Applied Science Grants by SRP

2008-2009 Application
Grades 9-12

Application and Proposal (Must be postmarked by midnight March 28, 2008)

Name of School: Fountain Hills High School

School Address: 16100 PALISADES Blvd City: FT HILLS ZIP: 85268

School District: Fountain Hills Unified School District #98

Amount of Request: $5,000

Name of Person Responsible for Proposal: Dr Paul McElligott

Affiliation with School: Science Chair

Home Phone: (480) 837-5809 School Phone: (480) 664-5573

Primary E-mail: PMCELLIGOTT@FHUSD.ORG Secondary E-mail: DRPMCE@HOTMAIL.COM

On a separate double-spaced typed sheet(s), please outline your proposal under all of the following headings:

1. Project Title
2. Project Description and Timeline
   - Describe the activities of your project and explain how it demonstrates practical application of scientific principles.
   - Explain student hands-on involvement in the project activities.
3. Student Impact
4. Innovation
5. Budget
6. Evaluation

A signed affidavit **MUST** be mailed by the deadline.

Applied Science Grants by SRP Program Affidavit

This is to certify that all the information contained in this application for the Learning Grants by SRP is true and factual to the best of my knowledge.

Principal's/School Official Name: Kari King

Principal's Signature: Kari King

Name of School: Fountain Hills High School

Please return with proposal to: Darrell Sheppard
PAB332, P.O. Box 52025, Phoenix, AZ 85072-2025
Delivery Address: 1521 N. Project Dr., Tempe 85281
(next to the Hall of Flame Museum)

SRP Applied Science Grant 2008-2009

Dr. Paul McElligott
Fountain Hills High School
16100 Palisades Blvd
Fountain Hills, AZ 85268

INTEGRATION OF A FUEL CELL INTO A PHOTOVOLTAIC SYSTEM SERVICING THE NEEDS OF THE FOUNTAIN HILLS SCHOOL DISTRICT

PROJECT DESCRIPTION AND TIMELINE

The rationale of this project is to develop alternative green energy sources to supplement the energy needs of the Fountain Hills Unified School District. The district budgets are growing tighter with legislative changes and financial constraints. The Science Research Club of Fountain Hills High School has a focus of exploring and testing alternative energy sources. The culmination of three years of research suggests that solar energy and hydrogen-driven fuel cells could produce cheap, non-polluting energy day or night. A large photovoltaic system was recently installed at the school district Transportation Center. While the efficiencies of this system are being studied, it is the proposal of this project to purchase and integrate a 1 kilowatt fuel cell into the photovoltaic system.

Project Background

Research began in 2005 with two objectives: a) to investigate the most efficient method of hydrogen production, and b) to examine various types of fuel cells and choose the best option for energy production. We have found that the most efficient method of hydrogen production utilizes high-saturated salt solutions at elevated temperatures augmented by ultrasonic waves. In addition, we have found that the best method of energy production from hydrogen will be PEM fuel cells that use air for an oxygen supply.

The second year had two evolving goals. The first goal was to produce a scale model of an electric system capable of delivering enough power to a moderate scale piece of equipment. We were successful at acquiring the electronics capable of several hours of power, delivering up to 150 watts of power draw from the four large photovoltaic array panels. In addition, the team constructed an electrolyzer and a hydrogen storage tower to feed hydrogen through the fuel cells.

The second goal of this project was completed in spring 2007. We acquired an electronic fuel cell analyzer and four of the five fuel cells we planned to assess. This phase of the studies measured gas consumption, energy production, and efficiencies. The goal was to study and identify the best PEM fuel cell system,

array and lifetime. Initial testing was completed in May. However, we realized that the optimal fuel cell was dependent on the photovoltaic system, so the final decision won't be made until we have an opportunity to assess the fuel cells with the recently installed permanent photovoltaic system.

