Fuel Cell and Alternative Energy Education Program and Projects in the High School

Ross McCurdy
Ponaganset High School

Session: Interdisciplinary programs, sustainability and alternative energy as related to engineering education

Abstract

Ponaganset High School began fuel cell and alternative energy education in 2001 and has gained momentum through innovative projects that strengthen the students' learning experiences. Students at Ponaganset initially demonstrated fuel cell technology with the formation of Protium, a fuel cell-powered rock and roll band. The successes of the Protium band led to the development of a Fuel Cell Systems pilot course that is now in its seventh year. The course covers fuel cell and other renewable energy technologies and strives to demonstrate the viability of these technologies through real-world projects. The alternative fuel vehicle projects began with a two person fuel cell-powered Quadracycle and have developed into more ambitious endeavors. The Fuel Cell Model T project began with the conversion of a 350 cubic inch V8 gasoline fueled hot rod to run on battery electric power and in September 2009 the Fuel Cell Model T successfully ran its first road tests using a Hydrogenics HyPM 12 kW fuel cell. To demonstrate biodiesel the Coast to Coast Biodiesel Pickup Project was initiated. Three students and a science teacher prepared and drove a GMC K3500 turbo diesel pickup donated by Con Edison Solutions from Rhode Island to Malibu, California on B99 biodiesel and made the trip without refueling along the way. One of the challenges with these projects was a lack of dedicated space in the school, requiring the majority of the work do be done after school and weekends. To maximize student learning opportunities during the school day a dedicated Energy Lab is now under construction at Ponaganset and is scheduled for completion during the 2009-2010 school year.

Introduction

The environmental effects of industrial society are considerable, and the fossil fuels the modern world relies upon are in limited supply. Industry, buildings, and the automobiles that we utilize daily all contribute to the environmental deterioration that includes air pollution, acid rain, and water pollution. As fuel cells produce zero emissions when fueled with hydrogen and hydrogen can be produced through sustainable means, fuel cell technology offers considerable hope for a cleaner, brighter, and sustainable future. While offering numerous benefits including a higher efficiency than internal combustion engines, zero emissions when fueled with hydrogen, and the potential for sustainability, fuel cells were rarely seen outside of news articles, magazines, and television documentaries. Since 2001 the Fuel Cell Program has broadened to become the Ponaganset Alternative Energy Program, which includes biofuels, solar, and other renewable energy learning and projects. Education through demonstration is our way of leading by example, and the initiative strives to demonstrate in a clear and exciting manner the potential for renewable energy applications in society. The students of today are the leaders of tomorrow;

by clearly showing our students the means for a better future, we can make this vision a reality and enable it to become a reality sooner.

Background

Ponaganset High's Fuel Cell Education Initiative began in the spring of 2001 with little more than a basic understanding of the benefits of clean, sustainable energy inherent to fuel cell technology, and the vision to educate and demonstrate to students the benefits of fuel cell energy in a science curriculum. As the students of today are the leaders and consumers of tomorrow, education represents a critical component toward furthering the wide-scale implementation of fuel cells in our society. Through a Perkins Foundation grant, ten solar hydrogen fuel cell lab kits were acquired for classroom use and were the first step in establishing fuel cell education at Ponaganset High. These Heliocentris lab kits enabled students to produce hydrogen through solar-powered electrolysis and use the generated hydrogen to power a small fuel cell in the one watt range. The electricity generated by these fuel cells was used to power a tiny light bulb and spin a small wheel about the size of a quarter. While these lab kits are outstanding for student learning of fuel cell fundamentals and continue to be a useful component in the classroom, seeing a wheel the size of a quarter spin does not generally instill a sense of awe or excitement among students. With another Perkins grant came the next fuel cell acquisition, a Ballard Airgen – a significant step for the school in regards to power output. The Airgen was capable of producing 1000 watts of usable AC wall-quality power, considerably raising the bar for fuel cell education. With this available power, *Protium*, the world's first fuel cell-powered band, was created to demonstrate fuel cell technology in an exciting and clearly understandable manner. The *Protium* fuel cell demonstration project was an immediate hit. Suddenly the entire student population knew about fuel cells and what they could do, and a high level of interest and enthusiasm was generated for this beneficial technology.

