Annual Report | Volume 4 | 2016

ADVANCED POWER & ENERGY PROGRAM

BRIDGING

Engineering Science to Practical Application

UCI MICROGRID

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UC IRVINE

Photo Courtesy University of California, Irvine

DIRECTOR'S MESSAGE

Professor Scott Samuelsen
Director, Advanced Power and Energy Program

As the umbrella organization for the National Fuel Cell Research Center (NFCRC) and the UCI Combustion Laboratory (UCICL), the Advanced Power and Energy Program (APEP) mission to "bridge" the gap between engineering science and practical application in close collaboration with industry, national and international agencies, and laboratories continues to be a cornerstone of our focus, efforts, and activities.

In this fourth edition of our annual "Bridging" report, the featured article highlights APEP's continuing work on the development and refinement of the UCI Microgrid. This ongoing effort now includes the development and demonstration of a Generic Microgrid Controller (GMC). Partnering with APEP on this **U.S. Department of Energy** project is **Southern California Edison, ETAP, MelRok, CalSO, and UCI Facilities Management**. Using the Southern California Edison (SCE) OPAL-RT dynamic simulation platform, the team is designing and systematically and thoroughly testing the GMC using an ETAP model of the UCI Microgrid. In parallel, the UCI Microgrid is being upgraded with a 2 MW SCE battery and over 120 MelRok high-resolution meters to inform the GMC design and enable the UCI Microgrid for a demonstration of the GMC.

In the past year, the NFCRC completed a major expansion of UCI's hydrogen fueling station that included a quadrupling of the previous dispensing capacity. The NFCRC also launched a major initiative to investigate the feasibility of using a solid oxide fuel cell combined with a gas turbine (SOFC-GT) to power long haul locomotives. The NFCRC has received funding from the Federal Rail Administration to take the next steps in this research that will allow for a SOFC-GT prototype design analysis, and for planning and preparation of prototype testing.

Working with **Horiba Instruments**, the UCICL is deploying a MEXA-1400QL-NX analyzer to explore fixed nitrogen species besides oxides of nitrogen by taking advantage of new emission quantification methods based on recently available quantum cascade laser technology. The UCICL is also collaborating with the Lawrence Berkeley National Laboratory (LBNL) on a California Energy Commission (CEC) funded research project to demonstrate an ultra-low emission boiler package burner at the Chiquita Water Reclamation Plant (CWRP) in Orange County California.

We are especially proud of the accomplishments of our students which during the past year include 11 graduates, a Fulbright Fellowship at the Paul Sherrer Institute in Switzerland, and 5 internships with diverse entities such as: **Schweitzer Engineering Laboratories, the Kennedy Space Center, the Stone Edge Farm Microgrid Project, University of Stuttgart Institute of Aerospace Thermodynamics, and Solar Turbines**.

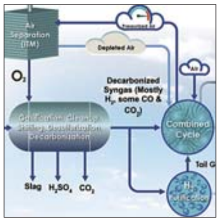
In summary, we continue to be indebted to our long standing relationships that contribute in so many ways to our research, real world demonstration projects, students, and to "bridging" from needed research in engineering science to the ultimate goal of deployment in practical application.

Scott Samuelsen

CONTENTS

1 FEATURE STORY
UCI MICROGRID

ADVANCED POWER AND ENERGY PROGRAM

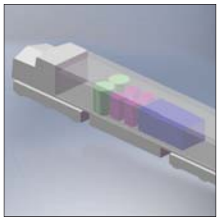


3 Hydrogen Coproduction in Biomass Cofed IGCC Plants

4 The Irvine Smart Grid Demonstration

NATIONAL FUEL CELL RESEARCH CENTER

5 UCI Hydrogen Station Upgrade Completed



6 Fuel Cell Powered Locomotives

UCI COMBUSTION LABORATORY

7 UCICL Uses HORIBA MEXA-1400QL-NX Analyzer in Emissions Research

8 UCICL Collaborating with Water Reclamation Plant to Improve Fuel Flexibility to Meet Strict Emission Standards

Also included in this issue:

9 Recent Graduates, Student Awards, and Internships
10 Publications
11 Highlights of the Year

THE UCI MICROGRID

A microgrid is a high voltage circuit or group of circuits that has both loads and generation assets and, as circled in red in Figure 1, at least one connection point to the local utility grid. Other attributes, such as energy storage, could be present as well. Examples of microgrids include university campuses, shopping centers, research centers, military bases, and industrial complexes.

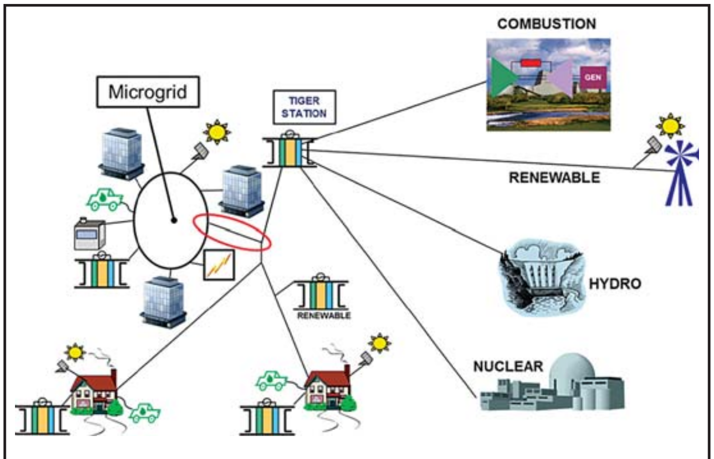


Figure 1. Microgrid Relative to the Utility Grid

In recent years, the interest in the performance, management, and ultimate potential of microgrids has been increasing. For example, if properly designed and controlled, a microgrid can remain energized in the event of a grid outage and thereby provide the community critically needed services such as electricity, shelter, food, vehicle fuel, and lodging.

The UC Irvine campus was carefully and systematically planned from its inception around a large, circular central park encircled by a one-mile utility tunnel loop. The tunnel houses a district heating and cooling system, communications, and the campus electrical grid. This forward thinking design today serves a community of 30,000 and encompasses a wide array of building types that include residential, office, research, and classrooms; transportation options such as automobiles, buses, shared-cars, and bicycles; and a wide array of distributed energy resources. As a result, UCI has one of the most remarkable examples of a world acclaimed microgrid which today serves as an outstanding platform to explore the microgrid future. Through multiple prior and current research programs[1], the UCI Advanced Power and Energy Program (APEP) has worked with UCI Facilities Management (FM) to establish key enhanced microgrid hardware, monitoring, and simulation assets.

