NEW ENERGY NEXUS

CalTestBed

Facilities Directory

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Technology Types Definitions

CalTestBed

Building Technologies	Energy Efficiency	Energy Storage	Grid Technologies	Industrial & Agricultural Innovation	Internet of Things	Material-Based	Renewable Generation	Transportation	Water Technologies
Hardware or integrated solutions that support energy efficiency in buildings including occupancy-based controls and building management system optimization, after treatment coatings for fenestration, insulation, and building envelopes.	Hardware or integrated solutions that demonstrate energy efficiency including appliances, solid-state lighting, non-vapor compression cooling, advanced electric heat pumps that use refrigerants with low or zero GWP.	Hardware or integrated enabling technologies for lithium-metal and lithium-sulfur batteries, Flow batteries, Ultra- or super-capacitors, Non-lithium battery chemistries, enabling technologies for green hydrogen for long duration, energy storage (including technologies such as electrolyzers).	Hardware or integrated solutions that modernize the electric grid, through enabling more clean energy and energy efficiency such as demand response, distributed energy resource management systems, electric vehicle to grid integration, etc.	Hardware or integrated solutions that work in the industrial and/or agricultural context to enable clean energy and/or energy efficiency in industrial and agricultural processes.	Hardware or integrated solutions , that are used to enable clean energy or energy efficiency through the automatic acquisition, storage manipulation, management, movement, control, display, switching, interchange, transmission or reception of data.	Hardware or integrated solutions that utilize novel materials to enable clean energy generation or greater energy efficiency.	Hardware or integrated renewable energy technologies that advance electricity, heat, and/or fuel from renewable sources including solar, wind, heat-exchange, and bioenergy technologies.	Hardware or integrated technologies that enable electric and alternative fuel vehicles, and related electric charging and alternative fueling infrastructure.	Hardware or integrated technologies that embrace forward-thinking applications and solutions that utilize waterflow for energy generation including hydro, wave, and tidal while advancing clean and safe water goals.


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Center for the Built Environment

UC Berkeley

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CBE collaborates with industry leaders to improve the performance of buildings by providing timely, unbiased research on building technologies, design strategies and operations.

Primary research program areas include:

- *Building HVAC Systems*
- *Indoor Environments*
- *Building Facade Systems*
- *Human Interactions*

Capabilities include laboratory studies, field studies, prototyping and building energy simulation.

Center for the Built Environment

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Controlled Environment Chamber

This full-scale test room resembles a contemporary office while allowing precise control over temperature, humidity, ventilation and lighting. The facility has been used for groundbreaking studies of thermal comfort, ventilation performance, and indoor air quality (with and without human subjects). Research staff have also designed and conducted numerous full-scale laboratory tests at FLEXLAB, LBNL, and other laboratories in the US and Canada.

Indoor Environmental Quality (IEQ) Evaluation Toolkit

CBE uses portable instruments (mobile carts and wireless sensor networks) to conduct field studies of indoor environments and HVAC performance. CBE's unique toolkit uses a wireless mesh network with a web-based data collection, analysis, and reporting application. It allows real-time evaluation of IEQ with a focus on advanced HVAC systems.

Boundary Layer Wind Tunnel

Boundary layer wind tunnels simulate characteristics of natural wind impacts on a building or community Researchers use flow visualization, velocity and turbulence intensity measurements to understand the air flow. The tunnel can be used for studies of wind effects around and within buildings, and to study innovative air measurement technologies.

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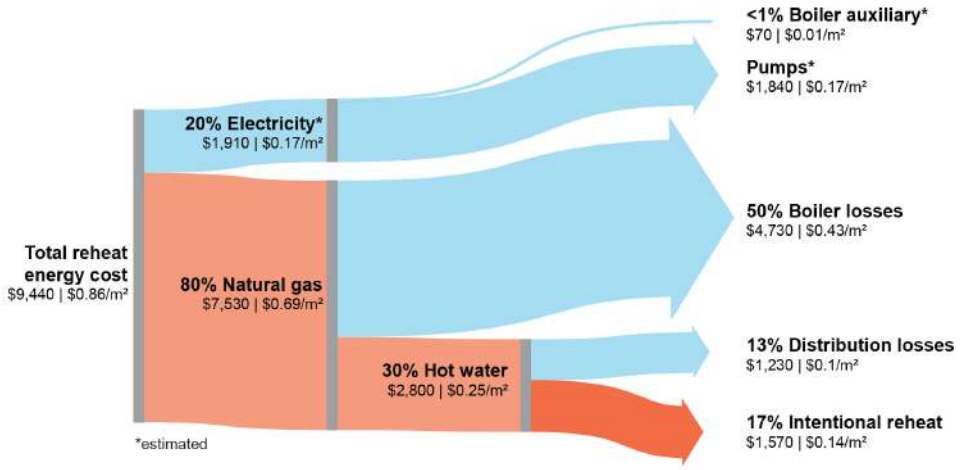
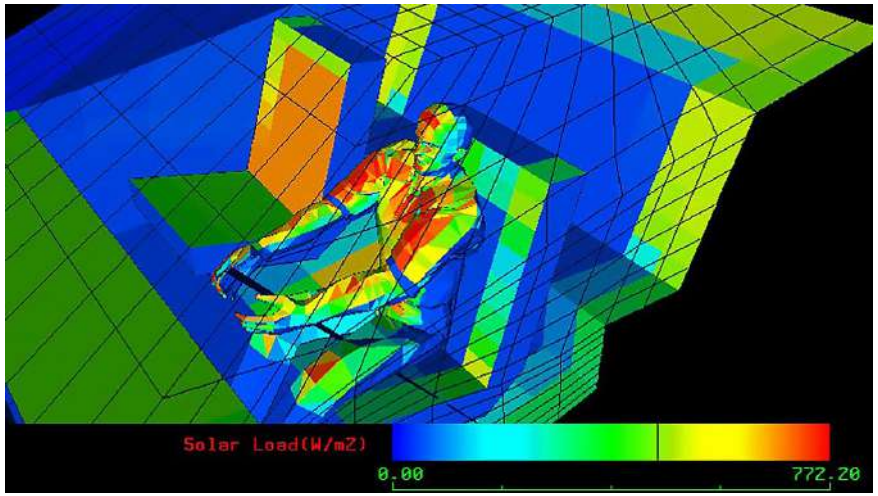
UC Berkeley



Technology Performance Assessment in Real Buildings

CBE has conducted several field investigations of heating, ventilation, and air-conditioning (HVAC) system and component performance. Researchers have developed novel methods for evaluating new technology energy use through analysis of large measured datasets from building automation systems



Thermal Comfort Automotive Research

CBE's world-class thermal comfort resources have been used to design and test automobile heating and cooling systems that are optimized for energy efficiency and comfort. Physical testing is done in CBE's Controlled Environment Chamber. Modeling is done using CBE's Advanced Thermal Comfort Model.

Technology Type	Testing Capabilities
Building Technologies	• Full-scale test chamber allows human subject experiments to assess thermal comfort performance and occupant satisfaction with indoor environmental quality. • Occupant response to HVAC system type, temperature, airflow, humidity, personal control. • Precision measurements of thermal conditions (temperature, humidity, air velocity, mean radiant/operative temperature), as well as indoor air quality. • Innovative HVAC systems studied include personal comfort systems, underfloor air distribution, displacement ventilation, and smart ceiling fans.
Building Technologies	• Wireless instrumentation toolkit allows field investigations of indoor environmental quality (IEQ) and HVAC performance in real buildings. • Measurement procedures based on ASHRAE's Performance Measurement Protocol (PMP). • Continuous real-time data collection and reporting • Data collected from building automation system can be used to supplement evaluation of energy and IEQ performance. • Occupant surveys used to assess occupant satisfaction.
Building Technologies	• Boundary layer wind tunnel allows studies of wind effects around and within buildings. • Boundary layer wind tunnel can be used for validation and comparison testing of advanced anemometer sensors.

Technology Type	Testing Capabilities
Energy Efficiency	• Large measured datasets from Building Automation Systems are used to evaluate energy performance of innovative building HVAC systems. • Novel methods allow reliable comparison between different control strategies by using, for example, a randomized cross-over trial over extended time periods. • These data analysis methods have been applied in Sutardja Dai Hall (see CITRIS entry).
Energy Efficiency	• Full-scale mock-ups of automobile cabins in CBE's Controlled Environment Chamber allow human subject testing of heating and cooling systems. • Advanced Thermal Comfort Model allows comparison of different designs and pre-selection for testing of most effective solutions. • Systems are evaluated to optimize thermal comfort with energy efficiency.

Center for Information Technology Research in the Interest of Society

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Sutardja Dai Hall has over 6000 sensing points from the Siemens Apogee Building Automation System and Wattstopper lighting system accessible through the simple Monitoring and Actuation Profile (developed at UC Berkeley).

With additional sensors, such as temperature and flow sensors on the chilled water supply, discharge air temperature sensors at most of the 135 zones.

The Center also provides wireless indoor environmental quality sensors.

Center for Information Technology Research in the Interest of Society

UC Berkeley

Sutardja Dai Hall: Living Laboratory

Sutardja Dai Hall (SDH) on the UC Berkeley campus is a 141,000-ft^2 building that houses office space, laboratories, and classrooms. SDH was deliberately designed and built as a living laboratory with multiple meters and submeters. SDH has a Siemens Apogee Building Automation System (BAS) that controls a "best practice" variable-air-volume (VAV) reheat system for space conditioning of the 135 zones. Both the BAS and WattStopper lighting system are accessible through BACnet. BACnet points have been mapped and used for sophisticated control sequence testing.

Technology Type	Testing Capabilities
Energy Efficiency	• Sutardja Dai Hall is a living lab with large numbers of installed sensors, innovative building systems, and a supportive building manager for research studies. • Large measured datasets from the Building Automation System have been used to evaluate and compare energy and cost performance of new building HVAC systems and control strategies. • Completed studies include time-averaged ventilation, cost-responsive supply air temperature reset, occupant voting-based temperature control with Comfy^{tm}, personal comfort systems, and demand response events.


UCDAVIS
UNIVERSITY OF CALIFORNIA

Western Cooling Efficiency Center

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The WCEC accelerates development and commercialization of efficient heating, cooling, and energy distribution solutions through innovation, R&D, stakeholder engagement, education, and outreach.

Conducts applied research, development, and demonstrations in the field and the laboratory, spanning a wide spectrum of HVAC technologies and approaches, building envelope sealing research, as well as supporting controls and behavioral research.

Western Cooling Efficiency Center

UC Davis

Readily available hot and chilled water, outdoor air supplies, natural gas, and electricity.

Ability to design and construct laboratory testing apparatuses to meet the needs of a particular experiment or to test a particular product.

In-house laboratory with environmental chamber capable of re-creating 95% of California's hot/dry climates. The environmental chamber is capable of handling HVAC units up to 8-tons. Types of equipment that WCEC has tested in the environmental chamber includes:

- Evaporative condenser air pre-coolers
- Variable speed fan and compressor controls
- Sub wet-bulb evaporative chillers
- Cooling towers
- Heat pumps, including a gas-engine heat pump
- Microchannel evaporators

Technology Type	Testing Capabilities
Energy Efficiency	An environmental chamber designed specifically for appliance testing at controlled indoor conditions.
Energy Efficiency	Two environmental chambers simulating indoor and outdoor climate conditions with high accuracy control of dry bulb and wet bulb temperatures. Types of equipment that WCEC has tested in the environmental chamber includes: • Evaporative condenser air pre-coolers • Variable speed fan and compressor controls • Sub wet-bulb evaporative chillers • Cooling towers • Heat pumps, including a gas-engine heat pump • Microchannel evaporators The environment chamber is capable of handling HVAC units up to 8-tons.
Energy Efficiency	High accuracy (±1%) airflow measurement capabilities

California Lighting Technology Center

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The CLTC is dedicated to accelerating the development and commercialization of next-generation, energy-efficient lighting and daylighting technologies.

Includes full-scale laboratories for research and development, prototyping, and product testing.

California Lighting Technology Center

UC Davis

14,000+ sq. ft. facility functions as a living laboratory where new lighting and daylighting technologies are researched, developed, and evaluated (both qualitatively and quantitatively).

Custom Performance Characterization

For many new technologies, standardized testing procedures do not exist. CLTC has the expertise to design and deploy custom product performance characterizations in a controlled laboratory setting or field demonstration.

Markets

CLTC works collaboratively with industry partners, regulatory agencies, utilities, contractors, workforce development teams, and others to ensure products and strategies are valuable to and appropriate for California markets.

Technology Type	Testing Capabilities
Energy Efficiency	Full-scale laboratories are fully equipped for product testing. Instrumentation is available to quantify such things as photometric performance, electrical performance such as flicker, power factor and THD, audible noise, air quality, thermal conditions and product life. Equipment includes: Five integrating spheres of different diameters: one small sphere, 20 inches in diameter, a medium 1-meter integrating sphere, and three 2-meter integrating spheres. These specialized devices support measurement of the spectral power distribution (SPD) of light sources. One of the two large integrating spheres is custom-made and features a controlled environment. It is designed to support multiple measurement protocols that address lamp orientation and thermal conditions. Two goniophotometers, one small and one large. Goniophotometers are devices that allow measurements of the candle-power distribution (CPD) of light sources. The small goniophotometer was designed for CPD measurements of small light sources, as well as measurements of the directional sensitivity of photosensors. The large goniophotometer supports conventional CPD measurements in terms of lumens per solid angle. Moreover, it supports SPD measurements for each outgoing direction, which is a unique capability. This is especially useful for characterizing the output of systems that use more than one light source, a relatively common approach with LED light sources.

Green Technology Laboratory

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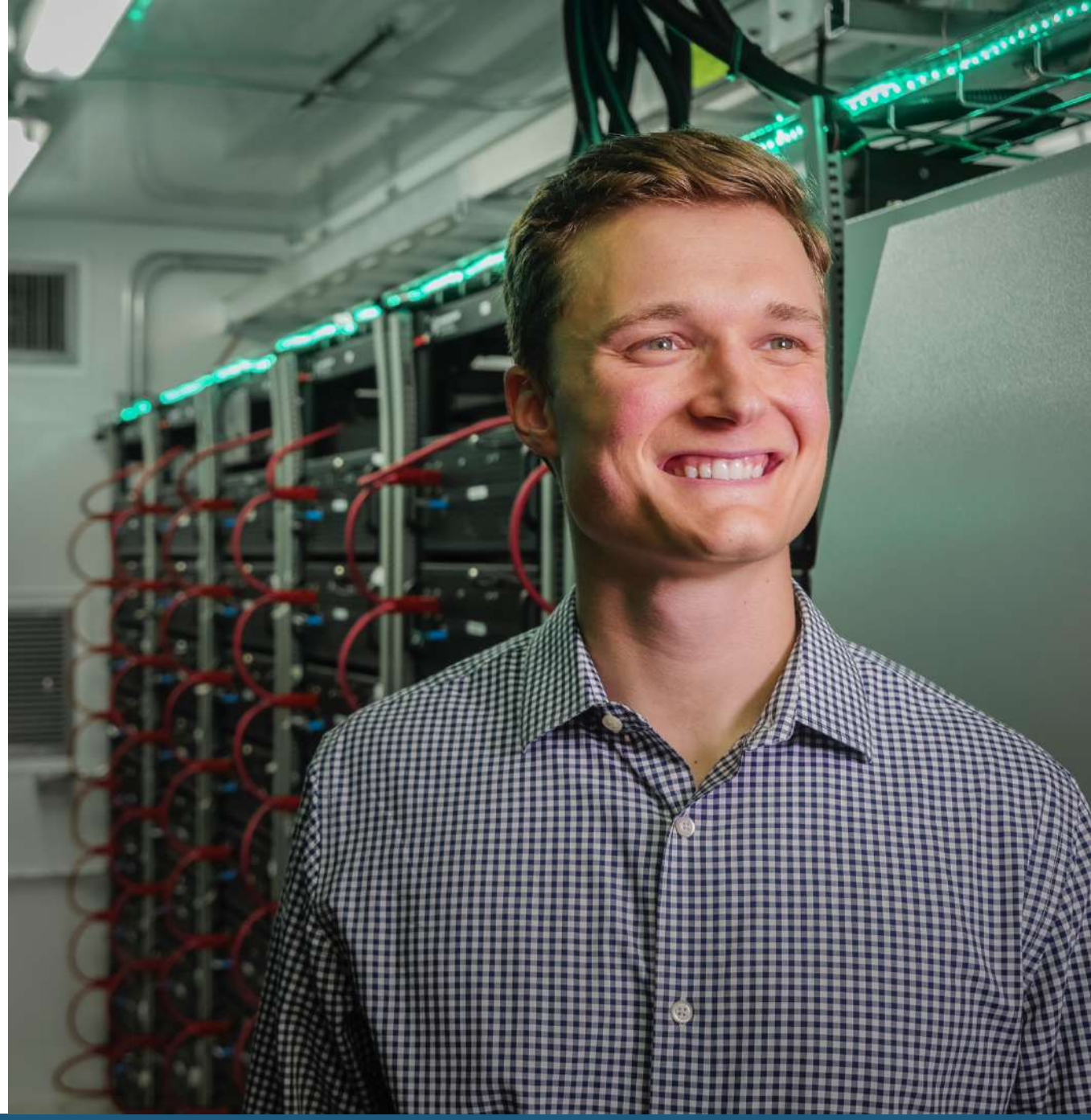
GTL studies the behavior of lithium-ion batteries of varying chemistries under different conditions. Using this data, we create models, new test procedures, controls, and design systems that take advantage of high energy density storage.

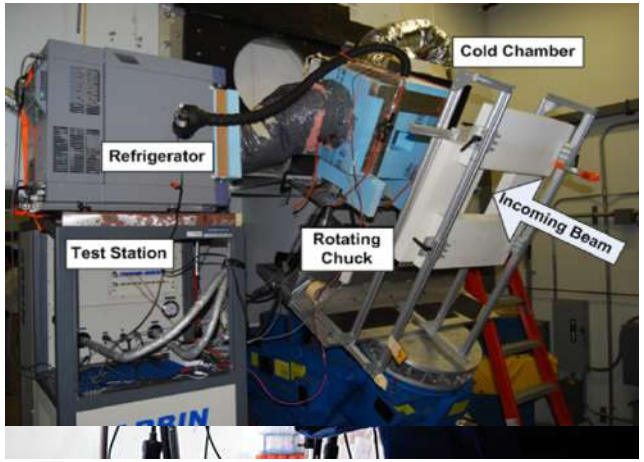
Combines mechanical design and analysis, electrical design, thermodynamics, heat transfer, energy systems, and machine shop skills to build "real-world" systems.

Expertise in using second-life batteries retired from electric vehicles for building energy storage



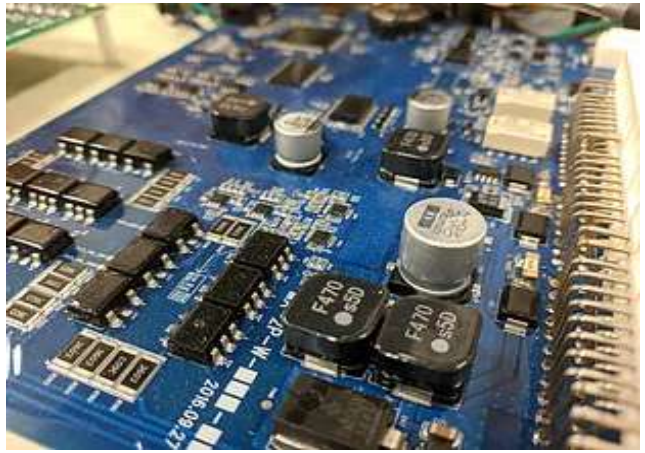
Green Technology Laboratory

UC Davis



- Access to UC Davis McClellan Nuclear Research Center (MNRC) for in-situ neutron radiography (NR) of fuel cells and batteries
- Equipped with fully automated fuel cell and battery test stations and various tools to perform in-situ NR imaging.
- The lab has access to a machining center with high precision machining tools, including a CNC, welding machine, and EDM cutting system.

- Green Technology Laboratory is equipped with various fuel cell, battery and energy storage test equipment along with cell design and fabrication capabilities
- Primary test units are Bitrode battery/pack testers, multi-channel Arbin battery testers, high voltage bi-directional inverters, and environment chambers. Test profiles (current and power) are PC-controlled and data can be sampled at rates from 10-100 Hz. The lab is able to supply and regulate bottled hydrogen and high pressure air for fuel cell testing. Hydrogen detectors are installed in the lab.



- Testing, evaluating and integrating high power, state-of-the-art energy storage including the latest battery and capacitor technology into hybrid systems for use by researchers and students.
- State of the art battery management system (BMS) to maintain the safety and efficiency of battery pack.
- Access to Robert Mondavi Institute (RMI) Microgrid with 220 kW solar PV and 300 kWh energy storage system using second life EV batteries.

Technology Type	Testing Capabilities
Energy Storage	Multichannel battery test station and various tools to test and assemble battery packs. The lab has access to a machining center with high precision machining tools, including a CNC, welding machine, and EDM cutting system. The associated fuel cell laboratory is equipped with an automated fuel cell/battery test station and environment chamber, along with cell design and fabrication capabilities. Ability to test batteries, fuel cells, and ultra-capacitors. The primary test units in the lab are **two Bitrode battery tester** (50/100V, 400A), **four multi-channel Arbin battery testers** (10V-204V, 20A - 200A), **four bi-directional Inverters** (5-60 kW/110-600V; **SMA, Ideal Power, Rhombus, Princeton Power**), and **three environment chambers** with temperature and humidity control. Test profiles (current and power) are PC-controlled and data can be sampled at rates from 10-100 Hz. The lab is able to supply and regulate bottled hydrogen and high pressure air for fuel cell testing. Hydrogen detectors are installed in the lab. Numerous fuel cell, battery, and ultra-capacitor test projects have been conducted using custom LabView software. Testing, evaluating and integrating high power, state-of-the-art battery management system (BMS) and energy storage including the latest battery and capacitor technology into hybrid systems for use by researchers and students is also conducted in the lab.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Advanced Power and Energy Program (APEP)

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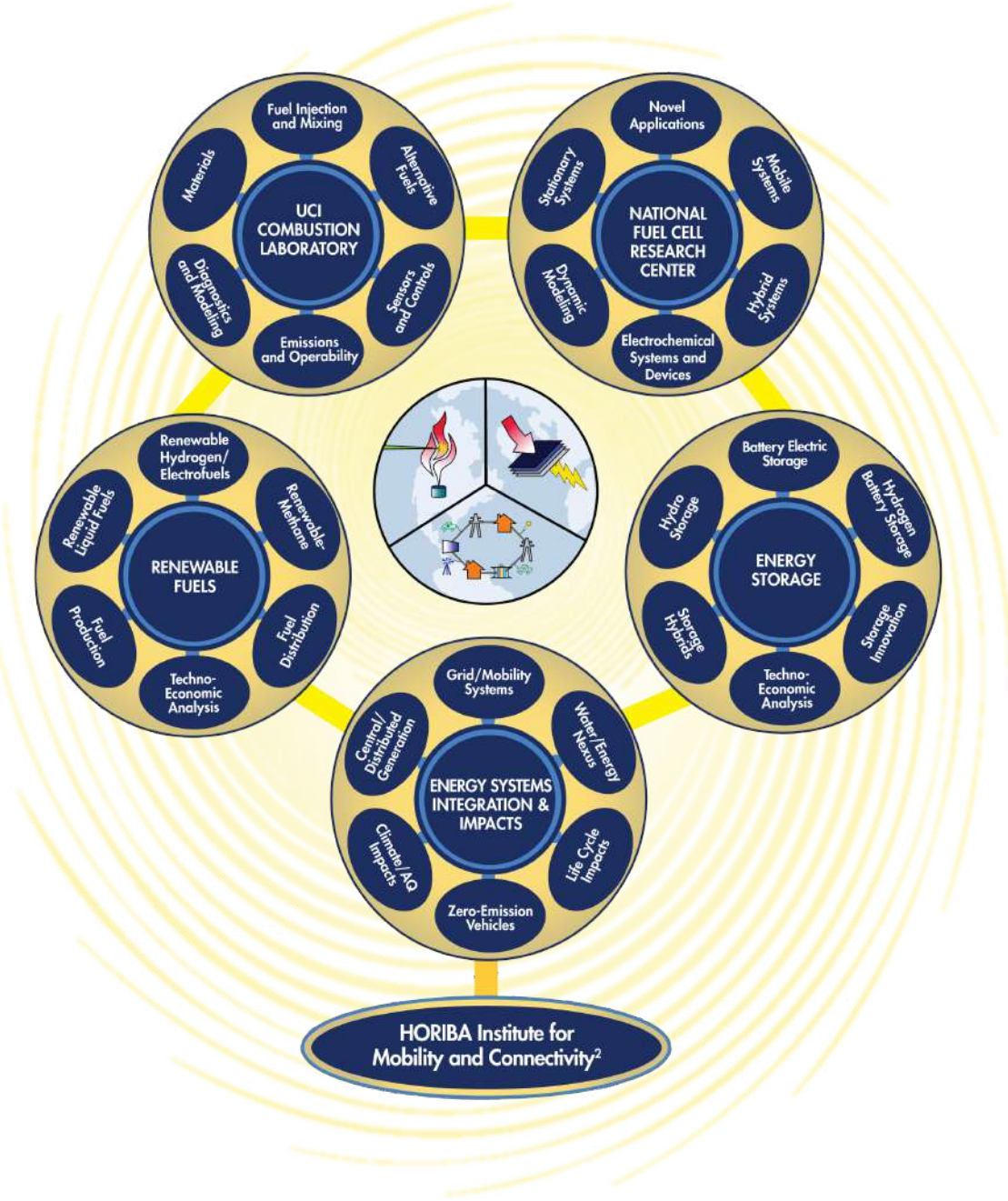
APEP focuses on the development and deployment of efficient, environmentally sensitive, sustainable power generation and energy conversion worldwide.

Rich tradition in energy and environmental studies and is located in the heart of a region that is internationally recognized for leadership in energy and transportation research and innovation.

Multiple on-site research capabilities that include:

- *Testing and demonstrating of distributed energy technologies from a few to 500 kilowatts with combined cooling, heating, and power*
- *Energy Systems Integration and Impacts, Renewable Fuels, Energy Storage, Vehicle Evolution Laboratory, Grid Evolution Laboratory.*



Advanced Power and Energy Program (APEP)

UC Irvine

Grid Technology

Capabilities that allow research at levels ranging from grid and microgrid simulation to practical application. These include the capability to evaluate distribute energy resources and the system integration of DER including nanogrid and microgrid control, islanding, fault detection and remediation, and overall reliability and resiliency.

Horiba Institute for Mobility and Connectivity[2]

The Horiba Institute for Mobility and Connectivity[2] addresses the evolution of zero emission vehicles, the coupling to the electric and hydrogen grids, and the communication between vehicles and with the infrastructure. Planned for opening in May 2020, HIMaC[2] provides platforms for testing electric-drive train vehicles, batteries and battery components, fuel cell engines, and connected and autonomous vehicles.

Sustainable Energy and Transportation Technology

Research at the interface of electrical power generation and transportation including the development of systems and models for the integration of renewable and complementary technologies (power generators, renewable fuel generation and dispensing, energy storage, controls) that produce a reliable resilient energy resource and the local, community, regional, and state scales.

Technology Type	Testing Capabilities
Energy Storage	Grid and off-grid test platforms and Simulation for Batteries
Energy Efficiency	Grid and off-grid test platforms and Simulation for Energy Systems

National Fuel Cell Research Center (NFCRC)

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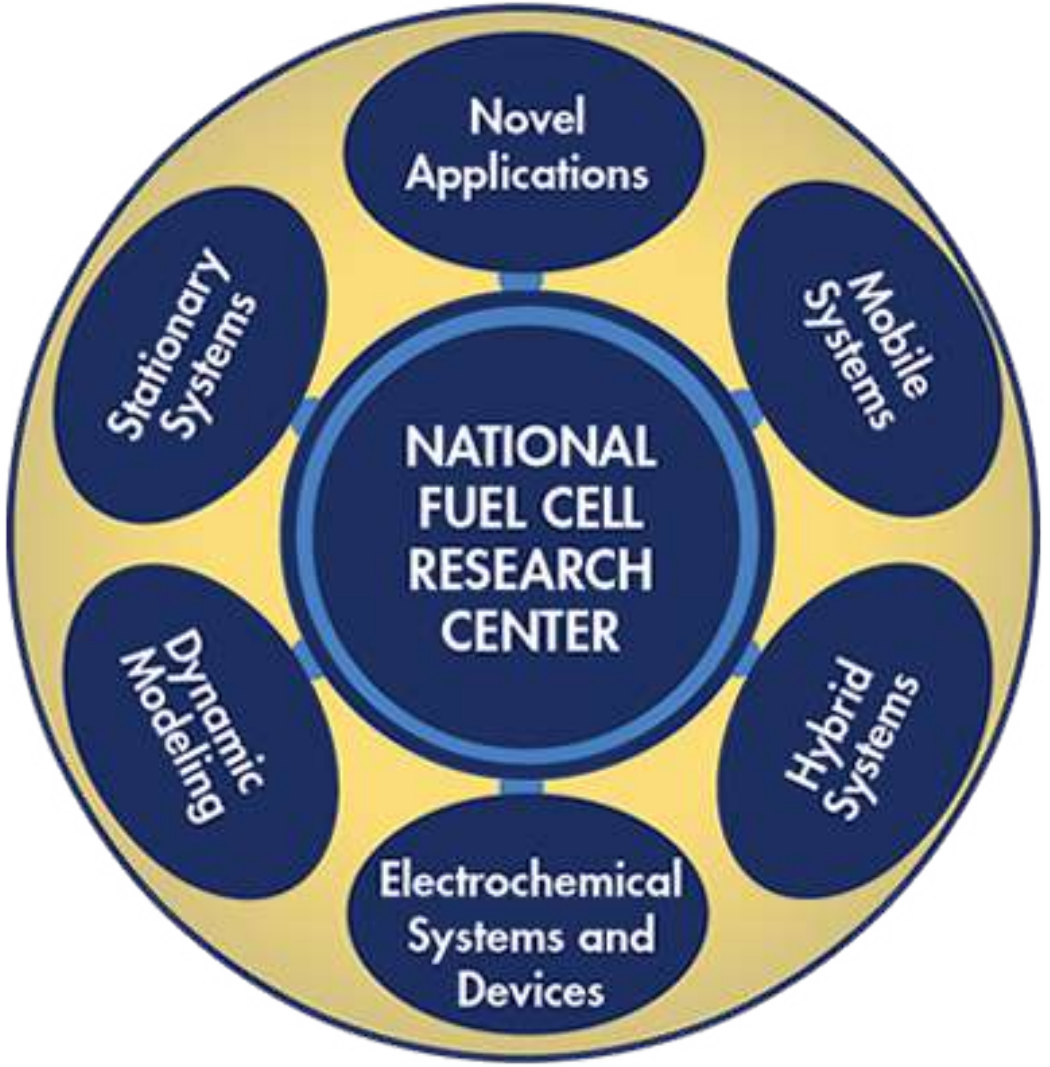
Accelerates the development and deployment of fuel cell technology. Forms strategic alliances to facilitate markets evolution.

Opportunities to connect with major institutions around the world.

Multiple on-site research capabilities that include:
- *Testing of batteries, fuel cells, and electrochemical systems*
- *Testing of electrolyzer and power-to-gas applications*



National Fuel Cell Research Center (NFCRC)

UC Irvine

Fuel Cell/Gas Turbine Hybrid Technology

Laboratory that provides international leadership in fuel cell/gas turbine (FC/GT) hybrid technology: the integration of a conventional heat engine with emerging advanced fuel cell technology that synergistically gives rise to an unusually high fuel-to-electricity conversion efficiency. Developed and continues to apply fundamental thermodynamic and dynamic models for the analyses and design of advanced systems from those suitable for distributed generation

Mobile Fuel Cells

Laboratory that provides international leadership in fuel cell/gas turbine (FC/GT) hybrid technology: the integration of a conventional heat engine with emerging advanced fuel cell technology that synergistically gives rise to an unusually high fuel-to-electricity conversion efficiency. Developed and continues to apply fundamental thermodynamic and dynamic models for the analyses and design of advanced systems from those suitable for distributed generation

Stationary Fuel Cells

Laboratory that provides international leadership in fuel cell/gas turbine (FC/GT) hybrid technology: the integration of a conventional heat engine with emerging advanced fuel cell technology that synergistically gives rise to an unusually high fuel-to-electricity conversion efficiency. Developed and continues to apply fundamental thermodynamic and dynamic models for the analyses and design of advanced systems from those suitable for distributed generation

Technology Type	Testing Capabilities
Energy Storage	Grid and off-grid test platforms for Batteries and Electrolyzers

UCI Combustion Laboratory (UCICL)

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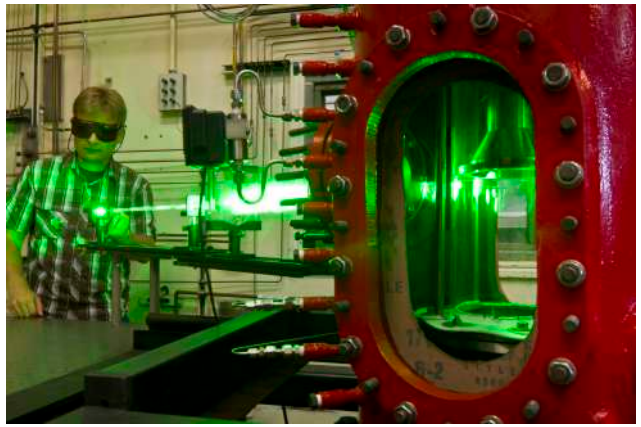
Reduction of pollutant formation in continuous combustion systems with a focus on fuel/air mixing with both gaseous and liquid fuels.