Because of the above issues, this past year focused on installing a $15,000 photovoltaic system. In a cooperative arrangement with ETA Engineering and SRP, a photovoltaic system was installed on the roof of the Transportation Center for the Fountain Hills School District in October 2007. Work on fuel cells will be on-going, but the primary work this year will be measuring the efficiency and payback of a photovoltaic system.

2008-9 Project Description

The current project will be in three phases:

1. The **first phase** involves the monitoring of the photovoltaic system, newly installed on the property. These results will be matched with the sun's intensity. A new weather station in place on our roof will monitor and record the sun intensity on a minute-by-minute basis. From this we will determine the efficiency of the system.

2. The **second phase** examines the actual output of energy from the photovoltaic system and the energy offset that will occur from this system. The power reading is monitored and regulated by a Sunny Boy Inverter that sends signals to our computer system. The data will be accumulated and compared to the daily usage from the transportation building. From this data the energy saved will be cost examined and a return on investment will be determined.

3. The **final stage** is to acquire and use the selected fuel cell in the 1 kilowatt sizing. It will be tested under normal field conditions with an online tool and examined for its useful life as well as the number of its rechargeable lifetimes. The longevity of the fuel cell and its match with the tool of choice will be examined over the course of a few months. The fuel cell will be hooked up to the Sunny Boy Inverter and power can now be added to the building, rain or shine.

Project Time Line and Results To-Date

Summer 05 – April 06

Extensive literature searches were done over the summer to research and investigate the technology of fuel cells. It appeared that the PEM cell would probably be the fuel cell of choice to convert hydrogen to electric

energy. Tours of the ASU-PTL facility revealed that the PEM cells are the cells of choice to convert to DC power.

Minor studies, examining the effectiveness of fuel cells, were conducted on two fuel cells purchased from the Hydrogen Organization. Our findings revealed the efficiency to approach 25-30% in the conversion of hydrogen to DC electricity. All other attempts at new fuel cells, both catalytic and chemical, were well under this efficiency.

Basic research, presented at the ASU CARSEF Competition in April 2006, revealed that there is a priority in effecting the rate and efficiency of hydrogen production. We have found that although the main driver for increased production is ionic concentration of the electrolyte solution, the early research did indeed point the way to improve the efficiency of hydrogen production by the addition of higher frequency radiation such as ultra-sonic waves, microwaves and potentially laser.

Since we are cost conscious, we opted for thermal, high current electrolyte solutions compounded with ultrasonic radiation. To further the use of clean power, solar energy will be used to supply pollution free energy. A grant written for ASU was funded and four solar panels were donated in spring 2006.

March 06 – December 06

Fuel cells and an analysis kit were ordered but not received until December. The cell kits were constructed and basic tests were conducted. Fall 2006 was spent developing a demonstration board. The electronics of this panel were developed to deliver the capability of taking the four large photovoltaic panels, converting its energy to a stable DC 12 volts and then converting it through an inverter to 120 volts and 10 amps of AC power.

The test panel was used to research the capability of the solar panels in several types of weather and determine their ability to deliver both DC and AC power. Test devices such as light bulbs and other pieces of equipment with specific energy draw were examined. The panel works at or above its design specifications and was found to be almost at the level that will be used for the project next year for the district.

In addition to this electrical design and test work the team took the research last year and designed an electrolyzer and a hydrogen gas storage unit. The experimental electrolyzer was developed out of ABS plastics and stainless fittings with power provided by a 30 volt 25 amp variable source. The electrolyzer had internal copper leads and was completely pressure sealed with one stainless port at the top for gas escape. The port was

connected to hydrogen impermeable tubing and connected to a six-foot water tower storage container.

The hydrogen container, also made of ABS and stainless fittings, was developed after the pattern of natural gas storage units. The outer tube was inverted up and contains water up to a foot below the top. The inner ABS is inverted down with a fitting on top. The inner tube would ride as gas enters the inner tube. It is shut off at the end of the generation cycle and can contain up to 15 liters of gas at slightly over ambient pressure. The tube is purged on occasion with helium gas to avoid oxygen contamination. Both the electrolyzer and storage tank worked to desired specifications.