UCI Microgrid Hardware Assets**.** As shown in Figure 2, the UCI Microgrid is a test bed that (1) is served by Southern California Edison through the UCI Substation that also serves the U.S. Department of Energy (DOE) funded Irvine Smart Grid Demonstration (ISGD) project and (2) encompasses ten 12 kV circuits, 4 MW of solar power, a 19 MW natural gas-fired combined cycle plant, centralized chilling, one of the largest thermal energy storage tanks in the country with a capacity of 4.5 million gallons/60,000 ton-hours, district heating and cooling, and electric vehicle charging at multiple parking locations.

Conventional metering is deployed throughout the microgrid, and advanced high-resolution and high-response metering has been installed at over 100 key locations identified by microgrid models and simulations.

UCI Microgrid Simulation Assets**.** APEP has collaborated with ETAP, an Irvine company, to develop a model of the UCI Microgrid and thereby establish a simulation platform for understanding and managing the

APEP's Research Engagement Partners

INDUSTRY	UTILITIES	AGENCIES
• Siemens • MelRok • Empowered Energy • Altura Associates • Itron • ETAP • Schweitzer Engineering Laboratories	• Southern California Edison • Pacific Gas & Electric • Sempra Energy Utilities	• U.S. Department of Energy • California Energy Commission • California Public Utilities Commission • California Air Resources Board • South Coast Air Quality Management District

A Broad and Trans-disciplinary Suite of Projects

- Dynamic simulation and control systems for energy conversion systems and circuits.
- Community design and control to enable renewable power.
- Field experiments of next-generation building energy control, demand response, and dispatchable power in the context of a high penetration of renewable power.
- Deployment of plug-in and hydrogen fuel cell electric vehicles.

effects of high penetrations of localized renewables in the community. The model's capabilities include:

- Simulating steady-state and dynamic phenomena.
- Simulating temporal events such as PV generation and capacitor switching.
- Steady-state qualities of real/reactive power flow and the voltage profile across the radial circuits.
- Dynamic phenomena include power quality (third harmonic distortion and flicker), frequency stability and transients (faults and voltage sags/swells).

Calibrating the campus model to measured data ensures the model accurately simulates the system's impedance and losses. Once calibrated, the model is capable of exploring the effects of future technology such as increased renewable generation, advanced inverter controls, and energy storage.

DOE "Generic Microgrid Controller" Research. Under funding from the DOE, APEP is collaborating with Southern California Edison to establish procedures and protocols for the utilization of microgrid resources, identify the policy and standards required to enable and foster the microgrid market, and systematically assess the associated economics. In conjunction with ETAP and MelRok, and four "Microgrid Partners[2]," APEP is developing the specifications for a Generic Microgrid Controller (GMC).

The principal deliverables of this project are to:

- Systematically assess the manner by which a microgrid can serve as an asset to the utility grid and the public.
- Identify and test the "smart demand and power response" (SDPR) capabilities required to meet this goal.
- Categorize the policy and standards needed to enable the market.
- Delineate the business models and overall economics for a matrix of realistic and spanning scenarios associated with the design and operation of a microgrid.
- Identify the roles of microgrids and necessary protocols in responding to grid emergencies triggered by natural causes, man-made causes, or accidents.

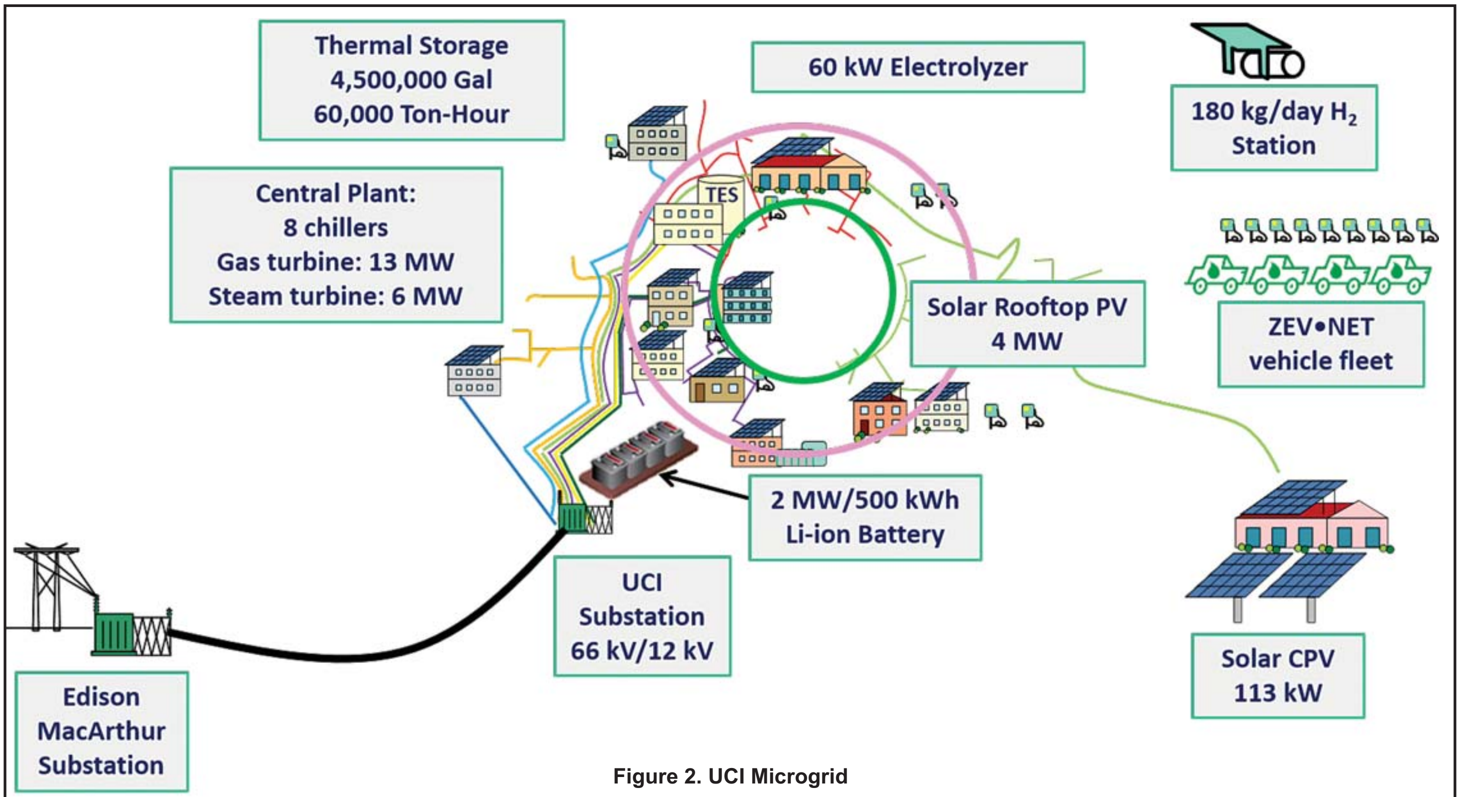


Figure 2. UCI Microgrid

[1] For example, programs funded by the California Public Utility Commission "California Solar Initiative (CPI);" the California Energy Commission "Renewable Energy Based Secure Communities (RESCO);" the U.S. Department of "Energy Building Technologies Program", the U.S. Department of Defense, the California Air Resources Board, and the South Coast Air Quality Management District.

