Development of a Renewable Fuel (Hydrogen) Generating Facility for Transportation Infrastructure

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Other Partnering Units: Materials Science Engineering, Mechanical and Aerospace Engineering

Objective:
This project will fund: a) a feasibility and design study to support the development of a renewable hydrogen generating facility for hydrogen fueled vehicles using the Rutgers Livingston Campus solar farm; b) a full-time graduate student and a part-time consultant; and c) an experimental field laboratory to support photovoltaic energy conversion and renewable hydrogen fuel as a teaching laboratory for graduate and undergraduate education in sustainable energy. This project advances carbon-free alternative fuel production for transportation and is a step forward in advancing sustainable energy technology.

Project description:
Sustainable energy for transportation has three central issues: oil, carbon, and growing global demand. We address these fundamental issues with a Phase 1 *design project* which incorporates the Rutgers Livingston 7-acre solar farm now under construction with a renewable hydrogen/electricity generating facility connected reversibly to the grid. Depending on demand and season, hydrogen is produced, stored in tanks, and dispensed to hydrogen-fueled vehicles. When excess power is in the grid, hydrogen gas will be produced and stored. Conversely, when summertime peak loads are high, the facility will provide electricity to the grid. The goal of this renewable hydrogen/electricity vehicle refueling facility is to transition to a Phase 2 *pilot research and testing project* that will involve corporate partners (e.g., Siemens, Linde Gas Corp.) and state government partners (e.g. NJDOT) to test a small vehicle fleet powered by renewable hydrogen fuel. Unlike fossil and renewable fuels containing carbon, hydrogen powered vehicles do not emit CO_2, SO_2, NO_X, or particulate matter. For large corporations and institutions in NJ, reducing aggregate green house gases and criteria air pollutants is essential for meeting current and future air emissions regulations and possible carbon tax and trade restrictions and quotas. Highly efficient carbon management could result possibly in revenue generation in terms of carbon offset trading.

The primary project deliverable will be a detailed design plan, cost-estimate, and commitments for hydrogen-powered vehicles provided by car manufacturers for Phase 2 research and testing. A comprehensive life-cycle analysis and projected operating cost of the renewable hydrogen/electricity refueling facility also will be generated in Phase 1. In addition, the Phase 1 effort will involve a field site that will be a teaching facility, functioning as an alternative fuel field laboratory for sustainable energy design courses. We will integrate the Rutgers EcoComplex as part of the alternative fuel field laboratory teaching facilities that will provide hands-on opportunities for graduate and undergraduate students in energy technology courses. Finally, we will convene a stakeholder workshop to facilitate technology transfer and participation by potential renewable hydrogen producers and consumers in NJ.

Project Work Plan:
<u>Task 1. Comprehensive design plan</u>
Our first objective in Phase 1 is to develop a comprehensive, detailed design plan centered on the Livingston solar farm and the components that would be necessary to construct a hydrogen vehicle refueling station. We have contacted engineer, Mike Stritzki, who has agreed to work as a consultant on this proposed Phase 1 Rutgers renewable hydrogen facility. Mr. Stritzki is a NJ based consultant and in 2008, received the NJ Clean Tech Company of the Year Award (along with his partners at the time).

Funds are requested in this AEF proposal for his assistance and expertise in designing a Phase 1 renewable hydrogen/electric refueling station on the Rutgers Livingston Campus. In addition, a pending SunGrant proposal (D. Specca, lead investigator) involving capture and purification of landfill gas at the Rutgers EcoComplex Center will connect well to the proposed Phase 1 design and lifecycle analysis work tasks in this AEF request. The proposed Quad-Gen project (SunGrant) will extract landfill gas from the landfill adjacent to the EcoComplex Center. A molten carbonate fuel cell then reforms internally the methane to hydrogen. The hydrogen gas from the landfill is intended as a fuel for vehicles: 1) for refuse trucks hauling solid waste to the landfill and 2) for on-road vehicles given the close proximity of Interstate-95 to the landfill. Stritzki has worked extensively in the design, construction and operation of renewable hydrogen refueling facilities in NJ, the U.S. and now internationally. With successful funding from AEF, SunGrant and other sources, Rutgers will be well-positioned to have to functioning renewable hydrogen refueling stations for use as 1) refueling sources for University fleet vehicles; 2) research facilities where engineering design, measurements, and systems analysis would be taught in new graduate and undergraduate energy and sustainability courses; and 3) opportunities to develop partnerships with NJ industries and new start-up companies on renewable energy systems for transportation infrastructure.