Multiple on-site research capabilities that include:

- *Provision of advanced diagnostic capabilities to study combustion and flow field behavior*
- *Computational Fluid Dynamics*
- *Extensive testing capabilities from STP to 10 atmosphere, 1200°F feed air, and an array of test platforms and laser diagnostics including laser anemometry and phase Doppler interferometry.*

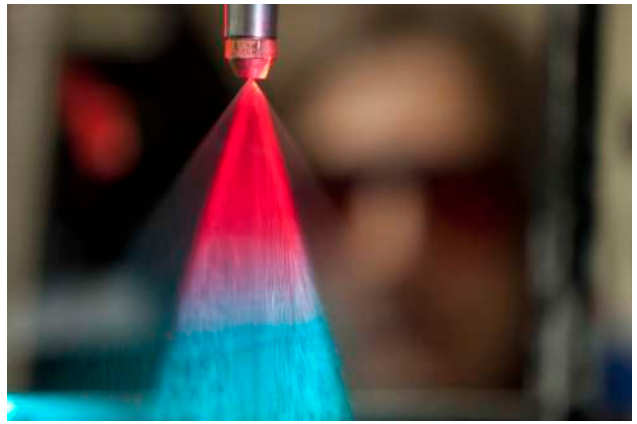
UCI Combustion Laboratory (UCICL)

UC Irvine



High-Pressure, High-Temperature Platform

Capabilities that allow research at levels ranging from basic science to practical application. These include the capability to operate practical combustion systems, including small gas turbine engines, boilers, and appliances on simulated fuels that are expected to play an increasing role in our future power generation, industrial processes, and transportation needs.



Array of Laser Diagnostics

The UCICL was founded in 1970 with the advent of laser diagnostics and, in 1988, relocated in a 23,000# purpose-built test facility for laser applications from STP to high-pressure, high-temperature conditions representative of gas turbine engines. The capabilities include high-resolution time-resolved laser imaging, laser anemometry, and phase Doppler interferometry that are applied to (1) liquid spray atomization, mixing, evaporation, and reaction, and (2) performance on renewable fuels.

Beta Test Facility

The Beta Test Facility allows, up to 100's of kilowatts, near-commercial, just-commercial, and practical combustion systems under development to be tested for thousands of hours on liquid and gaseous fuels of varying composition. Both grid-connected and off-grid performance, and testing with or without combined cooling, heat, and power can be accommodated.

Technology Type	Testing Capabilities
Renewable Generation	Grid and off-grid test platforms for conventional/renewable fuels, combined cooling, heat, and power.


UCLA


SMERC
UCLA Smart Grid Energy Research Center

Smart Grid Energy Research Center (SMERC)

UCLA Smart Grid Testbed

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The UCLA Smart Grid Testbed monitors and controls 117 level 1 and level 2 EV charging stations, 2 DC Fast Chargers, 135.2 kW Solar Panels, and 128.5 kWh of Battery Energy Storage System. The testbed allows integration of project partner's energy resources in a microgrid system through smart meters, controllers and sensor network.

The EV chargers in the Testbed are currently used by UCLA employees, fleet vehicles and residential charging at university housing. With 400+ active user participation to test on innovative energy management algorithms through mobile apps.

The Control Center in the testbed enables testing of various power management algorithms through easy access and control of all Distributed Energy Resources (DER) components in an aggregated manner.

Smart Grid Energy Research Center (SMERC)

UCLA Smart Grid Testbed
Facility Overview

28 Level 2 chargers in PS 9

100 kW PV in PS 9

2.5 kW mobile BESS cart with 200 W PV

56 kWh Saft BESS in PS 9

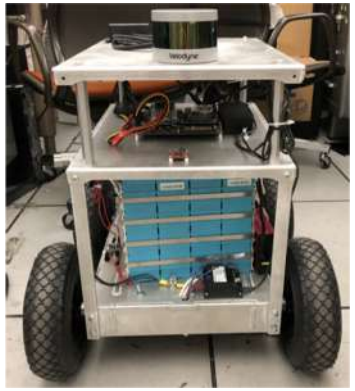
V2G System

50 kWh Microvast Li-ion Battery with EPC Power inverter

UCLA Microgrid control center

RTDS Simulation System

41 level 1 fleet chargers



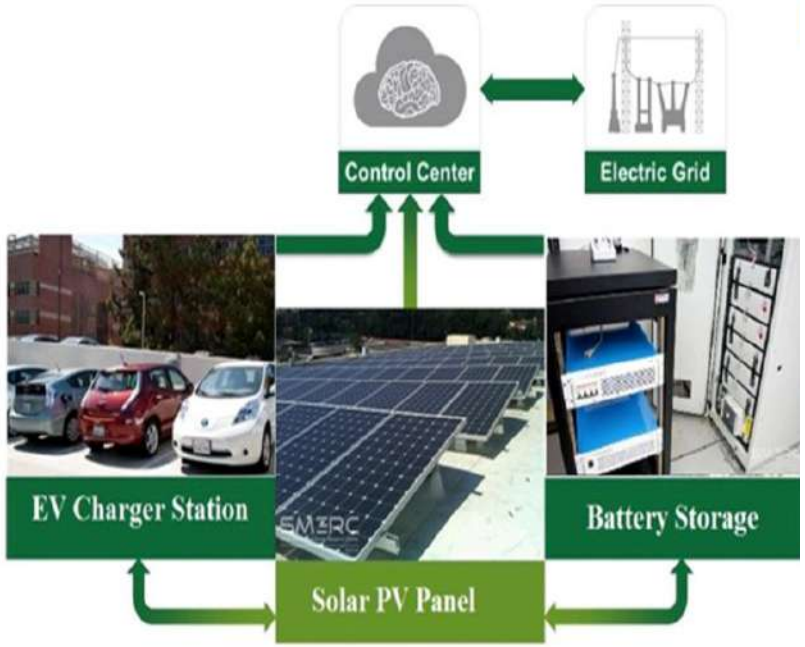
CAEV - ANTBOT™

Technology Type	Testing Capabilities
Internet of Things	Mobile App for User Participation – collect feedback and inputs from 400+ active user among UCLA faculties, employees and students. Testing of project partner's EVSE and/or mobile apps for interface design, collect data for EV load prediction, User incentivized smart charging, AI based user behavior prediction and analysis.
Internet of Things	Analyzing the pairwise correlation of the sensor data within a system and detect abnormal data transmission. Riverbed © modeler allows for communication network modeling and simulation and test with scaled up communication network.
Grid Technologies	Microgrid Control Dashboard System – Microgrid visualization system with real time meter and sensor data. The dashboard system allows for testing of various charge scheduling algorithms (TOU pricing, priority charging, OpenADR 2.0, Duck Curve mitigation, load shifting) and perform data collection and analysis through convenient GUI provided in the Dashboard system
Grid Technologies	BESS and Inverter Testing – Testing of project partner's inverters or BESS on speed of response to grid signals, voltage regulation, reactive power compensation, load leveling with DCFC, balancing intermittent photovoltaic generation, duck curve mitigation
Grid Technologies	Power Grid Simulation – ETAP® , RSCAD/RTDS, and IEC61850 gateway for scaled up grid impact and benefit analysis, integrated distribution network analysis, system planning and operations solution, hardware in the loop simulation, impact analysis of integrated DER, microgrid power system real time simulation
Grid Technologies	PS 9 Microgrid System – 250 kW capacity at 480 VAC 3P and 208 3P power lines. The microgrid system can test project partner's energy device such EVSE, inverters, BESS, PV panels and switching gears in the microgrid operation (islanding and grid-tie), demand response testing, load leveling, peak shaving testing, cost and stability analysis.

Technology Type	Testing Capabilities
Transportation	EV Fleet Charging Management and Operations – Testing of EVSE and management applications via UCLA EV fleets in housing and facility management. Target testing includes maintenance team cost optimization via charge scheduling and circuit sharing, EV fleet charging management, EV fleet operations, etc.
Transportation	Testing of V1G and V2G enabled EVSEs and vehicles with SAE, CHAdeMO, OCPP and ISO protocols. EVSE circuit and stub ready for installation of your EVSE on UCLA Campus.
Energy Efficiency	Home of Future – Testing of project partner's smart appliances (electric drier, refrigerator, HVAC, LED lighting, etc.) with communication protocols such as OpenADR, BACnet, DALI, DLMS for home energy saving and management, scheduling of energy consumption to minimize cost

PS 9 Microgrid System

UCLA Smart Grid Testbed



Description: P9 or Parking lot 9 microgrid consists of integrated solar PV, EV chargers, and a battery storage facility in the heart of the campus. The DERs in this facility communicate with Cloud software and can be controlled remotely. Additional DER elements can be added to this facility and integrated with the rest of the assets for testing purposes.

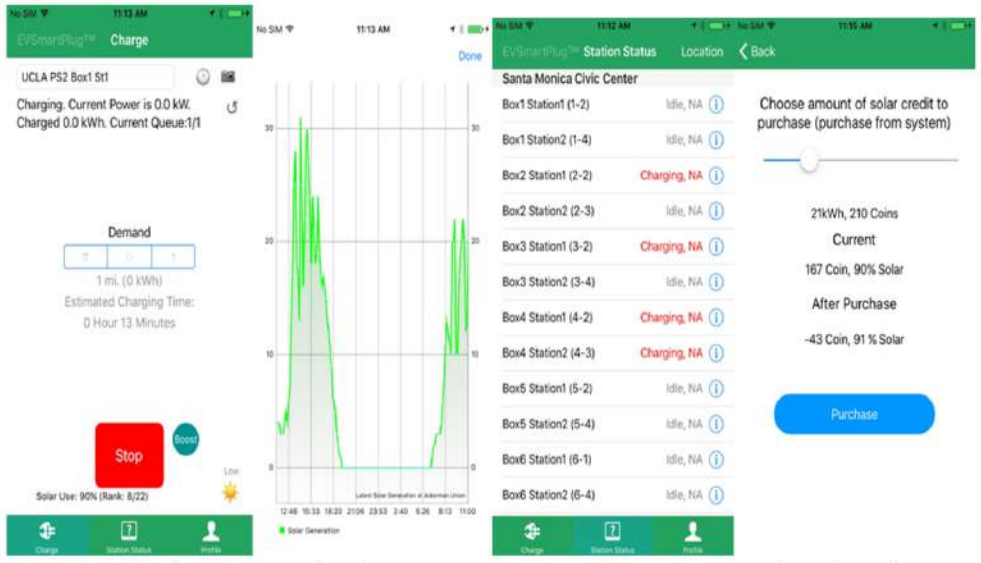
Technology Type: Microgrid System and Optimization

Testing Capabilities:

- Testing of energy devices on the microgrid:
  - EVSEs
  - Inverters
  - BESS
  - PV panels
  - Switching gears (islanding and grid-tie)
- Testing of device control for energy management algorithms:
  - Testing of solar duck curve mitigation
  - Load leveling for Direct Current Fast Charging (DCFC) with Battery Energy Storage System (BESS)
  - Peak load shaving
- Collect Data for Benefit Analysis
  - Energy Cost and Efficiency Analysis
  - GHG emission reduction
  - Power Grid stability improvement

Mobile App for User Participation

UCLA Smart Grid Testbed



Description: Over 400 EV drivers in UCLA have signed up to the SMERC research testbed with each of them having the ability to use mobile app. This mobile app can be customized depending on the testing needs of the project. Example of testing capability is as shown above – testing of "local solar" utilization algorithm.

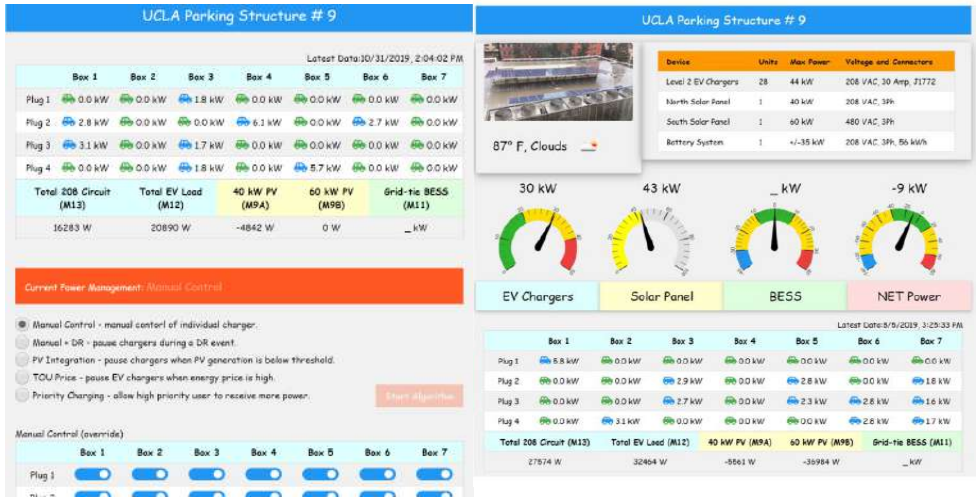
Technology Type: User Participation

Testing Capabilities:

- Collect feedback and inputs from 400+ active user among UCLA faculties, employees and students with multidisciplinary background
- Testing and collection of data for project partner's EVSE and/or mobile apps on:
  - Interface design
  - EV load prediction
  - User incentivized smart charging
  - AI based power load profile prediction, user behavior prediction and analysis

Microgrid Control Dashboard System – Data Analysis Platform

UCLA Smart Grid Testbed



Description: UCLA cloud software has a control center that enables real-time visualization of all the DER assets that are connected to the SMERC system in the UCLA campus. SMERC uses data science principles to perform data analysis in real time from the monitoring sensors connected to the DER assets.

Technology Type: Control Center Visualization and Operation

Testing Capabilities:

- Microgrid Visualization System allows for real time meter and sensor data integration in a GUI based dashboard.
- The dashboard system allows for testing of various energy scheduling and management algorithms (TOU pricing, priority charging, OpenADR 2.0, Duck Curve mitigation, load shifting) for project partner's device or management algorithms.
- Perform data collection and analysis through convenient GUI provided in the Dashboard system

V1G and V2G Testing

UCLA Smart Grid Testbed

Level 2 Smart Chargers with circuit sharing among 4 connected EVs

Mitsubishi i-MiEV Power box

Princeton Power CA 30 V2G DCFC with Nissan Leaf

Description: An array of smart chargers (with V1G capability) and two Vehicle to Grid (with V2G capability) chargers are available for testing of protocols, algorithms, and controls. Both DCFC and AC chargers are available for such testing. Car manufacturers can test V1 and V2G in this facility.

Technology Type: EV Smart Charging (V1G and V2G)

Testing Capabilities:

- EVSE:
  - Level 1 and level 2 smart chargers with circuit sharing
  - Mitsubishi i-MiEV Power box (1.5 kW bi-directional power flow)
  - Princeton Power CA 30 V2G DCFC (30 kW bi-directional power flow)
  - Bosch DCFC (30 kW DC Fast charger)
  - Nissan (50 kW DC Fast Charger)
- Testing of Communication and Protocols:
  - SAE J1772 and SAE J1772 CCS.
  - CHAdeMO
  - ISO 15118
  - OCPP

BESS and Inverter Testing

UCLA Smart Grid Testbed

Microvast Li-ion Battery with EPC Power Inverter

Saft Li-ion Battery with OCC Inverters

Technology Type: BESS and Inverters

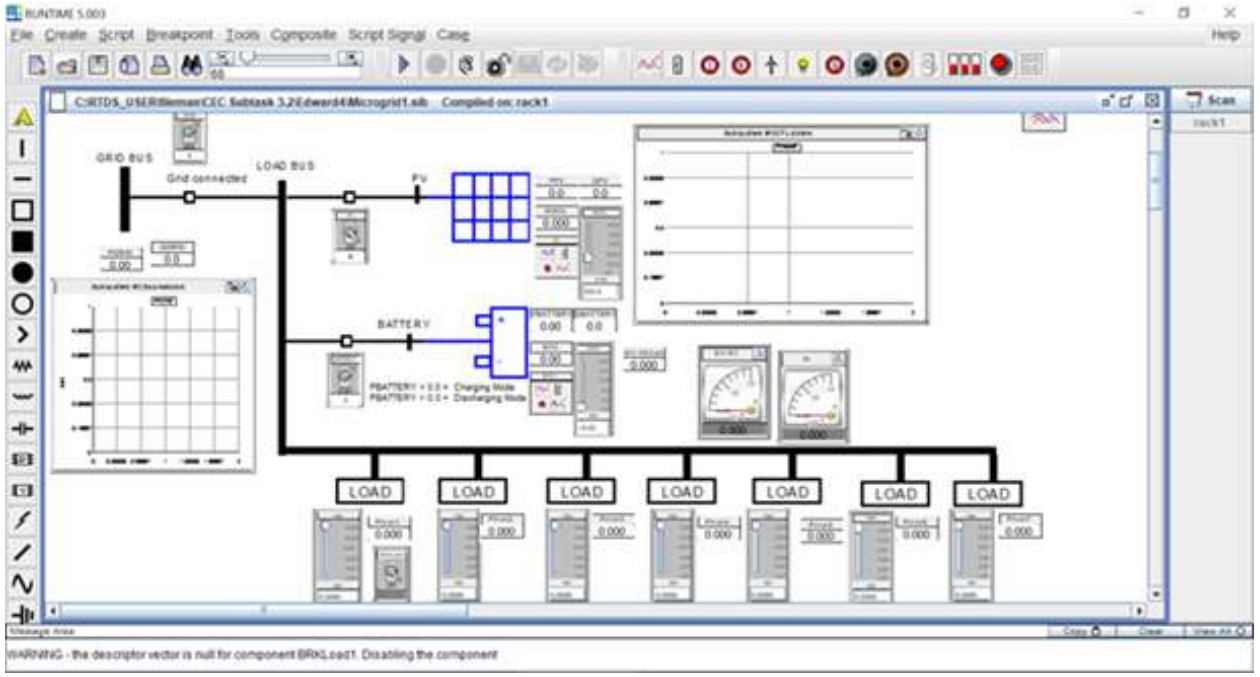
Testing Capabilities:

- BESS Testing
- Inverter Testing
- Grid Services via BESS and/or Inverter:
  - Speed of response to grid signals
  - Voltage regulation
  - 4 quadrant Reactive Power compensation
  - Load leveling with DCFC
  - Balancing intermittent Photovoltaic (PV) generation

Description: Two battery systems with inverters are available – one within a building and another in a parking structure – for testing of grid services. They are connected to high speed controllers which may be used to test fast response requirement from grid operators. This is an expandable facility to add additional battery storage or inverters for testing of larger scale as needed.

Power Grid Simulation

UCLA Smart Grid Testbed



Description: ETAP ® is an analysis platform for the design, simulation, operation, and automation of generation, distribution, and industrial power systems. RTDS is a real time simulator that allows hardware in the loop among other important functions. These systems enable virtual prototyping in advance of the building the real system.

Technology Type: Power Grid Simulation

Testing Capabilities:

- ETAP®
  - Scaled up grid impact and benefit analysis
  - Integrated distribution network analysis
  - System planning and operations solution
- RSCAD/RTDS real time simulator
  - Simulated Power System
  - Hardware in the loop simulation
  - Impact analysis of integrated DER
  - Microgrid power system real time simulation
- IEC61850
  - Virtual IEV61850 gateway for communication simulation

EV Fleet Charging Management and Operations – Sunset Village

UCLA Smart Grid Testbed

Technology Type: EV Fleet Operation and Scheduling

Testing Capabilities:

- EV Fleet Charging Management and Operations – Testing of EVSE and management applications via UCLA EV fleets in housing and facility management.
- Target testing includes maintenance team cost optimization via charge scheduling and circuit sharing, EV fleet charging management, EV fleet operations, etc.

Description: UCLA Sunset Village has installed an array of chargers supporting UCLA fleet which can be used to study fleet operations of EV charging within a campus including energy consumption, scheduling of charging, demand charge management, etc.

Home of Future

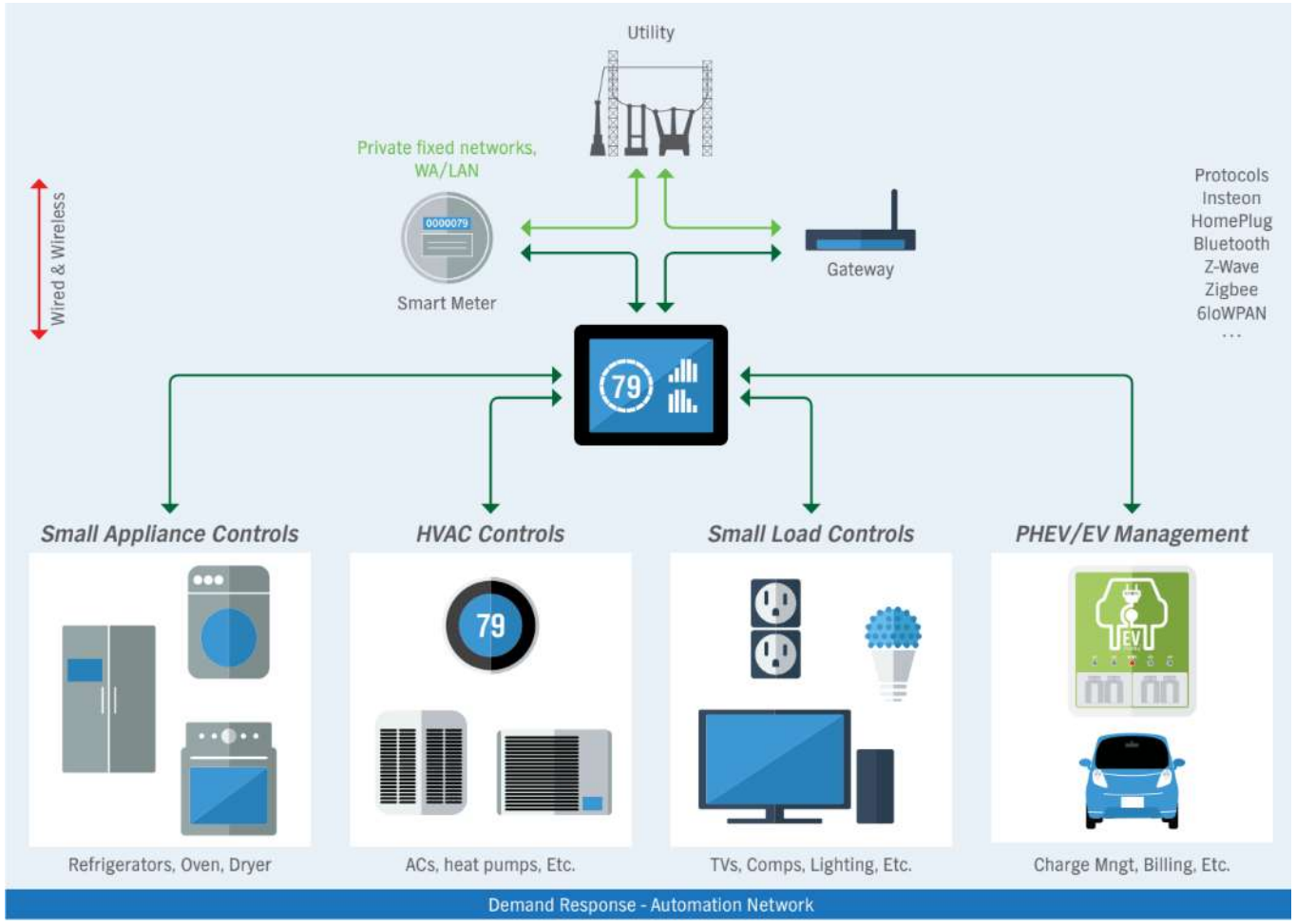
UCLA Smart Grid Testbed

Technology Type: Demand Response

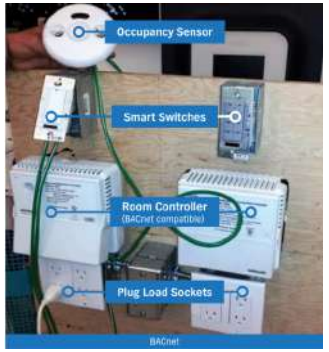
Testing Capabilities:

- Home of Future – Testing of project partner's smart appliances - electric drier, refrigerator, HVAC, LED lighting, etc.
- Testing of communication protocols - OpenADR, BACnet, DALI, DLMS for home energy saving and management, scheduling of energy consumption to minimize cost

Description: Appliances such as refrigerators, electric clothes driers, LED lighting, have been outfitted with real-time communications and controls to enable testing of demand response programs, load management, or, peak reduction programs. Variety of protocols are supported in this infrastructure. Testbed can add new appliances, protocols, or algorithms for testing.



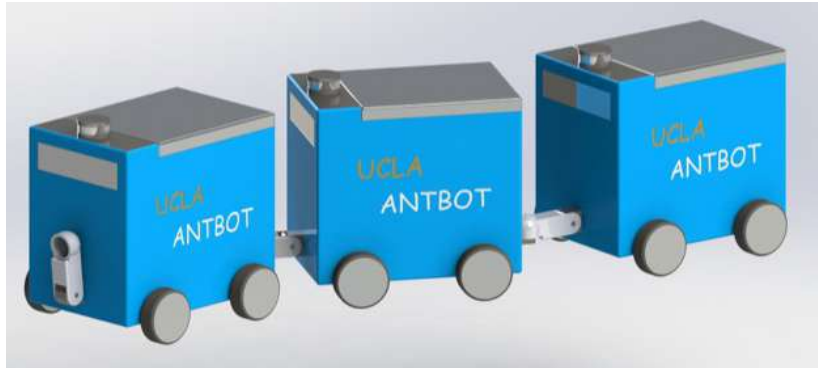

Dryer with appliance controller

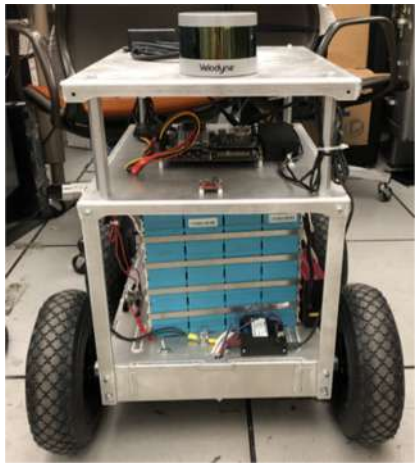



Refrigerator with appliance controller

ANTBOT™ autonomous electric vehicle

UCLA Smart Grid Testbed





Description: UCLA has developed a mobile EV+AV platform controlled by software that uses real-time data from Velodyne LiDAR to navigate within campus. The architecture enables testing of third party hardware or software.

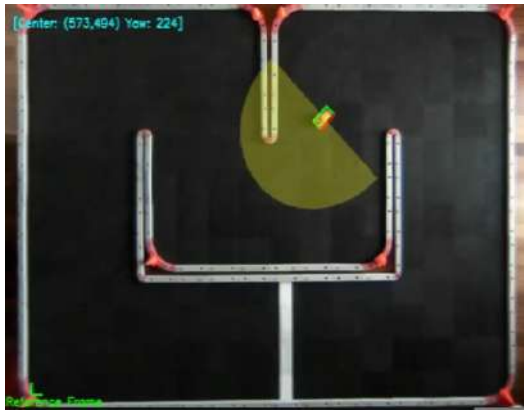
Technology Type: Connected Autonomous Electric Vehicle

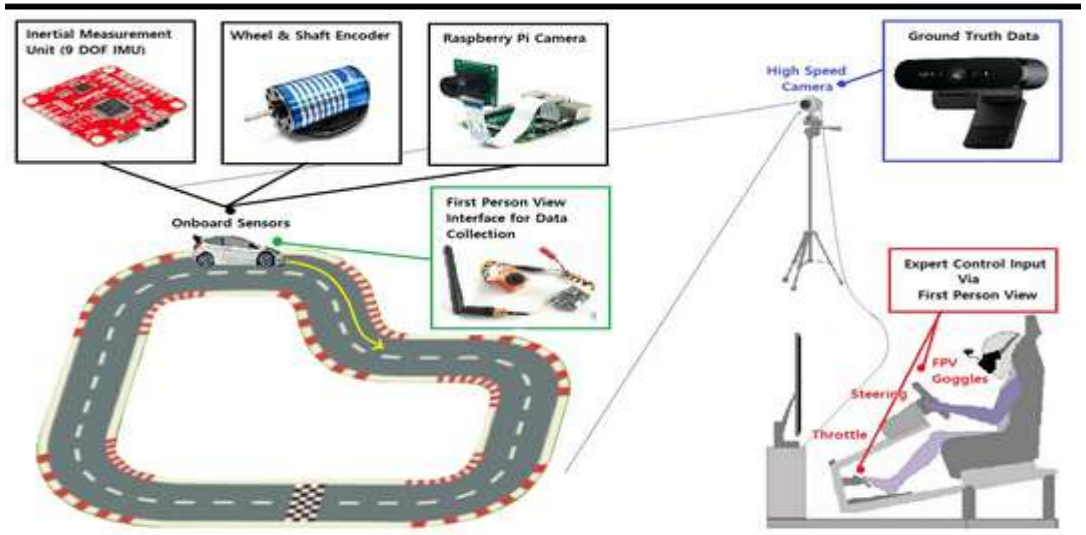
Testing Capabilities:

- Testing autonomous vehicles or their delivery applications within UCLA campus with UCLA autonomous navigation algorithms and hardware platform
- Hardware support:
  - Custom aluminum chassis and high-torque motors
  - 100Ah 24V LiFeMnPO4 Battery
  - NVIDIA Jetson TX2 embedded AI computer
  - Velodyne VLP-32 / VLP-16 LiDAR
  - Inertial Measurement Unit (IMU)
  - GPS
- Software and engineering support:
  - ROS, Carla software
  - ANTBOT™ conceptual autonomous vehicle
  - Last mile delivery vehicle design and testing
- Video demonstration available at https://smartgrid.ucla.edu/CAEV/troggie_v0.1.mp4

Autonomous Driving for Multi-Agent Environments

UCLA Smart Grid Testbed





Technology Type: Connected Autonomous Electric Vehicle

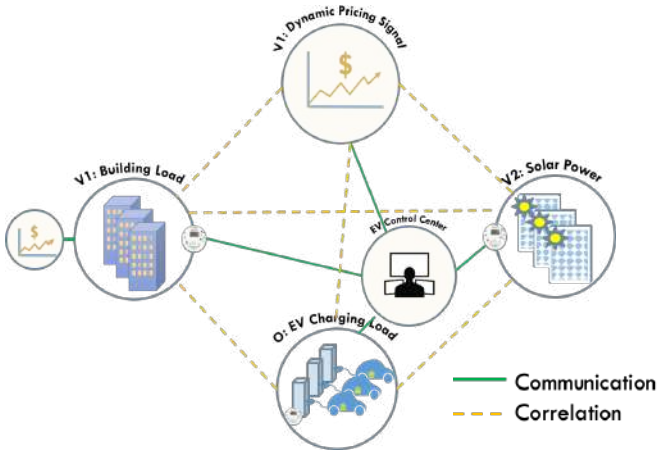
Testing Capabilities:

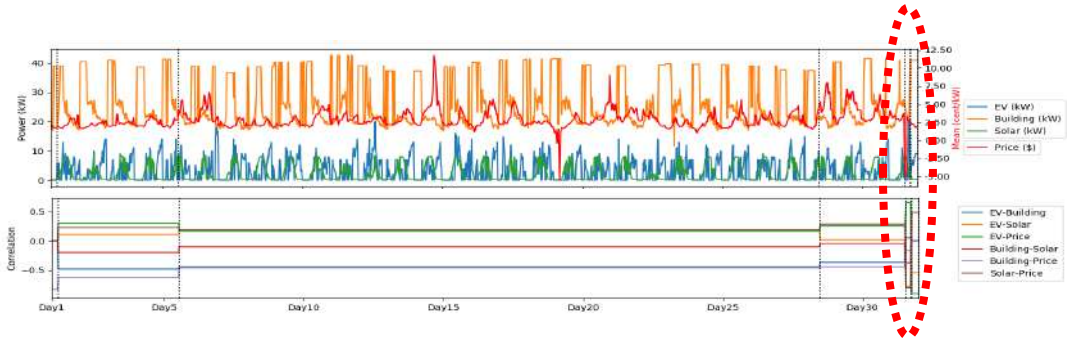
- Analysis of Multi-Agent Scenarios
  - Indoor closed-loop circuit testbed with birds eye view
  - Ground truth tracking of multiple vehicles and their state information
- Analysis of High Speed Scenarios
  - Identification of potential collisions
  - Evaluate driver behavior with problem specific data sets

Description: UCLA has developed a scaled down AV/EV testbed in which model vehicles can be tested for autonomous driving evaluation and evaluation of driver behavior. Multiple vehicles can be driven on the test-track at a time creating a realistic simulation scenario in the lab.