[2] Port of Los Angeles, Port of Long Beach, Irvine Ranch Water District, UCI Medical Center.

Hydrogen Coproduction in Biomass Cofed IGCC Plants

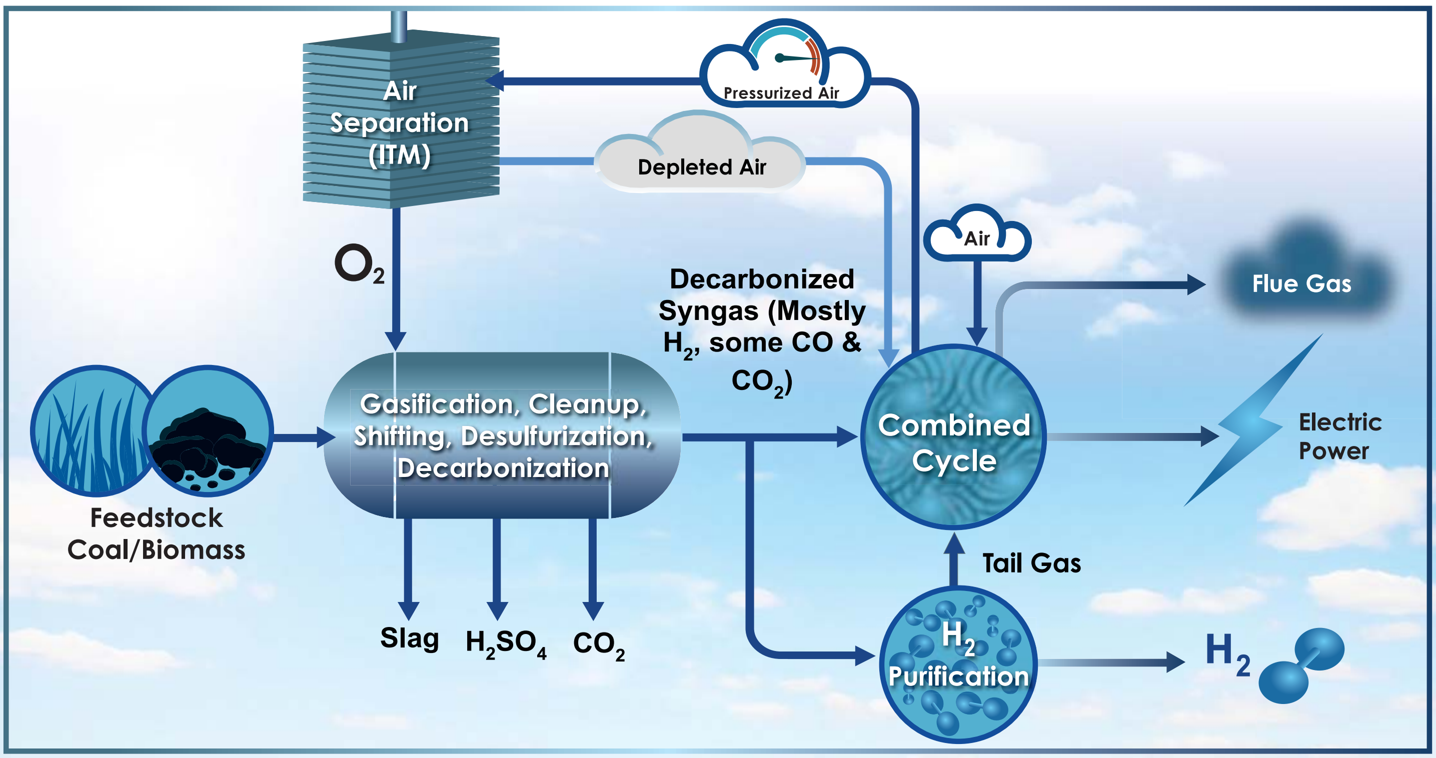
The Advanced Power and Energy Program (APEP) is participating in identifying and developing promising advanced technologies for Integrated Gasification Combined Cycle (IGCC) plants coproducing electricity and hydrogen. Utilized with carbon capture and storage (CCS) via coal and biomass mixtures, the evolved and advanced IGCC plant concept uses:

- Ion Transport Membrane (ITM) oxygen technology.
- Dry feed gasifier (entrained flow, slagging, single stage, downflow).
- Warm gas cleanup processes.
- Regenerable CO_2 sorbents technology.
- H class gas turbine with steam cooling.
- Pressure swing adsorption (PSA) for hydrogen separation.

The IGCC coproduction plants showed net equivalent power efficiencies ranging from 35.21% to 37.98%, nearly equal to efficiencies without coproduction which ranges from 36.76% to 38.26%.

Sensitivity analyses on various feedstock mixtures show that feedstock characteristics such as higher heating value and lower moisture content have a significant positive effect on gasifier efficiency and auxiliary power consumption.

Incremental analyses show cofeeding and coproduction are competitive with respect to plant performance. The calculated cost of electricity with a bituminous coal was $102.9/MWh while the cost with a lignite was $108.1/MWh, resulting in a cost of hydrogen that ranged from $1.42/kg to $2.77/kg depending on the feedstock. This cost is lower than the U.S. Department of Energy's announced goal of $3.00/kg in July 14, 2005.



