NEW ENERGY NEXUS

CalTestBed

Facilities Directory

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UC San Diego

Overview

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

Additional Test Site

Zero Net Energy Warehouse at
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Ombudsperson

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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.

Technology Type	Testing Capabilities
Renewable Generation **Cecil and Ida Green Piñon Flat Geophysical Observatory (POC: Rob Mellors)**	Real-world environment with numerous boreholes (cased and uncased) ranging in depth to 300 m as well as geophysical instrumentation. PFO can test geophysical monitoring equipment for monitoring subsurface reservoirs related to geothermal, CO_2 sequestration, or hydrogen storage.
Materials-Based **Geotechnical Centrifuge (POC: John McCartney)**	Centrifuge testing allows dense instrumentation arrays and imaging techniques for modeling the performance of the geotechnical system. Tests are for energy geotechnics applications such as energy piles, foundations for energy infrastructure, etc.
Energy Storage **Full Scale Geothermal Borehole Array for Storage of Solar Thermal Energy**	A full-scale geothermal energy storage system involving an array of 13 closely-spaced borehole heat exchangers and temperature measurements. Investigate different fluid control mechanisms and solar thermal panels (including co-generation systems) on the subsurface thermal energy storage.
Materials-Based **Geomechanics for Radioactive Waste Repositories (POC: John McCartney)**	Characterize the effects of high temperatures (up to 200 °C) on the mechanisms and material properties governing coupled heat transfer, water flow, and volume change in unsaturated, compacted granular bentonite. Applications in deep geological repositories with waste packages or dual purpose containers.
Renewable Generation **Powell Structural Engineering Research Laboratories (POC: Benson Shing)**	Among the largest and most active, full-scale structural testing facilities in the world. Study the performance of buildings, bridges, foundations, wind turbines, and other energy storage or generation structures subjected to earthquake and other extreme load conditions.
Grid Technology **Smart Inverters (POC: Antoni Tong)**	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.
Energy Storage **Battery Energy Storage Systems – utility scale (POC: Mike Ferry)**	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.
Energy Storage **Battery Energy Storage Systems – module level (POC: Mike Ferry)**	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.
Material-Based **Nanotechnology Infrastructure (POC: Bernd Fruhberger)**	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.
Grid Technology **Synchrophasor Grid Monitoring & Automation (POC: Raymond de Callafon)**	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.
Renewable Generation **Synthesis of Renewable Natural Gas (POC: Robert Cattolica)**	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.

Cecil and Ida Green Piñon Flat Geophysical Observatory (PFO)

UC San Diego

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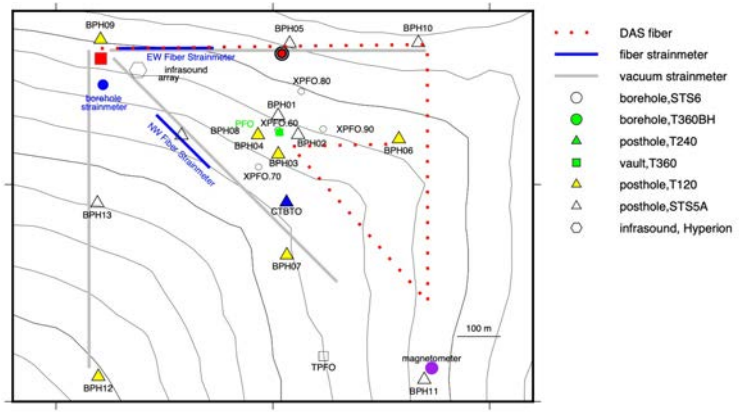
The Cecil and Ida Green Piñon Flat Geophysical Observatory (PFO) is a subsurface testbed located about 70 miles northeast of UCSD in the mountains above Palm Springs. Owned by UCSD, it is a roughly one half-mile square plot of land used to test geophysical and subsurface instruments. It is equipped with numerous boreholes (cased and uncased) ranging in depth to ~300 m available for use as well as multiple geophysical instrumentation. PFO has been used extensively to test geophysical monitoring equipment for monitoring subsurface reservoirs related to low-carbon energy, such as geothermal, CO^2 sequestration, or hydrogen storage. AC power, internet, an underground seismic test facility, and various trailers/storage containers are available on site.



Map of existing and planned sensors and boreholes at Piñon Flat

(Upper image) Drilling boreholes at Piñon Flat. (Lower image) Aerial view of storage facilities.