December 06 – April 07

Fuel cells were tested with a sophisticated analyzer and their capability was examined and used to determine the best fuel cell set-up for the district equipment. The PEM fuel cell is still the fuel cell of choice. The results of the 2006-7 studies demonstrated that the output of energy varied greatly with conditions of the cell as well as hydrogen pressure and flow, moisture in the cell, and temperature.

Our premise was that fuel cells could survive the Arizona desert under the right circumstances. The cells performed well in the winter and spring months giving peak performance, however the summer caused a high strain on the cells and the membranes became damaged. Further research demonstrated the temperature rose above ambient 105-110 F. This is where most cells fail. A cooling system for the cell will be needed or at least cooler than ambient conditions will be needed for the cells to survive. There are air conditioned areas in the Transportation Center (future location of permanent photovoltaic panels) and air cooled places in the garage that should help the fuel cell survive.

Our main problem was that we were not sure which photovoltaic system we could afford and this would impact our choice in inverters as well as fuel cells. The decision was to delay further fuel cell work until the photovoltaic panels were purchased and installed.

December 07 – May 09

A new photovoltaic panel system was purchased with installation at the School District Transportation Center in October 2007. Part delays and inspections postponed actual commissioning and operation until December 27, 2007. The system is being hooked up through the district intranet to acquire data which will be monitored and compared to the sun

radiation for efficiency studies. The energy produced by the panels will be monitored and the savings cost reviewed. A full return on investment will be examined.

A survey of the district facilities, but the equipment selection for the fuel cell study was delayed until the new photovoltaic system was installed. Fuel cell studies are on going but will be superseded by the photovoltaic panel studies that are now being organized. Fuel cell work this year will involve studying the capability of the fuel cell under stress of temperature and low moisture conditions.

At the conclusion of this fuel cell research recommendations will be made with the new system in mind. A 1.0 kilowatt fuel cell will be purchased with new grant money to integrate into this system through the inverter.

Student notebooks and a presentation will be completed for the 2008 Arizona Science Engineering Fair (AZSEF, formerly CARSEF) competition based on the current studies with the photovoltaic `the fuel cell into the photovoltaic system.

STUDENT IMPACT

The project will involve the members of the Research Club, numbering 12-15 high school students. The project demonstration model that the installation is based on, is a model used for learning in the Advanced Honors, AP Chemistry, and AP Physics classes numbering 125 students. In addition, the solar installation is available for demonstrations to 2,500 students in the school district. Teachers will be able to download active data generated from the photovoltaic system through the district web site. Potentially, teachers from all grades (K-12) and 200 classrooms can access real-time alternative energy data and match it with weather data generated by the district weather station.

Student Learning Outcomes

Research Phase

Students will:

- Understand and apply the scientific method;
- Maintain a research notebook;
- Learn literature research techniques at the ASU library;
- Learn laboratory research techniques;
- Apply their scientific knowledge to a real-time project.

Students will find a suitable fuel cell and:

- Learn to identify the power needs of the Transportation Center;
- Learn research optimization techniques;
- Apply optimization techniques to actual fuel cell evaluations;
- Learn to develop a cost-based research approach.

Development Phase

Students will work with the 1.0 kilowatt system and:

- Discover the efficiency of the photovoltaic panels;
- Determine the energy produced over several months;
- Determine the return on investment from photovoltaic system;
- Present a summary of the work to the school board;
- Prepare a presentation for the AZSEF Competition.

INNOVATION

This project is a unique blend of new technology [solar energy and fuel cell technology] applied to visual and computer graphics that will be accessible throughout the entire school district. The project is led by a PhD research chemist who teaches high school courses while supervising the Research Club through this investigation. The technology can be used to cover the a) physics competencies in electricity and energy, b) the chemistry competencies for energy conversions as well as reactions and change in states, and c) the physical science competencies in solar energy, weather contributions to geo-systems, and our environment. Finally, this is a great project that brings together all the aspects of Science, Technology, Engineering, and Mathematics (STEM), a federal initiative to teach from a multiple disciplined platform.