Smart Grid Cybersecurity Testing and Analysis

UCLA Smart Grid Testbed





Technology Type: Cybersecurity Analysis

Testing Capabilities:

- Monitoring the status of a system
  - Sensor data transmitted within the network.
- Analyzing the pairwise correlation of the sensor data within a system
  - Characterizing the normal state of the correlations
  - A sudden changes in the correlation will be captured and identified as an anomaly.
- Riverbed© Modeler Software
  - Communication network modeling and simulation
  - Scaled up network testing

Description: UCLA EV charging testbed is being used for cybersecurity testing and analysis. An EV charging management system has been modeled that controls and schedules EV load according to measurements of local building load, solar generation, and dynamic electricity price. Within this information network, any data replaced or modified by an attacker will disrupt the EV charging schedule and could cause damage to the electricity grid. The relationship of pairwise measures within the system to establish a correlation-invariant network and identify anomalous data within the network.

Smart Grid Energy Research Center (SMERC)

Santa Monica Testbed

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330 Olympic Dr,
Santa Monica, CA 90401

Ombudsperson
Peter Chu
Project Lead Electric Vehicle and Renewable Energy Integration

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E: peterchu@ucla.edu

The Santa Monica Testbed contains one 30 kW V2G fast charger, 38 level 1 and level 2 EV chargers, 8.7 kWh of LiFePO3 Flexible mobile battery cart, one 213 kW Solar PV Panel and one NI PQA/PMU meter.

The EV chargers in the Testbed are used by general public, city employees and fleet vehicles. The Dashboard System allows monitoring and control of each individual charging station to support energy management in the power grid.

The Control Center in the testbed provides testing capability of various power management algorithms through V2G operation and control of all DER components in an aggregated manner.

Smart Grid Energy Research Center (SMERC)

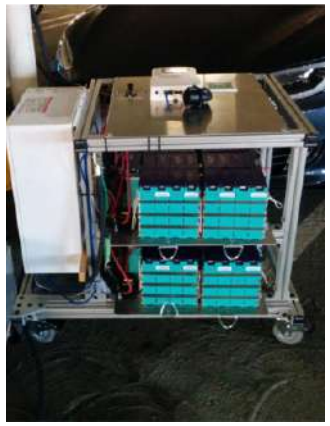
Santa Monica Testbed

20 Level 1, EV chargers

Colorado Fleet Yard

+/- 30 kW V2G

DCFC station

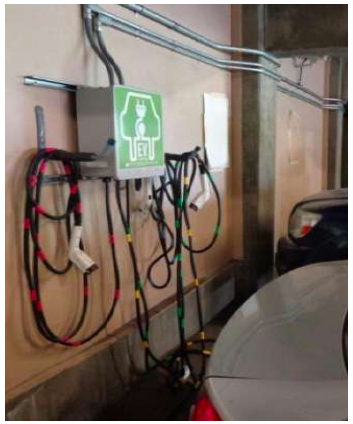


8.7 kW mobile Battery Cart

14 level 2 smart EV charging stations

213 kW PV

With PMU/PQA



4 level 2 smart EV charging stations at Santa Monica Hospital

Technology Type	Testing Capabilities
Transportation	EV Fleet Charging Management and Operations – Testing of EVSE and management applications via City of Santa Monica's EV fleets in facility management. Target testing includes maintenance team cost optimization via charge scheduling and circuit sharing, EV fleet charging management, EV fleet operations, etc.
Transportation	Level 2 Smart EV Charging System – testing of project partner's EVSE on V1G functions.
Transportation	Testing of V2G enabled EVSEs and vehicles with SAE, CHAdeMO and ISO protocols.
Transportation	Testing of Portable Battery Energy Storage System – Support EV charging with flexible BESS, Islanding operation, Grid Service (demand response, load shifting, energy cost reduction)
Transportation	Power Quality Analyzer Integration – Testing of project partner's device with Power Quality Analyzer (PQA), Using PQA to optimize and manage EV charging load and BESS power flow, power quality monitoring in parking structure

EV Fleet Yard Charging Management System

Santa Monica Testbed

Technology Type: EV Fleet Operation and Scheduling

Testing Capabilities:

- Load Shifting
- Cost Optimization via Scheduling of Charging Management
- Power sharing to reduce capacity requirement and infrastructure cost
- EV Fleet Charging management

Description: Electric fleets serving municipalities have unique needs for energy, driving schedules and sustainability. If managed improperly, the charging can result in highly irregular power usage and high bills. The scheduling system automatically manages and schedules such EV charging.

EV Smart Charging (V1G) – Santa Monica Civic Center and UCLA Santa Monica hospital

Santa Monica Testbed

Technology Type: EV Smart Charging (V1G)

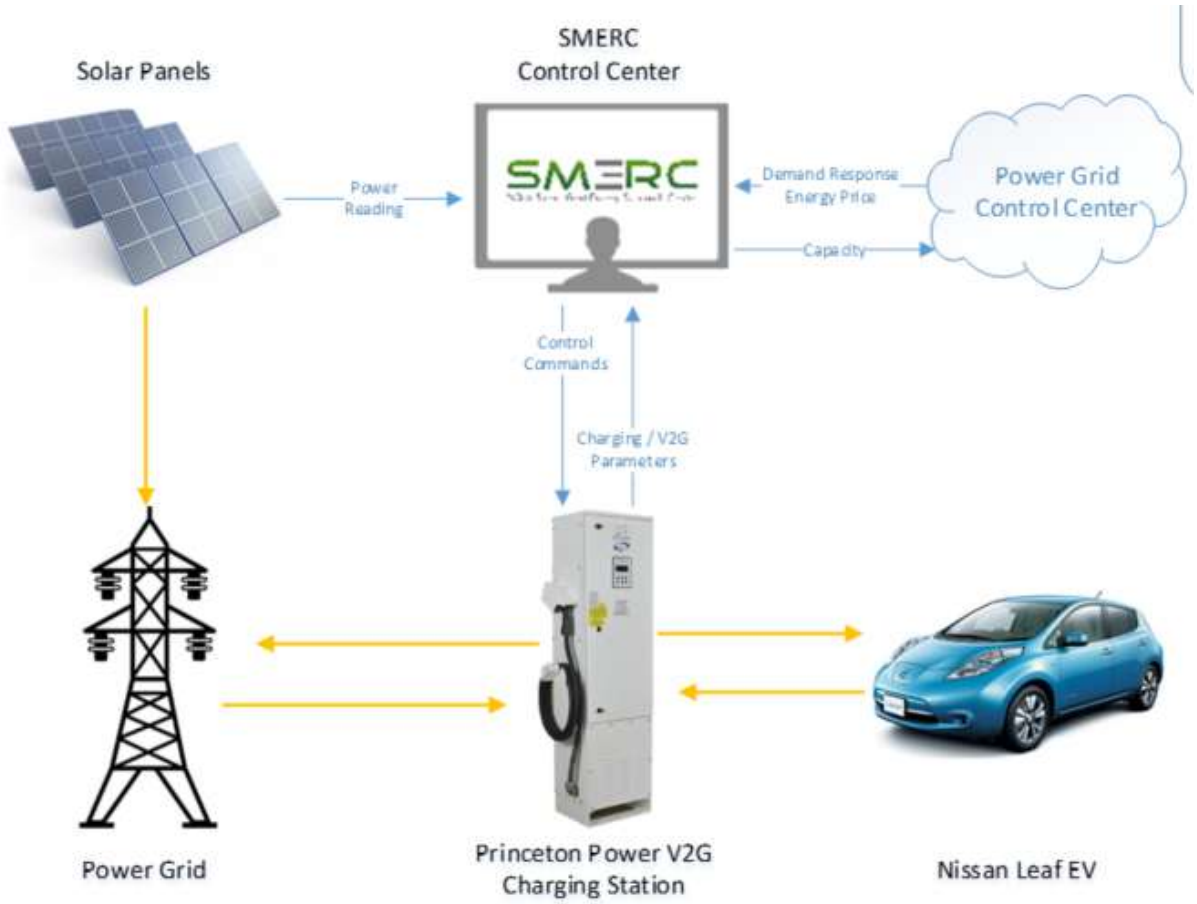
Testing Capabilities:

- Multiplexer for circuit sharing
- Smart charging algorithms with user participation
- Grid Service:
  - Load Shifting
  - Demand Response (DR)
  - Energy cost reduction

Description: EV charging, when managed properly and with scale, can help grid operators with their needs. Utilities' needs such as DR can be supported with proper management and protocols of EV chargers with minimal disruption to the drivers.

Vehicle-to-Grid (V2G) Test Bed

Santa Monica Testbed



Technology Type: EV Smart Charging (V2G)

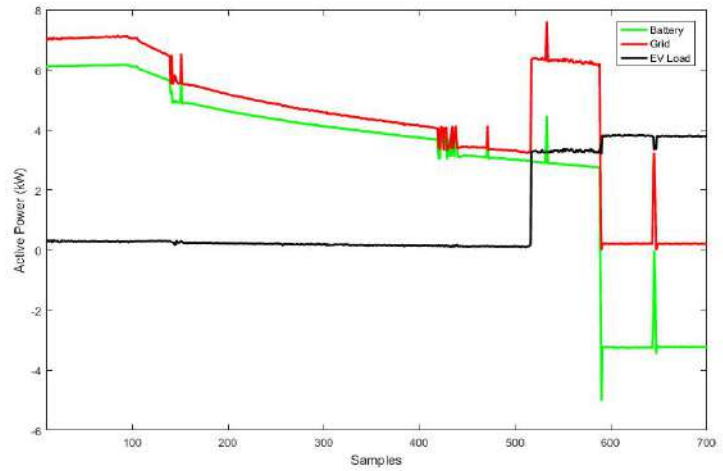
Testing Capabilities:

- Bi-directional power flow to support power grid.
- Grid Service via V2G support
  - Voltage regulation
  - Demand response
  - Duck curve mitigation
  - Vehicle-to-Building and Vehicle-to-Home capability testing

Description: V2G system developed at UCLA integrates software for scheduling when to charge and discharge an EV and hardware (Princeton Power and Mitsubishi supporting ChaDEMO DC based V2G). The system also performs Vehicle-to-Building or Vehicle-to-Home capability as needed. The value of V2G is for backup power as well as grid support needs.

Portable Battery Energy Storage System

Santa Monica Testbed



Technology Type: BESS and Inverter

Testing Capabilities:

- Testing of BESS and Inverters.
- Support EV charging with flexible BESS
- Islanding operation
- Grid Service:
  - Demand response
  - Load Shifting
  - Energy Cost Reduction

Description: The portable BESS enables localized energy storage and delivery of energy to other locations in the garage such as charging an EV or providing additional power. This platform can be used for testing of batteries, inverters, microgrid control systems or software.

Power Quality Analyzer Integration

Santa Monica Testbed

Technology Type: Power Quality Analyzer (PQA)

Testing Capabilities:

- Test your energy device's power quality.
- Power Quality Analyzer (PQA) with Solar Panel
- Using PQA to optimize and manage EV charging load and BESS power flow.
- Power quality monitoring in parking structure

Description: PQA installed in the Santa Monica Civic Center garage provides data on power quality which in turn may be impacted by solar PV or EV charging. If power quality starts to deteriorate in parking structures, eventually, it can result in grid collapse, therefore PQA can not only measure the power quality, but when integrate with other DER assets such as BESS or EV chargers, it can stabilize the local microgrid.

Smart Grid Energy Research Center (SMERC)

Pomona SCE Testbed

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265 N East End Ave
Pomona, CA 91767

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The Pomona SCE Testbed contains one level 2 Smart EV charger (4 level 2 charging stations).

The EV chargers in the Testbed are used by employees and SCE visitors at SCE EV Technical Center.

UCLA has a quad charger installed at the Southern California Edison Pomona Test Labs in their parking lot. It is a networked charger and is used for current sharing. User behavior tests can be performed with this or other chargers at this site.

Technology Type	Testing Capabilities
Transportation	Level 2 Smart EV Charging System – Multiplexer for circuit sharing, smart charging algorithms with user participation, Grid Service (load shifting, demand response, energy cost reduction)

Smart Grid Energy Research Center (SMERC)

Pasadena Testbed

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150 E Holly St
Pasadena, CA 91103

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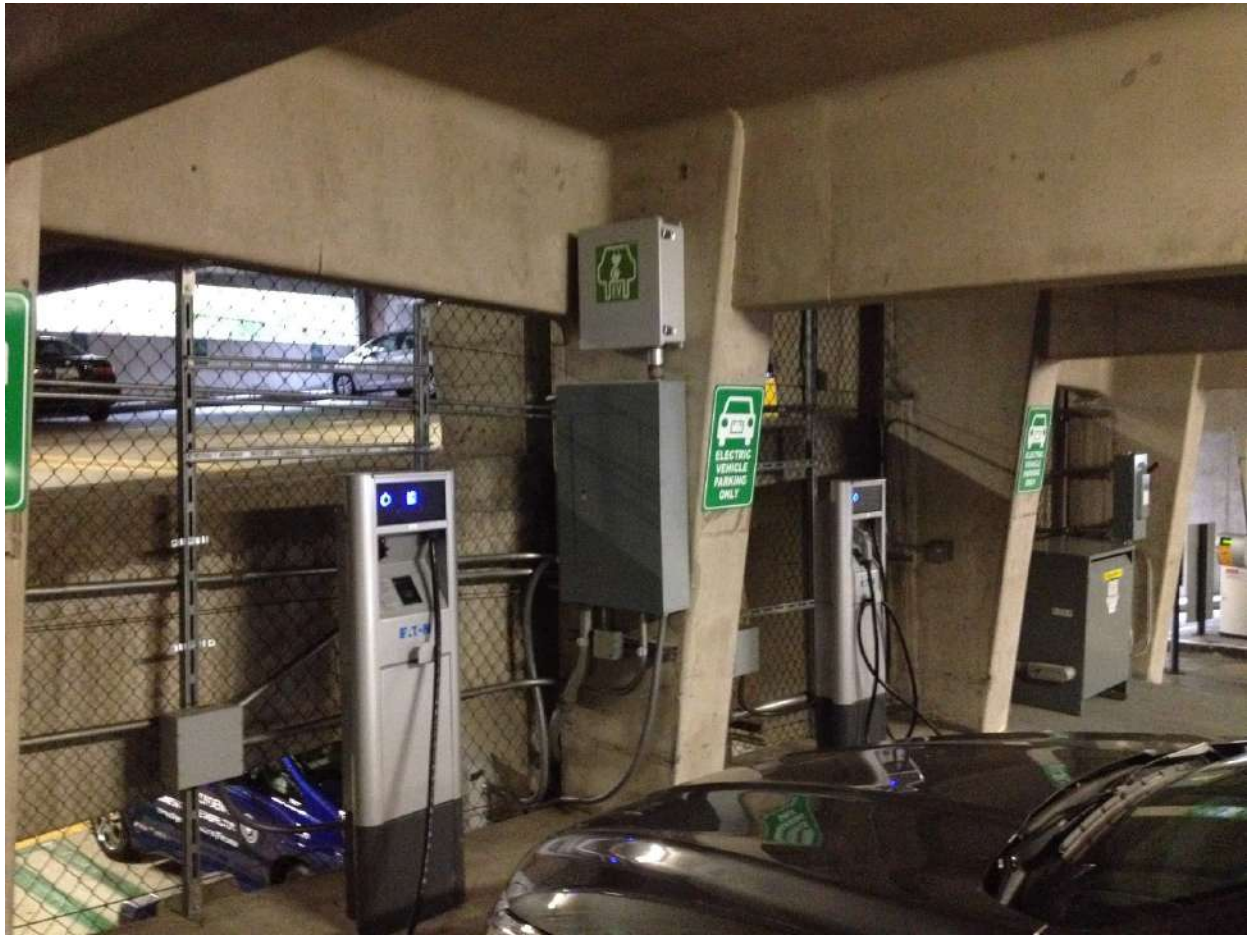
The Pasadena Testbed contains 32 power usage monitoring and control devices for commercial EV chargers within the city of Pasadena

The EV chargers in the Testbed are used by the public.

Technology Type	Testing Capabilities
Transportation	Monitoring and Control of Existing EV Chargers - Monitoring and Control of Commercial EV Chargers. Energy usage statistics for billing, Grid Service (load Shifting, demand response, energy cost reduction)

Monitor and Control of Existing EV Chargers

Pasadena Testbed



Monitor and Control of Existing EV Chargers

Technology Type: Energy Efficiency – EV Smart Charging

Testing Capabilities:

- Monitoring and Control of Commercial EV Chargers
- Energy usage statistics for billing
- Grid Service:
  - Load Shifting
  - Demand Response
  - Energy cost reduction

Description: UCLA has installed in Pasadena city public parking structures, it's EV monitoring and control capability which includes software and hardware. The network enables understanding of energy consumption in public EV charging scenarios which assists in understanding how grid services may be offered.


UNIVERSITY OF CALIFORNIA
MERCED

Advanced Solar Technologies Institute (UC Solar)

UC Merced

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Ombudsperson
Roland Winston
Director of UC Solar and Distinguished Professor, Schools of Natural Sciences & Engineering

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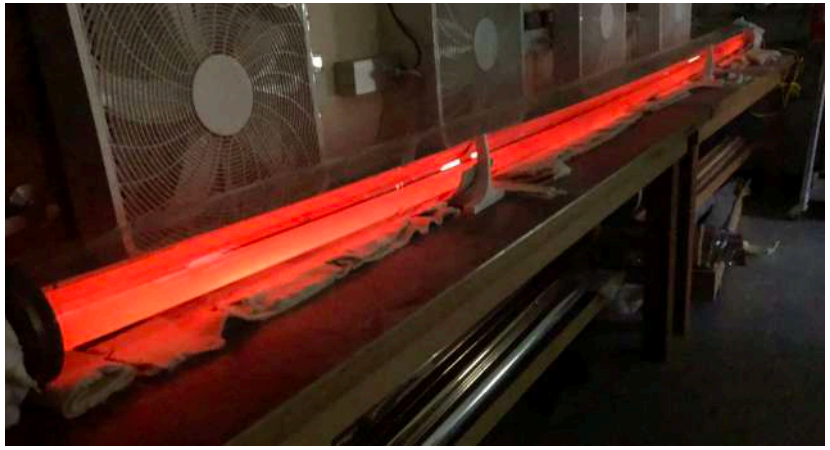
UC Merced has well established test beds and laboratories for pre-commercial testing of new technologies in a "living lab" environment.

UC Solar's 1-megawatt solar photovoltaic system which has been in operation since 2009 providing needed electrical energy on the campus, and consistently exceeding performance expectations. The solar thermal team has been operating a testbed for characterizing solar collectors from 100 to 250 Celsius for the last 10 years. The testbed for solar thermal driven cooling/drying/desalination is also available for data collection.

Advanced Solar Technologies Institute (UC Solar)

UC Merced

UC Solar creates technologies that make solar energy systems more efficient, more affordable, and the best choice for the people of California and the world. In addition, UC solar educates and develops tomorrow's solar energy leaders and entrepreneurs.



UC Merced faculty have invented Solar collectors, designed differently with various desired performances for application in solar energy generation. A Solar thermal collector is designed to collect heat by absorbing sunlight. A Solar electric generation system is designed to generate electricity.

Through collaboration with utilities, industry and other stakeholders, UC Solar researchers are tasked with creating solar technologies that can be brought to the marketplace quickly and integrated seamlessly. UC Solar partners with industry participants through the UC Solar Industry Consortium, which attracts companies that design, produce, implement, manage and invest in solar technologies.

Technology Type	Testing Capabilities
Energy Efficiency	Efficiency characterization up to 250C
Energy Efficiency	Heat loss measurement up to 650C
Energy Efficiency	Outdoor I-V data collection for PV module performance evaluation


UNIVERSITY OF CALIFORNIA
UCRIVERSIDE

Electric Drive Vehicle Testing Laboratories

UC Riverside

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UCR CE-CERT
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Ombudsperson
Matt Barth
Director of CE-CERT

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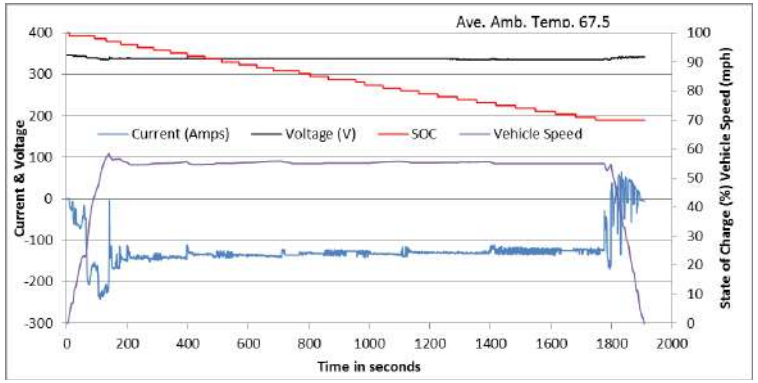
UC Riverside's Bourns College of Engineering-Center for Environmental Research and Technology (CE-CERT) has unique capabilities to test a variety of electric drive vehicles, including pure battery electric, fuel-cell, hybrid electric, and plug-in hybrid electric vehicles. With two state-of-the art chassis dynamometers, both light-duty and heavy-duty EVs can be tested. CE-CERT has developed a wide range of electric drive testing protocols, providing research results to industry, government agencies, and academia.

Electric Drive Vehicle Testing Laboratories

UC Riverside

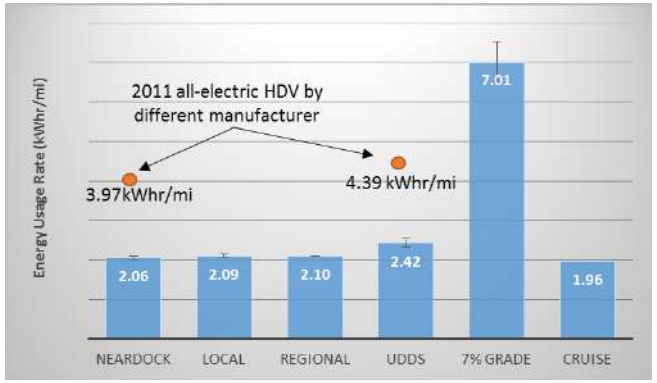
Dynamometer Systems capable of testing a wide range of electric-drive vehicles

CE-CERT's dynamometers have been designed to handle a range of vehicles and vehicle loads at on-road driving conditions. The Heavy-Duty 48" Electric AC Chassis Dynamometer has dual, direct connected, 300 horsepower motors attached to each roll set with a base inertia of 45,000 lb with the addition of a large flywheel. The dynamometer applies appropriate loads to a vehicle to simulate factors such as the friction of the roadway and wind resistance that it would experience under typical driving. A driver accelerates and decelerates following a driving trace while the vehicle is driven in place.



Working with CARB and the California Energy Commission, CE-CERT has developed and utilizes specific testing protocols for EVs

In addition to standard vehicle performance measurements of velocity and acceleration, CE-CERT is able to measure battery SOC, system voltage and current, energy efficiency per mile (kWh/mile) and gradability.



Electric Vehicle Drive Cycle Testing

Through extensive vehicle activity studies, CE-CERT has developed a number of "drive cycles" specific for electric vehicles and trucks. These drive cycles, in addition to certification drive cycles can be tested repeatedly in a controlled environment.

Technology Type	Testing Capabilities
Transportation	Capable of testing any electric truck in a wide range of configurations
Transportation	Capable of testing any light-duty electric vehicle in a wide range of configurations
Energy Efficiency	Capable of measuring dynamometer physical loads, battery SOC, vehicle voltage, current, energy efficiency

SIGI:
Sustainable Integrated Grid Initiative

UC Riverside

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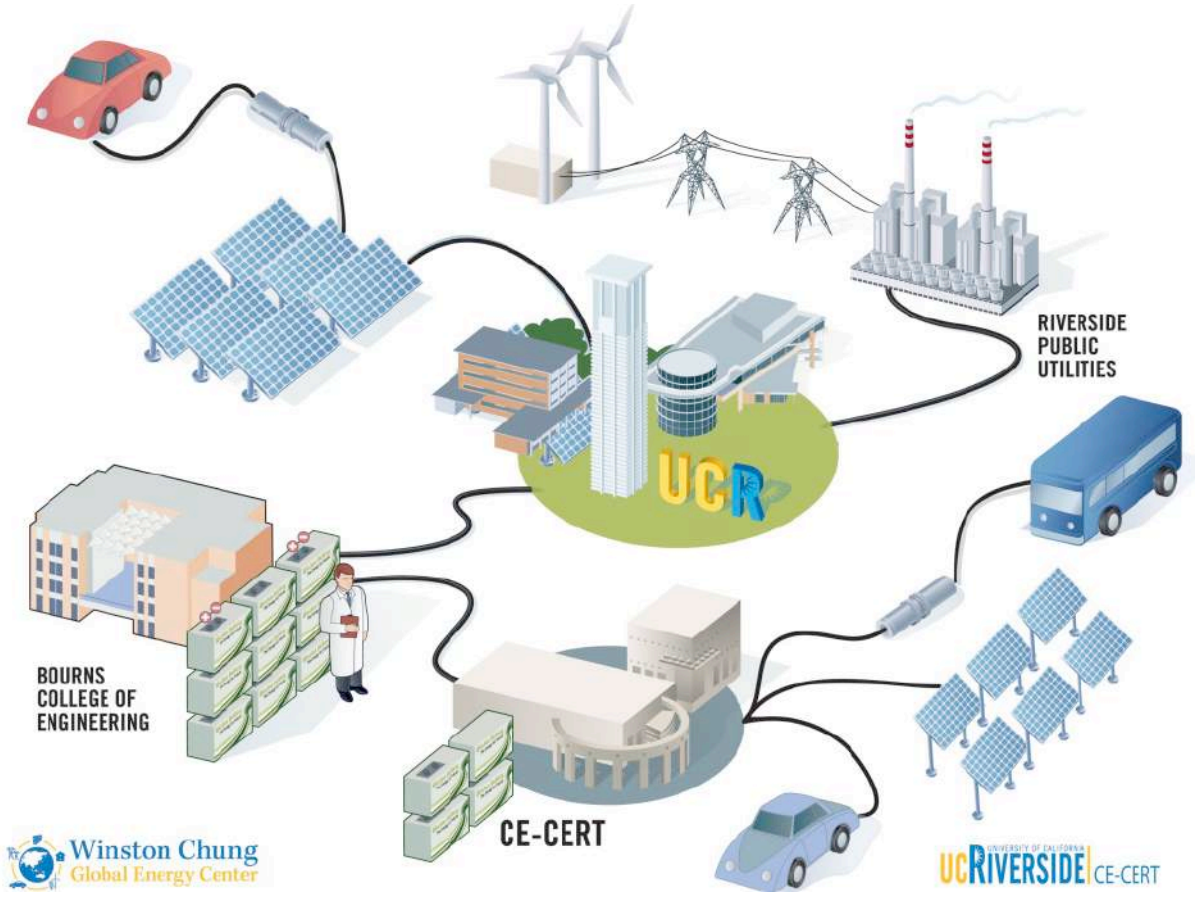
UCR has well established microgrid testbeds and laboratories for pre-commercial testing of new technologies in a "living lab" environment. Over the last six years, UCR researchers have designed and implemented numerous microgrid systems including 2.2 MWh of battery energy storage, over 11 MW solar PV, 8 MW of Thermal Energy Storage (TES) for chiller operations, and multiple electric vehicle chargers including supervisory control and data acquisition systems.

These unique microgrid/smartgrid testbeds with plug and play capabilities possess the ability to validate various Hardware in Loop (HiL) scenarios. In addition to energy system modeling, UCR can utilize its microgrid testbed for evaluating specific microgrid designs that will be placed elsewhere.



Sustainable Integrated Grid Initiative Testbed

UC Riverside

Battery Storage

- 2 MWh integrated battery energy storage
- Stationary and mobile battery platforms
- 10 MW of controllable loads
- Load shifting and peak shaving algorithm optimization
- Demand response

Renewable Energy Generation

- 8 MW of PV solar capacity islanding operation and control
- Curtailment optimization & Soiling evaluation
- Fixed vs. tracking characterization
- Zero net energy microgrid demonstration with storage and load control integration

System Integration

- SCADA microgrid controller development
- Power quality monitoring and analysis with load monitoring and control
- Microgrid optimization
- EV charging with microgrid integration
- Anomaly detection and response

Technology Type	Testing Capabilities
Energy Storage	Soiling, efficiency, curtailment, performance, microgrid integration, islanding
Energy Storage	Microgrid integration, control optimization, Battery Management System (BMS), performance, islanding
Energy Efficiency	Efficiency testing (5kW to MW+), curtailment, islanding, voltage support, reactive power control, grid ancillary services
Grid Technologies	System architecture, net zero configuration, controls, distributed generation, load management
Grid Technologies	SCADA, islanding, microgrid integration, control optimization, energy profiling
Grid Technologies	As of 2019, SIGI now offers testing of vehicle-to-grid algorithms using the latest V2G inverter systems.
Internet of Things	System optimization, system configuration, energy measurement, load management, performance monitoring

Shared, Electric, Connected, and Automated Vehicle Testing

UC Riverside

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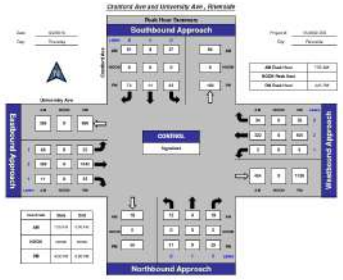
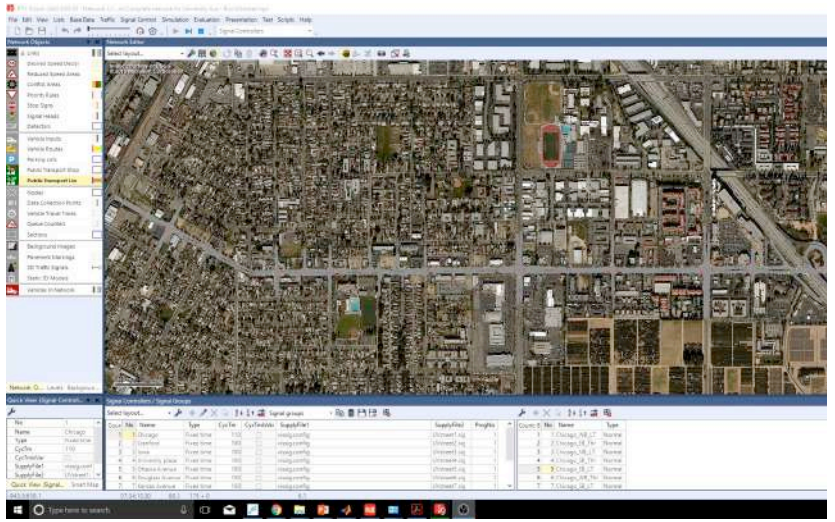
When considering how to get to zero-carbon mobility, there are generally four strategies to consider: 1) build more efficient vehicles that emit less carbon (e.g., HEVs, BEVs, and fuel-cell EVs); 2) utilize low- or zero-carbon fuel such as electricity or hydrogen; 3) implement programs that reduce overall VMT; and 4) employ ITS and automation technology to improve transportation system efficiency. UC Riverside has set up testbeds to evaluate Shared Mobility (addressing strategy 3), Transportation Electrification (addressing strategies 1 & 2), and Connected and Automated Vehicles (addressing strategy 4).

A key vehicle testbed, the *Innovation Corridor,* located in Riverside, California, consists of a six-mile section of University Avenue between the main UCR campus and downtown Riverside. This arterial corridor has been outfitted with traffic signal controllers that broadcast signal phase and timing, employ video analytics, and is used for experimentation with shared, electric, connected and automated vehicle (e.g., cars, buses, and trucks).