Simplified Plant Schematic for H_2 Coproduction

The Irvine Smart Grid Demonstration

Over the last 5 years, the Advanced Power and Energy Program (APEP) and Southern California Edison (SCE) have co-led the Irvine Smart Grid Demonstration (ISGD) project. During this major initiative, APEP and SCE worked with a host of entities that included contributions from Toyota, GE, A123 Systems, EPRI, and SunPower, with 50% of the $80 million of funding coming from the U.S. Department of Energy (DOE). **The ISGD project comprised one of the broadest investigations of smart grid technology accomplished anywhere in the world.** With a focus on greenhouse gases, rising energy demands, increased penetration of renewable solar generation, and charging loads from plug-in electric vehicles, it enabled APEP and SCE to evaluate and advance a host of individual smart grid technologies both on the UCI campus and in the adjacent Irvine Community of University Hills.

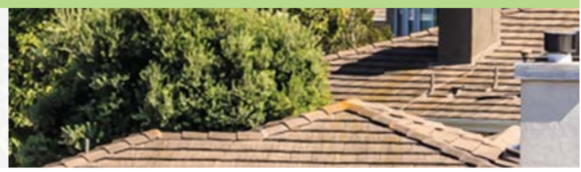


Photo by Paul Kennedy

Development, implementation and testing of the ISGD project included the installation of new distribution infrastructure, distributed energy resources (DER) such as photovoltaic systems and energy storage systems, and smart grid components that were installed and thoroughly evaluated.

Significant Research Areas

The project successfully demonstrated how customer technologies with demand response capabilities could help manage customer loads and reduce circuit peaks. Residential and neighborhood energy storage were utilized to help in shifting loads, leveling demand, and providing backup power. It was found that solar photovoltaic (PV) panels and light emitting diode (LED) lighting upgrades had the greatest impact on the goal to achieve zero net energy (ZNE) in the homes on an annual basis.

To evaluate the impact of charging plug-in electric vehicles (PEVs) in the workplace, a Solar Car Shade system with PV panels, battery energy storage and 20 PEV chargers was installed in a parking garage on the UCI campus. The system was measured and analyzed by UCI researchers to determine that it could reduce or eliminate the grid impact of PEV charging during peak periods, and that power quality issues associated with individual car charging events could be managed even with high numbers of simultaneous PEV charging events.

UCI worked with SCE colleagues to install and operate a 2 MW battery on one of the smart circuits, and to install phasor measurement technology at the SCE MacArthur Substation to successfully detect changes in distribution circuit load from the battery and simulated DER aggregation. The team explored the use of this approach for verifying DER dispatch when it participates in energy and ancillary services markets without having to monitor each resource separately.

The project successfully demonstrated that centralized control of substation and distribution capacitors under distribution volt/VAR control (DVVC) strategies could substantially reduce overall system voltage and customer energy use without requiring any change in customer behavior. Depending on the type of distribution circuit, DVVC can provide energy savings of 1% to 4%. As a result of this success, SCE plans to implement DVVC in all of their circuits that are part of its Grid Modernization program.

Overall the ISGD project advanced smart grid technologies and integrated systems that will allow integration of greater amounts of renewable power, use of electricity as a fuel for vehicles, enable consumers to become participants in the energy supply chain, and ensure the continued reliability and vitality of the electric grid.

APEP is very appreciative of the support from the U.S. Department of Energy and the leadership and collaboration of SCE in this exciting project. The relationships that have been established and technologies that have been deployed are being leveraged in current smart grid and microgrid projects.

EV Recharging Stations

Photo by Paul Kennedy

UCI

HYDROGEN STATION

Upgrade Completed

Construction began in July of 2015 on a major upgrade to the UC Irvine hydrogen fueling station. By November, the station was updated to a full retail station ready to serve the emerging hydrogen vehicle economy. Operated by the National Fuel Cell Research Center, it continues to provide hydrogen for fuel cell cars and SUV's, provide refueling research data, and is now refueling full-size fuel cell electric buses.

The update is just the latest development in the long, proud history of the UCI hydrogen station. The first station opened in 2003 to provide fuel to the National Fuel Cell Research Center's embryonic fuel cell vehicle fleet, and the research vehicles of auto manufacturers such as Toyota, Hyundai, Mercedes Benz, General Motors, and Honda. Thirteen years and several iterations later, the station is now ready to support the growing consumer demand for automotive hydrogen fuel.

During this latest upgrade, every piece of machinery from the former station was removed and replaced with state-of-the-art equipment. The canopy over the dispensing area and the wall of the equipment enclosure are the only features remaining from the previous station configuration. Under the new design, the station is able to dispense up to 180 kg per day (four times its prior capability). The dispenser is State certified for retail sale of hydrogen, and equipped with a credit card reader to accept payment. The station's new compressor and cooling systems are much more robust, allowing for multiple back-to-back fills and faster refueling times. The former on-site liquid hydrogen storage has been replaced with a new gaseous hydrogen trailer delivery system. When a trailer is depleted, a full trailer is delivered and swapped. The station is currently serviced by one 250 kg trailer, but is capable of accepting up to two 500 kg trailers at one time.

" the station was upgraded to a full retail station ready to serve the emerging hydrogen vehicle economy "

In addition to automobiles, the UCI station provides refueling for hydrogen fuel cell electric buses. The UCI Anteater Express fuel cell bus—the first of its kind on a University of California Campus—has been refueling at the station since November 2015. Recently, a new fuel cell bus acquired by the Orange County Transit Authority—also the first of its kind for the County's bus system—began test fills at the station. It is expected to refuel nightly at the site when testing is completed and it begins regular service.

Since November 2015, the station has provided over 1,800 fills and dispensed more than 6,000 kg of hydrogen, making it the busiest retail station in the State. With both the Toyota Mirai and the Hyundai Tucson fuel cell vehicles now being driven by consumers, and vehicles from other automakers such as Honda, Mercedes Benz, GM and Audi on the horizon, the UCI hydrogen station is and will remain, a vital link in California's growing hydrogen fueling infrastructure.

FUEL CELL POWERED LOCOMOTIVES

Long-haul locomotive transportation is one of the most prevalent methods of shipping goods in the United States. The fuel cost for long-haul locomotives is a major component in the economics of freight movement and subject to geo-politics. The challenges associated with both of these drivers must be resolved as the country works to achieve energy independence.

Long-haul locomotives also present significant environmental concerns. Although the average emission signature of locomotives nationwide is approximately 5% of the national total, locomotives in urban air basins substantially degrade air quality in the vicinity of their operation. For example, at classification railyards where railcars are separated and placed into their proper line or “classification” to form a train, locomotives are responsible for 96% of Particulate Matter (PM) emissions. At intermodal railyards where freight containers are moved between ship, rail, and trucks, the percentage is 39%. The general public living near rail operations is directly affected by these emissions and, as a result, improvements in locomotive emission signatures can significantly enhance the air quality for this population group.