The project is a green project that allows students to investigate first-hand alternative energy sources and to evaluate their ability to impact our world as a practical useful energy. This year we are looking at both fuel cell technology and photovoltaic systems. The long term goal is to integrate the two energies into a practical resource for the school district. The project allows real hands-on experiences that motivate students toward science. The fact that we have a 1.0 kilowatt system integrated into the power grid gives students a true feel of the usefulness of alternative energies.

Benefit Statement

The students will benefit by:

- Experiencing a real-time research program;
- Applying their chemical knowledge to a real problem;

- Working towards a project that will potentially be entered in regional competitions of the AZSEF Competition,
- Examining fuel cell cars as a model of a working system;
- Working towards a project that will potentially be an energy savings to the school district.

The school will benefit by:

- Drawing off the momentum of an accomplished science project that contributes to the environment;
- Starting a new Independent Study program in Research, looking at hydrogen and alternative energy (beginning fall 2006);
- Gaining free access to new rechargeable technology that will back up and drive needed machines;
- Having successful projects entered in the AZSEF Competition which offers visibility to the school's science programs, experience for our students, and potential student scholarships;
- Saving energy that would have been used by the district as well as gaining energy credits, investment rebates and tax credits.

The environment will benefit by

- Reducing solid waste from toxic batteries that are commonly thrown away;
- Developing renewable energy sources that will not pollute the air;
- Using energy directly from the sun and not from other polluting sources such as coal.

BUDGET

Projected Budget for Proposal, 2008-9

Fuel cell 1 KW	$8,000-$12,000
Hydrogen tank (low carbon steel)	$500
Tubing and fittings for hydrogen usage	$500
Electronic testing equipment & computer gear	$1,000
Total Projected Budget	**$11,000-$15,000**

Historical Budgets for Current and Previous Years

Budget 2007-8

Photovoltaic panels	$8,000
Installation of photovoltaic panels	$5,000
Rebate	($4,000)
District Contribution	($4,000)
Subtotal Photovoltaic Panel Budget	**$5,000**
Fuel cells	$2,000
Hydrogen tank (low carbon steel)	$500
Tubing & fittings for hydrogen usage	$500
Electronic testing equipment & computer gear	$1,000
Chemicals and gases	$1,000
Subtotal Fuel Cell Research Budget	**$5,000**
Total Projected Spending	**$10,000**
SRP Grant	($5,000)
Carryover from 2005-7 (Surplus)	($2,900)
Total Income	**($7,900)**
NET DEFICIT	**$2,100**

Budget 2005-7

DC/DC Voltage regulator	$500
Chemicals for Cells Includes small containers of gases (hydrogen, oxygen), electrodes (platinum, silver), and various salt solutions. ($1,000 spent)	$2,000

3 Teck fuel cells for development and testing	$500
One 3 stack fuel high voltage cell	$500
Fuel cell Technology books	$200
Photovoltaic panels to supply power	$15,000
One 10 stack fuel cell	$1,500
Storage Tanks (low carbon steel)	$200
AC/DC Intraverter	$100
Fuel cell testing device	$1,000
Batteries	$200
Hydrogen tank with regulator and gear	$800
Total Spending	**$22,500**
Private donations	($400)
SRP grants	($10,000)
FHUSD Science Department donation (storage tanks)	($200)
ASU donation (photovoltaic panels)	($15,000)
Total Income	**($25,600)**
NET SURPLUS	**($2,900)**