Geotechnical Centrifuge for Energy Geotechnics Applications

UC San Diego

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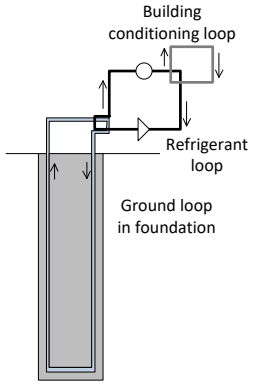
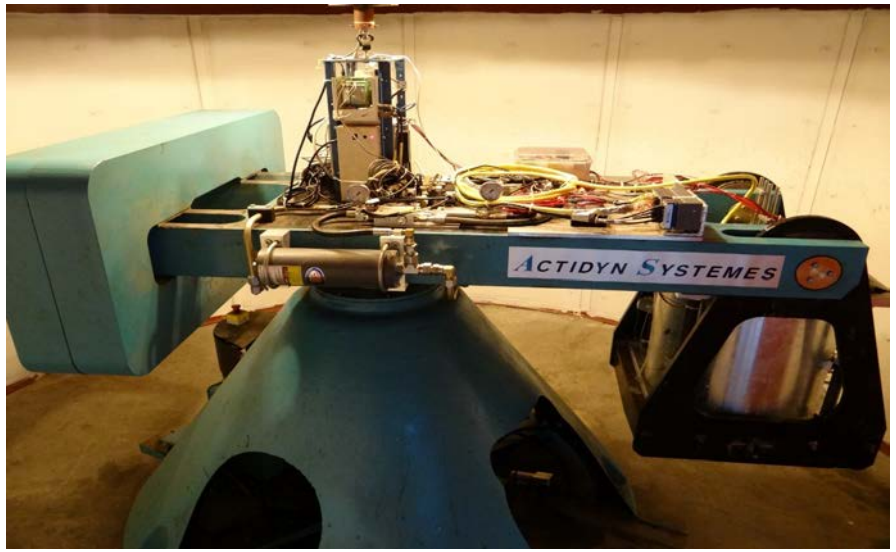
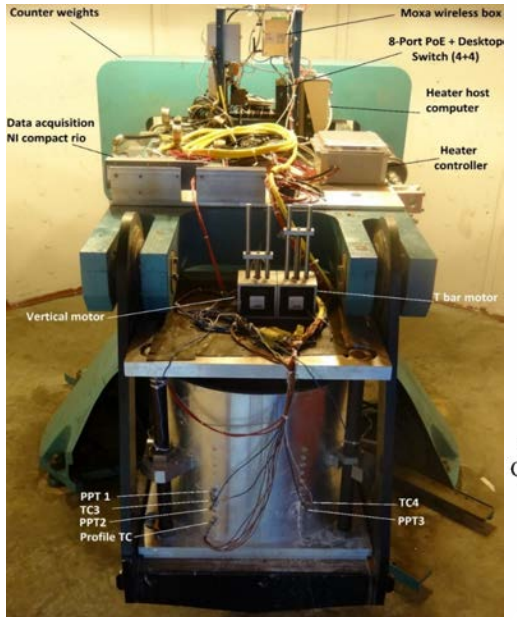
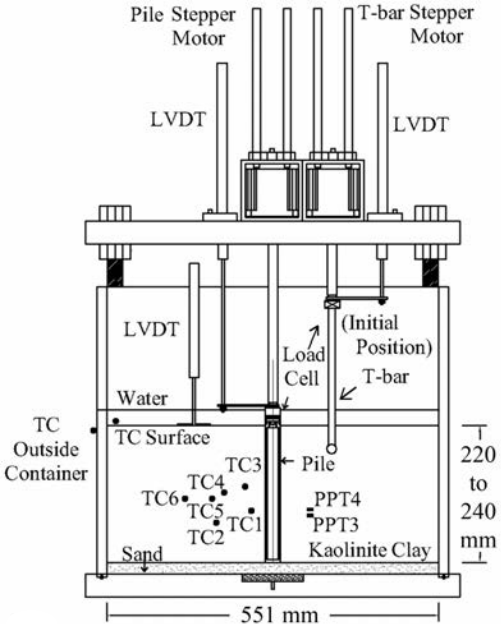






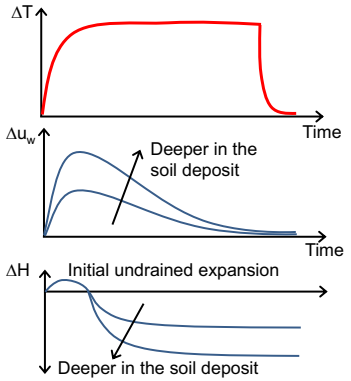


Energy Piles and Thermal Soil Improvement

Energy piles are created by integrating closed-loop heat exchangers into deep foundations used to support structures. They can be used to provide both structural support, heat exchange, or thermal energy storage. They have a lower cost than conventional borehole geothermal heat exchangers as they take advantage of the hole drilled for the foundation. Research at UCSD focuses on understanding the effects of thermal expansion and contraction on soil-structure interaction, as well as the effects of temperature on the thermo-hydro-mechanical behavior of the surrounding soil. The latter aspect may be exploited for thermal soil improvement as soils consolidate when heated.

