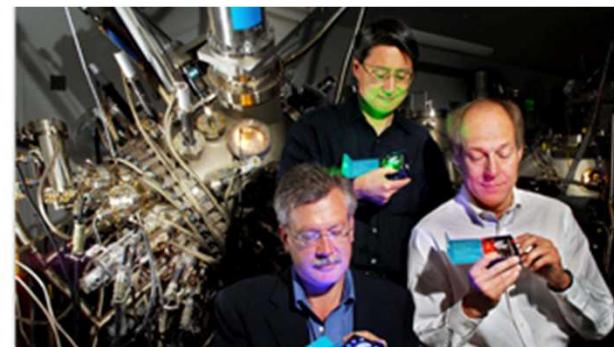


Exceptional service in the national interest



energy.sandia.gov



Renewable Energy Program Overview

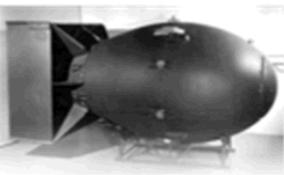
Juan Torres
Senior Manager, Renewable Energy Technologies

<http://energy.sandia.gov>



Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000. SAND 2012-3066 P.

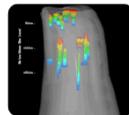
History of Sandia Energy Programs



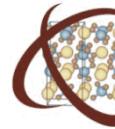
Sandia was born as a nuclear weapons engineering laboratory with deep science and engineering competencies

Energy crisis of the 1970s spawned the beginning of significant energy work

Strategic Petroleum Reserve – geological characterization of salt domes to host oil storage caverns



METAL HYDRIDE CENTER OF EXCELLENCE



DOE's Tech Transfer Initiative was established by Congress in 1991



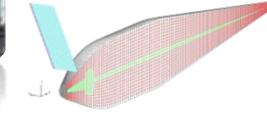
Energy Policy Act of 2005



Joint BioEnergy Institute



Combustion Research Facility (CRF) & Cummins partner on their newest diesel engine



Water Power Program

1950

1960

1970

1980

1990

2000

2007

2009

2010

Vertical axis wind turbine

NRC cask certification studies & core melt studies

Solar Tower opens

CRF opens to researchers

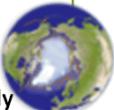


Power grid reliability study



Sunshine to Petrol Pilot Test

Consortium for Advanced Simulation of Light Water Reactors (CASL)