EVALUATION PROCESS

Measures of Student Goals

- Quality of research notebook (turned in monthly). **On-going**
- Investigation of solar panels for providing power for hydrogen production. **Complete**
- Identify fuel cells (deadline April 2007). **Complete**
- Identification of several tools for application of the battery/fuel cell (deadline May 2006). **Complete**
- Matching existing cells to tools. **Complete**
- Complete test device to regulate and convert solar energy to AC. **Complete**
- Develop a model electrolyzer and hydrogen storage unit. **Complete**
- Test several fuel cells in various configurations. **On-going and extended**
- Site survey of power plant in district. **Complete**
- Get district approval to purchase and install larger scale clean energy source. **Complete – Photovoltaic System**
- Buy and install equipment for power plant. **Complete December 2007**
- Monitor and adjust to optimize power consumption of this energy at the power plant. **Starting Spring 2008**
- Write up results for publication and competition. **Spring 2008 and 2009**
- Continue to do research and development on fuel cells and solar power delivery and optimization. **Spring 2009**

Measures of School Goals

- Create and test an electronic device. **On-going until 2009**
- Interface a renewable energy fuel cell with a photovoltaic system equipment device. **Delayed until 2008-9**
- School uses the power source and realizes savings. **Begins January 2008**
- Publicity for SRP and the school is gained from the success.

Measures of Environmental Impact Goals

Impact in the following areas can be calculated based on number of district machines converted to this energy source. **Scheduled for 2008-9**

- Less solid waste that creates financial savings and minimizes waste;
- Removal of toxic materials from the environment;
- Clean non-polluting fuel that improves air quality.

Solar project helps FH students learn

By Ofelia Madrid
THE REPUBLIC | AZCENTRAL.COM

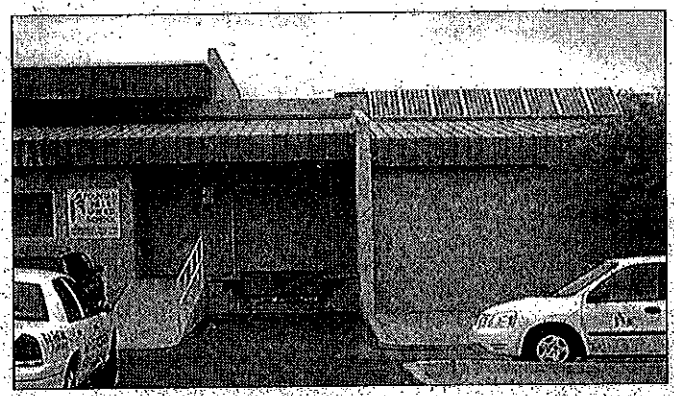
FOUNTAIN HILLS — When classes resume next week, a group of Fountain Hills High School students will get hands-on experience on how photoelectric energy saves money.

The students will gather data coming from eight photo panels installed on the roof of the Fountain Hills Unified School District's bus transportation barn. The panels turn sunlight into electricity.

"The data coming off the weather system tells us how much energy the sun is putting out and the computer system at the bus barn figures out how much energy is being produced," said Paul McElligott, the club's adviser.

"The eight cells on top of the building are active now, putting energy into the transportation building. The excess goes out to the grid and (the district gets) credits."

In November, the high school Research Club had photo panels installed by ETA Engineering. The $12,000 project is funded by Salt River Project, Arizona State University's Photovoltaic Testing Lab and the district. The panels were commissioned Thursday.



The Fountain Hills School District transportation building boasts solar panels as part of a three-year project to study alternative energy. Below, workers from ETA Engineering and SRP check out the power installation.

PHOTOS COURTESY OF PAUL MCELLIGOTT

"The 1,400-kilowatt system was installed as part of a three-year project to study alternative energy for supplying power to the district," McElligott said. "The system is expected to provide energy credits to the district as well as conserve power usage. The purchase also provides rebates from an SRP solar program as well as tax credits."

The project is also a way for the students to gain experience in researching photoelectric energy. The students plan to write reports and enter a spring ASU engineering competition with a chance of winning scholarship money, McElligott said.