Geotechnical Centrifuge Modeling

As full-scale geotechnical structures like energy piles are difficult to test in the field, a geotechnical centrifuge like the one at UCSD is useful for scale modeling. The properties of soils depend on their self-weight, so the increased centripetal acceleration in the centrifuge leads to an increased stress state that can be representative of a full-scale soil layer in the field. Centrifuge modeling allows dense instrumentation arrays and imaging techniques for modeling the performance of the geotechnical system. The focus of the UCSD geotechnical centrifuge is for energy geotechnics applications (energy piles, foundations for energy infrastructure, etc.)



Change in temperature of clay induced by a thermal drain

Initial increase in clay pore water pressure (undrained) followed by a decrease with drainage

Initial thermal expansion followed by thermal contraction

Full Scale Geothermal Borehole Array for Storage of Solar Thermal Energy

UC San Diego

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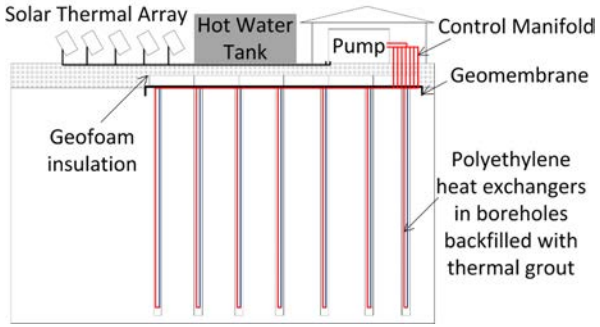
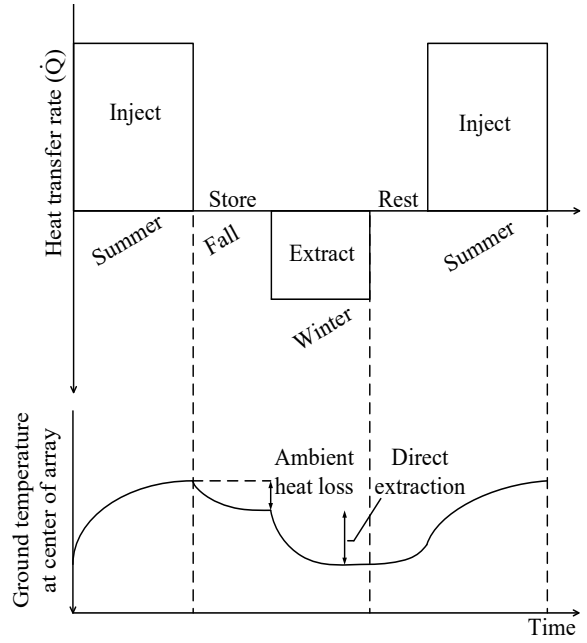
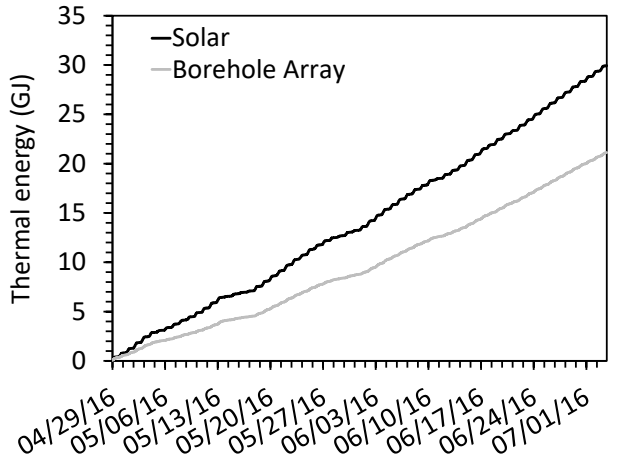


Soil Borehole Thermal Energy Storage System

The subsurface soil or rock is an excellent location for storing thermal energy obtained from renewable sources like solar thermal panels. A full-scale geothermal energy storage system involving an array of 13 closely-spaced borehole heat exchangers has been constructed at UCSD. This facility can be used to investigate different fluid control mechanisms and solar thermal panels (including co-generation systems) on the subsurface thermal energy storage. Instrumentation is incorporated in the subsurface to track changes in temperature within the borehole array and a numerical model of subsurface heat transfer and water flow has been calibrated with field measurements.