Climate study uncertainties to economies



Large-scale pool fire tests of liquefied natural gas (LNG) on water



Combustion Research Computation and Visualization (CRCV) opens

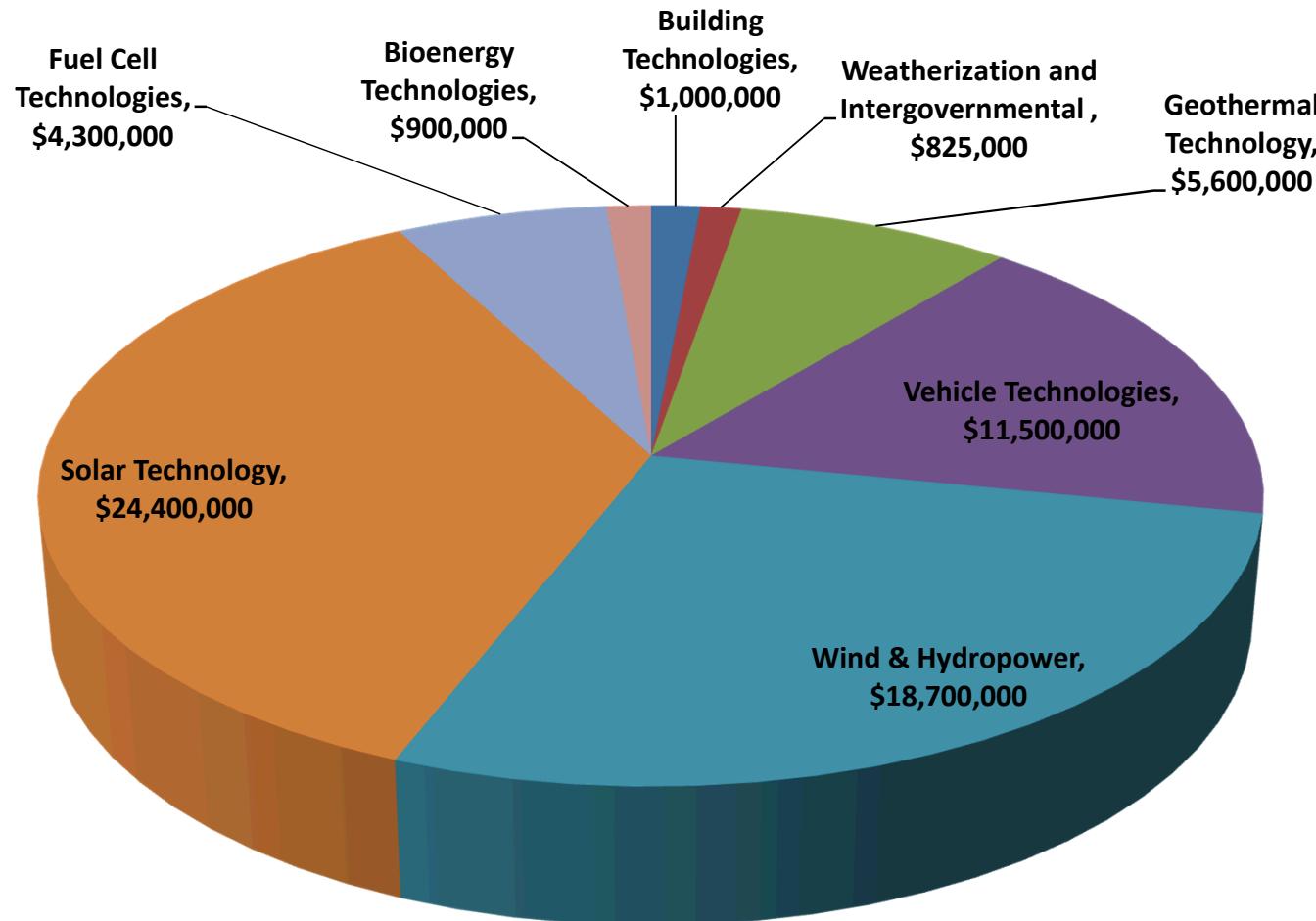
Our core NW competencies enabled us to take on additional large national security challenges



Distributed Energy Technology Laboratory (DETL) to integrate emerging energy technologies into new and existing electricity infrastructures

FY12 EERE Investments in Sandia

Total of \$67M



Photovoltaics & Distributed Systems

UNIQUE CAPABILITIES

- Comprehensive systems characterization and optimization
 - components -> grid interconnect
 - predictive models -> field reliability
 - PV system output -> electric grid impacts
- New power electronics to enable “smart grid” enhancements
- Distributed Energy Technologies Laboratory (DETL)
- Photovoltaic Systems Evaluation Laboratory (PSEL)

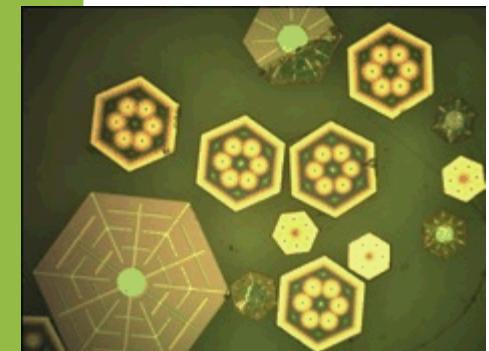


COLLABORATIVE PROJECTS

- Managing PV “Regional Test Centers” in NM, FL, VT, and NV
- CRADAs with utilities, manufacturers and integrators (i.e. EPRI, SunPower, NVEnergy)
- PV Performance Modeling Collaborative (350 members): open forum to improve modeling prediction and reduce uncertainty
- Chair working groups for new utility-scale PV models/interconnects