Shared, Electric, Connected, and Automated Vehicle Testing

UC Riverside





Innovation Corridor

Consists of 10 instrumented intersections along a 4 lane urban arterial. Intersections utilize modern traffic signal controllers that broadcast signal phase and timing and employ video analytics

Example connected vehicle application

The corridor is used to conduct Eco-approach and departure studies at signalized intersections. Vehicles can "listen" to an upcoming signal's phase and timing and adjust their speed to reduce energy consumption and improve throughput.

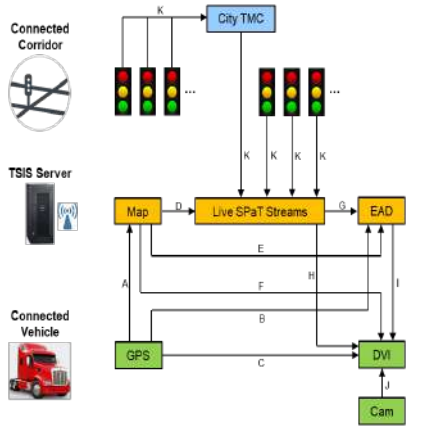
Demo at: https://youtu.be/j9Tg2g9YTjc

Simulation and testing platforms

Complementing real world testing, modeling enables the projection of mobility and environmental benefits from the wide-scale adoption of shared, electric, connected and automated vehicle technologies.

Shared, Electric, Connected, and Automated Vehicle Testing (for trucks)

UC Riverside



Component	Description
City TMC	Traffic management center
Map	Digital map of Southern California
Live SPaT Streams	Real-time SPaT from connected intersections
EAD	Eco-Approach and Departure algorithm
GPS	GPS for identifying truck position
Cam	Camera for detecting preceding vehicle
DVI	Driver-vehicle interface on tablet

ID	Data Elements	Update Frequency (Hz)
A	Latitude, longitude, & heading	1
B	Veicle speed (GPS)	1
C	Veicle speed (GPS)	10
D	Upcoming intersection & direction	1
E	Distance to intersection	1
	Roadway speed limit	1
F	Distance to intersection	1
	Roadway speed limit	1
G	Upcoming SPaT	1
H	Upcoming SPaT	1
I	Recommended driving speed	10
J	Preceding vehicle detection signal	10
K	Real-time SPaT	1

Traffic Signal Information System (TSIS)

The connectivity of these connected traffic signals is enabled by 4G/LTE cellular communication where real-time signal phase and timing (SPaT) information is sent to the Traffic Signal Information System (TSIS) server at UCR. Vehicles traveling on the testbed can request and receive the SPaT information from the TSIS server through the same cellular communication. Currently, the testbed is being used to test and evaluate an EAD application for heavy-duty trucks, developed by UCR.

Southern California CAV Testbed

Los Angeles Testbed

UCR has set up three arterial corridors with 15 connected traffic signals nearby the port of Los Angeles to support a variety of connected truck applications such as Eco-Approach and Departure, freight signal priority.

See demo at:
https://youtu.be/1CR4vMh8ufE

S. Wilmington Ave

- 2-mile segment
  - 2 lanes per direction
  - 40 mph speed limit
- 9 traffic signals
  - 5 connected
  - Actuated signal control

Alameda St

- 3-mile segment
  - 2-3 lanes per direction
  - 45 mph speed limit
- 6 traffic signals
  - 5 connected
  - Actuated signal control

W. Harry Bridges Blvd

- 0.5-mile segment
  - 2 lanes per direction
  - 35-40 mph speed limit
- 5 traffic signals
  - 5 connected
  - Fixed-time signal control

Technology Type	Testing Capabilities
Transportation	Using LBNL's BEAM model, travel demand activity can be evaluated for a number of shared mobility scenarios, measuring a variety of performance metrics
Transportation	Using a wide range of simulation tools (e.g., VISSIM, PARAMICS, SUMO) and specific APIs, a wide range of CAV scenarios can be tested
Transportation	A unique hardware-in-the-loop testing system for CAVs has been developed, combining traffic simulation and a real-world vehicle on a dynamometer
Transportation	UCR has developed several CAV testbed sites in Riverside California, and Carson California, installing communication infrastructure on the road

Electrical Motor Systems Testing Laboratory

UC Riverside

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UCR CE-CERT
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Ombudsperson
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Director of CE-CERT

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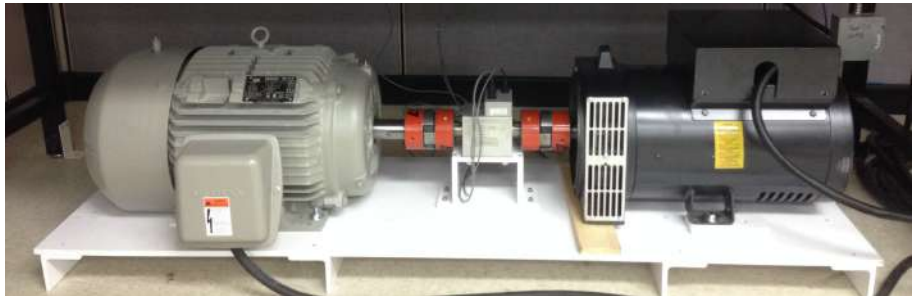
This testing facility, developed with California Energy Commission (CEC) funding, is capable of efficiency and load testing of electric motors and Adjustable Speed Drive (ASD) up to 100hp. The facility can also measure electric system harmonics.

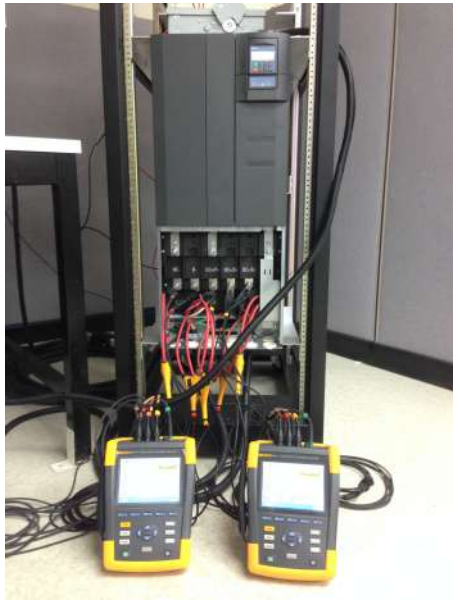
This is the first independent electric motor testing center in the state of California capable of providing unbiased evaluation of motor efficiency at various operating conditions. This facility is available for the use by the industry professionals, academics, and other stake holders.

Electrical Motor Systems Testing Laboratory

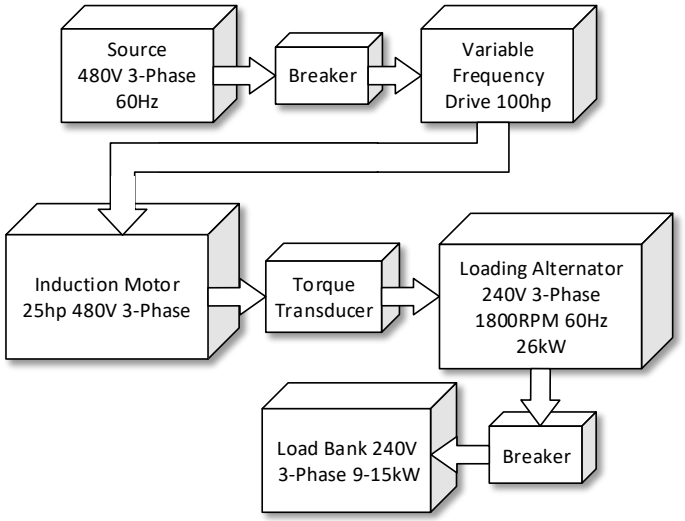
UC Riverside



motor torque transducer loading generator



power analyzers



Motor Efficiency Measurement & Verification

Output power is monitored and measured using the torque transducer, which separates the load from the motor to isolate output measurement at the shaft of the motor.

External portable Fluke Power Analyzers enable the accurate measurement of both input and output power necessary to find operational efficiency of a motor. This used to verify efficiency of an electric motor.

Improving Software for Efficient Motor Selection

- Many commercial and in-house software used by architectural and engineering firms design HVAC systems with inflated safety factors used in calculating three-phase motor sizes for buildings
- UCR quantifies energy waste due to the: (i) use of lower efficiency motors, (ii) use of oversized motors in existing buildings, and (iii) selection of oversized motors in the architectural and engineering design stage of new buildings.

Technology Type	Testing Capabilities
Transportation	Zero to Rated Torque, Efficiency at Various Loading Condition, Quantification of Voltage and Current Harmonics, Range 0-100hp
Transportation	Zero to Rated Torque, Efficiency at Various Loading Condition, Quantification of Voltage and Current Harmonics, Range 0-100hp
Energy Efficiency	Efficiency at Various Loading Condition, Quantification of Voltage and Current Harmonics, Range 0-100hp
Energy Efficiency	Zero to Rated Torque, Efficiency at Various Loading Condition, Quantification of Voltage and Current Harmonics, Range 0-100hp

Vehicle to Grid (V2G)

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Vehicle to Grid (V2G) architectures allow grid connected vehicles to transfer power from the vehicle back to the electric supply infrastructure. The optimization of V2G requires properly configured vehicles and electric vehicle supply equipment (EVSE).

UC Riverside has created a microgrid testbed with integrated V2G capabilities. The system utilizes both light duty passenger EVs and larger transit vehicles.

Research is focused on system architectures, controls, optimization, energy management, and communications.

Shown in Picture: Electric Vehicle supplying power to the storage bank (inside trailer) which is connected to the building microgrid

Vehicle to Grid (V2G)

UC Riverside

Diesel to Electric Conversions

- Equipped for bi-directional energy transfer
- Light duty and transit vehicle platforms
- 100 kW V2G capability
- Load shifting and peak shaving algorithm optimization
- Demand response

Battery Energy Storage with V2G Integration

- Load management utilizing V2G algorithms
- Smart charging based on distributed generation
- Aggregation algorithm development
- Vehicle activity monitoring
- Carbon based pricing for EV charging

EV charging Monitoring and Control

- Peak shaving and shifting
- Energy cost optimization
- Zero net energy algorithm development
- Utility integrated demand response

Technology Type	Testing Capabilities
Transportation	V2G capability, performance, measurement, access control, billing, communications
Transportation	Energy measurement, capacity, vehicle connectivity, protocols
Transportation	Energy profiles, trip activity, charging activity, GIS based analysis, vehicle energy monitoring
Grid Technologies	System architecture, net zero configuration, controls, load management
Grid Technologies	SCADA, islanding, microgrid integration, control optimization, energy profiling

Water Energy Nexus

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About 20% of electricity use in California is treating, pumping, and distribution of water. With funding from California Energy Commission (CEC), College of Engineering – Center for Environmental Research and Technology (CE-CERT) at the University of California, Riverside (UCR) has demonstrated and deployed an energy management and data acquisition and supervisory control strategies that reduce peak loads and electricity costs in the delivery and treatment of water at each of the three water district locations. The three deployments utilize existing on-site SCADA architecture and implement the Energy Management System (EMS) within the existing architecture.

This demonstration project highlights a pathway for water agencies in California to reduce their peak energy consumption substantially with no decrement in service or reliability. The project also identifies "real world" implementation issues that have not emerged in previous proof-of-concept research.

CALIFORNIA ENERGY COMMISSION

OLIVENHAIN Municipal Water District

Cucamonga Valley Water District

Inland Empire Utilities Agency
A MUNICIPAL WATER DISTRICT

OSIsoft.

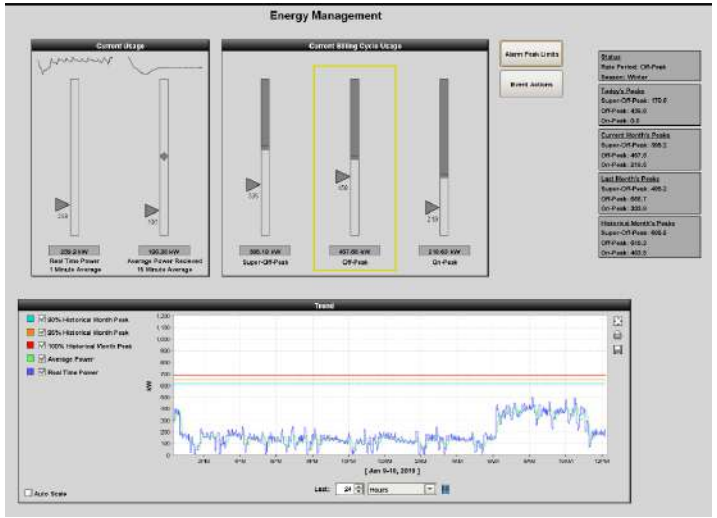
OPTO 22

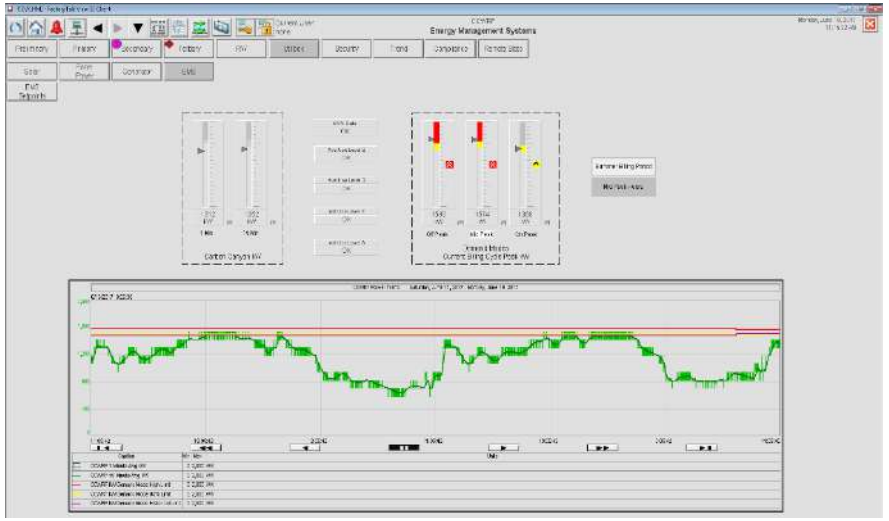
SDGE
A Sempra Energy utility®

SOUTHERN CALIFORNIA EDISON®
An EDISON INTERNATIONAL® Company

Water Energy Nexus

UC Riverside





Water Delivery Optimization

Integration of software and hardware at water delivery pumping, storage, or treatment facilities that enable the integration and transmission of data from energy meters directly or indirectly into Supervisory Control and Data Acquisition (SCADA).

Reducing Peak Energy Consumption

- This demonstration project highlights a pathway for water agencies in California to reduce their peak energy consumption substantially with no decrement in service or reliability.
- The project also identifies "real world" implementation issues that have not emerged in previous proof-of-concept research.

Individual SCADA System Integration

- Combined with historical energy use integrated with real time SCADA control displays, operators can manage systems in real time to monitor and control peak demand.
- Real time energy usage monitoring provides both instantaneous and 15min average relative to Time of Use (TOU) rate schedules, and alarm notifications optimized to provide operators with real time energy demand and the current existing peak load that has been recorded to date.

Technology Type	Testing Capabilities
Energy Efficiency	Customized Development and Validation of Energy Management Systems (EMS)
Internet of Things	Customized Development and Validation for Supervisory Control and Data Acquisition (SCADA)
Internet of Things	Development, Testing, and Validation for real-time system software and sensors


UC San Diego

Overview

UC San Diego, 9500 Gilman Drive, La Jolla, CA 92037

Additional Test Site
Zero Net Energy Warehouse at
7835 Trade Street, San Diego, CA 92121

Ombudsperson
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Director, UCSD Center for Energy Research

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Well established test beds for pre-commercial testing of energy technologies in a "Living Lab" environment., including advanced energy storage systems, smart inverters, distributed energy resources, PV systems, solar forecast engines, 2nd life EV battery storage, EV V2G charging infrastructure, and control and optimization algorithms.

Access to full scale, grid-connected testing on one of the world's most advanced and diversified portfolios of distributed energy resources.

Overview

UC San Diego

Electric Vehicles

UC San Diego collaborates with seven OEM electric vehicle manufacturers and more than 10 makers of V1G and V2G supply equipment. Since UC San Diego is self-permitting, testing partners can bypass complicated IOU interconnection procedures.

Energy Storage

Through CHARGES, the DOE ARPA-e designated UC San Diego as one of two national facilities for testing of new advanced energy storage technology, including: platforms for cell level, module level, and full-scale grid-connected testing; grid-connected outdoor test platform to test three systems; and remote monitoring and testing capability.

Smart Inverters

The smart inverter testing lab includes a Grid and a PV Simulator that can simulating almost any power grid disturbance and PV signal. The test setup includes high speed data acquisition with high power and voltage monitoring capabilities.

Smart Inverter Testing Lab

UC San Diego

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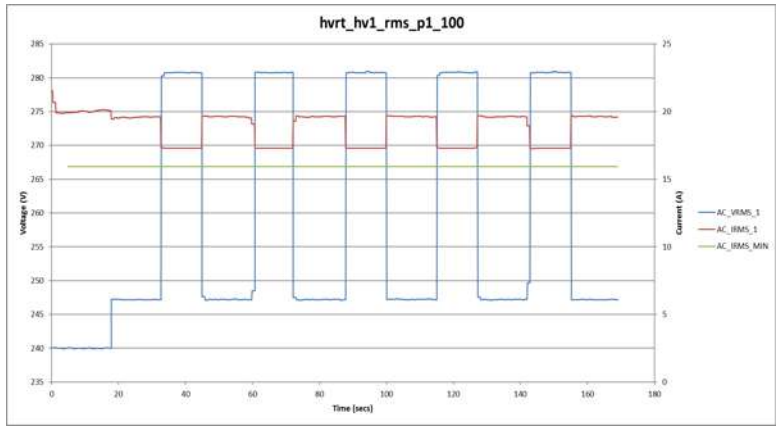
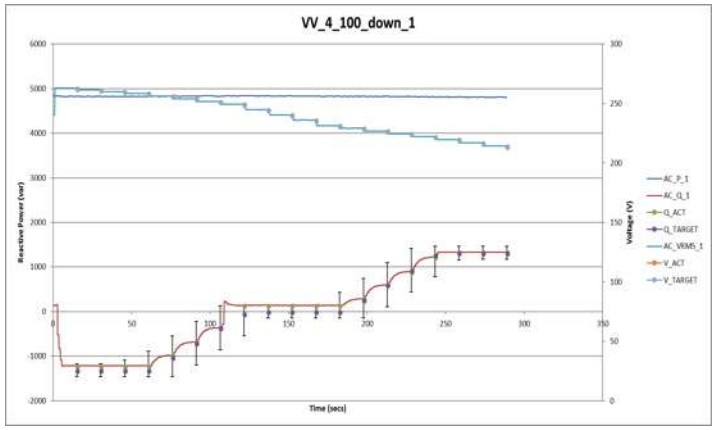
The smart inverter testing lab includes PV and Grid Simulators that can simulate virtually any power grid disturbance and PV array up to 30 kW. The test setup includes high speed data acquisition with high power and voltage monitoring capabilities, and the Sunspec Validation Platform (SVP) software for controlled testing and performance analysis of CA Rule 21 advanced inverter functions.

Smart Inverter Testing Lab

UC San Diego





Smart Inverter Testing

The Smart Inverter Lab can test and evaluate single-phase and 3-phase inverters up to 30 kW capability under a wide variety of simulated real-world scenarios. The testing is based on CA Rule 21 standards, is automated and repeatable. Approximately a dozen of the first generation of smart inverters, from several different manufacturers, have been tested under the CEC project to date.

Grid Support

Advanced functions and capabilities allow smart inverters to perform grid support functions, such as Volt-VAR support. As the grid voltage deviates from nominal (typically 240 VAC at the inverter) the inverter can inject or absorb reactive power to help regulate the voltage. The power factor of the inverter output can be programmed for fixed support, and power ramp rates modified to minimize impact on the grid during power changes.

Smart Inverters testing

The Smart Inverter Lab can test and evaluate single-phase and 3-phase inverters up to 30 kW capability. The testing is based on CA Rule 21 standards, is automated and repeatable. Approximately a dozen of the first generation of smart inverters, from several different manufacturers, have been tested under the CEC project to date.

Battery Energy Storage Systems – Utility Scale

UC San Diego

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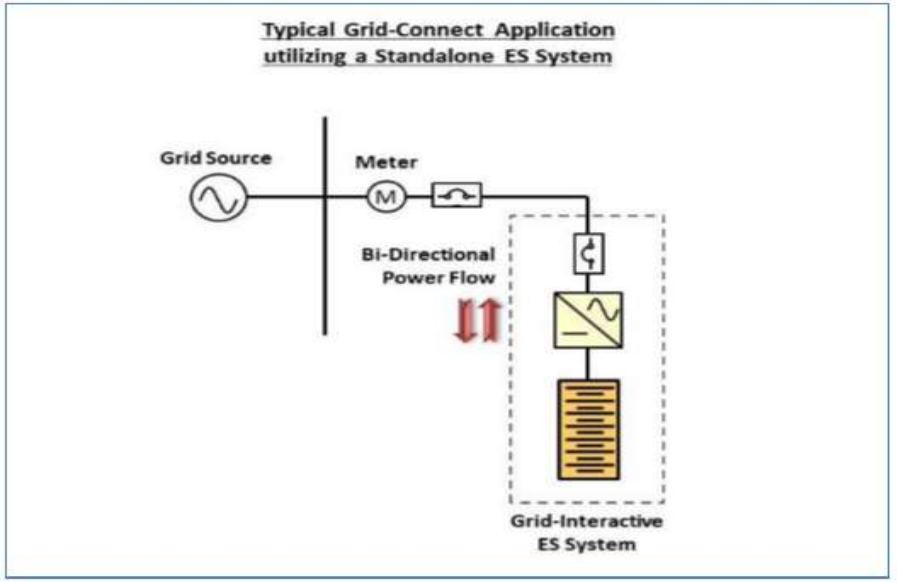
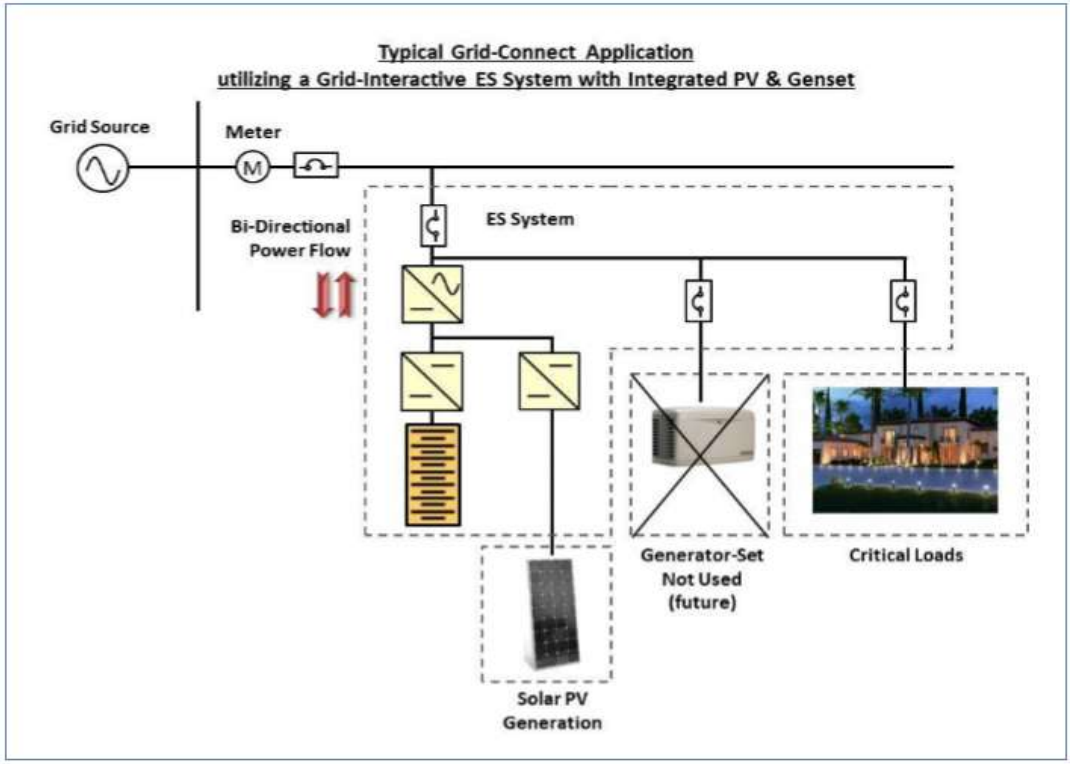
Through CHARGES, the DOE ARPA-e designated UC San Diego as one of two national facilities for testing of new advanced energy storage technology, including: platforms for cell level, module level, and full-scale grid-connected testing; grid-connected outdoor test platform to test three systems; and remote monitoring and testing capability.



Battery Energy Storage Systems – Utility Scale

UC San Diego

- Conduct testing, data acquisition and analysis – Commercialization
- Solar and Load Forecasting Integration with Energy Storage Systems



Energy Storage

Through ARPA-E CHARGES program, the U.S. DOE designated UC San Diego as one of two national facilities for testing advanced energy storage technology, including: platforms for cell level, module level, and full-scale, MW-level grid-connected testing.

Battery Energy Storage Systems – Module Level

UC San Diego

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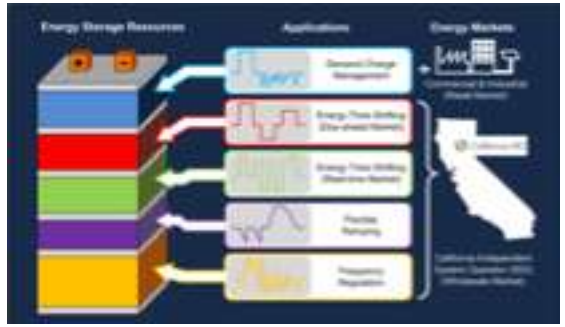
Through the support of DoE ARPA-E CHARGES program and other state and federal grants, UC San Diego is providing third party testing and validation of grid storage technologies, leveraging its experience in battery testing, economic modeling, grid-connected validation to identify the market-ready energy storage solutions for the future utility grid, and to maximize performance and benefit of energy storage systems.

Energy Storage Systems Module Testing Lab

- Comprehensive testing setup for indoor implementation environment.
- A fleet of bi-directional battery testers ranging from 5V/60A, 80V/200A, 100V/100A and 400V/400A for testing of a variety of battery modules.
- 480 VAC three phase power interfaces, and 240 VAC split phase power interfaces for testing of inverter integrated battery modules.
- Equipped with advanced communication, controllers, signal processing and data acquisition equipment for advanced battery control and management.
- Advanced lab safety including a hydrogen alarm system, fire suppression, temperature and humanity monitoring, and enhanced ventilation.

Battery Energy Storage Systems – Module Level

UC San Diego

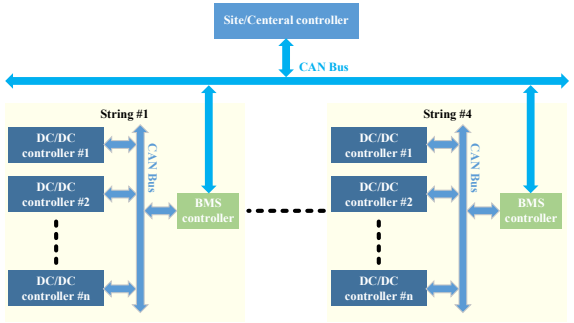


Energy Storage Market Dispatch and Optimization

California energy market based energy storage application modeling and demonstration. We can perform over five energy storage applications backed by real-world market data:

(1) Day-ahead energy time shifting
(2) Real-time energy time shifting
(3) Flexible ramping
(4) Frequency regulation
(5) Demand charge management

We can conduct testing of both single service and stacked service applications with advanced forecasting algorithm and model based dispatch optimization.



Advanced Battery Integration and Management

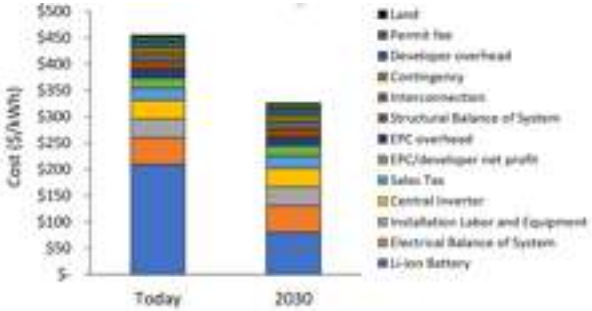
Fully integrated test setup with four CAN communication equipped testers and inverters, five commercial grade battery management systems, 16CH high frequency data acquisition systems, and the capability to custom build power electronics and embedded controllers offers innovators to setup robust hardware-in-loop testing, helping validate and test integrated battery solutions or their sub-components such as controller, BMS, and power converters.

Robust Testing Capabilities from Battery Cells to Systems

A board range of battery testing equipment:

- 5V 60A 16-channels Arbin tester
- 80V 200A Rexgear battery testers (2CH)
- 100V 100A Digatron battery testers (5 CH)
- 400V 150A Rhombus Inverter
- 400V 400A Arbin battery tester

Depending on different levels of commercial maturity, innovators will be able to choose a suitable equipment for comprehensive cell/module/system testing and valuation.



Energy Storage Economic Modeling and Valuation

Expertise in energy market analysis and techno-economic modeling. We can help energy storage innovators to batter understand capital and operational cost of their solutions at scale, and further understand their product's revenue potential in a progressing energy market, in order to provide valuable insight for making strategic investment in their technology and developing go-to-market strategies

Nanotechnology Infrastructure - http://sdni.ucsd.edu

UC San Diego

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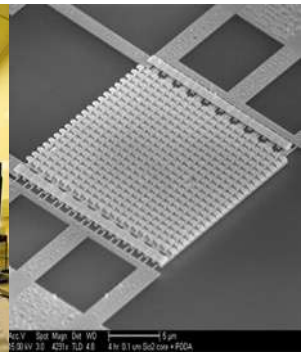
The San Diego Nanotechnology Infrastructure (SDNI), part of the NSF supported National Nanotechnology Coordinated Infrastructure (NNCI), offers users from academic, industry and government laboratories open, affordable access to a broad spectrum of nanofabrication and characterization technologies and expertise that enable and accelerate cutting edge scientific research, proof-of-concept demonstration, device and system prototyping, product development, and technology translation.
Centered on UCSD's Nano3 (Nanoscience, Nanoengineering, Nanomedicine) user facility, SDNI leverages additional specialized resources and expertise at UCSD for biomedicine, photonics, magnetics, energy, quantum systems, and converging sciences, enabling transformative research and education, and accelerating the translation of discoveries and new nanotechnologies to the marketplace.

Nanotechnology Infrastructure - http://sdni.ucsd.edu

UC San Diego

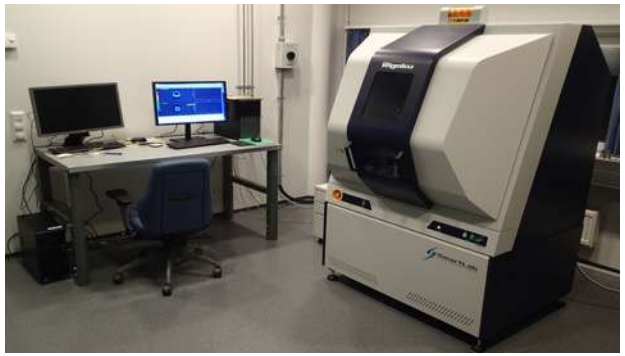


Nano3 Cleanroom Fabrication and Characterization Facility

Cleanroom device fabrication and materials characterization facility:

- Class 100/1000 cleanroom for lithography, materials deposition, etching, metrology
- State-of-the-art electron-beam writing capabilities
- Advanced microscopy capabilities, including several SEMs, FIB, TEM
- Highly trained and experienced staff available for support or direct fabrication services

(https://nano3.calit2.net)



CMRR Materials Characterization Facility

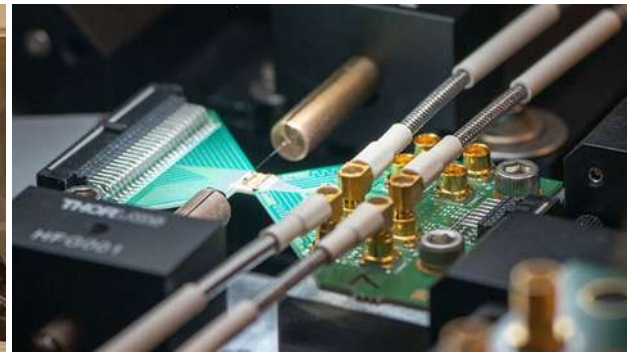
The CMRR Materials Characterization facility provides access to an array of state-of-the-art equipment for nanomaterial (both thin-film and powder) characterization, including XRD, XPS, Hall effect, UV-Vis, AFM/MFM, SEM, and photo current systems to measure crystal structure, and magnetic, surface, transport, and optical properties.