Geomechanics Laboratory for Bentonite Buffers for Radioactive Waste Repositories

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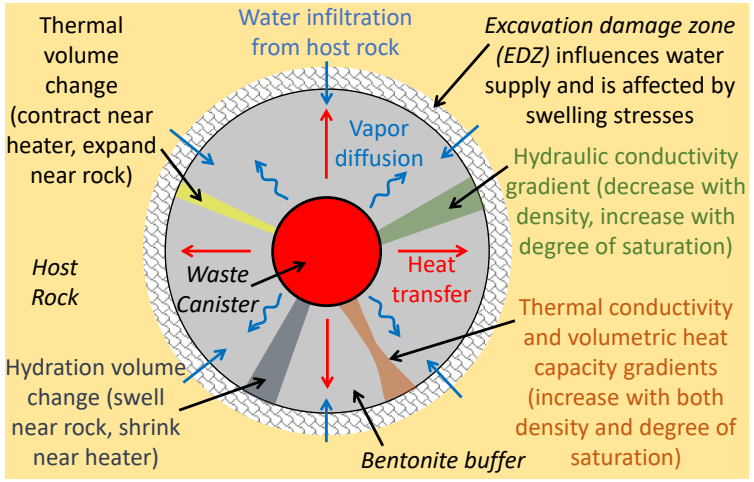
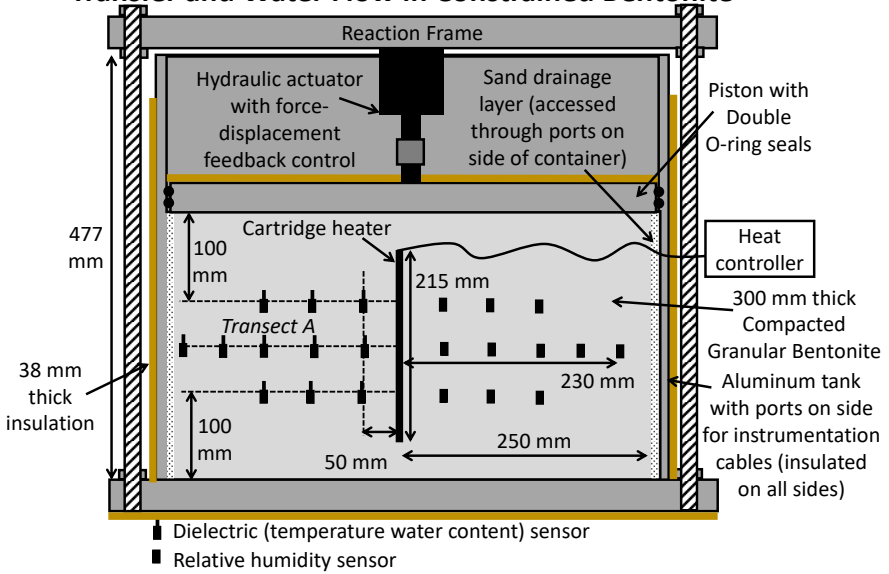
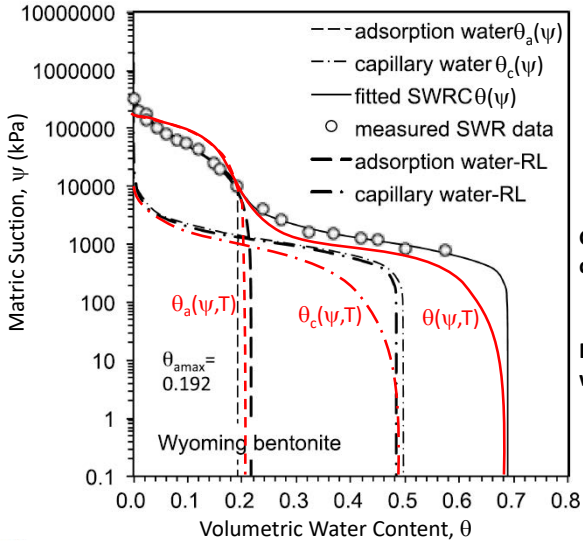


Developing Constitutive Relationships for the Properties of Unsaturated Bentonite Buffers under High Temperature

A new geomechanics laboratory at UCSD has been developed as part of a recent DOE-NEUP project. The objective of this project is to characterize the effects of high temperatures (up to 200 °C) on the mechanisms and material properties governing coupled heat transfer, water flow, and volume change in unsaturated, compacted granular bentonite, and to understand and simulate the multiphase hydration process of bentonite buffers in deep geological repositories with closely spaced waste packages or Dual Purpose Containers.

Tank-scale Test for Physical Modeling of Heat Transfer and Water Flow in Constrained Bentonite





High-Temperature (200 °C) and High Pressure (15 MPa) triaxial cell for Thermo-Hydro-Mechanical Testing of Unsaturated, Compacted Bentonite

Powell Structural Engineering Research Laboratories

UC San Diego

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Large-scale Structural Systems Testing Facilities

The Powell Structural Engineering Research Laboratories were commissioned in 1986 with fundings from the Charles Lee Powell Foundation, National Science Foundation, and the California Department of Transportation. The facilities are among the largest and most active, full-scale structural testing facilities in the world. They can be used to study the performance of buildings, bridges, foundations, wind turbines, and other energy storage or generation structures subjected to earthquake and other extreme load conditions; structural protective systems; performance of civil, aerospace, and marine structures constructed of advanced composites and other innovative materials; and structural health monitoring and prognosis technologies. Research in the laboratories has been conducted by a number of faculty members, who have a broad range of expertise from material science to geotechnical engineering and structural analysis and design, in the Department of Structural Engineering at UC San Diego (https://se.ucsd.edu/people/faculty). The laboratory operations are supported by a team of professional staff members.