IMPACT EXAMPLES

- Microsystems Enabled PV (2012 R&D100 Award)
- Advanced tools for large-scale grid integration of renewables
 - PV, storage, and controls
 - Solar Energy Grid Integration Systems (SEGIS) – new inverters for enhanced capabilities (2011 R&D100 Award)
- Improving PV Systems Reliability tools adopted by much of U.S. industry



Concentrating Solar Program

UNIQUE CAPABILITIES

Broad portfolio of CSP testing capabilities including:

- Only major power tower test facility (heliostat field and solar tower - 6 MWt) available for customer testing in western hemisphere
- Solar furnace, high-flow-rate molten salt test loop, rotating platform (trough)

COLABORATIVE PROJECTS

- Molten salt power towers with Gemasolar in Spain, Solar Reserve in Nevada
- Dish engine technology with Infinia
- Perform testing for Abengoa, Solar Reserve, NASA, Nooter/Eriksen, 3M, BP, eSolar

IMPACT EXAMPLES

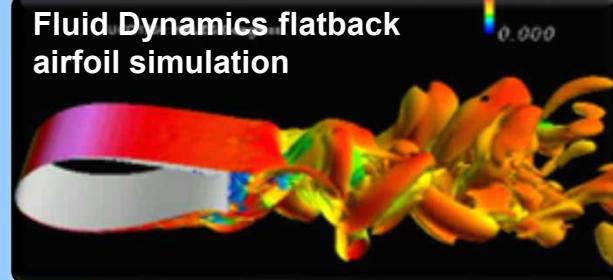
- Extending temperature range of CSP (>600C) to meet SunShot Goals of 6¢/kWh
- Developing key systems to reduce cost of CSP including heliostats, power block (advanced thermodynamic cycles), heat transfer fluid, storage materials, receiver
- World record solar to electricity conversion efficiency



Wind Program

UNIQUE CAPABILITIES

- Test facilities for scaled blade testing and turbine-to-turbine interaction studies (SWIFT test site, Lubbock, TX)
- Wind-turbine blade design and modeling, and wind system reliability

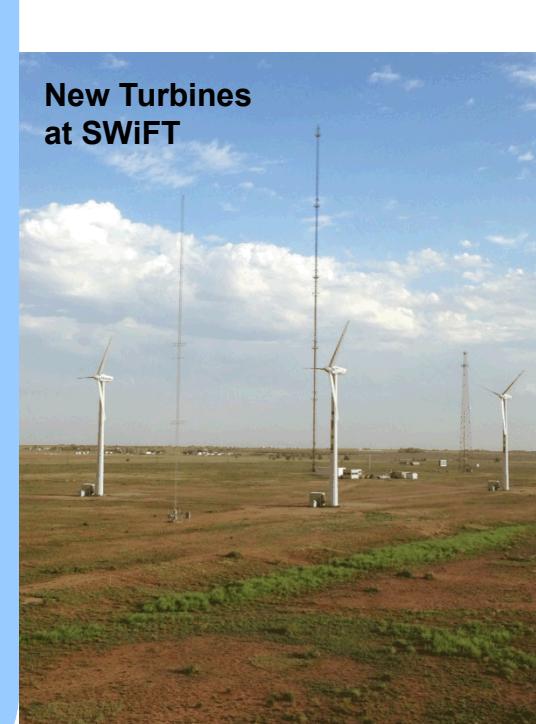


COLLABORATIVE PROJECTS

- GE, Vestas, Texas Tech University – complex wind flow; active controls; scaled wind farm testing
- MIT Lincoln Lab – wind turbine radar interference
- Montana State University – blade material testing
- NREL – systems engineering, wind farm planning, blade testing