(http://cmrr.ucsd.edu/resources/Recharge%20Facility%20.html)

Microfluidic Medical Device Facility

The Microfluidic Medical Device Facility provides a well-equipped facility with experienced staff to allow users to independently fabricate microfluidic devices and we offer foundry or contractual fabrication services. The facility can offer several unique capabilities and services, including metallization of microfluidic circuits, incorporation of small features with microfluidics, multi-layer microfluidics with active (valve/pump) components and more.

(https://nano3.calit2.net/microfluidics/)



Chip-Scale Photonics Testing Facility

The Chip-scale Photonics Testing facility, connected to the UCSD data center testing system, enables real-time testing of developed devices and circuits in a realistic system application environment. The facility houses unique tools that allow external and internal users to measure the electrical/optical response of photonic devices and circuits. The equipment is highly integrated due to a custom cross-platform scripting framework and device drivers created by UCSD. All of the software is open source in order to better serve the facility users and the wider community.

(http://sdni.ucsd.edu/chip-scale-photonics.php)

Synchrophasor Grid Monitoring and Automation Lab (SyGMA Lab)

UC San Diego

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Leverage technology on electric grid instrumentation, development of new data processing, modeling and model validation tools based on synchrophasor data for advanced grid monitoring and automatic control of electric networks.

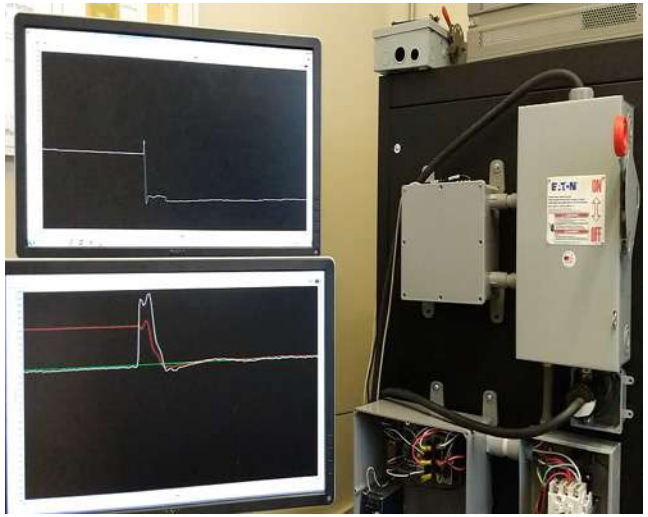
The SyGMA lab fosters collaborations between industry, faculty and students at UCSD. With the displays, conference room and separate offices, the lab is a show case for industrial software (OSIsoft, NI) and research at UCSD.

https://sygma.sdsc.edu/

OSIsoft.
NATIONAL INSTRUMENTS
SEL SCHWEITZER ENGINEERING LABORATORIES
SDGE
A Sempra Energy utility
SDSC
SAN DIEGO SUPERCOMPUTER CENTER

Synchrophasor Grid Monitoring and Automation Lab (SyGMA Lab)

UC San Diego



Dynamic (Micro)Grid Simulation

Three phase circuit simulation with synchrophasor data output and analog/digital DER inputs for Hardware-in-the-Loop simulation of DER and network dynamics.

Real-time 3 Phase Control

Three phase oscillatory circuit with islanding capabilities, one-cycle-control, programmable DC power supply and NI-cRIO hardware for control implementation

Dedicated SEL hardware

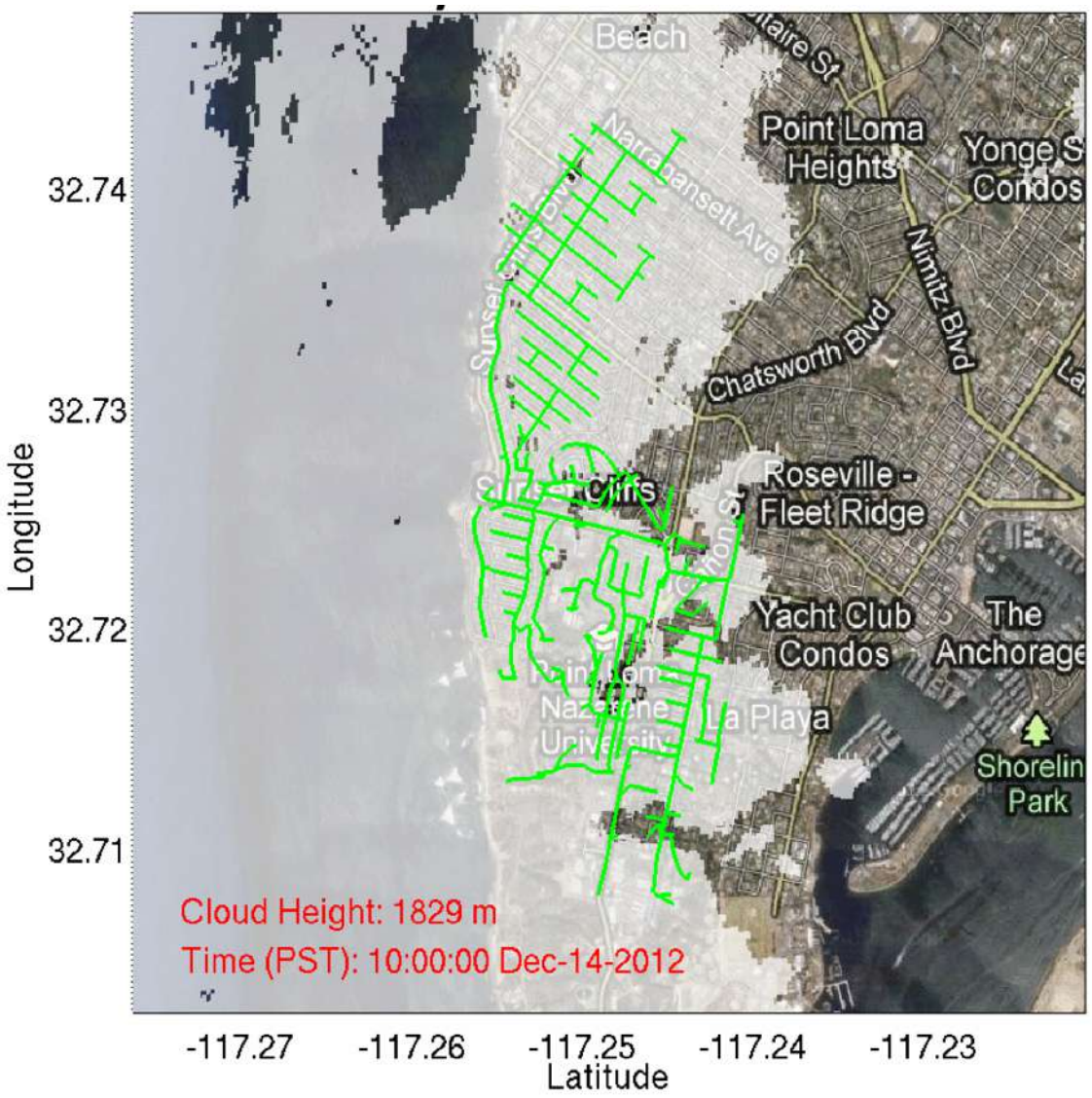
Industry leading Sweitzer Engineering Laboratories (SEL) hardware for synchrophasor data and real-time control implementation.

Solar Forecasting and Distribution System Integration

UC San Diego

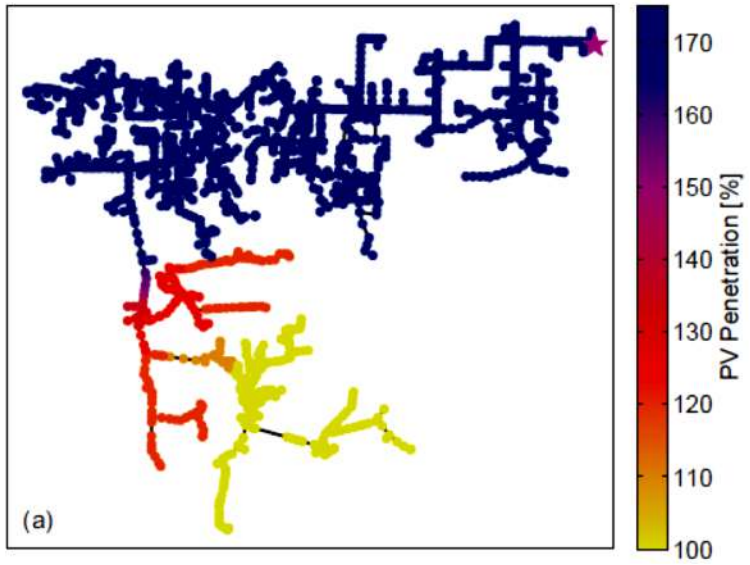
Test Lab Director and **Ombudsperson**
Jan Kleissl
Director, UCSD Center for Energy Research
P: (619) 376-3971
E: jkleissl@ucsd.edu

Virtual environment for solar power integration into distribution feeders including complete specifications for 15 real distribution feeders with 1000s of buses each; output from 20 solar PV systems at high resolution; forecast algorithms and data from numerical weather prediction, machine learning, and sky imagery, and optimization algorithms.



Solar Forecasting and Distribution System Integration

UC San Diego

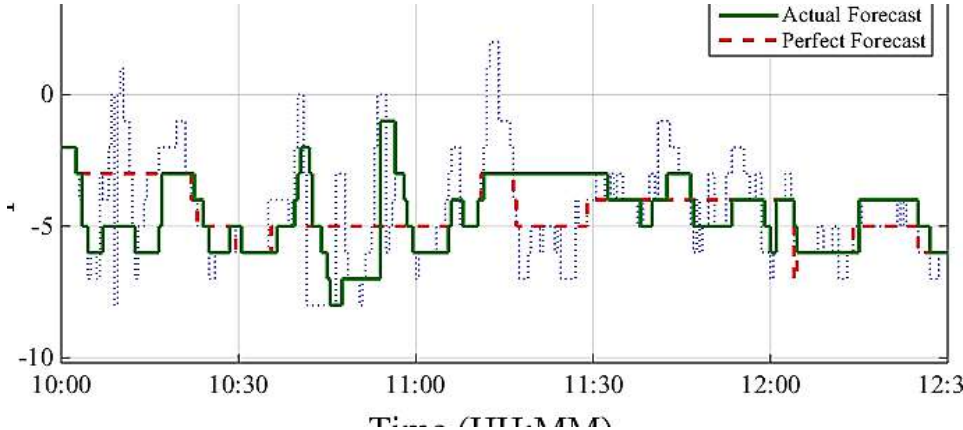


15 Real Distribution Feeders

Realistic distribution feeders can be simulated using quasi-steady state power flow in OpenDSS for various solar power penetration scenarios and smart inverter voltage control schemes.

Solar Forecasts

Solar forecasts from sky imagery, satellites, and numerical weather prediction models.



Transformer Tab Operations

Investigate the performance of different distributed or centralized control algorithms for minimizing the number of utility transformer tap operations by leveraging Phase 3 solar inverter functions.

Renewable Natural Gas Development Laboratory

UC San Diego

Test Lab Director
Robert Cattolica
Professor, Department of Mechanical and Aerospace Engineering
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Ombudsperson
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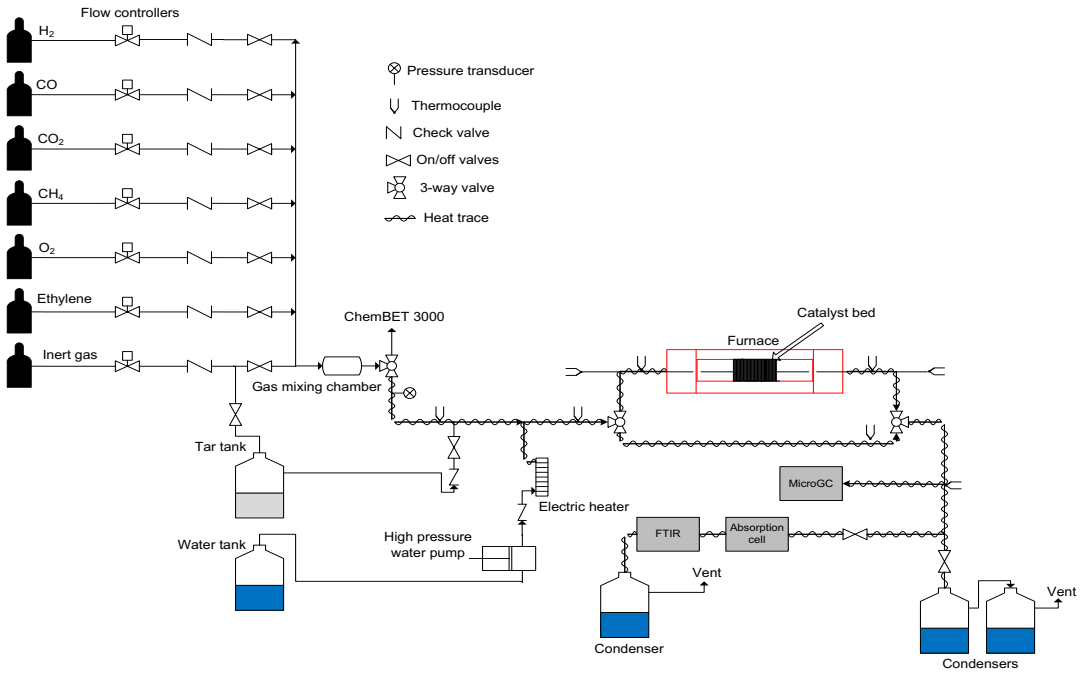
This laboratory provides fixed-bed and fluidized-bed reactors for the development and testing of catalysts and the associated design of chemical reactors for the synthesis of natural gas from renewable sources of syngas. UC San Diego has experience in the preparation and characterization of unique catalyst formulations, support matrices, and operating parameter optimization for increased performance. Computational fluid dynamic modeling of fluidized-bed reactors for the methanation of syngas is available scaling laboratory experiments to commercial scale.



Fixed-Bed Flow Reactor for Methanation Catalyst Testing

- Fixed-Bed and Fluidized-Bed Methanation Reactors
- Capability to simulate specified syngas compositions
- Gas analysis with micro-GC and advanced GC-Chemiluminescent system for ultra-low sulfur measurement
- Catalyst characterization: ChemBet, XRD, EDX, XRF, and SEM
- CFD modeling of fluidized-bed chemical reactor design on parallel-processing workstation

Electric Vehicle Smart Charging

UC San Diego

Test Lab Director
Byron Washom
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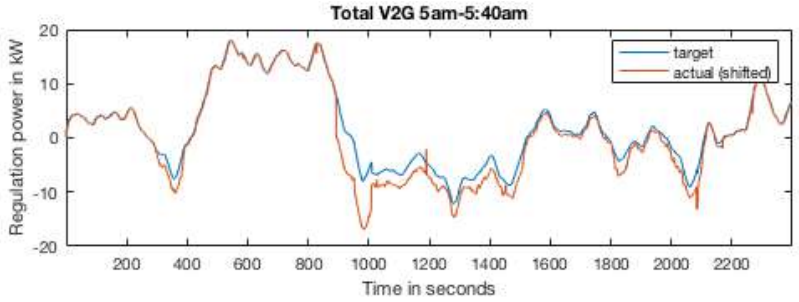
Through CHARGES, the DOE ARPA-e designated UC San Diego as one of two national facilities for testing of new advanced energy storage technology, including: platforms for cell level, module level, and full-scale grid-connected testing; grid-connected outdoor test platform to test three systems; and remote monitoring and testing capability.

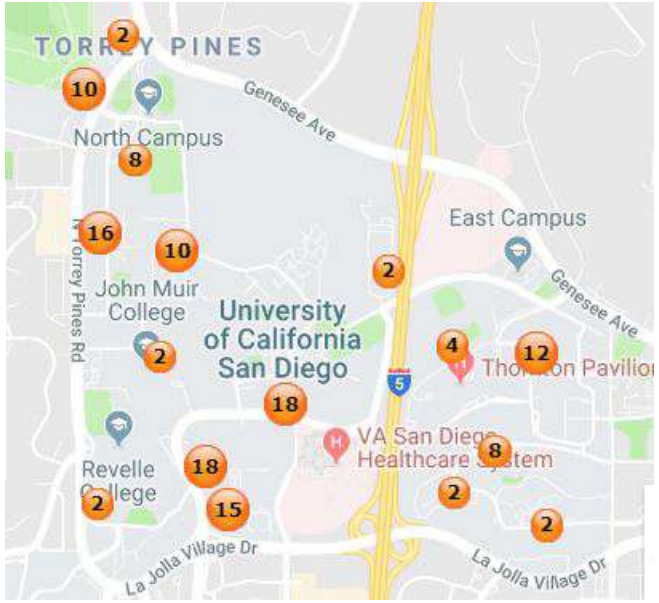
Electric Vehicle Smart Charging

UC San Diego



Smart Charging

Together with ChargePoint, PowerFlex / EDF, and Nuvve we have demonstrated V1G and V2G charging via an API to charging rates between 1.2 to 7 kW for the Level 2 stations. Modulating charging requires consent from EV drivers. We have extensive expertise in securing IRB approval and recruiting drivers.



ChargePoint

UC San Diego is the largest ChargePoint customer by energy consumed. ChargePoint presently owns and operates 183 Electric Vehicle (EV) charging stations at the UCSD campus (Figure 3) consisting of 182 Level 2 (up to 7 kW) charging stations and one DC fast charger at 75 kW.

Customer Base

These stations serve a monthly base of 1200+ individual public, commuter and fleet patrons that are growing at a rate of 8% per *month* in response to the incentive pricing to over 39 makes and models of new and used EVs and accessibility to workplace charging. Given the planned build-out we anticipate 210 charging stations by the time of the start of the NSF Mid-Scale RI-2 award.

Technology Type	Testing Capabilities
Grid Technology	All California Rule 21 Phase 3 functions such as Volt-var, Volt-Watt, LVRT, LFRT, etc.. Grid simulator. PV simulator. Inverters up to 30 kW. Verify inverter performance compliance for all California Rule 21 Phase 1-3 functions, e.g., High- and Low-Voltage Ride-through, High- and Low-Frequency Ride-through, Volt-VAR response, Specified Power Factor, etc. Grid and PV simulators for testing inverters up to 30 kW capability under specified conditions Smart Inverters (POC: Antoni Tong)
Energy Storage	The grid-connected outdoor test platform consists of three 40 ft test pads up to 1 MW. Remote monitoring and testing capability. Special safety features allow testing of many different types of battery systems. Battery Energy Storage Systems – utility scale (POC: Mike Ferry)
Energy Storage	Up to 10 battery modules up to a maximum of 100 kW under controlled laboratory conditions. High resolution testing equipment with full bi-directional power capability allows very flexible testing and ability to simulate almost any DER connected condition. Battery Energy Storage Systems – module level (POC: Mike Ferry)
Material-Based	Broad spectrum of nanofabrication and characterization technologies and expertise that enable and accelerate cutting edge energy research, proof-of-concept demonstration, device and system prototyping, product development, and technology translation. Nanotechnology Infrastructure (POC: Bernd Fruhberger)
Grid Technology	Access to Synchrophasor (PMU) data from multiple locations in the Western Grid. Dedicated grid simulator hardware for computing real-time power flow dynamics. Three-phase grid-tied inverter, and switchable capacitive and inductive loads to simulate microgrid islanding capabilities in a lab environment. Synchrophasor Grid Monitoring and Automation (SyGMA) Laboratory (POC: Raymond de Callafon)
Grid Technologies	Virtual environment for solar power integration into distribution feeders including complete specifications for 15 real distribution feeders with 1000s of buses each; output from 20 solar PV systems at high resolution; forecast algorithms and data from numerical weather prediction, machine learning, and sky imagery, and optimization algorithms. Solar Forecasting and Distribution System Integration (POC: Jan Kleissl)
Renewable Generation	Testing and characterization of catalysts for the synthesis of natural gas from renewable syngas. Laboratory facilities include fixed-bed and fluidized-bed methanation reactors and associated analytical instruments. Micro analysts of catalyst with: ChemBet, XRD, EDX, XRF, and SEM. Advanced computational fluid dynamic modeling of methanation reactor designs. Synthesis of Renewable Natural Gas (POC: Robert Cattolica)
Transportation	UC San Diego collaborates with seven OEM electric vehicle manufacturers and more than 10 makers of V1G and V2G supply equipment. Since UC San Diego is self-permitting, testing partners can bypass complicated IOU interconnection procedures. Electric Vehicles (POC: Byron Washom)

UC SANTA BARBARA

Materials Research Lab Polymer Facility

UC Santa Barbara

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615 Science Ln, Materials Research Lab, UC Santa Barbara, Santa Barbara, CA 93106-5121

Ombudsperson
Leslie Edwards

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Analytical testing of polymers and small molecules. Instrumentation available for obtaining molecular weights, thermal transitions, rheology, and particle sizing.

Materials Research Lab Polymer Facility

UC Santa Barbara

Polymer Testing: Gel Permeation Chromatography (GPC)

Determining molecular weight distributions is essential for polymer synthesis and the understanding of how a polymer behaves. In the Polymer Facility, six GPC instruments are dedicated to the purification and analysis of polymer materials.

Rheology, Thermal, and Mechanical Analysis of Materials

Study flow and deformation of materials under applied forces and temperatures. Dynamical Mechanical Analyzer (DMA), Differential Scanning Calorimeter (DSC), and state of the art rheometer can measure dampening, thermal transitions, viscosities, and the storage and loss moduli.

ESI Mass Spectrometry

Separate and identify analytes by mass with high sensitivity and selectivity. The mass spectrometer aids in identifying unknown compounds, determining the isotopic composition of elements in a molecule, and determining the structure of a compound by observing its fragmentation

Technology Type	Testing Capabilities
Material-Based	Determining relative and absolute molecular weights, polydispersity, and particle sizing
Material-Based	Measuring viscosity and modulus of solids and polymer melts in relation to stress, strain, frequency, and temperature
Material-Based	Measuring heat capacity, glassy transitions, and heat flow
Material-Based	Chromatographic separation and mass identification of organic and inorganic compounds

Materials Research Lab TEMPO Facility

UC Santa Barbara

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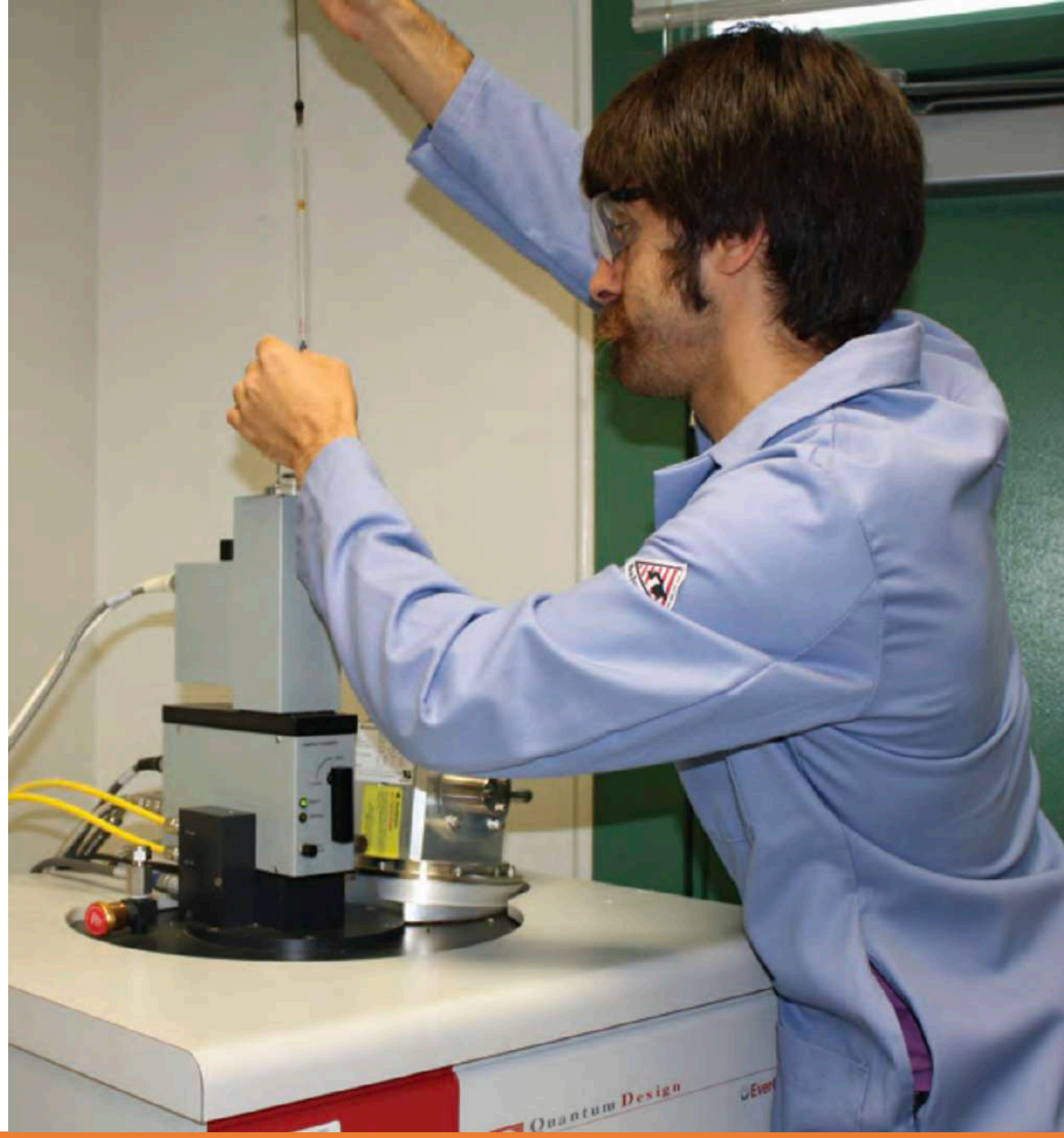
Porosimetry and surface area, elemental analysis, thermal properties, evolved gas analysis, fluorescence, absolute quantum yield, density, absorption of light, magnetism, resistance, thermal and electrical conductivity, heat capacity (1.8 K to 1800 K)



Materials Research Lab
TEMPO Facility

UC Santa Barbara

Thermal Electronic/Elemental Magnetic Porosity and Optical

The TEMPO facility is for testing fundamental properties of materials such as magnetism, thermal stability or absorption of light. We have 15 different tools for materials testing. The Low-Temp Lab is pictured above.

TEMPO Low Temperature Lab:

Can test the electrical and thermal transport, i.e. conductivity, as well as magnetic properties of materials as a function of temperature (1.8 to 1000 Kelvin) and/or magnetic field (up to 14 Tesla).

The TEMPO facility houses instruments would be most useful in early-stage development or choice of materials for energy applications such as the TGA, above, for thermal analysis.

Accessible sample sizes are small scale and typically not intended for device testing.

Technology Type	Testing Capabilities
Material-Based	resistivity, charge carriers, thermoelectric figure of merit, IV curves, critical current, superconductors
Material-Based	High-precision density, porosity, surface area, chemi- and physi- absorption, xray diffraction
Material-Based	Decomposition, heat capacity, thermal transport, heat flow
Material-Based	absorption in UV, visible, Near-IR, mid- IR. Emission and quantum yield.
Material-Based	ICP and high-temp Xray diffraction

Materials Research Laboratory Spectroscopy Facility

UC Santa Barbara

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615 Science Ln, Materials Research Lab, UC Santa Barbara,
Santa Barbara, CA 93106-5121

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The spectroscopy facility is the home to magnetic resonance instruments that include seven NMR spectrometers (100MHz, 300MHz, 400MHz, 500MHz (x2), 600MHz, and 800MHz) and a X-band EPR spectrometer. The facility focuses on materials research through structure determination, physical property measurement, kinetics, thermodynamics, quality control and quantification.

Materials Research Laboratory Spectroscopy Facility

UC Santa Barbara

The cutting edge dynamic nuclear polarization (DNP) NMR instrument addresses the most serious disadvantage of NMR by enhancing sensitivity by up to 660 times, opening new avenues to materials research such as catalysis, coating, and doping, and to materials of limited amount, low loading and insensitive nuclei.

The high field 800MHz NMR spectrometer is equipped with both solution- and solid-state NMR capabilities, suitable for studies of proteins, polymers and other macromolecules where resolution and sensitivity are essential and for researches of materials with quadrupolar nuclei (^{27}Al, ^{23}Na, ^{71}Ga, etc).

This unique 300MHz super-wide bore (SWB) instrument is loaded with a variety of NMR capabilities from solid-state NMR, PFG diffusion measurement (DOSY), rheology NMR (rheo-NMR), magnetic resonance imaging (MRI), to the newly implemented electrophoretic NMR. The 150mm bore size of the magnet allows easy hardware customization and fabrication.

Technology Type	Testing Capabilities
Material-Based	Diffusion range 10^{-8} to 10^{-14} m^2/s for nuclei including, but not limited to, ^{1}H, ^{19}F, ^{7}Li, ^{2}H, ^{23}Na, and ^{31}P
Material-Based	Mapping velocity, strain, and stress to study rheological properties of fluids and soft matters
Material-Based	Transport of charged particles (e.g. ^{19}F, ^{7}Li) measured with PFG NMR in an electric field
Material-Based	Solid-state NMR studies of materials with insensitive nuclei, low loading or limited sample amounts
Material-Based	Structures, physical properties, kinetics, and quantification of materials

NRI-MCDB Microscopy Facility

UC Santa Barbara

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UCSB NRI
5173 Biological Sci Bldg II
Santa Barbara, CA 93106-5060

Ombudsperson
Leslie Edwards

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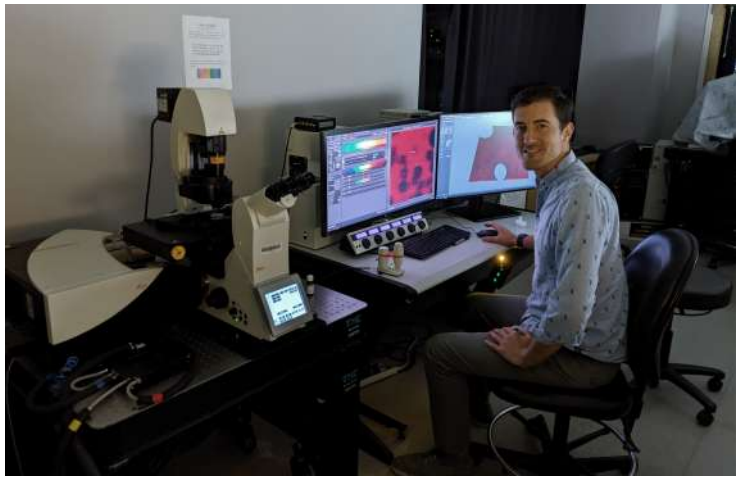
Light microscopy, Brightfield, Polarization, DIC, Fluorescence, Transmission Electron Microscopy.

NRI-MCDB
Microscopy Facility

UC Santa Barbara



The NRI-MCDB Microscopy Facility serves the entire UCSB community in its mission to provide access and training to cutting edge microscopy instrumentation. Researchers and students in numerous departments use the facility to acquire the images they need to accomplish their research.

While primarily a light microscope facility focusing on confocal and epi-fluorescence microscopes, the Facility also houses an easy-to-use, high contrast transmission electron microscope. Image analysis is covered too with two high-end PC workstations equipped with visualization and analysis software.

A couple less conventional imaging modalities are available. The lightsheet microscope allows 3D imaging of sample too large for confocal imaging. The 3D Cell Explorer enables long-term label-free imaging of live cells. Contact the Facility Director for more information.

Technology Type	Testing Capabilities
Material-Based	• 3D fluorescence imaging • temperature controlled stage • video rate time-lapses • fluorescence lifetime imaging (FLIM) • motorized stage for multiple field-of-view stitching
Material-Based	• high contrast for biological samples • 40-120 kV
Material-Based	• 3D fluorescence imaging of larger (millimeter scale) objects • 2-color simultaneous imaging • rotation capable sample holder for Multiview imaging
Material-Based	• Inverted or upright • high-end CCD or CMOS cameras • 4x to 100x objective lenses
Material-Based	• 3D imaging of unlabeled samples with contrast determine by refractive index • incubation stage allowing days long timelapses with low photodoses

UC SANTA CRUZ

Center for Agroecology & Sustainable Food Systems (CASFS)

UC Santa Cruz

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1156 High Street
Santa Cruz, CA 95064

Ombudsperson
Sue Carter

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The mission of the Center for Agroecology & Sustainable Food Systems (CASFS or the Center) is to research, develop, and advance sustainable food and agricultural systems that are environmentally sound, economically viable, socially responsible, nonexploitative, and that serve as a foundation for future generations.