Wind Turbine Test

Bridge Pier Test

Bridge Pile Test

Smart Inverter Testing Lab

UC San Diego

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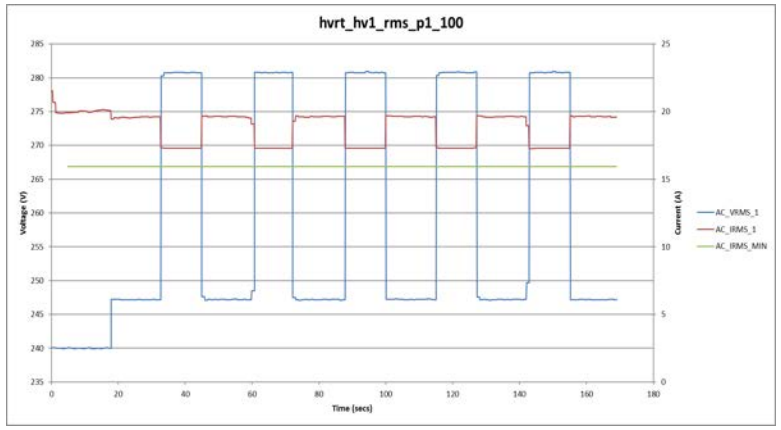
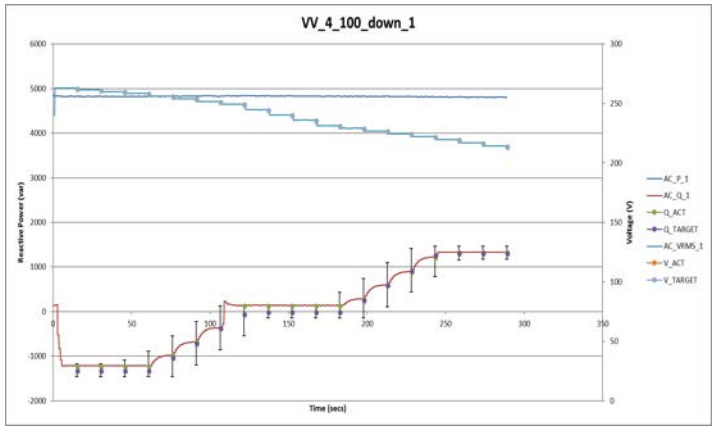
The smart inverter testing lab includes PV and Grid Simulators that can simulate virtually any power grid disturbance and PV array up to 30 kW. The test setup includes high speed data acquisition with high power and voltage monitoring capabilities, and the Sunspec Validation Platform (SVP) software for 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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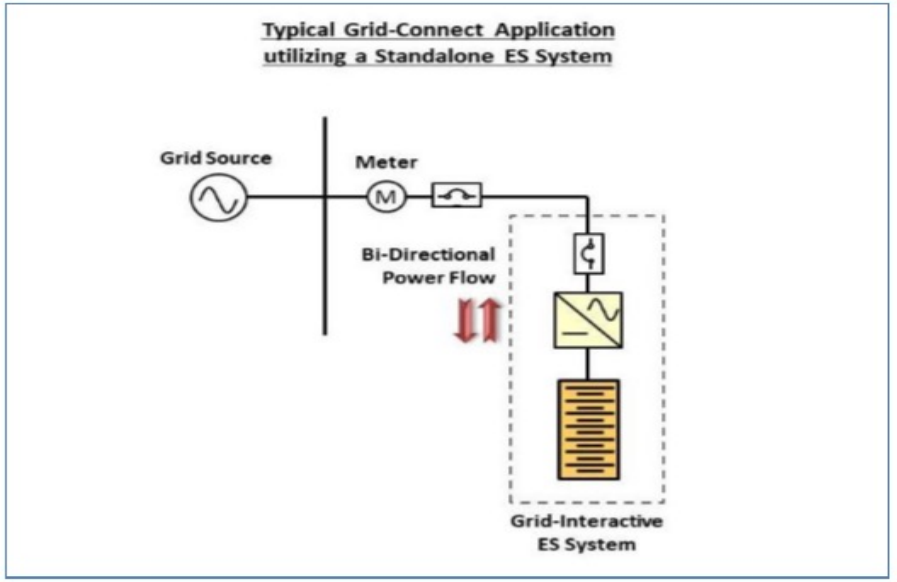
Through CHARGES, the DOE ARPA-e designated UC San Diego as one of two national facilities for testing of new advanced energy storage technology, including: platforms for cell level, module level, and full-scale grid-connected testing; grid-connected outdoor test platform to test three systems; and remote monitoring and testing capability.