Similar to passenger vehicles and diesel freight trucks, locomotives have been assigned a progressively limiting tier-based schedule of emissions standards to promote ongoing reductions in the emission of NOx, CO, hydrocarbons, smoke, and particulates. Satisfying, and potentially exceeding, the Tier standards will be facilitated by a new technology to replace the conventional combustion reciprocating engine that today powers the modern diesel electric locomotive.

One promising technology is the combination of a solid oxide fuel cell (SOFC) with a gas turbine (GT), known as an SOFC-GT that has an unusually high fuel-to-electric conversion efficiency. Consequently, the SOFC-GT is an ideal candidate for stationary power applications, especially large-scale and centralized power. This feature is also attractive for locomotive applications, since the wheels are powered by electric traction motors.

With support from the California Air Resources Board and the South Coast Air Quality Management District, the National Fuel Cell Research Center (NFCRC) investigated the feasibility of using SOFC-GT technology in locomotives. The results established that SOFC-GT’s can be an effective

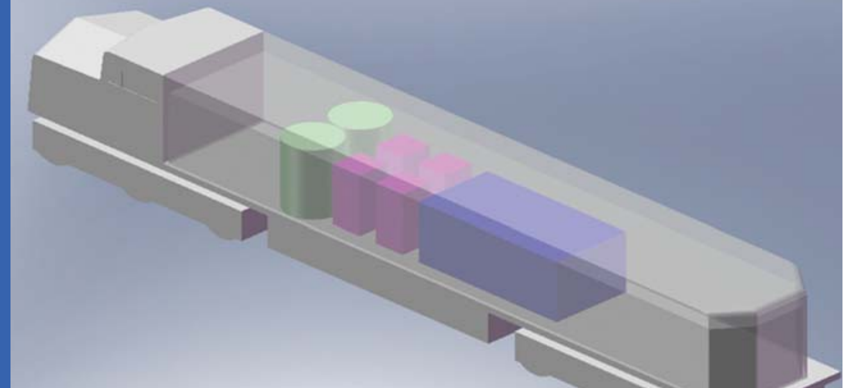


Figure 1. Artist Rendering of the Hybrid SOFC-GT System as Installed in the Locomotive Engine Compartment

engine to power a long-haul locomotive. In the first set of analyses, the potential system size was established to verify that the SOFC-GT technology could fit into the engine compartment of a typical locomotive. A typical configuration is shown in the artist rendering presented in Figure 1.

NFCRC researchers also developed dynamic simulation and control capabilities for the SOFC-GT locomotive operating on diesel fuel, natural gas, and hydrogen. Dynamic simulation tools were then applied to a real world operating route from the Port of Los Angeles over the Cajon Pass to Barstow. The results established that a hybrid SOFC-GT locomotive could be controlled and operated in the typical fashion to power a locomotive over the Cajon Pass, the elevation and grade demands of which are shown in Figure 2.

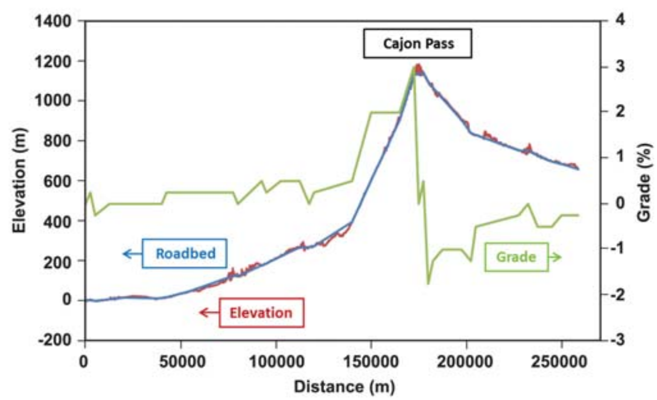


Figure 2. Elevation and Grade for the Real-world Locomotive Operating Route from the Port of Los Angelesto Barstow Through the Cajon Pass

This past year, the NFCRC received funding from the Federal Railroad Administration[1] to address the following next steps in demonstrating the feasibility of fuel cell powered locomotives:

- Complete a prototype design analyses.
- Identify technology partners to construct a prototype for testing.
- Plan and prepare a prototype test of the hybrid SOFC locomotive concept.

[1]In collaboration with the U.S. Environmental Protection Agency, the U.S. Department of Energy, the California Air Resources Board, and the South Coast Air Quality Management District.

UCI Combustion Laboratory
Uses HORIBA MEXA-1400QL-NX Analyzer in Emissions Research

Researchers at the University of California, Irvine Combustion Laboratory (UCICL) are taking advantage of new emission quantification methods based on recently available quantum cascade laser technology. Working with HORIBA Instruments, the UCICL is deploying a MEXA-1400QL-NX analyzer to explore fixed nitrogen species besides oxides of nitrogen.

As combustion systems drive towards lower emissions of NOx, CO, and unburned hydrocarbons, advanced technology based on lean premixed strategies are becoming more and more prevalent. Essentially, this approach allows operation at low combustion temperatures which minimizes conversion of molecular nitrogen in the air into the pollutants classified as oxides of nitrogen. By operating at low combustion temperatures, however, the reaction is less stable leading to possible operability issues such as blow off.

Another driver in combustion technology is the desire to incorporate additional amounts of renewable fuels such as those derived from biomass, waste streams, or hydrolysis of water, into the fuel mix. As a result, opportunities for possible synergies between low emissions and increased renewable fuel content may present themselves. Renewably derived hydrogen from either gasification or water hydrolysis offers the ability to increase the stability of the low temperature combustion process to help maintain low criteria pollutant emissions while at the same time reducing carbon emissions. However, more work is needed to assess how transients (start up/shut down, load changes), fuel compositional variation, and burner operation affect pollutants beyond those typically studied such as oxides of nitrogen.

Using a series of hierarchal experiments, the UCICL is seeking to understand how the incremental addition of hydrogen to natural gas might impact emissions of nitrous oxide (N_2O—a powerful greenhouse gas) and ammonia (NH_3) in addition to oxides of nitrogen. The MEXA-1400QL-NX being utilized uniquely quantifies four nitrogen species (NO, NO_2, N_2O, and NH_3) with a fast enough response (10 Hz) so that the transient behavior of the exhaust emissions can be quantified.

Thus far, measurements on a laminar flat flame (shown in Figure 1), a low swirl burner, and a surface stabilized burner have shown that, with high levels of hydrogen addition, especially during shut down and startup, the emissions of N_2O and NH_3 can be significant. Work is underway to quantify the trends and to establish the link between burner type, fuel composition, and operating conditions.