Beyond the campus we collaborate with non-governmental organizations (NGOs), growers, community members, visiting students and researchers, and state and federal agencies, including UC Cooperative Extension and the US Department of Agriculture.

Center for Agroecology & Sustainable Food Systems (CASFS)

UC Santa Cruz

UCSC Farms: CASFS manages the 30-acre UCSC Farm and the 3-acre Aland Chadwick Garden which provide testing of clean energy technologies related to Ag-tech and sustainable food systems. CASFS is part of the UC Global Food Initiative whose efforts are focused on using UC expertise to improve food security throughout the state and nation and world.

Farm Apprenticeship: For entrepreneurs who would like to become familiar with sustainable food grown practices, CASFS offers Farm apprenticeships in ecological horticulture which The Apprenticeship training program offers 300 hours of classroom instruction and 700 hours of in-field training and hands-on experience in the greenhouses, gardens, orchards, and fields. https://casfs.ucsc.edu/apprenticeship/

Greenhouse Facilities: In addition to open field, CASFS has greenhouse available to test impact on clean energy technologies on plant growth under more controlled growing conditions. A wide variety of LiCor sensor technology systems are available for monitoring plant production, CO2 uptake, and gas emissions as a function of environmental conditions.

Technology Type	Testing Capabilities
Industrial & Agricultural Innovation	CASFS manages the 30-acre UCSC Farm and the 3-acre Aland Chadwick Garden which provide testing of clean energy technologies related to Ag-tech and sustainable food systems.

UC Santa Cruz Natural Reserves

UC Santa Cruz

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The University of California Natural Reserve System is a network of protected natural areas throughout California. Its 39 sites include more than 756,000 acres, making it the largest university-administered reserve system in the world. UCSCS manages the natural reserves that stretch from Ano Nuevo in Pescadero to Big Creek Reserves in Big Sur.

Most major state ecosystems are represented, from coastal tidepools to inland deserts, and lush wetlands to Sierra Nevada forests.

The reserves also serve as a gateway to more than a million acres of public lands.

UC Santa Cruz Natural Reserves

UC Santa Cruz

Younger Lagoon Reserve)72 acres): One of the few relatively undisturbed wetlands remaining on the California Central Coast, the Younger Lagoon Reserve next to UCSC's coasta campus in Santa Cruz encompasses a remnant Y-shaped lagoon on the open coast just north of Monterey Bay. Reserve habitats include salt and freshwater marsh, coastal strand, backdune pickleweed flat, steep bluffs with dense coastal scrub, pocket beach, grassland, and dense willow thickets. Along with the Long Marine Laboratories, it provides a location for testing clean energy technologies that rely on proximity to ocean ecosystems.

Landel-Hills Big Creek Natural Reserve (4328 acres): Protected by the Santa Lucia Mountains and rocky cliffs, the Landel-Hills Bid Creek reserve in Big Sur coast includes the largest and most pristine coastal wildlands in central and southern California. Directly adjacent to the terrestrial reserve are two state marine protected areas: the Big Creek State Marine Reserve and the Big Creek State Conservation Area. These locations provide pristine areas for testing clean energy technologies in elevations ranging from 0 to 2000 feet .

UCSC Campus Natural Reserves (410 acres): UC Santa Cruz Campus Natural Reserve are spread over the UCSC main campus and represent habitat types that include grasslands, coastal prairie, redwood forest, dwarf redwood forest, mixed evergreen, northern maritime chaparral, and riparian woodland. Several long-term research projects take place on reserve lands, including the UCSC Forest Ecology Research Plot (FERP). It provides a location for testing clean energy technologies in a variety of coastal forestry systems and open spaces.

Technology Type	Testing Capabilities
Water Technologies	Testing clean energy technologies in a variety of coastal forestry systems and open spaces.
Industrial & Agricultural Innovation	Testing clean energy technologies in a variety of coastal forestry systems and open spaces.

S-Lab Facilities

UC Santa Cruz

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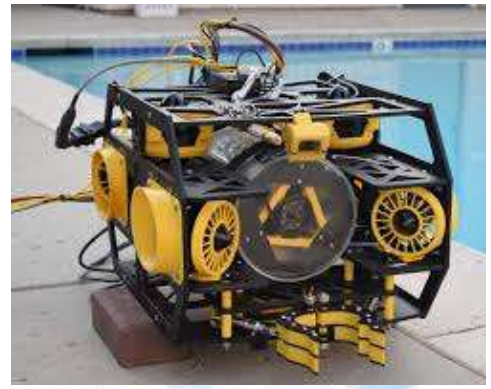
Facilities span multiple locations: Thimann Labs, Carter Labs and the UC Natura Reserves, as well as a number of partner facilities through the IDEA Hub network. Student teams such as Formula Slug, Slugbotics, Water lab and the Rocket Club are housed in the Slab.

The S-lab provide access to hardware and software for hands-on development and innovation in design, manufacturing, communications, and fabrication focused on sustainability and encompassing both indoor and outdoor project space.

Slab offer training, consumables, and access to equipment, with the ability to purchase other parts quickly and at cost.



S-Lab Facilities

UC Santa Cruz

Prototyping and metal-shop

The metal shop contains a Hardinge Precision Manual Lathe, Vertical Manual Milling Machine, Bench Mount Drill Press, Vertical Metal/Wood Bandsaw, Rotary Indexing Table, Tap and Die Sets, Xcarve CNC Router 1m x 1m, Tormach 770M CNC Milling Machine.

The Prototyping shop consistes of a Kudo Titan2 SLA Printer, FormLabs Form2 SLA Printer and Wash & Cure, Ultimaker 2+ FDM Printer, Flashforge CreaterPro FDM Printer, 3x Monoprice MP Select Mini FDM Printer, CNC Laser Cutter and 3D Scanner.

Training Workshops

The Slab offers several classes and training sessions in Power systems design, 3D design and fabrication, Remote sensing, and water response management. These courses, as well as workshops in material and devices characterization, could be made available to entrepreneurs interested in gaining extra technical skill-sets.

Materials and Device Characterization

The S-lab contains a variety of equipment for testing and working with clean energy materials and devices, including fume hoods, spin coaters, glove boxes, thermal evaporators, glass ware and material deposition equipment, oscilloscopes, HP universal sources, Source-measure units, LCR meter, solar simulator, UV-Vis spectrometers, fluorometers, Voltmeters and connections to facilities such as FIB-SEM and AFM.

Technology Type	Testing Capabilities
Industrial & Agricultural Innovation	Access to hardware and software for hands-on development and innovation in design, manufacturing, communications, and fabrication focused on sustainability and encompassing both indoor and outdoor project space.

IDEA Hub: The Hive, Community media Mapping Lab and the VizLab

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IDEA HUB
Creative and Social Entrepreneurship at UCSC

Led by the Center for Innovation and Entrepreneurial Development, the IDEA Hub is a campus-wide initiative, created to spread social and creative entrepreneurship at UC Santa Cruz. A network of incubation facilities, fellowships, training, and mentorships provides space to think critically about the challenges facing society and propose pathways for meaningful intervention.

These campus work spaces provide access to hardware and software for hands-on development and innovation in design, manufacturing, communications, and data visualization; encompassing both indoor and outdoor project space.

We offer training, consumables, and access to equipment, with the ability to purchase other parts quickly and at cost.

IDEA Hub Facilities

UC Santa Cruz

openlab
UCSC COLLABORATIVE RESEARCH

The Open Lab is located in the Arts Department and provides a variety of collaborative maker spaces, including a foundry with an overhead crane, two furnaces, and a burn-out kiln for evacuation of the wax; a woodshop with bandsaws, table saws and all wood-working equipment; a metal shop has all tools and machinery necessary to work with a variety of metals, including welding, bending, and cutting; and a Prototyping Lab consists of an Epilog Legend 36EXT 120 Watt Laser Cutter, Formech Vacuum Former, MakerBot Replicator Z18 3D Printer, Tormach PCNC770 CNC Mill, Sherline desktop CNC Mill, Grizzly Manual Mill / Drill Press, Mold Making & Casting Equipment, various hand & power tools, electronics workbench, handheld 3D scanner

everett program
DIGITAL TOOLS FOR SOCIAL INNOVATION

The Community Media and Mapping Lab is located within the Everett Program in Social Sciences (http://www.everettprogram.org/), and provides training in web design and mobile app development, with a focus on promoting social good. The Everett program provides a networking and training resource to clean-tech companies focused on promoting environmental and energy justice . Their facilities provide a variety of computer systems and training focused on web design and mobile app creation; however, the strength on the center is its experience and networked communities for promoting social justice.

Technology Type	Testing Capabilities
Internet of Things	Facilities provide a variety of computer systems and training focused on web design and mobile app creation; however, the strength of the center is its experience and networked communities for promoting social justice.
Industrial & Agricultural Innovation	Provides a variety of collaborative maker spaces

Jean H. Langenheim and UCSC Greenhouses

UC Santa Cruz

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The Jean Langenheim Greenhouses is an instructional facility open to the public on the rooftop of Thimann Labs. It is located on the roof of Thimann Labs. This facility has a botanical collection as well as a lab, library, and outdoor seating areas. The campus also has rooftop greenhouses on Sinsheimer and ISB buildings and at the coastal campus that are available for research and testing.

In addition to providing access to greenhouse facilities for research and development, we can connect clean energy companies to campus experts in greenhouse technologies and plant science.

Technology Type	Testing Capabilities
Industrial & Agricultural Innovation	This facility has a botanical collection as well as a lab, library, and outdoor seating areas. The campus also has rooftop greenhouses on Sinsheimer and ISB buildings and at the coastal campus that are available for research and testing.


BERKELEY LAB

FLEXLAB®

Lawrence Berkeley National Lab

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Principal Investigator
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FLEXLAB® is a one-of-a-kind of testing facility for energy-efficient building technologies that is helping to develop the next generation of innovative, energy-saving systems.

FLEXLAB® allows users to develop and test energy-efficient building and grid technologies individually or as an integrated system, under real-world conditions.

FLEXGRID is a FLEXLAB® testing system that offers distributed energy resources testing capabilities, enabling real-time comparisons between demand, renewables, inverters and storage.

FLEXLAB®

Lawrence Berkeley National Lab

FLEXLAB® allows real-world testing under controlled occupied or unoccupied conditions, including the use of thermal mannequins to generate occupancy heat signatures. Designed to study system technologies, FLEXLAB is home to thousands of sensors, including power measurement at every outlet and device.

FLEXLAB uniquely incorporates all major building end use technologies as well as DERs under one roof, to enable real-time comparison tests. Base case conditions can represent the existing building stock, competing technology conditions, or energy code conditions.

FLEXLAB was designed to enable the integration and testing of a full range of technologies and controls. Our data acquisition and controls systems allow for integration across building technologies, renewable energy sources, storage and electric vehicle charging.

Technology Type	Testing Capabilities

Building Technologies	4 testbeds with 2 cells each for comparison studies. Each 600sf cell representative of a single thermal HVAC zone in a commercial building. Real-time comparison studies under live conditions (identical base case and test case chambers). One testbed fully rotates to allow studies under different solar orientations (e.g south-, west-, north- facing). High accuracy and high granularity of sensing at individual device through to system level. Testing includes:
	• All major building end use systems – HVAC, lighting, shading, envelope, plug loads and integrated controls:
	  • Whole building (end use system integration, performance)
	  - HVAC zone level systems (e.g. VAV boxes, fan coils, in-slab radiant systems, air handlers, rooftop systems and controls)
	  - Lighting and controls (e.g. overhead, task, zone level, fixture specific, dimming, occupancy based)
	  - Deep daylighting technologies (light redirecting louvers, skylights)
	  - Exterior shading, interior shading
	  - Building integrated photovoltaics
	  - Phase change materials (envelope and interior applications)
	  - Thermal mass conditions (light weight construction to heavy mass)
	  - Plug load devices and controls
	• HVAC systems support packaged Rooftop Units, Air handlers, radiant panels and radiant in-slab systems, Duct sealing technologies
	• Other performance characterization (e.g. flow hood testing, tracer gas and other airflow measurement techniques, calibration)
	• Thermal comfort performance (e.g. dry bulb temperature, mean radiant/operative temperature, humidity, stratified space temps, air velocity, other)
	• Visual comfort performance (e.g. illuminance, glare)
	• Indoor air quality characteristics

Energy Efficiency	• Energy performance studies at device and system level (e.g. consumption, peak, demand response, power quality) • Integration and interoperability between devices and systems • Controls optimization at end use level and between end use systems

Technology Type	Testing Capabilities
Energy Storage	Studies of storage in application with PV generation, and building loads, including: - Grid optimized DER (e.g. storage) and building technologies controls testing - Comparison of technologies or control strategies (3 sets of solar/inverter/battery arrangements)
Grid Technologies	Building technologies grid integration controls studies including: - AutoDR integration and custom applications - Demand response controls for HVAC, lighting, shading and plug load technologies - Model Predictive Control - Peak energy reduction - Communications testing, including latencies, response - Grid system operator signal integration
Grid Technologies	FLEXGRID – A Distributed Energy Resources testing infrastructure at FLEXLAB. Technologies covered include battery storage (19kWh currently, may be changed);, bidirectional electric vehicle charging; 3 set of PV inverter arrays (15kW total); inverters with API access for controls integration; Opal-RT real time grid simulator; Ametek MX-30 regenerative power supply (emulates grid or other power conditions such as harmonics, voltage sag etc.); ~100 programmable loads, including DC, AC, from 1/4hp to 3kW, variable speed loads, fans, resistive loads DER technology integration studies: - Grid optimized EV, DER and building technologies controls testing - Comparison of technologies or control strategies (3 sets of solar/inverter/battery arrangements) - Microgrid controls development and testing - Real-time integration of DER and FLEXLAB building technologies controls strategies - Grid conditions emulation (<480V) - Grid system operator controls signal integration - Inverters in delta or wye configuration - Micro psynchrophasor power quality measurements at key locations in DER and testbed electrical distribution

Technology Type	Testing Capabilities
Renewable Generation	Studies of solar PV generation in application with DER technologies and building loads, including: - Grid optimized DER and building technologies controls testing - Comparison of technologies or control strategies (3 sets of solar/inverter/battery arrangements) - Microgrid controls development and testing - Real-time integration of DER and FLEXLAB building technologies controls strategies
Transportation	Bidirectional Electric Vehicle charger, in application with other DER and building load technologies. Testing includes: - Bidirectional charging, use of EV as a power supply to buildings, or a grid resource - Grid optimized EV, DER and building technologies controls testing

Connected Devices Lab

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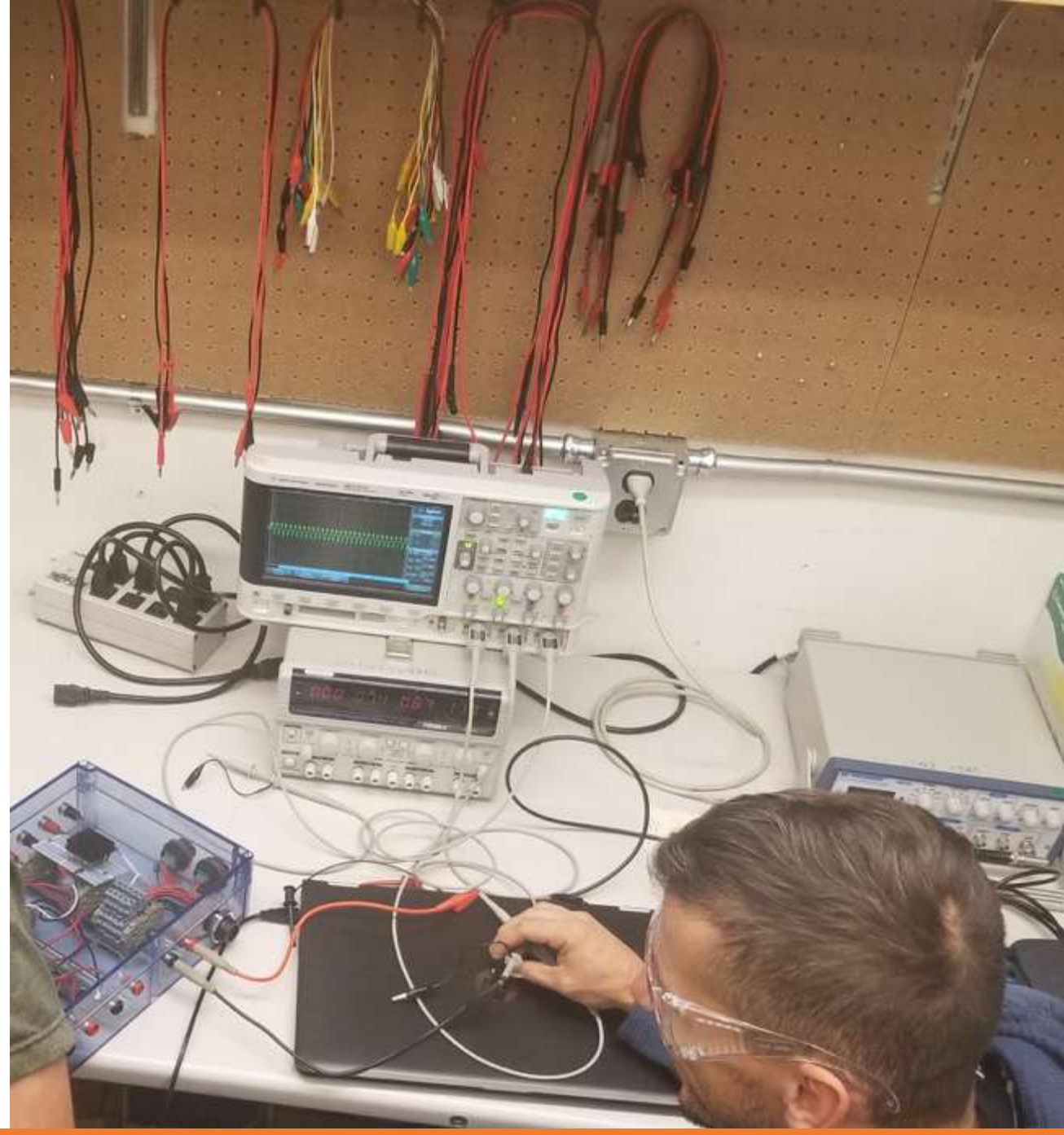
The Connected Devices lab develops prototypes and tests small devices and plug loads with a focus on:

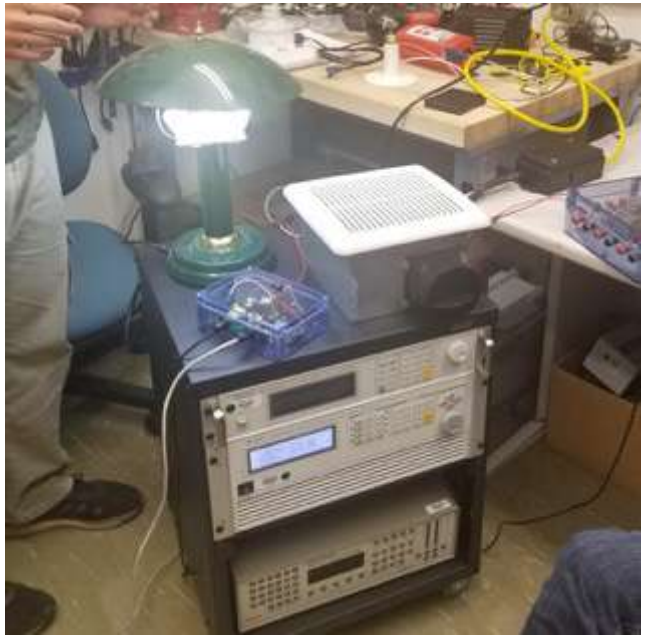
- *Energy Reporting*
- *Zero Standby Energy*
- *Direct DC Devices*
- *Small DC System Testing*
- *Communication and Networks*



Connected Devices Lab

Lawrence Berkeley National Lab

The Lab contains equipment intended to support design, fabrication, and testing of electronic products. Available instrumentation focuses on accurately measuring and evaluating the products' energy and communication characteristics.



Probing signals and voltage levels are tested for various prototypes, including the zero-standby wake-up radio pictured. The lab has measurement equipment suitable for conducting IEC 62301 tests (standby power) and other communications test procedures.

This lab is particularly well suited for examining energy use and communications characteristics of the devices, such as in routers, computers, PoE lighting, and other networked equipment.

Technology Type	Testing Capabilities
Building Technologies	Small electronics, power supplies, direct DC devices, small DC systems, communications and network equipment testing and evaluation: - Design, fabrication and testing - Communications evaluation (e.g. latency, other characteristics) - Power measurement (current, voltage, power, power quality) - Standby power evaluations
Energy Efficiency	Small electronics, power supplies, direct DC devices, small DC systems, communications and network equipment testing and evaluation: - Power measurement (current, voltage, power, power quality) - Standby power evaluations
Internet of Things	Small electronics, power supplies, direct DC devices, small DC systems, communications and network equipment testing and evaluation: - Design, fabrication and testing - Communications evaluation (e.g. latency, other characteristics) - Power measurement (current, voltage, power, power quality) - Standby power evaluations

Advanced Windows Testbed

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Investigates building façade systems to promote the advancement of interactive façade, lighting, and HVAC systems.

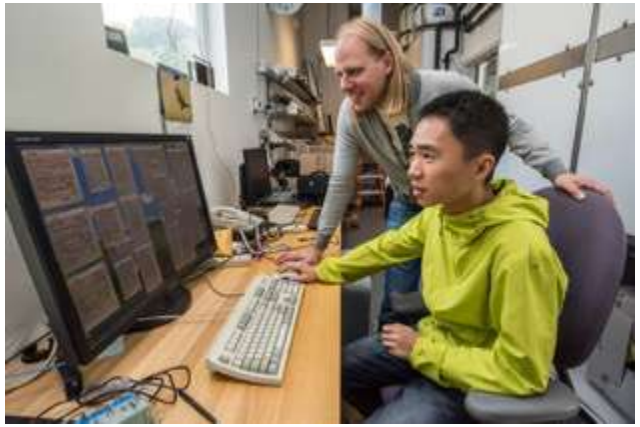
Test chambers are thermally isolated to enable window heat flow measurements to be made on a comparative basis. The chambers are designed to emulate typical private offices so that daylighting, comfort, and human factors studies can be conducted as well.

Advanced Windows Testbed

Lawrence Berkeley National Lab

Enables investigations of system-level interactions between innovative façade systems and impacted lighting and HVAC systems using outdoor tests in three full-scale, side-by-side instrumented test chambers with south-facing interchangeable façade openings, interior or exterior shading devices, and dedicated air handlers.

Each chamber is thermally isolated so that window heat flow measurements can be made on a comparative basis. The chambers are designed to emulate typical private offices for daylighting, comfort, and human factors studies. The test cells are highly instrumented with research-grade sensors for power metering, heat flow measurement, and photometric light and glare sensors.



Scientists collaborate with industry to evaluate prototype systems, working out control system designs for dynamic, intelligent façade systems or characterizing the luminous environment resulting from innovative daylighting systems. The performance is evaluated for lighting and daylighting, visual comfort, thermal comfort, and energy use.

Technology Type	Testing Capabilities
Building Technologies	3 side by side thermally isolated test chambers each emulating a typical private office. Studies of building façade technologies; Glazing (glazing assemblies, films, coatings, electrochromic, thermochromic); Envelope; Exterior shading; Interior shading and controls; Lighting (single office, overhead and task); Building integrated photovoltaics; Integrated controls strategies; DC power (PV, battery, lights) including: • Real time comparison studies (base case to new technology) • Daylighting characterization and evaluation • System controls interoperability and interactions between façade, shading and lighting - Model predictive controls - Sensor and controls testing - HVAC interactive thermal response, energy use - Thermal comfort performance (dry bulb temperature, mean radiant/operative temperature, humidity, stratified space temps, air velocity, other) - Visual comfort performance (illuminance, glare)
Energy Efficiency	3 side by side thermally isolated test chambers each emulating a typical private office. Studies of building façade technologies; Glazing (glazing assemblies, films, coatings, electrochromic, thermochromic); Envelope; Exterior shading; Interior shading and controls; Lighting (single office, overhead and task); Building integrated photovoltaics; Integrated controls strategies; DC power (PV, battery, lights) including: • Real time comparison studies (base case to new technology) - Energy performance (consumption, peak demand)
Grid Technologies	3 side by side thermally isolated test chambers each emulating a typical private office. Studies of building façade technologies; Glazing (glazing assemblies, films, coatings, electrochromic, thermochromic); Envelope; Exterior shading; Interior shading and controls; Lighting (single office, overhead and task); Building integrated photovoltaics; Integrated controls strategies; DC power (PV, battery, lights) including: - Demand response controls (e.g. AutoDR) - Model predictive controls

Technology Type	Testing Capabilities
Renewable Generation	3 side by side thermally isolated test chambers each emulating a typical private office. Studies of building façade technologies; Glazing (glazing assemblies, films, coatings, electrochromic, thermochromic); Envelope; Exterior shading; Interior shading and controls; Lighting (single office, overhead and task); Building integrated photovoltaics; Integrated controls strategies; DC power (PV, battery, lights) including: - Solar technology integration - Energy performance (consumption, peak demand) - Demand response controls (e.g. AutoDR) - Model predictive controls

Window Thermal Properties Laboratory

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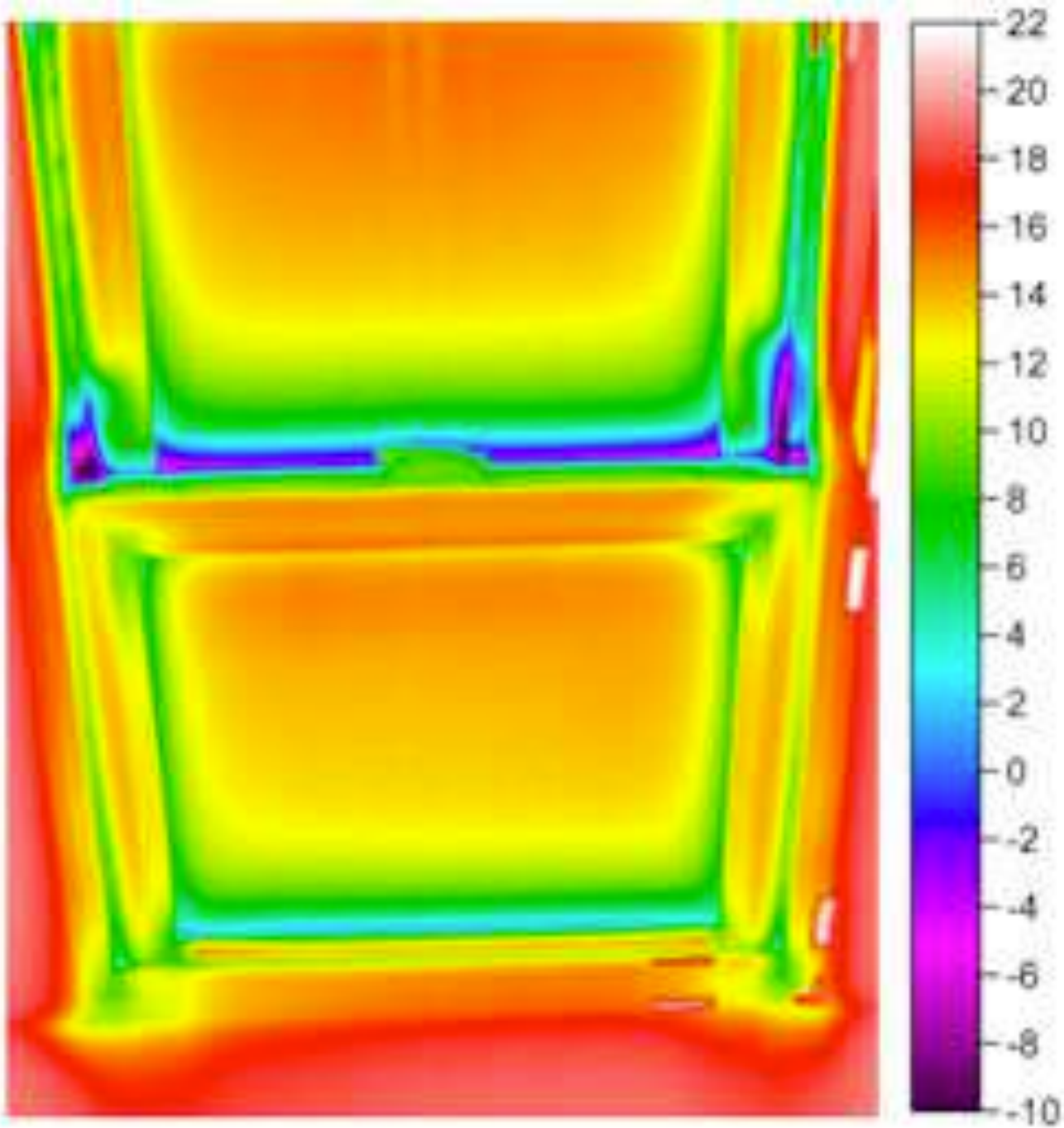
The Window Thermal Properties Laboratory produces empirical data for thermal model validation and development, in steady state controlled environmental chambers, as well as outdoor (solar) calorimeter chambers.

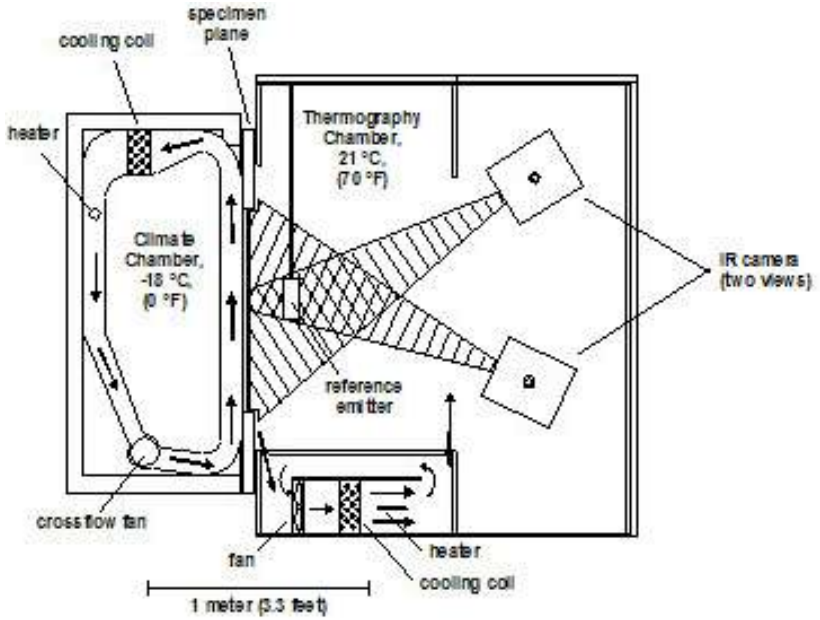
Quantitative Infrared Thermography provides detailed, high resolution, surface temperature measurements for model validation, as well as the development and evaluation of high-performance insulating building envelope products.



Window Thermal Properties Laboratory

Lawrence Berkeley National Lab

The Infrared Thermography Laboratory (IRLab) conducts detailed laboratory experiments on the thermal performance of windows and other insulated systems.



Environmental chambers simulate a long, cold winter night to test the performance of a window or another insulated system.

New products and technologies are tested to understand and validate their performance capabilities.