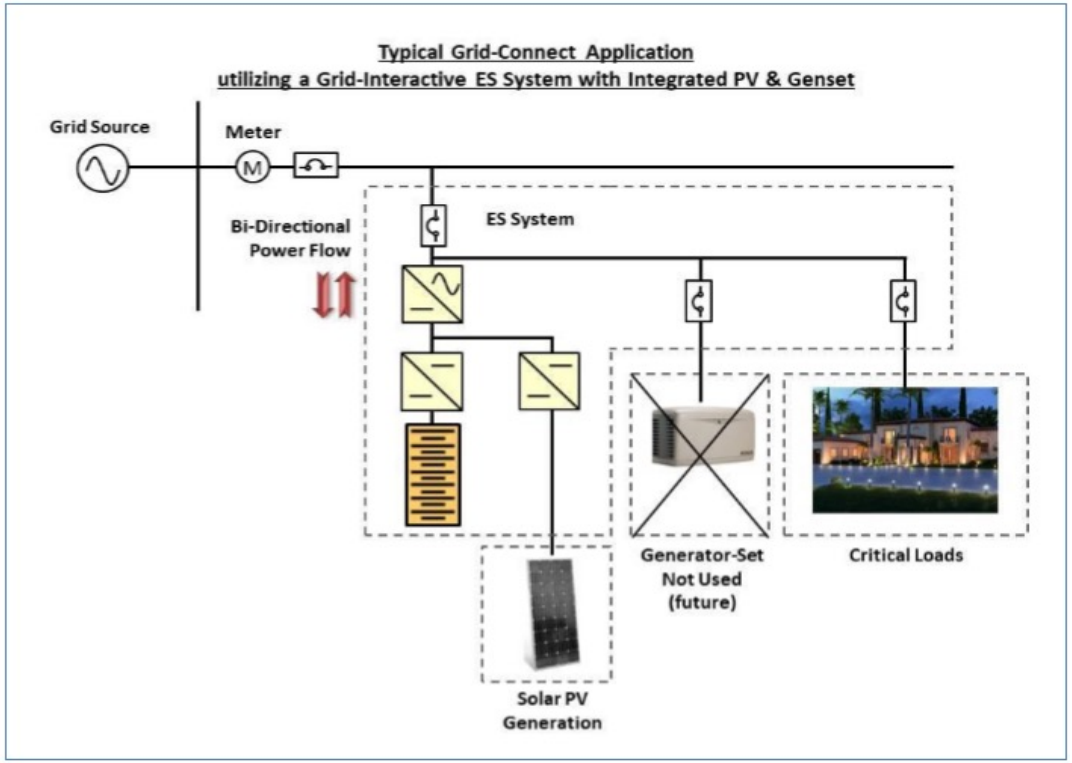
Battery Energy Storage Systems – Utility Scale

UC San Diego

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.

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



Battery Energy Storage Systems – Module Level

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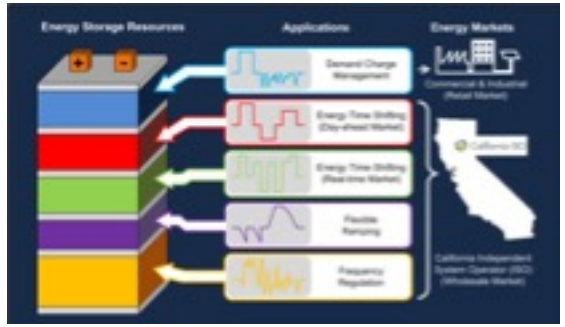
Through the support of DoE ARPA-E CHARGES program and other state and federal grants, UC San Diego is providing third party testing and validation of grid storage technologies, leveraging its experience in battery testing, economic modeling, grid-connected validation to identify the market-ready energy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

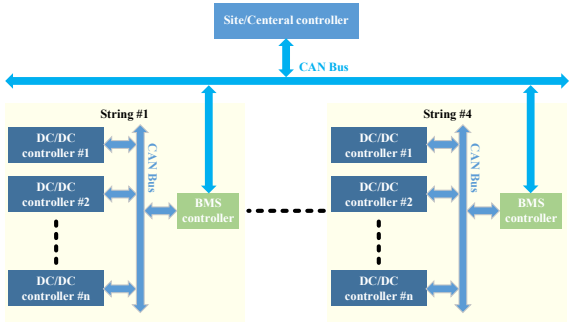


Energy Storage Market Dispatch and Optimization

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

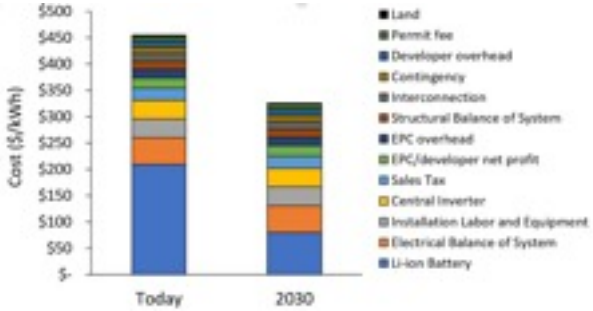
Fully integrated test setup with four CAN communication equipped testers and inverters, five commercial grade battery management systems, 16CH high frequency data acquisition systems, and the capability to custom build power electronics and embedded controllers offers innovators to setup robust hardware-in-loop 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