Figure 1. Quartz Microprobe Sampling the Laminar Flat Flame Produced by Premixed Natural Gas, Hydrogen, and Air

UCICL Collaborating

with Water Reclamation Plant to Improve Fuel Flexibility to Meet Strict Emission Standards

The University of California, Irvine Combustion Laboratory (UCICL) is collaborating with the Lawrence Berkeley National Laboratory (LBNL) on a California Energy Commission (CEC) funded research project to demonstrate an ultra-low emission boiler package burner on a 1.99 MMBtu/hr Johnston boiler at the Chiquita Water Reclamation Plant (CWRP) in Orange County California (Figure 1).

UCICL students (Jamie Ibrahim, Nathan Kirksey and Dimas Avila) document dimensions of the fuel gas delivery system for "Boiler #2" at the Chiquita Water Reclamation Facility.

The primary task is to demonstrate the ability to switch between biogas produced at the facility and propane in real time to avoid long and expensive shut down procedures. The project is a combination of two previously funded CEC projects which include LBNL's low swirl burner (LSB) and UCICL's fuel composition sensor.

Waste streams that are either a product of agricultural and industrial plants or the feedstock for water treatment plants can be converted into biogas through the process of anaerobic digestion, a process in which bacteria breaks down organic waste in an oxygen deficient environment. Biogas is a renewable fuel due to its low carbon contribution to the carbon cycle, that offers a clean useful energy source that can help offset dependence on other fossil fuels such as natural gas.

Figure 1. Chiquita Water Reclamation Plant

Because of the inability to optimally utilize biogas due to the variability in composition and low heating values, currently, many existing organic waste stream facilities often dispose of their energy-rich waste stock by flaring. The low cost fuel composition sensor developed at the UCICL helps overcome these issues by detecting the speed of sound of gas mixtures flowing through the device, and deriving the corresponding fuel composition that will enter the boiler. The sensor then updates the boiler controls in real time to compensate for the fuel composition while avoiding flame instabilities and meeting emission requirements.

To date, the project has involved:

- Deployment of the fuel sensor on the biogas fuel train to monitor variations in the biogas composition.
- Using a HORIBA FIA-510 flame ionization detector to test the premixing of the fuel into the air stream at the UCICL with a set of fuel injectors to diagnose their premixing capabilities.
- Emissions measurement using a 1/5 scale low swirl burner (LSB) provided by LBNL and using a HORIBA PG-250 instrument to monitor carbon monoxide (CO) and oxides of nitrogen (NOx).

GRADUATES 2015 - 2016

Doctor of Philosophy (Ph.D.) in Mechanical and Aerospace Engineering

Andrés Colorado
Dissertation: Pollutant Emissions and Lean Blowoff Limits of Fuel Flexible Burners Operating on Gaseous Renewable and Fossil Fuels

Gia Nguyen
Dissertation: Optimal Design and Model Predictive Control of Fuel Cells with Photovoltaics and Storage in Buildings

Master of Science (M.S.) in Mechanical and Aerospace Engineering

Dimas Avila
Thesis: Design and Verification of a Speed of Sound Sensor for Biogas for Fuel Flexible Burners

Kate Forrest
Thesis: Demonstrating a Framework to Evaluate the Impacts of Different Strategies to Meet California Sustainability Goals

Laura Novoa
Thesis: Integration of Solar Powered Electric Vehicle Charging in a Nano-grid

Hannah Bower
Thesis: Optimization of Dual Planar Laser Induced Fluorescence (DPLIF) Instrumentation for Characterization of Liquid Mixing in Sprays

Alexa Johnson
Thesis: Reliability and Availability of Solid Oxide Fuel Cell Systems in Data Centers

Van Wifvat
Thesis: A Planning Tool to Assess Advanced Vehicle Sensor Technologies on Traffic Flow, Fuel Economy, and Emissions

Siavash Ebrahimi
Thesis: Emissions and Air Quality Impacts of Using More Renewables and Electrification of End Uses

Analy Castillo Muñoz
Thesis: Deployment of Fuel Cell Electric Buses in Transit Agencies: Hydrogen Demand Allocation and Preferable Hydrogen Infrastructure Rollout Scenarios

David White
Thesis: Important Factors for Early Market Microgrids: Demand Response and Plug-in Electric Vehicle Charging

Awards

Fulbright Fellowship

- **Analy Castillo Muñoz**
- **Paul Scherrer Institute, Switzerland 2016-2017**

Senior Design Project Dean's Choice Award

- **Aaron Cheng, Gabrielle Cobos, Michael Crowley, Robert Miller, Allen Schellerup, John Stansberry**
- **Renewable Fuel Cell Powered Data Centers**

Chancellor's Award of Distinction

- **Gabrielle Cobos**

Internships

- **Hannah Bower—Institute of Aerospace Thermodynamics, University of Stuttgart Germany (Spring 2015); Kennedy Space Center (Fall 2015)**
- **Daniel Jaimes—Solar Turbines (Summer 2016)**
- **Gabrielle Cobos—Stone Edge Farm (Summer 2016)**
- **Derek McVay—Stone Edge Farm (Summer 2016)**
- **Laura Novoa—Schweitzer Engineering Laboratories (Summer 2016)**

PUBLICATIONS

Journal Articles:

REFUELING HYDROGEN FUEL CELL VEHICLES WITH 68 PROPOSED REFUELING STATIONS IN CALIFORNIA: MEASURING DEVIATIONS FROM DAILY TRAVEL PATTERNS (2014). International Journal of Hydrogen Energy, Volume 39, Issue 7, pp. 3444-3449 (Jee Eun Kang, Tim Brown, Will W. Recker, and Scott Samuelsen).

DEVELOPMENT OF AN OPEN ACCESS TOOL FOR DESIGN, SIMULATED DISPATCH, AND ECONOMIC ASSESSMENT OF DISTRIBUTED GENERATION TECHNOLOGIES (2015). Energy and Buildings, Volume 105, pp. 314-325 (Dustin McLarty, Jack Brouwer, and Chris Ainscough).

THE OPTIMIZATION OF DC FAST CHARGING DEPLOYMENT IN CALIFORNIA (2015). Applied Energy, Volume 157, pp. 111-122 (Li Zhang, Brendan Shaffer, Tim Brown, and Scott Samuelsen).