Technology Type	Testing Capabilities
Building Technologies	MOWITT – Mobile Windows Thermal Test facility, studying single window, window framing and/or shading assemblies under realistic conditions including: - Thermal properties including conductive heat transfer (U-value), Solar Heat Gain Coefficient - Visible Transmittance (VT) - Hot plate thermal conductivity apparatus - Handheld tools for in situ non-destructive assessment - Machine tools for experimental apparatus or prototype fabrication
Energy Efficiency	MOWITT – Mobile Windows Thermal Test facility, studying single window, window framing and/or shading assemblies under realistic conditions including: - Thermal properties including conductive heat transfer (U-value), Solar Heat Gain Coefficient - Visible Transmittance (VT) - Hot plate thermal conductivity apparatus - Handheld tools for in situ non-destructive assessment - Machine tools for experimental apparatus or prototype fabrication
Material-Based	MOWITT – Mobile Windows Thermal Test facility, studying single window, window framing and/or shading assemblies under realistic conditions including: - Thermal properties including conductive heat transfer (U-value), Solar Heat Gain Coefficient - Visible Transmittance (VT) - Hot plate thermal conductivity apparatus - Handheld tools for in situ non-destructive assessment - Machine tools for experimental apparatus or prototype fabrication

Solar Optical Properties Laboratory

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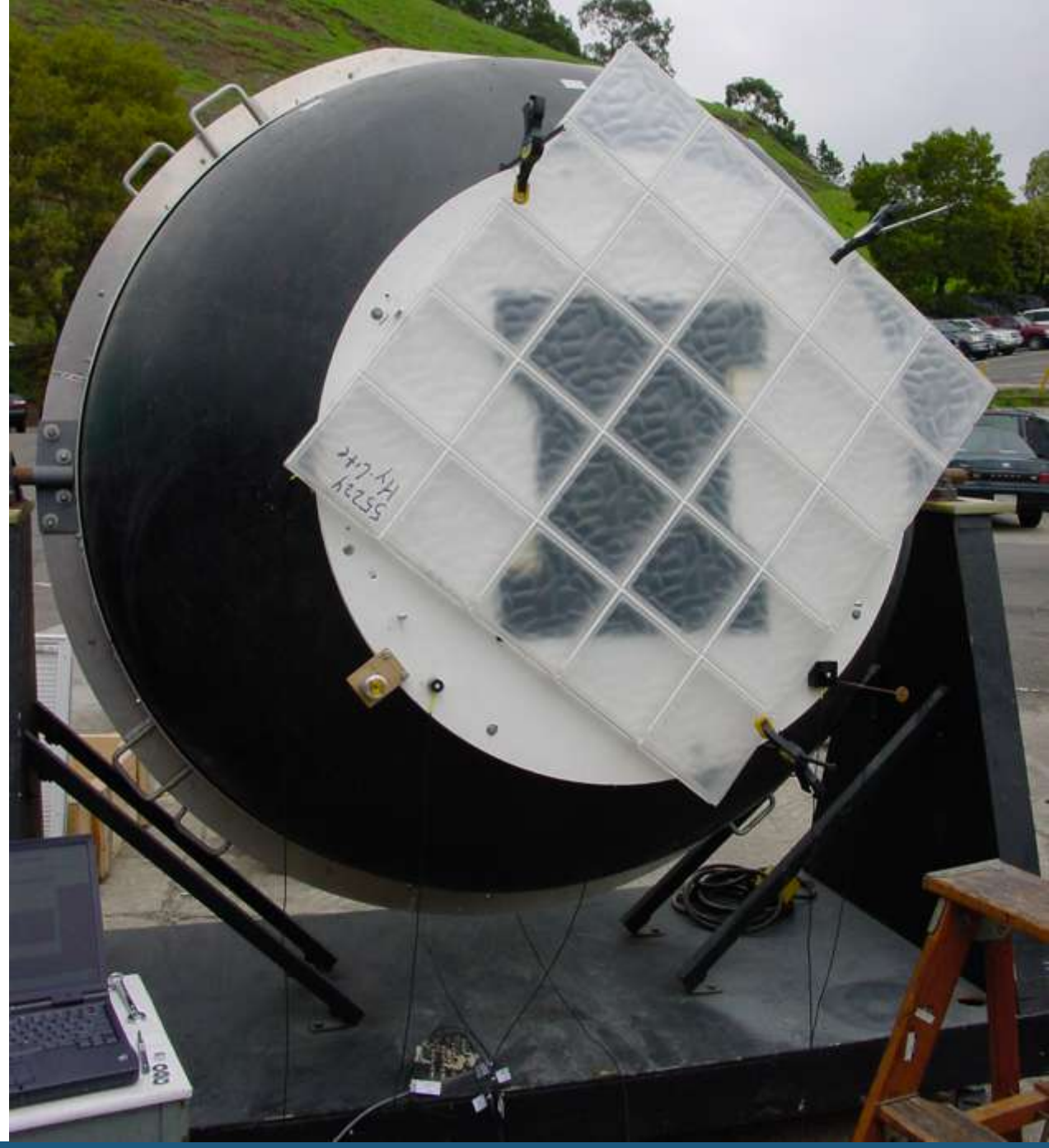
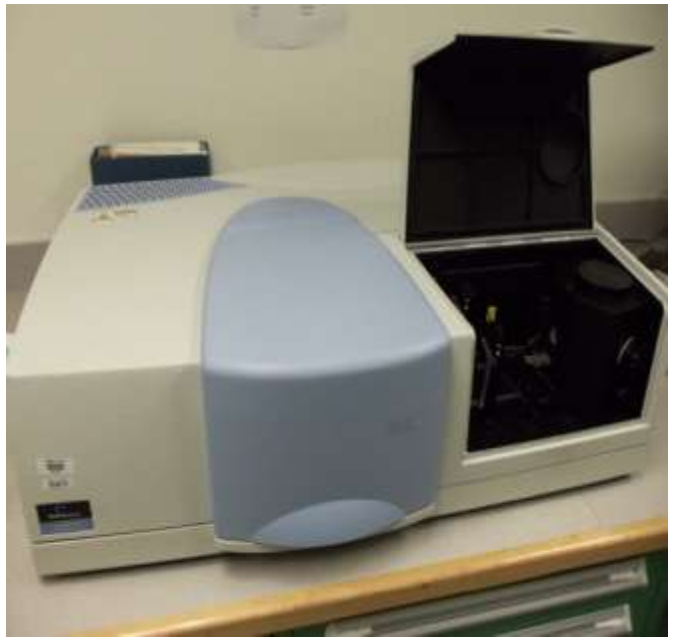
The Solar Optical Properties laboratory characterizes solar optical properties of windows and window materials. It consists of several instruments, allowing measurements of optical properties in the solar range (300-2500 nm) at normal incidence as well as goniophotometric measurements for full resolution of incident and outgoing angles, with the ability to construct complete bi-directional scattering distribution function (BSDF) of a material.

The research activities enable development of complex fenestration systems (CFS) and new coatings for energy-efficient glazing and windows.



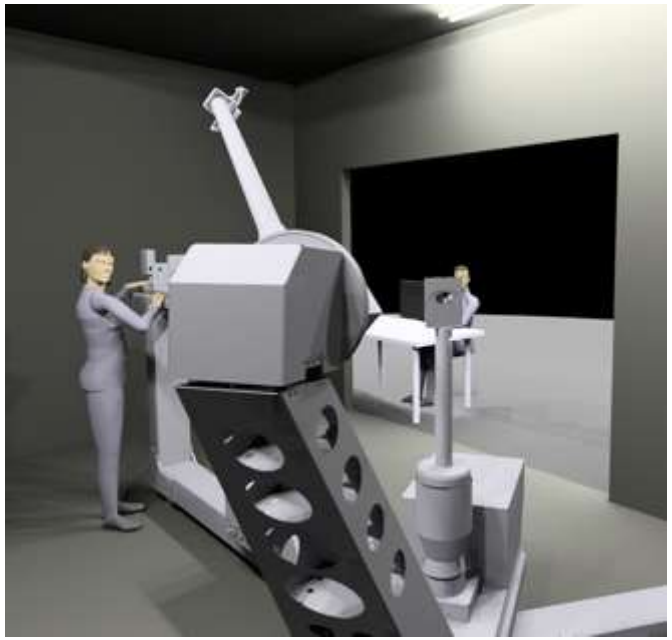
Solar Optical Properties Laboratory

Lawrence Berkeley National Lab



UV/Vis/NIR spectrophotometers with integrating spheres are used to measure transmittance and reflectance from 300nm – 2500 nm. Using the 270 mm sphere it is possible to adhere to the NFRC 300-2017 standard for measurement of thick translucent samples.

Measurement of emissivity is done in the thermal IR range (2-40 micron) using FTIR. An integrating sphere with MCT detector gives wavelength dependent results for scattering samples. A broadband emissometer complements the FTIR to get integrated measurements.



Rendering by Peter Apian-Bennewit

The large goniometer is can measure the bi-directional scattering distribution of samples for transparent samples for any combination of incident and outgoing direction. 4 broad band detectors provides integrated information over the solar spectrum.

Technology Type	Testing Capabilities
Building Technologies	Characterization of optical properties of glazing materials, window films, shading materials, thermochromic materials, complex fenestration assemblies, new coatings for glazing and windows, and development of measurement standards. Tests include: - Solar optical (UV/Vis/NIR) reflectance and transmittance - Thermal emissivity of low-e coatings - BSDF of scattering glazing materials - Development of optically complex fenestration systems (CFS); - Development of new coatings for energy-efficient glazing and windows - Data for simulation tools.
Energy Efficiency	Characterization of optical properties of glazing materials, window films, shading materials, thermochromic materials, complex fenestration assemblies, new coatings for glazing and windows, and development of measurement standards. Tests include: - Solar optical (UV/Vis/NIR) reflectance and transmittance - Thermal emissivity of low-e coatings - BSDF of scattering glazing materials - Development of optically complex fenestration systems (CFS); - Development of new coatings for energy-efficient glazing and windows - Data for simulation tools.
Material-Based	Characterization of optical properties of glazing materials, window films, shading materials, thermochromic materials, complex fenestration assemblies, new coatings for glazing and windows, and development of measurement standards. Tests include: - Solar optical (UV/Vis/NIR) reflectance and transmittance - Thermal emissivity of low-e coatings - BSDF of scattering glazing materials - Development of optically complex fenestration systems (CFS); - Development of new coatings for energy-efficient glazing and windows - Data for simulation tools.

Refrigeration Testing Facility

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This testing facility primarily evaluates the performance of refrigerator-freezers, refrigerators, freezers, wine chillers, and ice makers. It is a temperature and humidity controlled environmental room that provides controlled environmental conditions.

New technologies can be evaluated to assess increased efficiency performance and potential standardized test protocol modifications.

Refrigeration Testing Facility

Lawrence Berkeley National Lab

The refrigeration testing facility is a full scale test facility for assessing the energy performance of refrigerating appliances under standard and custom operating conditions.

The test chamber can accommodate up to four full-size refrigerators, freezers, wine chillers, ice makers, or other refrigerating appliances. Room temperature range is 40 F to 120 F, and relative humidity range is 30% to 95%.

Testing capabilities include standard energy efficiency tests, evaluation of new and advanced designs, as well as simulation of common field use cases.

Technology Type	Testing Capabilities
Building Technologies	Temperature and humidity controlled environmental room for studies on refrigeration products such as refrigerator-freezers, refrigerators, freezers, wine chillers, ice makers, other refrigeration products and equipment. Tests include: - Performance testing (e.g. power consumption, efficiency evaluation) - Testing available under standardized test protocols
Energy Efficiency	Temperature and humidity controlled environmental room for studies on refrigeration products such as refrigerator-freezers, refrigerators, freezers, wine chillers, ice makers, other refrigeration products and equipment. Tests include: - Performance testing (e.g. power consumption, efficiency evaluation) - Testing available under standardized test protocols

Psychrometric Test Chamber

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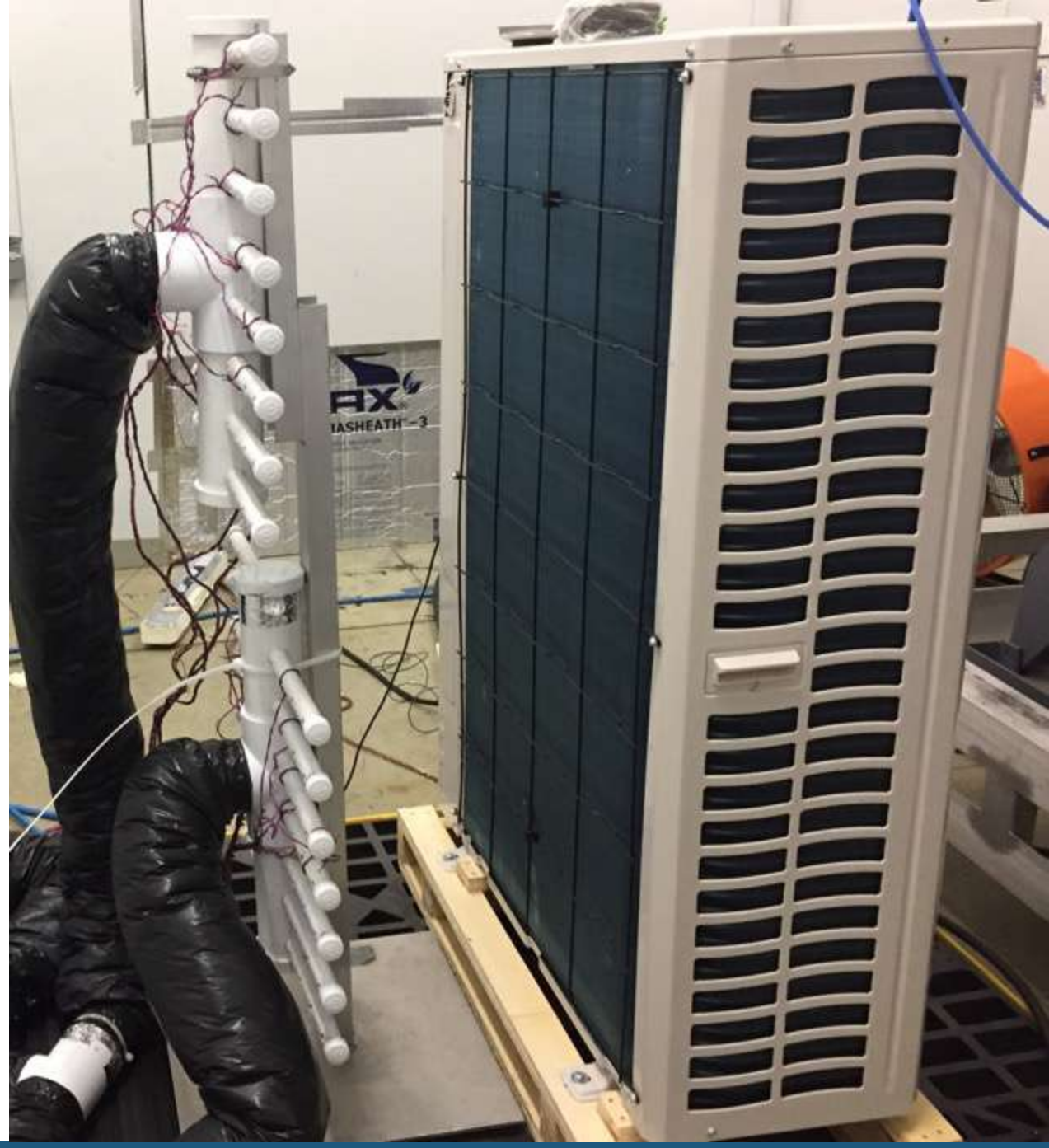
The Psychrometric Test Chamber evaluates the performance of air conditioners and heat pumps, as well as other air conditioning and refrigeration products and equipment.

New technologies can be evaluated to assess increased efficiency performance and potential standardized test protocol modifications.



Psychrometric Test Chamber – A/C and Heat Pumps

Lawrence Berkeley National Laboratory

The Psychrometric Test Chamber can evaluate the performance of central air conditioners and heat pumps with cooling capacity in range of 6,000 to 90,000 Btu/h (½ to 7½ rated tons), and with heating capacity in range of 6,000 to 60,000 (½ to 5 rated tons).

This full-scale test facility for assesses energy performance of residential and light commercial central air conditioners and heat pumps, including mini-split units, to optimize efficiency.

Side-by-side indoor and outdoor chambers control temperature (-20° - 120°F), humidity (15 - 90%), and air flow independently.

Technology Type	Testing Capabilities
Building Technologies	Temperature and humidity controlled environmental chambers for studies on air conditioners, heat pumps, and split system products: - Performance of equipment – energy consumption, efficiency - Side-by-side indoor and outdoor chambers, with temperature, humidity and air flow controlled independently - Testing available under standardized test protocols
Energy Efficiency	Temperature and humidity controlled environmental chambers for studies on air conditioners, heat pumps, and split system products: - Performance of equipment – energy consumption, efficiency - Side-by-side indoor and outdoor chambers, with temperature, humidity and air flow controlled independently - Testing available under standardized test protocols

Balanced Ambient Calorimeter Test Chamber

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The Balanced Ambient Calorimeter Test Chamber assesses the performance of room air conditioners, packaged terminal air conditioners and packaged terminal heat pumps, as well as other air conditioning and refrigeration products and equipment.

New technologies can be evaluated to assess increased efficiency performance and potential standardized test protocol modifications.

Balanced Ambient Calorimeter Test Chamber

Lawrence Berkeley National Lab

The Balanced Ambient Calorimeter Test Chamber's is primarily used to evaluate the performance of room air conditioners and packaged terminal heat pumps in the cooling capacity range of 6,000 to 42,000 Btu/h (½ to 3 ½ rated tons).

Tests portable air conditioners, dehumidifiers, and walk-in coolers and freezers.

Testing in indoor and outdoor chambers enables temperature (10° - 120°F) and humidity (10 - 90%) control to research air conditioning technology for energy optimization and efficiency.

Technology Type	Testing Capabilities
Building Technologies	Temperature and humidity controlled environmental chamber for studies of packaged room air conditioners, terminal unit air conditioners, dehumidifiers, walk in coolers and freezer products: - Performance of equipment – energy consumption, efficiency - Side-by-side indoor and outdoor chambers, with temperature, humidity and air flow controlled independently - Testing available under standardized test protocols
Energy Efficiency	Temperature and humidity controlled environmental chamber for studies of packaged room air conditioners, terminal unit air conditioners, dehumidifiers, walk in coolers and freezer products: - Performance of equipment – energy consumption, efficiency - Side-by-side indoor and outdoor chambers, with temperature, humidity and air flow controlled independently - Testing available under standardized test protocols

Reacting Flow Applications Laboratory

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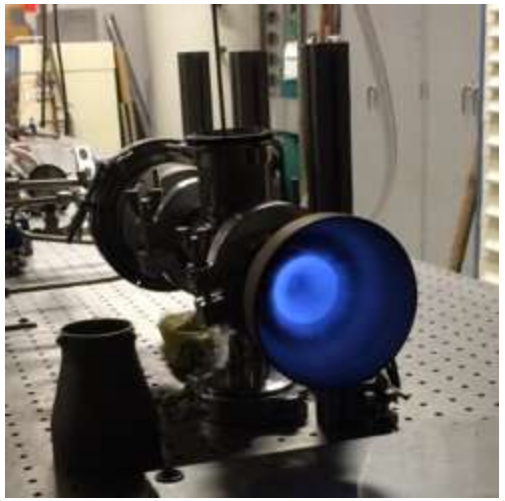
Developing novel, fuel-flexible heat generation technologies for power and process system, and partnering with private organizations to advance residential and industrial technologies.

Reacting Flow Applications Laboratory

Lawrence Berkeley National Lab

The Reacting Flow Applications Laboratory partners with private organizations to advance residential and industrial combustion technologies.



The group works to advance combustion power system and validate performance and emissions.

Novel, fuel-flexible burners for power and process system are developed in the Reacting Flow Applications Laboratory.

Technology Type	Testing Capabilities
Building Technologies	Residential and industrial heating and power systems (e.g. water heaters, furnaces, microturbine generators, combined heat and power systems). Tests include: - Design, development and validation of open flow reacting systems - Characterization of advanced biofuel and bioproducts - Product performance and emissions validation and optimization
Building Technologies	Gas appliances, testing includes: Performance (e.g. thermal efficiency, heat output, etc.) and Emissions (NO_X, CO, CO_2, O2, SO_X, $PM_{2.5}$)
Building Technologies	Combustion burner development and validation (gas and liquid fueled). Testing Includes: - Performance (e.g. thermal efficiency, heat output, flame flow field), Emissions (NO_X, CO, CO_2, O2, SO_X, $PM_{2.5}$), and optimization
Building Technologies	Combustion power system development and validation (gas and liquid fueled). Testing includes: - Performance (e.g. thermal efficiency, heat output, recuperation), Emissions (NO_X, CO, CO_2, O2, SO_X, $PM_{2.5}$), and optimization
Energy Efficiency	Residential and industrial heating and power systems (e.g. water heaters, furnaces, microturbine generators, combined heat and power systems). Tests include: - Design, development and validation of open flow reacting systems - Characterization of advanced biofuel and bioproducts - Product performance and emissions validation and optimization
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Energy Efficiency	Combustion burner development and validation (gas and liquid fueled). Testing Includes: - Performance (e.g. thermal efficiency, heat output, flame flow field), Emissions (NO_X, CO, CO_2, O2, SO_X, $PM_{2.5}$), and optimization

Technology Type	Testing Capabilities
Energy Efficiency	Combustion power system development and validation (gas and liquid fueled). Testing includes: - Performance (e.g. thermal efficiency, heat output, recuperation), Emissions (NO_X, CO, CO_2, O2, SO_X, $PM_{2.5}$), and optimization

Biomass Combustion Emissions and Efficiency Testing Lab

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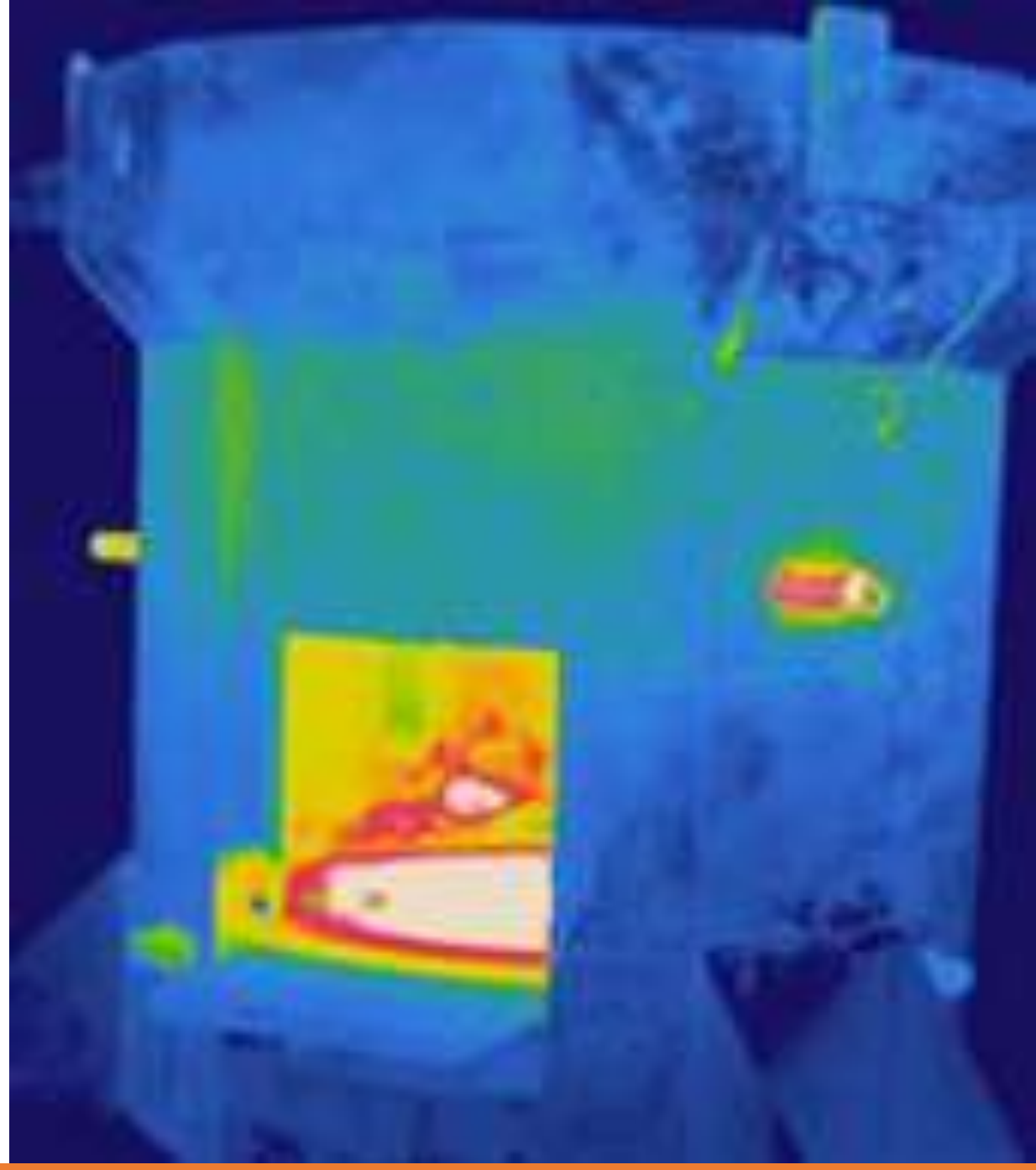
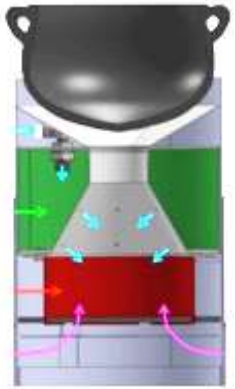
This state-of-the-art biomass combustion testing facility is equipped with redundant sensors integrated with data management software allowing rapid data validation.

Efficient reliable operations and measurement results are enabled with a documented quality assurance plan, standard operating procedures, and testing protocols.



Biomass Combustion Emissions and Efficiency Testing Lab

Lawrence Berkeley National Lab



The Biomass Combustion Emissions and Efficiency Testing Lab is focused on testing small biomass combustion devices. It conducts standard and advanced testing for small-scale biomass heat and power technologies, and biomass technology performance and emissions validation.

Lab and field testing standards are developed and evaluated to validate technology performance and accelerate private company innovation.

New proposed simplified testing methods can be validated against very high quality reliable laboratory testing measurements under a variety of controlled conditions.

Novel biomass heat-generation technologies are designed, built, and evaluated in laboratory conditions, under standard and advanced test protocols. Technology applications range in both developing and industrial countries.

Technology Type	Testing Capabilities
Building Technologies	Residential woody biomass cookstoves, and wood-fired space-heating stoves. Testing includes: - Performance evaluation - Emissions testing, including PM2.5 mass, size distribution (5nm to 50µm), and gaseous emissions, at 1Hz.
Building Technologies	Biomass gasifier generators and torrefaction technologies Testing includes: - Real time performance (e.g., thermal efficiency, heat output, etc.) and emissions (NO_X, CO, CO_2, O_2, SO_X, black carbon, size resolved PM, $PM_{2.5}$)
Energy Efficiency	Residential woody biomass cookstoves, and wood-fired space-heating stoves. Testing includes: - Performance evaluation - Emissions testing, including PM2.5 mass, size distribution (5nm to 50µm), and gaseous emissions, at 1Hz.
Energy Efficiency	Biomass gasifier generators and torrefaction technologies Testing includes: - Real time performance (e.g., thermal efficiency, heat output, etc.) and emissions (NO_X, CO, CO_2, O_2, SO_X, black carbon, size resolved PM, $PM_{2.5}$)

Range Hood Test Facility

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W: https://energyanalysis.lbl.gov/range-hood-test-facility

The Range Hood Test Facility enables performance testing of kitchen ventilation appliances and development and validation of both lab and field test methods.

Range Hood Test Facility

Lawrence Berkeley National Lab

The facility enables characterization of pollutant emissions associated with cooking devices and cooking activities using real-world cooking equipment with carefully controlled procedures. Performance measures include airflow, sound pressure and pollutant capture efficiency.

The facility can be instrumented to measure size-resolved particles, nitrogen oxides, organics ranging from very volatile irritant acids and aldehydes to semi-volatile polycyclic aromatic hydrocarbons. A recent project examined the effectiveness of carbon filters in recirculating range hoods to remove particles and organics.

Projects have included development of an ASTM standard method for capture efficiency, performance assessment of an automatic smart range hood, comparison of over-the-range microwave exhaust devices to standard range hoods, and determination of factors that impact capture efficiency performance.

Technology Type	Testing Capabilities
Building Technologies	Testing of range hood airflows, sound, and capture efficiency for pollutants from cooking burners and food preparation / cooking in both laboratory and field conditions. - Application of test methods to evaluate performance of novel product designs and features.
Energy Efficiency	Testing of range hood airflows, sound, and capture efficiency for pollutants from cooking burners and food preparation / cooking in both laboratory and field conditions. - Application of test methods to evaluate performance of novel product designs and features.

Indoor Environment Facilities

Lawrence Berkeley National Lab

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Our facilities feature 100 m^3 of reconfigurable rooms, room to bench scale chambers, analytical laboratory capabilities for varied gaseous and semi-volatile organic and inorganic analytes, aerosol monitors, and access to Berkeley Lab user facilities. These resources are used to study study the factors that impact emissions from indoor pollutant sources such as materials, combustion, cooking, electronics and consumer products; physical-chemical processes that impact exposure; performance of novel air cleaning technologies; and air quality sensing devices among other applications. The facilities enable study of sources and air cleaning technologies in commercial and residential buildings, large public spaces including airports, and transport environments including aircraft.

Indoor Environment Facilities

Lawrence Berkeley National Lab

We develop custom test methods and experimental configurations to test filtration and air cleaning devices for building and transportation environments. Test facilities include FLEXLAB chambers, reconfigurable rooms and lab scale chambers.

Using these facilities, we have studied primary and secondary emissions from cleaning products and office equipment, secondhand and thirdhand tobacco smoke, photo-catalytic air cleaning materials, sorption of surrogate chemical warfare agents, aircraft air cleaning systems, chemical reactions on building air filters and air sensing technologies among many other applications.

Our air sampling equipment and analytical laboratories enable quantification of organic gases ranging from very volatile irritant aldehydes to semivolatile flame retardants and plasticizers, organic acids and inorganics by ion chromatography. We track organics in real-time using proton transfer mass spectrometry and have instrumentation to measure size-resolved particles, ozone, nitrogen oxides, and other hazardous air pollutants.

Technology Type	Testing Capabilities
Building Technologies	Indoor environment sensing, air cleaning technologies, emissions testing of materials, electronics, and products. Tests include: • Quantification of primary emissions from indoor materials and products. • Chemical transformations and interactions under typical indoor environment conditions. • Performance of consumer and enterprise indoor air quality sensors and monitors. • Performance of novel air cleaning technologies and devices. • Elucidation of physical-chemical processes that impact transformations and fate of chemical hazards in indoor environments.
Material-Based	Indoor environment sensing, air cleaning technologies, emissions testing of materials, electronics, and products. Tests include: • Quantification of primary emissions from indoor materials and products. • Chemical transformations and interactions under typical indoor environment conditions. • Performance of consumer and enterprise indoor air quality sensors and monitors. • Performance of novel air cleaning technologies and devices. • Elucidation of physical-chemical processes that impact transformations and fate of chemical hazards in indoor environments.

Battery Research & Testing Facility

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The LBNL battery test facility has a complete set of capabilities for the fabrication of cathodes and anodes and for producing hermetically sealed coin cells and pouch cells under inert atmospheric conditions.

The LBNL battery testing facility consists of over 300 battery cycling channels capable of cycling cells between 0 and 5 V at 15 micro amps to 5 amps.

The LBNL battery research and diagnostics facility consist of state of the art diagnostics capabilities for surface and bulk analysis.

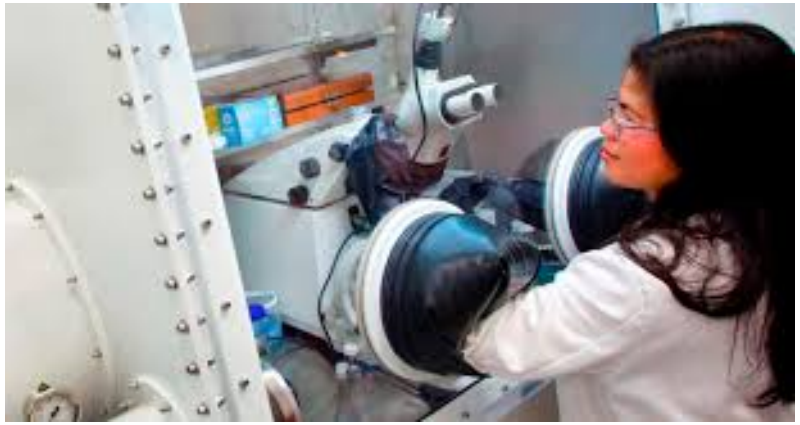
The battery research and testing team performs joint research with colleagues across the LBNL campus including those at the major Lab user facilities, including the ALS, NERSC, NCEM, and the Molecular Foundry.

The energy storage program has established a streamline methodology for achieving rapid contract approval from the DOE (Calcharge).

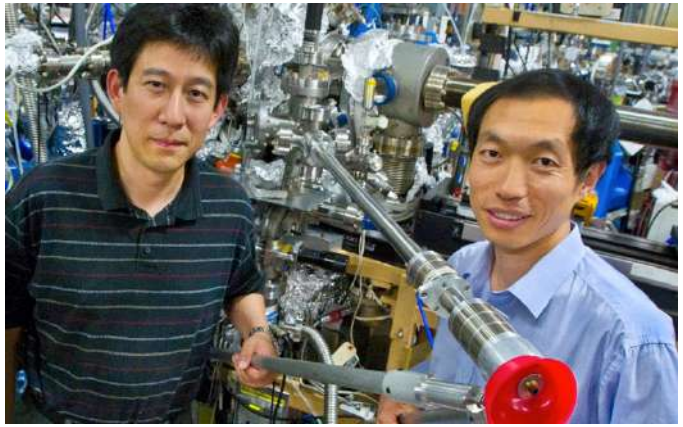
Battery Research & Testing Facility

Lawrence Berkeley National Lab

Over 300 battery cycling channels for coin and pouch cells.