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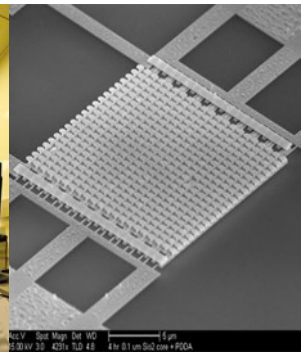
The San Diego Nanotechnology Infrastructure (SDNI), part of the NSF supported National Nanotechnology Coordinated Infrastructure (NNCI), offers users from academic, industry and government laboratories open, affordable access to a broad spectrum of nanofabrication and characterization technologies and 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

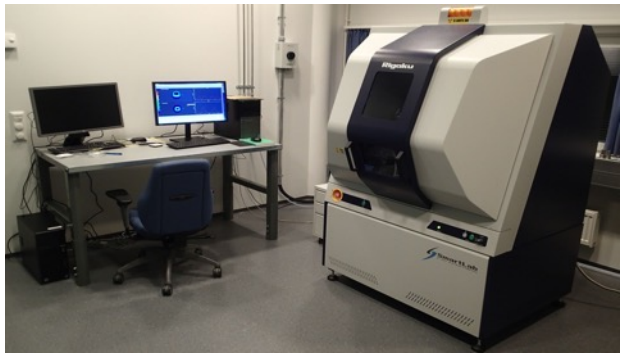


Nano3 Cleanroom Fabrication and Characterization Facility

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

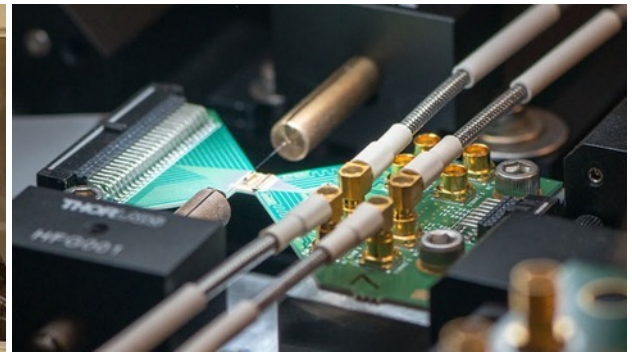
The CMRR Materials Characterization facility provides access to an array of state-of-the-art equipment for nanomaterial (both thin-film and powder) characterization, including XRD, XPS, Hall effect, UV-Vis, AFM/MFM, SEM, and photo current systems to measure crystal structure, and magnetic, surface, transport,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

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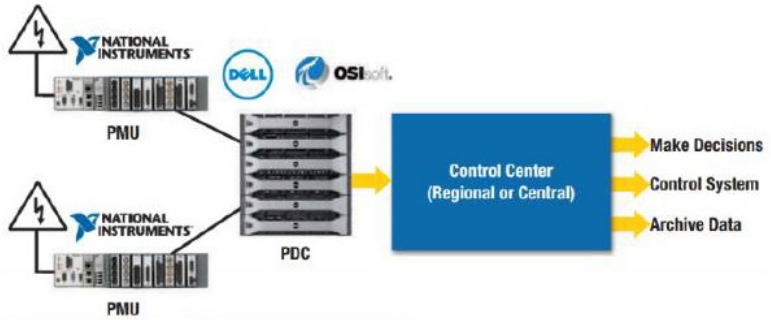


Leverage technology on electric grid instrumentation, development of new data processing, modeling and model validation tools based on synchrophasor data for **advanced grid monitoring and automatic control of electric networks**.

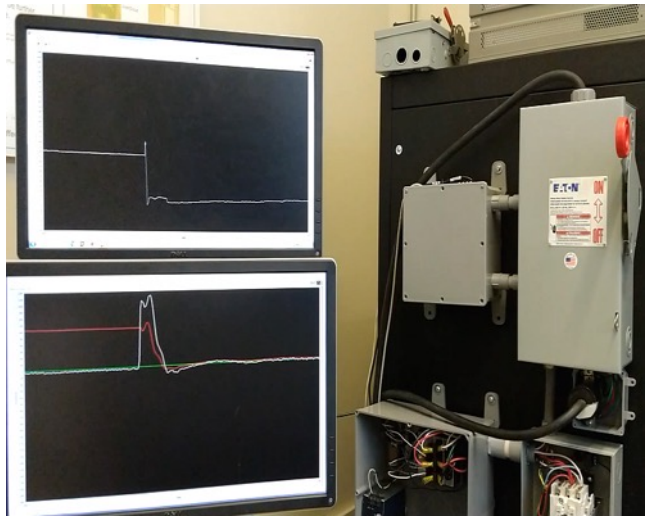
The SyGMA lab fosters collaborations between industry, faculty and students at UCSD. With the displays, conference room and separate offices, the lab is a show case for industrial software (OSIsoft, NI) and research at UCSD.

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.