The design plan will accommodate hydrogen fuel cell vehicles that now are available from major U.S. and international car manufacturers. Stritzki will assist Rutgers faculty in obtaining vehicles from his contacts within major motor vehicle manufacturing companies. The hydrogen fuel cell vehicles will be used in Phase 2 testing of the renewable hydrogen/electric refueling system on Livingston Campus and possibly, the EcoComplex refueling station. A working NJ hydrogen fuel cell vehicle is shown in Figure 1.

Figure 1. The New Jersey Genesis, a previous Rutgers/CAIT research project, the next evolution in hydrogen fuel cell vehicles. Developed through a partnership of the New Jersey Department of Transportation, technology companies and state educational institutions, , the Genesis achieved unprecedented range and performance, breaking the distance record for a zero-emission vehicle by traveling over 400 miles on a single refueling. M. Stritzki was a lead contributor to the development of the Genesis vehicle *Source:* http://www.hopewellproject.org/pages/project.html

<u>Task 2. Life Cycle Analysis of Renewable Hydrogen/Electric Fuel Systems</u>

A key component of this proposed project is the detailed life-cycle analysis we will perform. Our goal is to design (Phase 1, AEF this proposal), develop and test (Phase 2 other funding to be decided) an alternative fuel system for transportation infrastructure. A critical assessment is to determine the "well to wheels" cost of such an alternative fuel system and to compare this to other alternative fuel options. Recently, Jafari and colleagues submitted an NSF proposal centered on a systems engineering approach for defining and modeling energy, resources and environmental valuation into the production of consumer goods and services. Figure 2 shows the relationship of energy, materials and environmental valuation for a generic consumer product (or service).

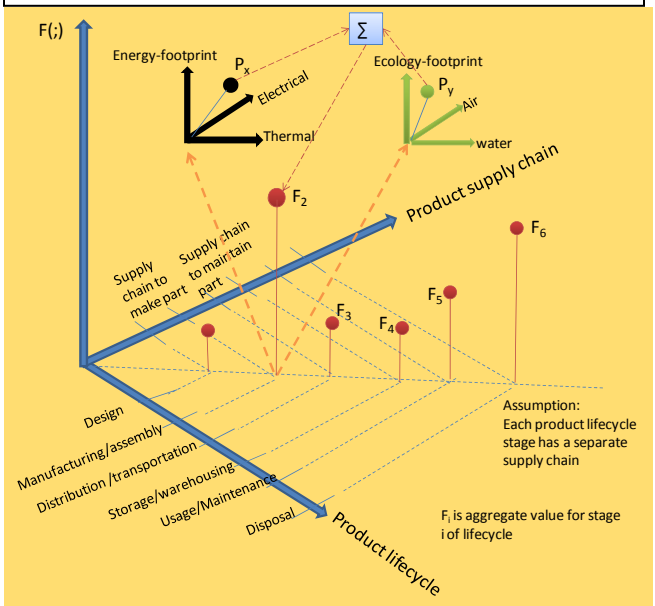

Figure 2. Modeling energy, materials and environmental components for consumer goods and services.

We intend to apply this modeling approach to the Phase 1 Rutgers renewable hydrogen facility as part of the initial conceptual design we propose in Task 1. Our preliminary model includes air, land and water. Each of these meta-elements then further decomposes to their own respective elements and sub-elements. In further decomposing these elements, we will attempt to utilize the recommendations developed by the NAE Committee on Industrial Environmental Performance Metrics (1999). However, in the same report the committee concluded there were few robust metrics and in practice, none were used systematically across all manufacturing sectors. Ideally, environmental metrics would link specific industrial activities and emissions to secular and spatial environmental impacts. However, *establishing a causal relationship between pollutants and impacts* was judged an even greater challenge and was described as a "complex undertaking" (NAE Committee on Industrial Environmental Performance Metrics, 1999).

Task 3. Experimental Field Laboratory for Graduate and Undergraduate Education in Sustainable Energy

Our Phase 1 life cycle analysis of renewable hydrogen/electric fuel systems will be an opportunity to *conduct fundamental engineering systems research and analysis, including defining metrics important for assessing the energy and ecological footprints of the system* as shown in Figure 2 for a generic product. Here, we will support a full-time graduate student whose PhD thesis will be linked to life cycle analysis of renewable energy systems for transportation infrastructure. Rutgers faculty members on this AEF proposal as well as others in partnering units have expressed interest in developing engineering systems analysis courses. The renewable hydrogen/electricity projects we hope to conduct on Livingston Campus and at the Rutgers EcoComplex will be functioning laboratories for students and faculty to design and model, particularly for metrics that can be used to assess the status or impact of the system's individual components (see Figure 2).