DYNAMIC OPERATION AND FEASIBILITY STUDY OF A SELF-SUSTAINABLE HYDROGEN FUELING STATION USING RENEWABLE ENERGY SOURCES (2015). International Journal of Hydrogen Energy, Volume 40, Issue 10, pp. 3822-3837 (Li Zhao and Jack Brouwer).

SYSTEMATIC SELECTION AND SITING OF VEHICLE FUELING INFRASTRUCTURE TO SYNERGISTICALLY MEET FUTURE DEMANDS FOR ALTERNATIVE FUELS (2015). Journal of Energy Resources Technology, Volume 137, Issue 6, pp. 062201-1 - 062201-9 (Peter Willette, Brendan Shaffer, and Scott Samuelsen).

INFLUENCE OF EMULSIONS AND STEAM INJECTION ON A DIESEL FUELED MODEL GAS TURBINE COMBUSTOR (2015). Atomization and Sprays, Volume 25, Issue 12, pp. 1025-1045 (Megan Sung and Vince McDonell).

THE EFFECTIVENESS OF PLUG-IN HYBRID ELECTRIC VEHICLES AND RENEWABLE POWER IN SUPPORT OF HOLISTIC ENVIRONMENTAL GOALS: PART 2 – DESIGN AND OPERATION IMPLICATIONS FOR LOAD-BALANCING RESOURCES ON THE ELECTRIC GRID (2015). Journal of Power Sources, Volume 2787, pp. 782-793 (Brian Tarroja, Josh Eichman, Li Zhang, Tim Brown, and Scott Samuelsen).

MICRO-GRID ENERGY DISPATCH OPTIMIZATION AND PREDICTIVE CONTROL ALGORITHMS; A UC IRVINE CASE STUDY (2015). International Journal of Electrical Power & Energy Systems, Volume 65, pp. 179-190 (Dustin McLarty, Carles C. Sabate, Jack Brouwer, and Faryar Jabbari).

THE IMPORTANCE OF GRID INTEGRATION FOR ACHIEVABLE GREENHOUSE GAS EMISSIONS REDUCTIONS FROM ALTERNATIVE VEHICLE TECHNOLOGIES (2015). Energy, Volume 87, pp. 504-519 (Brian Tarroja, Brendan Shaffer, and Scott Samuelsen).

ASSESSMENT OF A RICH-BURN, QUICK-MIX, LEAN-BURN-BASED SUPPLEMENTAL BURNER SYSTEM IN A VITIATED AIR-STREAM (2016). Combustion Science and Technology, Volume 188, Issue 3, pp. 397-415 (Elliot Sullivan-Lewis, Richard Hack, and Vince McDonell).

DYNAMIC MODELING AND EXPERIMENTAL INVESTIGATION OF A HIGH TEMPERATURE PEM FUEL CELL STACK (2016). International Journal of Hydrogen Energy, Volume 41, Issue 8, pp. 4729-4739 (Gia Nguyen, Simon Sahlin, Søren Juhl Andreasen, Brendan Shaffer, and Jack Brouwer).

ECONOMIC ANALYSIS OF FUEL CELL INSTALLATIONS AT COMMERCIAL BUILDINGS INCLUDING REGIONAL PRICING AND COMPLEMENTARY TECHNOLOGIES (2016). Energy and Buildings, Volume 113, pp. 112-122 (Dustin McLarty, Jack Brouwer, and Chris Ainscough).

ELECTRICITY COSTS FOR AN ELECTRIC VEHICLE FUELING STATION WITH LEVEL 3 CHARGING (2016). Applied Energy, Volume 169, pp. 813-830 (Robert J. Flores, Brendan P. Shaffer, and Jack Brouwer).

EPISODIC AIR QUALITY IMPACTS OF PLUG-IN ELECTRIC VEHICLES (2016). Atmospheric Environment, Volume 137, pp. 90-100 (Ghazal Razeghi, Marc Carreras-Sospedra, Tim Brown, Jack Brouwer, Donald Dabdub, and Scott Samuelsen).

FLASHBACK PROPENSITY OF TURBULENT HYDROGEN-AIR JET FLAMES AT GAS TURBINE PREMIXER CONDITIONS (2016). ASME Journal of Engineering Gas Turbines and Power, Volume 138, Issue 6, pp. 061506-1-061506-8 (Alireza Kalantari, Elliot Sullivan-Lewis, and Vince McDonell).

EVALUATION AND OPTIMIZATION OF A MICRO-TUBULAR SOLID OXIDE FUEL CELL STACK MODEL INCLUDING AN INTEGRATED COOLING SYSTEM (2016). Journal of Power Sources, Volume 303, pp. 10-16 (Martin Hering, Jack Brouwer, and Wolfgang Winkler).

QUANTIFYING CLIMATE CHANGE IMPACTS ON HYDROPOWER GENERATION AND IMPLICATIONS ON ELECTRIC GRID GREENHOUSE GAS EMISSIONS AND OPERATION (2016). Energy, Volume 111, pp. 295-305 (Brian Tarroja, Amir AghaKouchak, and Scott Samuelsen).

NUMERICAL AND EXPERIMENTAL ANALYSIS OF THE EFFECT OF ADDING WATER ELECTROLYSIS PRODUCTS ON THE LAMINAR BURNING VELOCITY AND STABILITY OF LEAN PREMIXED METHANE/AIR FLAMES AT SUB-ATMOSPHERIC PRESSURES (2016). Fuel, Volume 180, pp. 565-573 (Camilo Echeverri-Uribe, Andrés A. Amell, Lina M. Rubio-Gaviria, Andrés Colorado, and Vince McDonell).

SPATIALLY AND TEMPORALLY RESOLVED MODEL OF THE ELECTRICITY GRID-ECONOMIC VS ENVIRONMENTAL DISPATCH (2016). Applied Energy, Volume 178, pp. 540-556 (Ghazal Razeghi, Jack Brouwer, and Scott Samuelsen).

HIGHLIGHTS

SPRING 2016

APEP Hosted Conferences and Short Courses:

National Fuel Cell Symposium - May 12, 2016

- A one day Symposium that convened the public, investment community, industry, government, and academia to discuss the current state of mobile fuel cell development and deployment in the United States and abroad.

Short Course: Fuel Cells 101 - May 11, 2016

- Addressed the basics of fuel cell technology, the spectrum of fuel cell types, stationary and mobile fuel cell markets, and the role of fuel cell technology in complementing and managing the high-penetration of intermittent renewable wind and solar power associated with both the electric grid and emerging microgrid technology.