Renewable Natural Gas Development Laboratory

UC San Diego

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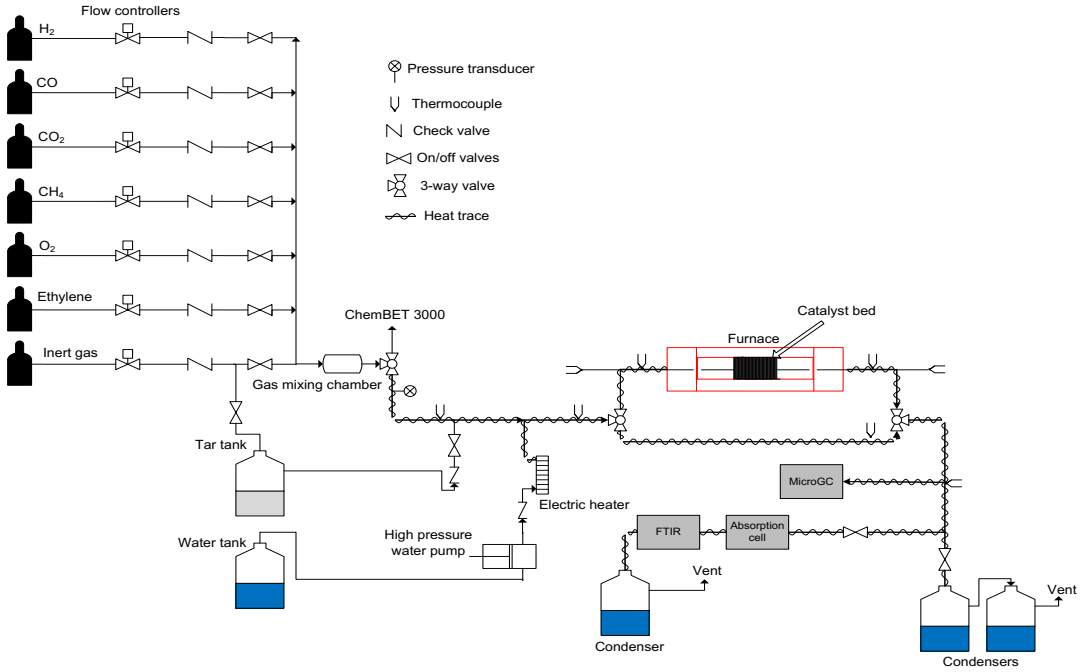
This laboratory provides fixed-bed and fluidized-bed reactors for the development and testing of catalysts and the associated design of chemical reactors for the synthesis of natural gas from renewable sources of syngas. UC San Diego has experience in the preparation and characterization of unique catalyst 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

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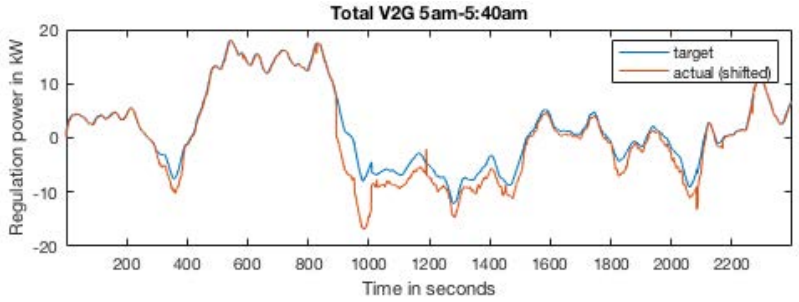
Through CHARGES, the DOE ARPA-e designated UC San Diego as one of two national facilities for testing of new advanced energy storage technology, including: platforms for cell level, module level, and full-scale grid-connected testing; grid-connected outdoor test platform to test three systems; and remote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

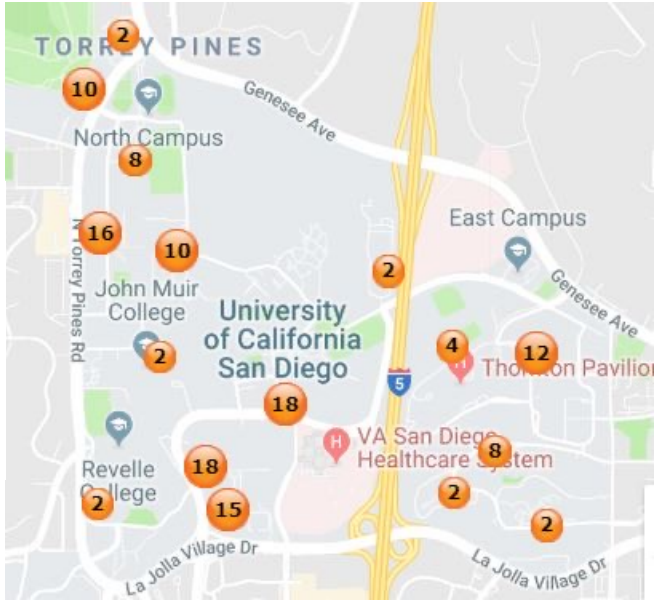
Electric Vehicle Smart Charging

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.