Word of Ponaganset High School's fuel cell education program soon spread among the local renewable energy community and *Protium* was invited to provide a fuel cell demonstration performance at the 1st Annual Connecticut Clean Energy Fund's Fuel Cell Investors Summit held on March 17th 2003. This was a major turning point, for it was at this event that Ponaganset High School's fuel cell education program came to the attention of Dr. Michael Binder with DOD's ERDC/CERL. Dr. Binder immediately recognized the educational value and potential of this nascent program and with members of the Fuel Cell Test and Evaluation Center (FC*Tec*) established a highly beneficial collaboration between FC*Tec* and Ponaganset High School's Fuel Cell Education Initiative. The objectives of this collaboration were further development of the fuel cell program, fuel cell demonstration of the program, sharing the results of the program, and program documentation. This joint venture between FC*Tec* and Ponaganset High School enabled a quantum leap to be made in fuel cell education and demonstration, effectively transforming an under-funded local program to a highly successful initiative recognized throughout the global fuel cell community. Through a contract with FC*Tec*, Ponaganset High School's Fuel Cell Education Initiative was able to procure the fuel cells and equipment required to achieve the objectives of the program.

An Avista Labs Independence 1000, generously donated by ReliOn (previously Avista), was the next fuel cell obtained by the Initiative. This fuel cell further contributed to fuel cell education both in and out of the classroom, creating learning opportunities involving hot-swappable removable cartridges, volts, amps, and power conversion. With the Avista fuel cell,

the available fuel cell power output was now doubled, enabling the demonstration project to attain the audio output level to perform in a large concert hall, ballrooms, and outdoor shows, while delivering top quality sound. A sponsorship by Millennium Cell and the generous donation of one of their RM1500 Hydrogen on Demand systems enabled components of the fuel cell demonstration to be operated without pressurized hydrogen through the use of an aqueous Sodium Borohydride solution. The underlying chemistry and operation of the Millennium Cell system also provided an outstanding chemistry lesson to the students of Ponaganset High.

As Ponaganset High's Fuel Cell Education Initiative gained momentum and equipment, the learning opportunities were significant. In science class the projects-based learning involved the creation of an operational fuel cell vehicle, and the benefits of fuel cell technology were shared with students school-wide and beyond as numerous fuel cell demonstrations were performed by *Protium*.

To further develop the fuel cell program, a year-long pilot Fuel Cell Systems course was created. The course has since broadened to cover a wide range of renewable energy topics and projects and is currently running for the seventh consecutive year. With four individual classes now running, the course instructs students on the fundamentals of fuel cell technology, solar, biofuels, and other energy topics and related science.

Fuel Cell-Powered Band

Education through demonstration is a significant component of Ponaganset High's Fuel Cell Education Initiative. To further the mission, *Protium*, the world's first fuel cell-powered band, was created to demonstrate fuel cell technology in an exciting and understandable manner. Beginning with a single1 kW fuel cell and a very modest sound system, *Protium* is now using 3 kW of fuel cells to power a professional PA system. Since the band began in February 2003, *Protium* has performed numerous fuel cell shows including charity fundraisers at school and fuel cell conferences throughout the country. *Protium* has performed for the National Hydrogen Association in Hollywood, the 2003, 2004, and 2005 Fuel Cell Seminars in Miami, San Antonio, and Palm Springs, respectively, and the Rhode Island Earth Day Festival. The fuel cell band was the catalyst that led to the creation of the Fuel Cell Systems course and brought the program to national attention, building a foundation of success for following projects. With the members now graduated from high school and enrolled or about to graduate from college, Protium is currently on hiatus.

Protium fuel cell demonstration performance at the 2005 Fuel Cell Seminar in Palm Springs, California.

Fuel Cell Model T

As a component of the course, students learn about transportation applications of fuel cells and have researched and designed plans for a simple, yet functional 2-person fuel cell-powered Quadracycle. These research and design plans became a functioning reality when the Fuel Cell Quadracycle, Rhode Island's first fuel cell vehicle, was completed. After successfully completing the road tests, the Fuel Cell Quadracycle made its debut at the school's Field Day. Rides were given to students, teachers, and even the principal throughout the afternoon of the event. While many have read about fuel cell vehicles or seen them on television, this was the first opportunity for members of the school community to actually ride in a fuel cell vehicle. Knowing the FC Quadracycle was actually designed and assembled by Ponaganset High's students made this exciting demonstration even more meaningful. With the completion of the Fuel Cell Quadracycle, several performance upgrades were considered. After reflection and discussion it was decided to begin a completely new vehicle project - a full-size, street legal fuel cell vehicle capable of normal cruising speeds and range. It was actually a student who suggested the use of a "T–bucket" as the platform vehicle. The T-bucket is the original hot rod created from the Ford Model T, and being lightweight, relatively simple to work on, and historically significant, is well-suited for the endeavor. With that student's suggestion, our Fuel Cell Model T (FCT) project was born. Not surprisingly, the student who suggested the T-bucket platform became an engineering student in college and earned a 4.0 GPA his first semester! Working from a foundation of success established with the previous fuel cell education projects, presentations were made and funds were raised to begin the project. Sponsorships for the FCT came from various sources including the Fuel Cell Test and Evaluation Center, Logan Energy, RI Resource Recovery Corp., and the RI State Energy Office. The first steps included locating, purchasing, inspecting, and registering the T-bucket vehicle with FUELCL vanity plates, purchasing the electric motor and controller system, and road testing the vehicle.