ICEPAG 2016: Microgrid Global Summit - March 22-24, 2016

- A three day Summit that brought together experts from industry, government, and academia from around the world to examine issues and share critical, cutting edge information about real-world, on-the-ground microgrid developments that are pushing the envelope of energy reliability, quality and accessibility.

Short Course: Atomization and Sprays - March 18-19, 2016

- An introduction to the theory of atomization and evaporation and how these concepts connect to practical devices used in various applications including fuel injection, coatings, and pharmaceuticals.

Short Course: Gas Turbine Combustion - March 14-17, 2016

- Instruction in the emissions, design, performance, theory, and regulations associated with gas turbine combustion systems.

WINTER 2016

The NFCRC Says Farewell to the Toyota FCHV

- In February 2016, the NFCRC said goodbye to the last Toyota pre-production prototype Fuel Cell Hybrid Vehicle (FCHV) in the NFCRC fleet. Expanding from a single vehicle in 2002, to seventeen by 2010, various versions of the SUV joined and departed the fleet, culminating in the FCHV-ADV (Fuel Cell Hybrid Vehicle-Advanced) version. With the production and sale of the Mirai fuel cell sedan in October 2015, Toyota has retired the fleet of demonstration FCHVs.

UC Irvine Medical Center's High-Temperature Fuel Cell Now in Operation

- The UC Irvine Medical Center's high-temperature fuel cell and absorption chiller (HTFC/AC) system has been commissioned and is now generating about 30% of the facility's power needs and supplying 200 refrigeration tons of cooling (800 kW). The fuel cell installation will annually remove the emission of 28 tons of nitrogen oxide (NOx), 64 tons of sulfur dioxide (SOx), 3,000 pounds of particulate matter (PM10), and more than 7,000 tons of CO_2.

UC Irvine Combustion Laboratory Presents at the DOE's University Turbine Systems Research Program

- Professor Vincent McDonell presented research sponsored by the U.S. Department of Energy's University Turbine Systems Research program at their annual review meeting, held at Georgia Tech University. An overview of work completed towards predicting the onset of flashback for turbulent jet flames at elevated temperature and pressure conditions was provided.

UCI Fuel Cell Bus Showcased at the Anaheim Ducks Hockey Game

- The UCI Fuel Cell Bus was a main attraction at the UCI Spirit Night with the Anaheim Ducks vs. Calgary Flames hockey game in February. Showcasing the Fuel Cell Bus at the event provided the opportunity for the Orange County community to learn of UC Irvine's dedication to adopting alternative, clean-renewable transportation.

APEP is Staying Connected

- APEP launched ongoing outreach efforts to its former students through its Alumni Outreach Program. The program is designed to build community with APEP Alumni and to keep them up-to-date on APEP, NFCRC, and UCICL research and events.

FALL 2015

APEP Co-Leads U.S.-China Clean Energy Research Center's Water-Energy Track (CERC-WET)

- In 2009, President Obama and former Chinese President Hu Jintao introduced the U.S.-China Clean Energy Research Center (CERC) to create an efficient, low-carbon economy to offset climate change. UC Irvine along with UC Berkeley, UC Davis, UC Merced, UCLA, and the Stockholm Environmental Institute have joined together for a five year, $50 million research collaboration dedicated to the water-energy track (WET) of the CERC. APEP's Director, Professor Scott Samuelsen, and Civil and Environmental Engineering and Earth System's Science Professor Soroosh Sorooshian are co-leaders on the project.

Team Orange Receives Engineering Praise in Solar Decathlon

- 2015 was the first year that Orange County was represented in the U.S. Department of Energy's Solar Decathlon. APEP's Associate Director Jack Brouwer served as the Faculty Advisor for Team Orange, a collaboration of students from UC Irvine, Chapman University, Saddleback College, and Irvine Valley College. The Team Orange entry "Casa Del Sol" placed second in the category of Engineering and featured an AC/DC biodirectional inverter, a rooftop solar thermal system, graywater recycling for an aquaponic garden, and a 3-D printer for household use.

SUMMER 2015

APEP Provides Educational Tours

- During the summer, both local and international student organizations had the opportunity to learn about clean energy production, utilization and sustainability while visiting APEP's research laboratories. Students from FABcamp hosted by UCI's Henry Samueli School of Engineering, Garden Grove High School, and the American Association of University Women's TechTrek summer math camp participated in visits over the summer. International college students were hosted from Japan, Saudi Arabia, and China.

APEP Educational Tours

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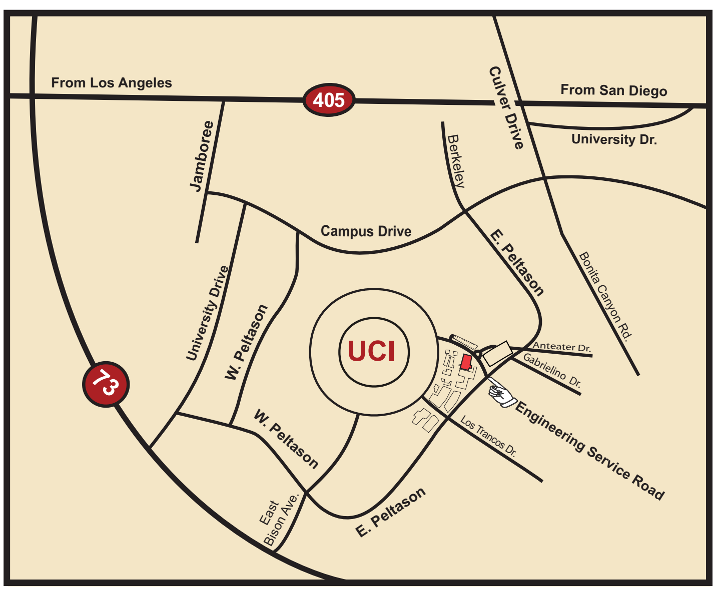
The Advanced Power and Energy Program (APEP) encompasses three organizational elements: the National Fuel Cell Research Center, the UCI Combustion Laboratory, and the Pacific Rim Consortium on Combustion, Energy, and the Environment.

APEP advances the development and deployment of efficient, environmentally sensitive, and sustainable power generation, storage, and conservation. At the center of APEP's efforts is the creation of new knowledge brought about through fundamental and applied research and the sharing of this knowledge through education and outreach.

The connection of APEP's research to practical application is achieved through our close collaboration with industry, national agencies, and laboratories to "bridge" engineering science and practical application.

APEP is affiliated with The Henry Samueli School of Engineering at the University of California, Irvine and is located in the Engineering Laboratory Facility (Building 323) near East Peltason Drive and the Engineering Service Road.



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