IMPACT EXAMPLES

- The SWIFT facility being built at TTU will allow turbine and farm testing at approximately 1/20th of full scale cost
- Evaluation of methods for mitigating radar interference to benefit DOD, DOE, DHS, and DOT and potential increase U.S. wind resources
- Reliability data base and analysis
- Development of tools for wind turbine design & modeling
- Blade testing and materials analysis to improve efficiency



Water Power Program

Marine Hydrokinetics, Offshore Wind, Conventional Hydropower

UNIQUE CAPABILITIES

- SEAWOLF laboratory/field oscillatory-flow sediment transport testing
- MHK-capable environmental circulation and performance code (SNL-EFDC)
- Renewables-appropriate composite structural materials and anti-biofouling coatings test facilities
- Sandia Lake Facility – TRL 6 appropriate for wave testing
- HydroSCOPE Seasonal Optimization Tool (CH)

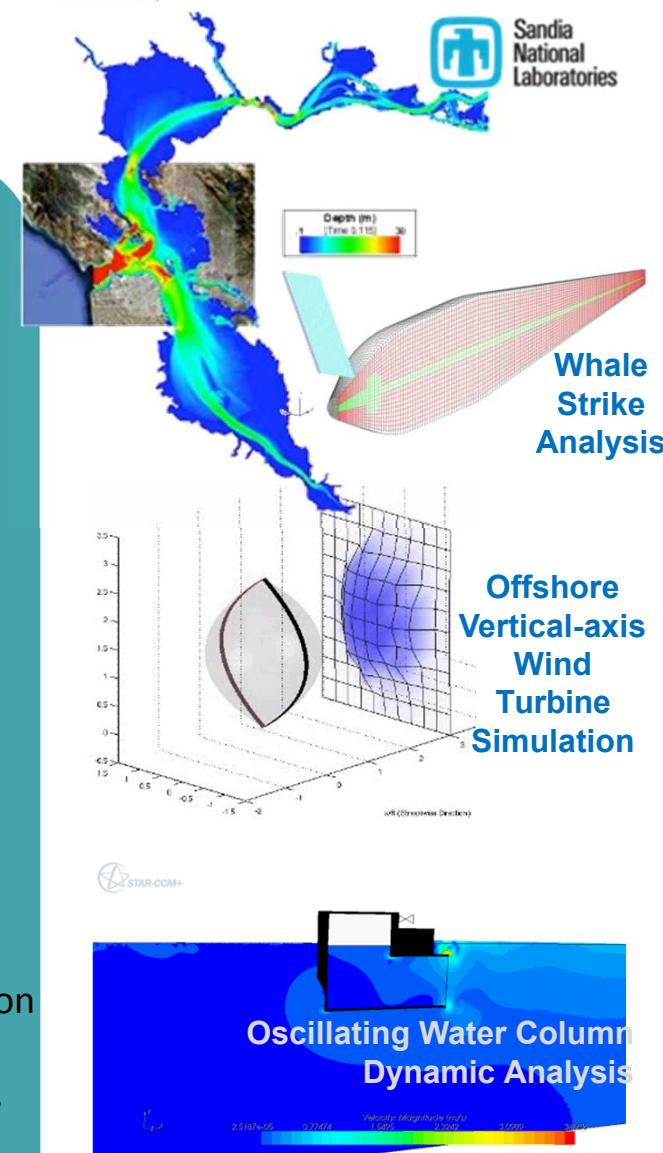
COLLABORATIVE PROJECTS

- Technical Industry FOA Support
 - Ocean Renewable Power Company, Ocean Power Technologies, Snohomish PUD
- SNL-EFDC Technology Transfer to
 - Free Flow Power, NOAA, FERC, BOEM, Verdant, ORPC

IMPACT EXAMPLES

- Whale strike analysis (collaboration with PNNL) allowing demonstration project to proceed in Puget Sound
- Leading the techno-economic report to Congress detailing what steps need to be taken to ensure the growth of the WEC industry.
- Novel vertical axis wind turbine designs and structural health monitoring for offshore wind devices.