The battery research and diagnostics capabilities allow for state of the art diagnostics tests in inert atmospheres.



Experience and access to the Advanced Light Source.

Technology Type	Testing Capabilities
Energy Storage	Testing of most flow batteries and hybrid systems, all ion batteries (Graphite, Si, LTO/NCM, LFP, DRX, Ni-rich NCM, pouch/coin cells, half/full cells), fuel cells and electrolyzers (PEM and SOFC). Tests include: • Physical characterization of materials (SEM, BET, PSA, XRD) • Mechanical properties of electrodes (peel tests, pull tests, bend tests) • Electrochemical performance of cells (HPPC tests, GITT) • Electrochemical performance of individual electrodes (reference electrodes with EIS) • Rate performance of electrodes and cells • Application of USABC recommended cycling conditions and data analysis • Cycle life testing • Calendar life testing • Dynamic cycling testing • Fast charge protocol development
Materials-Based	Testing of most flow batteries and hybrid systems, all ion batteries (Graphite, Si, LTO/NCM, LFP, DRX, Ni-rich NCM, pouch/coin cells, half/full cells), fuel cells and electrolyzers (PEM and SOFC). Tests include: • Physical characterization of materials (SEM, BET, PSA, XRD) • Mechanical properties of electrodes (peel tests, pull tests, bend tests) • Electrochemical performance of cells (HPPC tests, GITT) • Electrochemical performance of individual electrodes (reference electrodes with EIS) • Rate performance of electrodes and cells • Application of USABC recommended cycling conditions and data analysis • Cycle life testing • Calendar life testing • Dynamic cycling testing • Fast charge protocol development

Demand to Grid Lab

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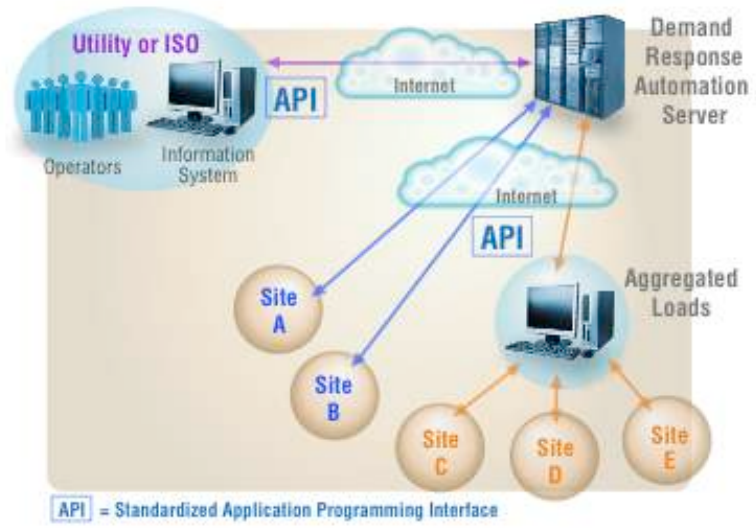
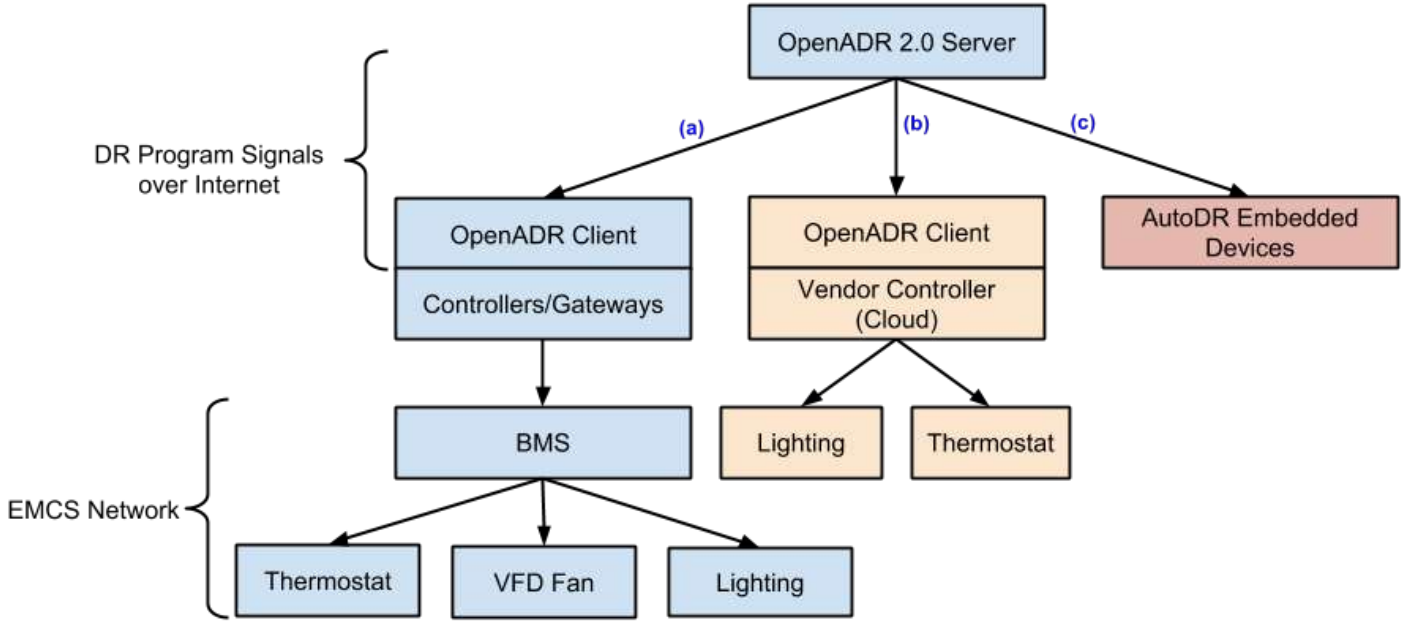
The Demand to Grid lab tests demand response signaling to devices. We have a simulated OpenADR2.0a/b server and client (VTN and VEN) and the following equipment:

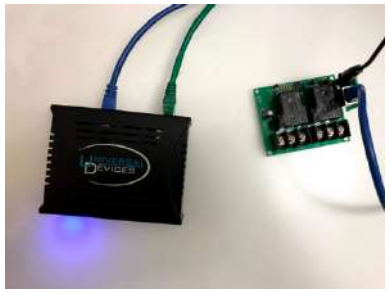
- Communicating Thermostat for benchtop or FLEXLAB testing
- OpenADR embedded devices:
  - MelRok Smart Gateway
  - Universal Device - ISY994 PRO OADR
- DR Suitcase (Tstat, SmartPlug)

Demand to Grid Lab

Lawrence Berkeley National Lab







The Lab hosts an EPRI OpenADR 2.0a/b-compliant Virtual Top Node (VTN) a Demand Response Automation Server (DRAS) to create and communicate various DR signals (e.g., price, event, capacity) to different types of OpenADR device (e.g., OpenADR embedded, cloud-based and gateway).

D2G lab allows the testing of various OpenADR products (a) Gateway/Auto-DR Controller, (b) Cloud-based OpenADR and (c) OpenADR embedded devices. The lab has measurement equipment suitable for conducting OpenADR communications test procedures. Additionally, this lab is particularly well suited for testing communication and control characteristics of the devices, including commutation latency, response speed, demand response performance and other metrics.

Technology Type	Testing Capabilities
Building Technologies	Testing of OPENADR devices, including: OpenADR 2.0a/b VTN as a Demand Response Automation Server, OpenADR embedded or cloud-based devices (e.g., smart thermostat, smart lights and smart plug), smart energy manager gateway, and OpenADR communications and networks. Tests include: - DR signals testing (e.g., price, event, capacity) - Communications evaluation (e.g. latency, other characteristics) - Plug and play automation test of OpenADR compliant devices - DR control sequences design, testing and evaluation
Internet of Things	Testing of OPENADR devices, including: OpenADR 2.0a/b VTN as a Demand Response Automation Server, OpenADR embedded or cloud-based devices (e.g., smart thermostat, smart lights and smart plug), smart energy manager gateway, and OpenADR communications and networks. Tests include: - DR signals testing (e.g., price, event, capacity) - Communications evaluation (e.g. latency, other characteristics) - Plug and play automation test of OpenADR compliant devices - DR control sequences design, testing and evaluation
Grid Technologies	Testing of OPENADR devices, including: OpenADR 2.0a/b VTN as a Demand Response Automation Server, OpenADR embedded or cloud-based devices (e.g., smart thermostat, smart lights and smart plug), smart energy manager gateway, and OpenADR communications and networks. Tests include: - DR signals testing (e.g., price, event, capacity) - Communications evaluation (e.g. latency, other characteristics) - Plug and play automation test of OpenADR compliant devices - DR control sequences design, testing and evaluation

Advanced Biofuels/Bioproducts Process Development Unit (ABPDU)

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Enabling process R&D and scale-up of technologies that generate advanced biofuels, biomaterials, biochemicals, and other bioproducts. Generate g to kg scale product for testing in end-use applications.

Located in the San Francisco Bay Area's local bio-innovation hub allows users to tap into expertise and best practices that are required for the new generation of biofuels and bioproducts

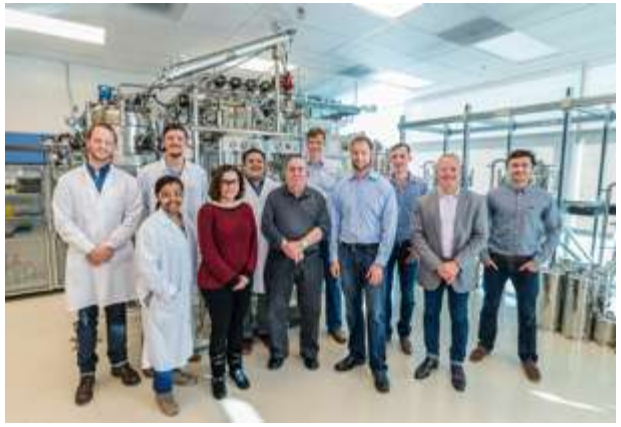
Helping lower the capital expenditures for researchers in industry and academia through as a $17 million state-of-the-art facility.

Advanced Biofuels/Bioproducts Process Development Unit (ABPDU)

Lawrence Berkeley National Laboratory

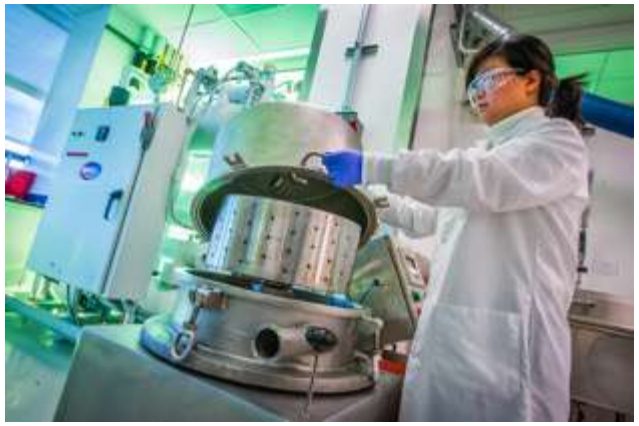
Driven by passion for bio-innovation

Since, 2012, the Advanced Biofuels/Bioproducts Process Development Unit (ABPDU) has helped businesses successfully take bio-innovation to market.



Bio-innovation Incubator and Proving Ground

Businesses optimize and scale technologies to enable commercialization of bio-based chemicals, materials, and fuels. Biomass evaluation, experimenting with microorganisms, optimizing processes, and performing assays and analysis



Research Areas:

- Fermentation
- Purification & Advanced Recovery
- Feedstock Deconstruction (including Pretreatment and Saccharification)
- Analytical Chemistry
- Materials Handling & Solids Characterization
- Techno-Economic analysis

Technology Type	Testing Capabilities
Industrial and Agricultural Innovation	Biomass/Biofuels/Bioproduct Deconstruction Pretreatment & Saccharification testing. Available test setups include: • 2L IKA Reactor • 10L Parr Reactor • 10L Basket Centrifuge • 50L IKA SPP50 Reactors • 210 L Andritz Hastelloy Reactor • 10L Basket Centrifuge • 6m³/hr Andritz Decanter Centrifuge
Industrial and Agricultural Innovation	Biomass/Biofuels/Bioproduct Fermentation testing. Available test setups include: • 250 mL Ambr Sartorius Reactors • 2L Reactors • 50L ABEC Bioreactor • 300L ABEC Bioreactor • 15L Bioengineering Bioreactor
Industrial and Agricultural Innovation	Biomass/Biofuels/Bioproduct Purification & Advanced Recovery testing. Available test setups include: • 2L Liquid-Liquid Extraction Karr Column • ÄKTA Avant 150 Chromatography • Millipore Tangential Flow Filtration • Qsonica-Q700 Sonicator • Rotovap Distiller • Labonco Lyophilizer
Industrial and Agricultural Innovation	Biomass/Biofuels/Bioproduct Analytical Chemistry & Solids Characterization testing. Available test setups include: • Gas Chromatography • Analytical Rheometer • High-Performance Liquid Chromatography • Analytical-Ysi Gas Analyzer • High-Performance Anion Exchange Chromatography • Analytical Rheometer

Technology Type	Testing Capabilities
Industrial and Agricultural Innovation	Biomass evaluation, experimenting with microorganisms, optimizing processes, and performing assays and analysis
Industrial and Agricultural Innovation	Using software tools and team expertise to characterize process flows and economics incorporating development data and commercial assumptions
Renewable Generation	Biomass/Biofuels/Bioproduct Deconstruction Pretreatment & Saccharification testing. Available test setups include: • 2L IKA Reactor • 10L Parr Reactor • 10L Basket Centrifuge • 50L IKA SPP50 Reactors • 210 L Andritz Hastelloy Reactor • 10L Basket Centrifuge • 6m^3/hr Andritz Decanter Centrifuge
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Renewable Generation	Biomass evaluation, experimenting with microorganisms, optimizing processes, and performing assays and analysis
Renewable Generation	Using software tools and team expertise to characterize process flows and economics incorporating development data and commercial assumptions

Advanced Light Source (ALS)

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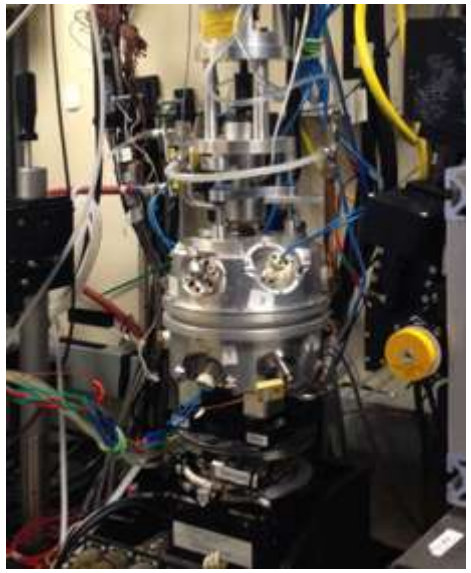
The ALS is a national user facility open to scientists around the world and provides tools for exploring the properties of materials using x-rays, infrared and extreme ultraviolet light.

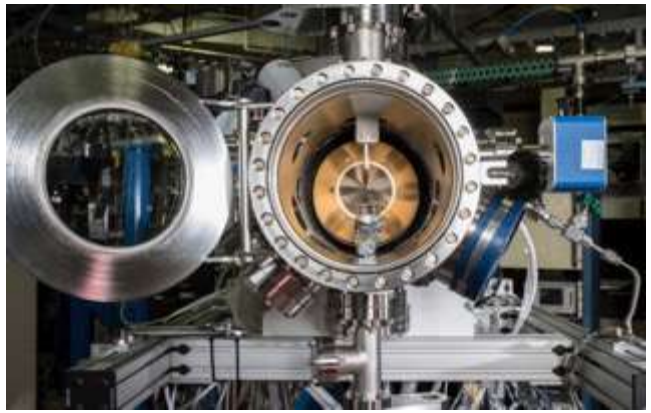
It serves over 2000 users per year working on research related to energy, the earth & environment, materials, biology, chemistry, and physics.

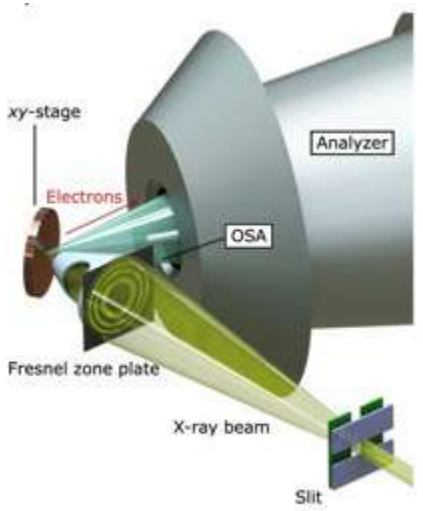
Access to the ALS is through a peer-reviewed proposal process and can accommodate non-proprietary work (for free) and proprietary work (for a fee). Access mechanisms include general user proposals accepted twice a year, rapid access for time-critical work, and approved program access for longer-term collaborative studies.

Advanced Light Source (ALS)

Lawrence Berkeley National Laboratory







Use techniques to measure the physical and chemical morphology of materials

- 3D computed tomography and crystallography with micrometer resolution of functional materials and devices.
- Scanning transmission x-ray microscopy with nanometer-scale resolution of energy and functional materials under operando conditions.
- Scattering techniques to study the structure of organic materials and polymers.

Follow chemical processes under operando conditions

- Operando x-ray spectroscopy of solar cell, battery, and fuel cell materials.
- Ambient-pressure photoelectron spectroscopy of the solid-gas and solid-liquid interlayer to study catalytic and electrochemical processes.

Measure fundamental materials properties

- Photoelectron spectroscopy of quantum materials and materials for computing applications.
- Surface microscopy with nanometer-scale resolution, and chemical and magnetic sensitivity.
- Nanometer-resolved infrared spectroscopy for chemical and electronic structure measurements.

Technology Type	Testing Capabilities
Material-Based	Spectroscopy – tests include study of the energies of particles that are emitted or absorbed by samples that are exposed to the light-source beam and commonly used to determine the characteristics of chemical bonding and electron motion
Material-Based	Microscopy/Imaging – tests can obtain pictures with fine special resolution of the samples under study. Used in a diverse number of research areas.
Material-Based	Scattering/Diffraction – tests study patterns of light produced when x-rays are deflected by the closely spaced lattice of atoms in solids and commonly. Used to determine the structures of crystals and large molecules such as proteins.

Chu Hall – Solar Fuels Labs

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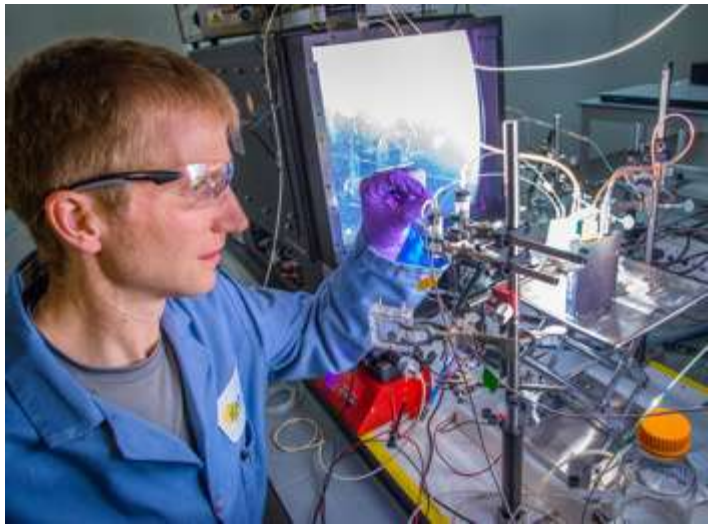
Home to largest research program in the U.S. dedicated to creating scalable technology that converts carbon dioxide, water, and sunlight into renewable transportation fuels.

Leading scientific advances toward solar hydrogen generation systems, carbon dioxide reduction and production of energy-dense fuels.

Supporting distributed Energy Resources (DERs) through advancing the understanding of catalytic mechanisms, materials discovery, and demonstrating prototypes.

Chu Hall (B30) – Solar Fuels Labs

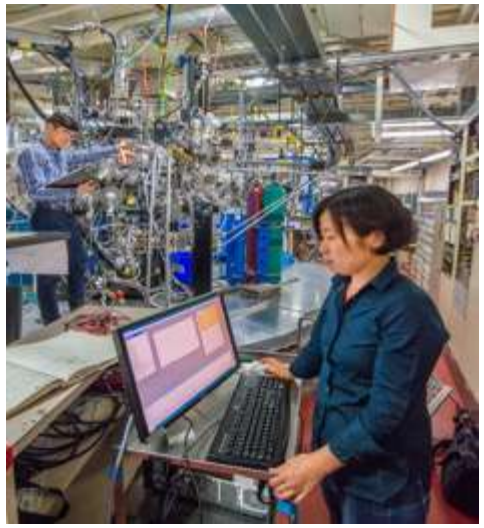
Lawrence Berkeley National Laboratory



Small Businesses and start ups can advance their technologies to contribute to a new generation of sustainable, scalable source of energy-dense chemical fuels.

Partner with our labs to:

- Advance solar-energy-to-fuels components for key processes including light capture, energy transfer, electron transport and charge separation
- Discover electrocatalytic and photo electrocatalytic material and light-absorber photoelectrodes
- Use test-bed prototypes to determine practicality of prototype solar-fuels systems



Capitalize on the local scientific community at LBNL and the Bay Area

With approval from DOE, the Solar Fuels programs will work with you to access the expertise, equipment, and labs needed to achieve your goals.

Technology Type	Testing Capabilities
Material-Based	Solar fuels – tests include: • DFT and Ab Initio Calculations for Water Splitting Including Real-Time Time-Dependent Density Functional Theory • In-Situ and Operando Nanoscale Characterization Capabilities for Photoelectrochemical Materials and Integrated Assemblies • Laboratory and On-Sun PEC Device Testing • Microelectrode Testing of LTE Electrocatalysts, Ionomers, and their Interactions in the Solid State • Multiscale Modeling of Water-Splitting Devices • Photoelectrochemical Device Fabrication Facility • Photoelectrochemical Device In Situ and Operando Testing Using X-Rays • Photophysical Characterization of Photoelectrochemical Materials and Assemblies • Probing and Mitigating Chemical, Electrochemical, and Photochemical Corrosion of Electrochemical and Photoelectrochemical Assemblies • Prospective LCA Model for 1-GW Scale PEC Hydrogen Plant • Real-World Modeling of PEC Devices • Thin Film and Bulk Ionomer Characterization

Technology Type	Testing Capabilities
Renewable Generation	Solar fuels – tests include: • DFT and Ab Initio Calculations for Water Splitting Including Real-Time Time-Dependent Density Functional Theory • In-Situ and Operando Nanoscale Characterization Capabilities for Photoelectrochemical Materials and Integrated Assemblies • Laboratory and On-Sun PEC Device Testing • Microelectrode Testing of LTE Electrocatalysts, Ionomers, and their Interactions in the Solid State • Multiscale Modeling of Water-Splitting Devices • Photoelectrochemical Device Fabrication Facility • Photoelectrochemical Device In Situ and Operando Testing Using X-Rays • Photophysical Characterization of Photoelectrochemical Materials and Assemblies • Probing and Mitigating Chemical, Electrochemical, and Photochemical Corrosion of Electrochemical and Photoelectrochemical Assemblies • Prospective LCA Model for 1-GW Scale PEC Hydrogen Plant • Real-World Modeling of PEC Devices • Thin Film and Bulk Ionomer Characterization

Joint BioEnergy Institute (JBEI)

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JBEI collaborates with industry and small businesses to accelerate development of emerging cellulosic biofuels and renewable chemicals.

JBEI has a network of collaborators and licensees comprised of approximately 50 companies, with six spin-off start-ups to date.

Produce clean, sustainable, carbon-neutral biofuels and bioproducts by utilizing JBEI's capabilities.

Joint BioEnergy Institute (JBEI)

Lawrence Berkeley National Laboratory

Working with Small Business is JBEI's Priority

Advancing alternative energy sources through exploration of plant systems biology, cell wall biosynthesis, grass genetics, and cell wall engineering.

Deconstruct to advance technology through biomass pretreatment, enzyme optimization, fungal biotechnology, and microbial communities.

Advanced Biofuel and Bioproduct Technologies

Use the latest techniques in molecular biology and chemical and genetic engineering to develop new biological systems, processes, and technologies

Advanced tools in molecular biology and chemical engineering, including computational and robotic technologies

Research Areas:

- Life-Cycle, Economics and Agronomy
- Feedstocks
- Deconstruction
- Biofuels and Bioproducts
- Lab, Computational and Information System Technology

Technology Type	Testing Capabilities
Renewable Generation	Biomass / Biofuels – tests include: • Inventory of Composable Elements (ICE), a cloud-based open-source DNA part, plasmid, microbial strain, and Arabidopsis seed repository • VectorEditor, a DNA editing and annotation tool • DeviceEditor, a biological computer-aided design canvas • j5, a cloud-based DNA assembly protocol design automation • PR-PR, a open-source laboratory automation programming platform. • MASCP Gator, a proteomics aggregation utility • 1001 Proteomes, a simple way to browse changes to proteins • Plant Protein Alignment and Phosphorylation Resource • Technoeconomic Model Wiki, models of various aspects of lignocellulosic biofuel production • Rice Oligonucleotide Array Database (ROAD), a resource for gene expression and coexpression analysis in rice • RiceNet, a probabilistic functional gene network • Rice Glycosyl Hydrolase Database, Rice Kinase Database, and Rice • GT Database, to integrate and host functional genomic information • Directory of Databases for Plant Cell Wall-Related Enzymes • JBEI GT Collection, to drive basic scientific understanding of GTs • MaxBin software package • Targeted Proteomic toolkit for Escherichia coli proteins

The Materials Project

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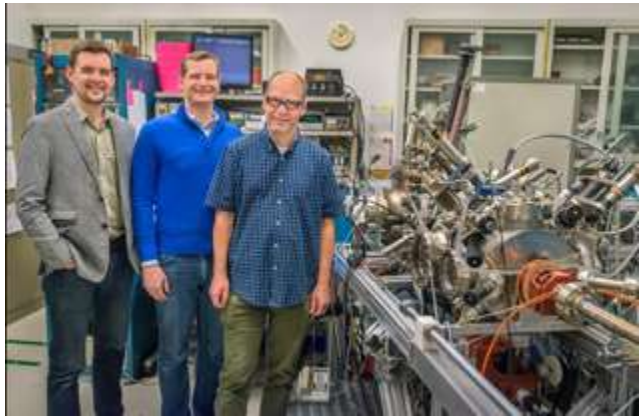
The Materials Project aims to remove guess work from materials design in a variety of applications.

A supercomputing partnership cluster provides infrastructure that enables computations, data, and algorithms to run at unparalleled speed.

Thanks to supercomputing , predictability of new materials is now possible without material synthesis in the lab. Identify new materials for DER and energy efficient applications.

The Materials Project

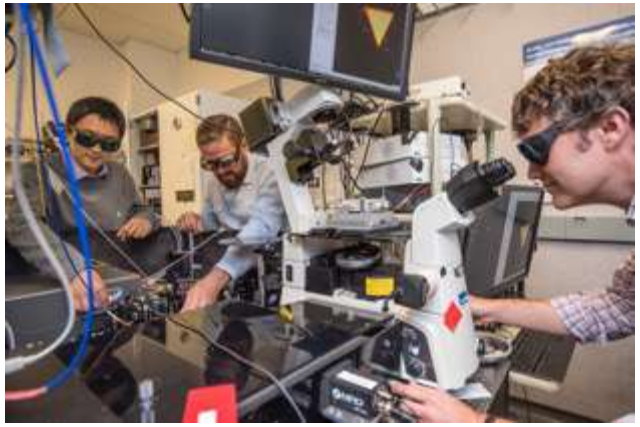
Lawrence Berkeley National Laboratory



Small Businesses and start ups can discover new materials for a variety of applications including batteries, thermoelectric, and corrosion resistances.

Powerful software, supercomputers, and screening:

- Provides open web-based access to computed information on known and predicted materials
- Provides powerful analysis tools to inspire and facilitate design of novel materials
- Harnesses the power of supercomputing and state-of-the-art electronic structure methods



Partner with the Materials Project to:

- Data-mine scientific trends in materials properties for production and scale up
- Use high throughput tools to synthesize and characterize materials
- Use machine learning to predict materials properties and local environments to accelerate the innovation cycle

Technology Type	• Testing Capabilities
Material-Based	Materials characterization, modeling, synthesis – tests capabilities include: • Search material information by chemistry, composition, or property • Explore batteries and their candidate materials. Get voltage profiles and oxygen evolution data • Stability visualization – generate phase and pourbaix diagrams to find stable phases and study reaction pathways • Invent structures – design new compounds with the structure editor and substitution algorithms • Calculate – enthalpy of 10,000+ reaction and compare with experimental values

The Molecular Foundry

Lawrence Berkeley National Laboratory

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A National User Facility supported by the Department of Energy Office of Basic Energy Sciences through their Nanoscale Science Research Center program.

Organized into seven interdependent research facilities that support crosscutting scientific themes, the Foundry provides access to state-of-the-art instrumentation, laboratories, unique scientific expertise, and specified techniques to help users address big challenges.

Foundational in helping small businesses and early stage companies develop materials and devices for Distributed Energy Resources (DER) advancement.

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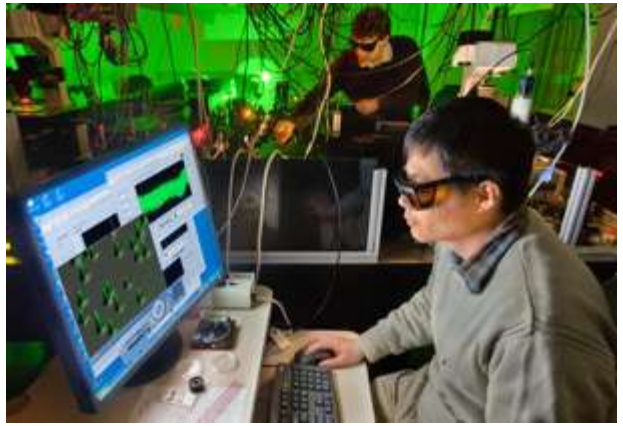

The Molecular Foundry's vision is to provide multidisciplinary communities the opportunity to develop, probe, understand, and control matter and its behavior at fundamental length scales to address the most important technological challenges in energy, the environment and beyond.

Discover New Materials

Examples of work in advancing new materials includes re-engineering of organisms, creating new biomolecules to interface with devices, electro-chemical energy storage, and super hydrophobic / hydrophilic surface modifications.

Capitalize on the local scientific community at LBNL and the Bay Area

The Foundry will work with users to access other facilities needed to achieve their goals

Access to the Foundry is provided by a competitive, peer review process and if users intend to publish the outcome, there is no charge to use the facility.

Technology Type	Testing Capabilities
Material-Based	State of the Art Electron Microscopes – tests include: • Characterization of materials at high (0.5Å) resolution; Other capabilities include: in-situ nanoindentation; spin-polarized low-energy microscopy; and tomography
Material-Based	Imaging and Manipulation of Nanostructures – tests include: • Create and utilize the newest tools and techniques in electron, optical and scanning probe microscopy to enable multi-modal observations at the nanoscale
Material-Based	Nanofabrication – tests include: • Examine fundamental nanofabrication processes and understand nanoscale structures on ultrafast timescales • Expertise in single digit nanofabrication, nanoimprint lithography, integrating multi-modal optical devices, and creating thin films to control exciton flow
Material-Based	Theory of Nanostructured Materials – tests include: • Connect structural and dynamical properties of materials to their functions using advanced electronic structure theory, excited-state methods, model Hamiltonians, and statistical mechanical models
Material-Based	Inorganic Nanostructures – tests include: • Prepare, characterize and utilize carbon and semiconductor nanostructures, and use these materials in functional, multi-component devices • High-throughput, combinatorial robotic synthesis of nanocrystals and molecular metal chalcogenide clusters
Material-Based	Biological Nanostructures – tests include: • Develop sequence-defined, bioinspired polymers, biocompatible imaging probes, and functionalized nanocrystals • Synthetic biology techniques are used re-engineer organisms and create hybrid biomolecules to interface with devices
Material-Based	Organic and Macromolecular Structures – tests include: • Synthesize and utilize porous soft, hard, and hybrid materials as bulk solids, thin films, or in confined geometries.