- 4) A replacement engineering firm began analysis of prior work at the end of this project.

Task R. Lease Payments, Utilities and Insurance Costs Related to Maintenance of the Site during Design and Detailed Engineering

Perform site-preparation activities needed to retrofit the Trenton plant. Detailed information on, and ongoing access to, the existing equipment is need for Tasks N, O, P and Q. The outcome of this task enables the Company to maintain ongoing access to the site in Trenton while design activities proceed.

Specific Results Obtained:

- 1) Site costs were paid to property owner during the period and necessary access was granted as planned.

Task S. Application for Environmental Permits

Specific Outcome Targeted: (as per SOPO)

The outcome of Task S will be a receipt of all water, air, land-use, solid waste and community outreach permits and reviews required at the local, state and federal levels.

Deliverables: (1) Water Quality Management Planning Approval. (2) Water Supply Approval. (3) Significant Indirect User (SIU) Permit. (4) Treatment Works Approval. (5) General Permits for Construction Dewatering, Storm Water during Construction, Storm

Water for Industrial Use (all if necessary). (6) Creation of a Discharge Prevention, Containment and Countermeasure Plan. (7) Obtaining of relevant Air Permit(s). (8) Obtaining of relevant Land Use Permit(s) (if additional are required). (9) Obtaining of Recycling and other Waste Permit(s).

Stage-gate reviews: (1) Completion of Task R will be dependent on the completion of Tasks N, O and P.

Specific Results Obtained:

- 1) WQMP plan approved, no permit required
- 2) Water supply approval was found to not be necessary
- 3) SIU permit was issued
- 4) Treatment Works approval resulted in issuance of SIU permit
- 5) Storm Water permit office does not require plan until construction permit application is submitted.
- 6) Discharge prevention and containment plan was not required due to diminimous amount of stored material.
- 7) All air permits were obtained long after the period of this program expired. This program enabled the identification of additional engineering and vendor data that was eventually obtained and submitted for permits.
- 8) The land use permit was obtained
- 9) The Class C recycle permit was obtained

Task T. External Review and Financial Modeling

Specific Outcome Targeted: (as per SOPO)

Task T will provide for ongoing external review of the facility's overall approach and its specific technology and business-strategy decisions. The review will variously evaluate: technology at all process stages, feedstock mix, product mix, off-take agreements and pricing strategy. The review will be conducted by leading figures in both industry and academia.

In addition, Task T will provide for ongoing financial modeling. This work will be conducted in-house by analyst(s) hired for this finance-specific role. Deliverables will serve two main purposes. First, they will provide the financial data required by external reviewers as they evaluate the economic merits of the technologies being deployed. Second, they will form the basis of the business plan that the Company aims to take to the private capital markets.

Deliverables: (1) Comprehensive technical and financial models. (2) Business plan.

Specific Results Obtained:

- 1 A comprehensive financial model was created and utilized for technical review by both engineers and financial institutions.
- 2 An initial business memo was created to outline the key aspects of the project.
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Task U. Facility Detailed Engineering

Specific Outcome Targeted: (as per SOPO)

The outcome of Task U will be completion of detailed engineering for the proposed integrated biorefinery at Trenton, NJ. This deliverable will enable negotiation of an EPC contract on terms to be negotiated.

This activity follows Task Q, which will have provided FEL-3/4 level engineering of the entire integrated facility. See Task Q for details of the scope of the engineering.

Deliverables: Package containing sufficient detailed engineering to negotiate an EPC contract on market terms. Detailed engineering includes: layout planning, design of pipe layout and instrumentation, arrangement of components, comprehensive calculation of materials requirements, definition of interfaces, instrumentation and control, and cost control of the foregoing.

Stage-gate reviews: Commencement of Task U will be conditioned on completion of Tasks N, O, and P, and on appropriate “Go” reviews from Task T.

Specific Results Obtained:

- 1) This task was completed to the extent that a GMP was proposed by initial EPC and the proposal provided written descriptions of scope and P&IDs.