FHHS science students helping shrink environmental footprint

If you're worrying about environmental footprints and the like, Fountain Hills High School science students are working hard to do something about it.

Students in Dr. Paul McElligott's advanced placement and honors physics classes recently began working with a photovoltaic solar project.

A solar system has been installed at the school district's transportation building. Students have begun researching the effects of the solar system and will be doing a full analysis of the project before the school year ends.

"We want to get the school district involved with the project," McElligott said. "Our primary drive is to get a return on the physical investment, get tax and energy credits and to prove to the district what a benefit solar can be."

The solar system is being used to run the main power at the transportation building. It is designed to help the district earn energy credits to offset utility costs.

"The long-range goal is to convince the district that this is a great way to watch capital expenditures," McElligott said.

"Meanwhile, the students are learning about one aspect of going green." McElligott said about 120 young people are involved with the solar project.

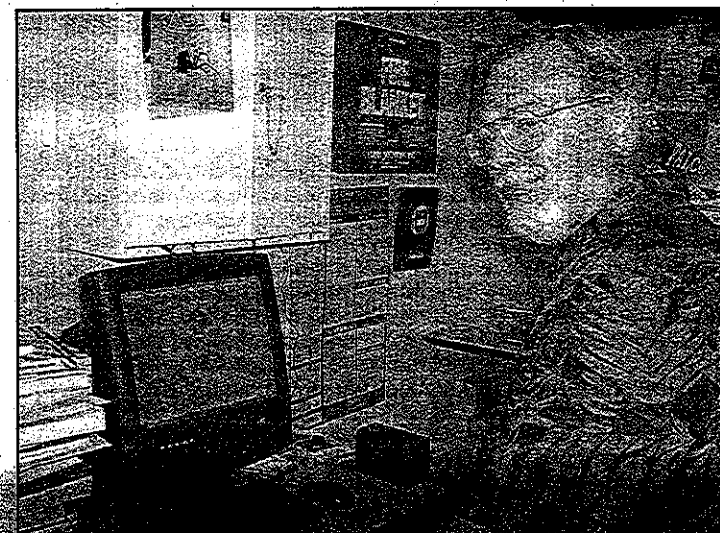
"The more they get involved with it, the more excited they are," he said. "We are beginning full research in January."

McElligott said he and his students are hoping to have preliminary data available by May, but they also plan to participate in a research competition in March.

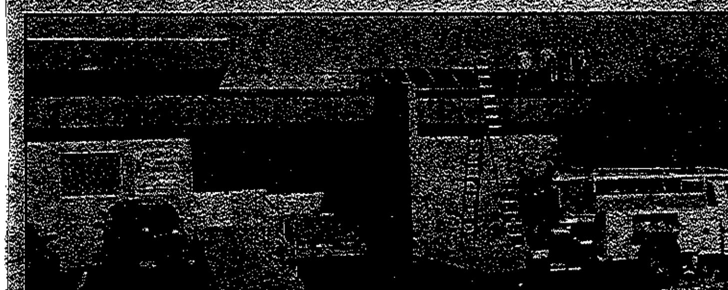
McElligott is teaching his students a variety of ways they can affect the environment. The students have modified one car to use hydrogen and will begin another hydrogen car in the coming weeks. They also will be studying other alternative fuel sources.

"This is an exciting time," McElligott said.

McElligott has taught at Fountain Hills high school for 10 years. Prior to that he taught chemistry at Grand Canyon University. All his classes at FHHS are advanced placement or honors classes.



Dr. Paul McElligott reviews some of the information he and his students gather from a weather station on the high school's roof. The weather data helps students learn how solar energy can benefit the school district.



Dependable Solar Products of Mesa installed the solar panels at Fountain Hills Unified School District's transportation building. Working on the project were T.J. Bartlesman, Enrique Rojas, Louis Chu and Kent Farnsworth. Fountain Hills High School science students are working on a research project under the direction of Dr. Paul McElligott.