In March 2006 the Model T roared into the off campus garage powered by its Chevy 350 V8. Working weekends and after school, the team removed the engine and transmission and began Phase I of the project, conversion to a battery-electric Model T. Three months later the electric conversion was complete and the Model T rolled out of the garage with the uncanny silence of an EV. While the EV conversion was challenging, Phase II of the project, integration of the fuel cell, was even more ambitious. The hardest part of any fuel cell project is actually getting the fuel cell. Our previous successes with Protium, our fuel cell powered band, enabled us to meet the people at Hydrogenics and with their help acquire an HyPM 12 kW mobility fuel cell. The first step was learning to use the fuel cell in the lab using Controller Area Network (CAN) and labVIEW programs along with a donated TrippLite inverter to produce AC power. Once the Hydrogenics fuel cell operation in the lab was routine we began work to fit the fuel cell and support components in the rather small Model T. To make room for the fuel cell, radiator, and deionized water cooling loop we literally cut the car in half with an oxy acetylene cutting torch and stretching the frame 29". This provided plenty of room for the fuel cell system as well as our twin hydrogen cylinders donated by Lincoln Composites. Considerably longer, and now painted flat black, the lines of the Model T have the custom cool look of a classic hot rod with an eclectic mix of the latest propulsion technology. A remaining challenge was integrating the electrical output of the fuel cell with the Model T's electric drive system. Using a Curtis controller and a dozen 12 volt Optima deep cycle Yellow Top batteries wired in series the T had a 144 volt drive system. Our Hydrogenics HyPM 12 kW fuel cell put out approximately 48 volts. The plan was to acquire a DC-DC upconverter to bring the fuel cell voltage output up to

the 144 volts of the electric drive system. Unable to find a suitable DC-DC upconverter at the time we did the next best thing and installed an Alltrax 48 volt controller with four Optima batteries wired in series. While this system has reasonable performance, it is lacking the power of the 144 volt system and work is underway to acquire and integrate a DC-DC upconverter and utilize the twelve battery 144 volt system. Around April of 2009 a reporter for the Rhode Island newspaper, The Providence Journal, contacted us to do a story on our Fuel Cell Model T. We didn't want a story until our vehicle was finished, and after a summer of work our Model T was finally operational on fuel cell power in September 2009, and the newspaper article was printed. Along with the article our Fuel Cell Model T also appeared on local television news and perhaps the crowning achievement, photos and an article are in the March 2010 issue of "Hot Rod Magazine". The world of digital media is not limited by geographical distance and word has spread about our Fuel Cell Model T. Another photo article has been written and will be appearing in an issue of the Australian car magazine "Street Machine".

Fuel Cell Model T
September 2009

Coast to Coast Biodiesel Pickup Project

Along with fuel cell technology, the program has broadened to encompass other renewable energy technologies including biodiesel and biofuels. One of the great advantages of biodiesel as an alternative fuel is that it can be readily purchased at prices comparable to or better than petroleum diesel and used in existing diesel vehicles without modifications. With minimal equipment and expertise biodiesel can also be "home-brewed" from used vegetable oil. To demonstrate the benefits and reliability of biodiesel the Coast to Coast Biodiesel Pickup Project was developed. For this project three students and I drove a GMC K3500 turbo diesel donated by Con Edison Solutions from Rhode Island to California on B99 (99% pure) biodiesel. Inspired by Charles Lindbergh's historic 1927 New York to Paris flight across the Atlantic, the goal of the project was to drive the entire 3,000 mile trip without refueling by using biodiesel stored in three Delta Consolidated auxiliary tanks mounted in the bed of the pickup. With 250 gallons stored in the three auxiliary tanks and an additional 30 gallons in the stock tank the entire fuel supply was 280 gallons, over one ton of fuel. This venture was successful and in August 2008 the Biodiesel Team arrived at Surfrider Beach in Malibu, California with approximately 40 gallons of biodiesel remaining. Refueling with more B99 biodiesel in California and Missouri, the two week round trip covered over 7,000 miles, all using biodiesel. The stock turbo diesel engine ran fine and the only repair made on the journey was the replacement of a headlight. The trip received considerable media attention from newspapers, television news, the internet, and diesel truck magazines "8 Lug" and "MaxxTorque", all helping to promote biodiesel as a viable,

reliable, cost effective, and easy to use alternative fuel. More information can be found at www.biodieselpickup.blogspot.com