San Francisco Bay



Geothermal Program

UNIQUE CAPABILITIES

- Drilling Dynamics Simulator - real world drilling dynamics in the laboratory
- Rotary head and coil tubing test machines
- Electronics fabrication and facilities for high-temperature testing and evaluation
- Dynamometer test stand
- Facilities for testing energetic materials



COLLABORATIVE PROJECTS

- Partnered with Atlas Copco in the development of down-the-hole hammers for geothermal applications
- Working with GE in the testing of SiC microelectronics and evaluation of optical fiber performance in high-temperature H₂ rich environments
- Demonstration and evaluation of advanced polycrystalline diamond compact (PDC) bits with US Navy and National Oilwell Varco ReedHycalog



IMPACT EXAMPLES

- Development of PDC Bits, the mainstay of industry exploration/drilling—over 60 percent of borehole footage world wide since 2000, \$1.9 billion in sales in 2007.
- Evaluation and development of high-temperature tools and devices for downhole applications
- Application of environmentally friendly energetics for reservoir stimulation





KEY FACILITIES SUPPORTING RENEWABLES RESEARCH @ SANDIA

National Solar Thermal Test Facility (NSTTF)



UNIQUE CAPABILITIES

The NSTTF is the only central receiver test facility in the U.S. with over 700 man-years of staff experience to support CSP R&D including the solar furnace, molten salt test loop, and rotating platform.

NATIONAL VALUE

NSTTF is the only facility in the U.S. that:

- Provides large scale, high flux material testing
- Tests large scale molten salt components (pumps, valves, etc.)
- Provides a target for long range heliostat beam evaluation
- Tests Solar Central Receivers

Also, one of 3 facilities in the U.S. that has been selected as a PV Regional Test Facility.

RESEARCH IMPACT

- **NASA** – Ablator testing, Shuttle Tile testing, Hypersonic vehicle material testing
- **Solar Reserve** – Heliostat evaluation
- **Areva Solar** – Compact Linear Fresnel Reflector Technology utilizing molten salt (under negotiation)
- **PWR** – Solar Receiver Tube/Shroud testing (under negotiation)
- **Sierra Nevada Corporation** – Solar Air Receiver
- **Nooter Eriksen** – Solar Receiver Shroud Test
- **Aerojet** – Material sample testing
- **Boeing** – Material testing
- **Infinia** – Evaluating Dishes and Stirling Engines
- **SunPower** – Concentrating PV
- **Department of Energy (DOE)**



Photovoltaic Systems Evaluation Laboratory (PSEL)



UNIQUE CAPABILITIES

PSEL is a multi-user, multi-sponsor facility that conducts research in PV cells, modules, and arrays and performs detailed, comprehensive analysis in PV systems design, optimization, and characterization in real-world scenarios.

NATIONAL VALUE

- DOE User Facility for cell-to-system measurements of new PV technologies
 - Develop predictive performance models
 - Working with industry to better address reliability/lifetime concerns
- New, standard characterization methods reduce risk and improve bankability of PV projects
- Partnerships span the U.S. PV industry

RESEARCH IMPACT

Cell/Module Companies

- Abound
- Amonix (RIP)
- Applied Materials
- BP Solar (RIP)
- Concentrix (now part of Soitec)
- Dow Solar
- Emcore
- enXco
- First Solar
- Gratings Solar
- Greenray
- Greenvolts
- Miasole
- NanoSolar
- Prism Solar

- Semprius
- Sharp
- Sierra Solar
- Skyline
- Solaria
- SolFocus
- Soliant
- SoloPower
- SunPower
- Unisolar

Government/National Labs

- DOE
- GSA
- NREL
- SNL (MEPV, etc)



Private Labs

- CFV
- Fraunhofer - CSE
- TUV/PTL

Integrators/Project Developers

- enXco
- Recurrent Energy

Universities

- FSEC
- NMSU
- UVM



UNIQUE CAPABILITIES

DETL conducts research with industry and academic partners to integrate emerging energy technologies into new and existing electricity infrastructures.