Alternative Energy Lab

The newest development for the program is the construction of an Alternative Energy Lab, scheduled to open in the Spring of 2010. One of the biggest program challenges has been the lack of space available to work on and store the Fuel Cell Model T and similar projects planned for the future. The Fuel Cell Model T was constructed five miles from Ponaganset High School in garage space donated by community member and parent team leader Jim Sullivan, with the work taking place after school and on weekends. While we look forward to continued project work in Jim's well-equipped garage, the Alternative Energy Lab will be a dedicated space designed to address the serious need for comprehensive energy education including stationary, mobile, and portable energy applications covering both cutting edge and traditional energy sources. The Alternative Energy Lab is equipped with a garage door, dry chemical fire suppression system, and 220 volt outlets for EV fast-charging and welding. The Alternative Energy Lab also includes a separate Communications Technology room that will be equipped with a full computer lab, video conferencing system and other digital resources. The projects will address relevant, current issues and will include electric vehicles, fuel cells, biofuels, solar, wind, and other energy technologies. The Alternative Energy Lab will provide the environment needed to shape energy education and innovative energy projects well into the future.

Engineering Education for the Digital Generation

Many of our alternative energy projects including our fuel cell band, fuel cell Quadracycle, and Biodiesel Pickup required little if any direct requirement for personal involvement with digital systems. While the equipment used for these projects utilized digital systems operating in the background, user involvement was not required. Conversely, sharing the results of the program and projects relied almost completely on digital media. Digital photography, camcorders, emails, the internet, and websites including www.protium.us were all used to develop the program and to share information on these projects. Entering the realm of serious fuel cell power with the Hydrogenics 12 kW fuel cell required the utilization of digital systems at an entirely new level. Operation of the Hydrogenics fuel cell required the built-in Operating System Controller to be controlled by a laptop computer using a C.A.N. (Controller Area Network) program. The CAN computer program was developed by Bosch in the 1980's and is the program used by virtually all cars and trucks built since the late 80's. The CAN program is not particularly intuitive or user friendly to the inexperienced. To make the CAN system intuitive and easy to use the labVIEW program is used to operate the CAN system. The end result of this is a laptop screen with a user-friendly interface composed of mouse clickable buttons written in simple terms such as "on", "off", "system cool down" combined with real time data including temperature, volts, amps, etc. Using the labVIEW virtual interfaces (VI's) just about anyone with a quick introduction is capable of operating the fuel cell system.

Another area where digital skills were essential was in the repair of one of our Ballard Airgen 1 kW fuel cells. After using the Ballard Airgen at a GovEnergy Conference demonstration the fuel cell would not work the next time an attempt to use it was made. Using labVIEW again a diagnostics test was run on the Airgen and we were able to get it running

again. Digital manipulation of the Alltrax EV controller through a laptop is also required to set the system. Working with these systems it is clear that knowledge of digital systems is essential for the 21st Century engineer and the use of CAN, labVIEW, and other computer programs will be necessary engineering tools.

Acknowledgement

The Ponaganset Alternative Energy Program and Projects have been made possible through the support of many people and organizations. For their vision and support we would like the thank the Ponaganset High School Administration and School Committee, the remarkable students and parents who have spent near endless hours on these projects including student team leader Zane Lewis, parent team leaders Mike Lewis, Jim Sullivan, and John Murphy, Julie Capobianco and the Rhode Island Office of Energy Resources, Ray Fogarty and the Ponaganset Building Committee, Architects Aharonian and Associates, and the Fuel Cell Test and Evaluation Center. Our sponsors include Hydrogenics Fuel Cells, Con Edison Solutions, Lincoln Composites and many others. A complete list can be found on our website at www.protium.us/sponsors/index.php

We also want to extend our sincere thanks to Dr. Michael Binder, whose dedication and effort has contributed so much to fuel cell education and the industry. To the many, many people who have been involved with these endeavors, thanks for believing in our students!

Biography:

Ross McCurdy, Ponaganset High School

Ross McCurdy served in the Air Force as a Russian Linguist and received a B.A. in Biology and Masters in Science Education from Rhode Island College. Currently teaching Chemistry and Fuel Cell classes at Ponaganset High School in Glocester, Rhode Island, he has developed a fuel cell and alternative energy program to demonstrate renewable energy technologies and bring innovative and exciting learning opportunities to students.

Ross McCurdy
Ponaganset High School
137 Anan Wade Road
N. Scituate, RI 02857
rkmccurdy@yahoo.com
www.protium.us
401-710-7500