NATIONAL VALUE

- DOE User Facility for new smart grid technologies in an integrated, fully functioning environment
 - New photovoltaic inverters and energy management systems
 - Integrated storage and new controls
 - Demand-side management and utility interactions
- Provides lab evaluations prior to field installations

RESEARCH IMPACT

- Electric Power Research Institute (EPRI)
- Department of Defense
- PNM (NM utility)
- GreenSmith
- GreenRay
- Enphase
- Petra AMPT
- Princeton
- AE (PVPowered)
- StatCon
- SMA
- Fronius
- Xantrex (Schneider)
- Aurora



Scaled Wind Farm Technology Center (SWIFT)

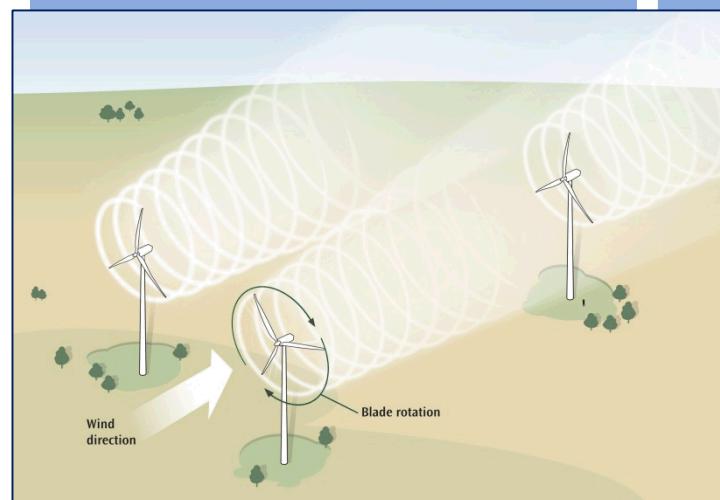


U.S. DEPARTMENT OF
ENERGY



UNIQUE CAPABILITIES

- 1st facility in the world to specifically study wind farm wakes and their interaction with wind turbines
- Highest category wind class, with average winds of 17 mph (7.5 m/s) directly from the South
- Scaled research turbines (Vestas model V27) allow for rapid technology development at ~1/20th the experimental cost



NATIONAL VALUE

- Reduce performance losses and maintenance costs from turbine-turbine interaction
- Develop advanced wind turbine rotors for increased energy capture and improved reliability
- Turbine models and data are being developed as a public open-source research asset to aid the entire wind energy community



RESEARCH IMPACTS

- Vestas Research and Development, the world's largest wind turbine manufacturer, is installing its own V27 turbine to perform both cooperative and proprietary research.
- Texas Tech University has partnered to develop the test facility, which will be used to foster academic research and wind energy education.
- Currently finalizing NDA's to perform research testing at the facility for General Electric Wind Energy, Gamesa Wind, and Alstom Wind.

Battery Abuse Testing Lab (BatLab)



UNIQUE CAPABILITIES

The BatLab is at the forefront of testing the limits of what batteries can safely handle and provides critical data for developing the next generation of batteries—doing everything imaginable to batteries (e.g., crushing, piercing with nails, heating to boiling) in the lab to make sure that once a battery is in commercial use, it will be safe and reliable.

NATIONAL VALUE

- The nation's leading experts in battery safety research and unique facilities for battery abuse testing for doe and industry
- The world's largest and most comprehensive battery calorimetry laboratory
- DOE's largest lithium-ion cell prototyping facility
- State-of-the art battery abuse testing facilities to perform a variety of electrical, thermal, and mechanical abuse tests
- Materials to full system test capabilities
- Access to Sandia's Power Source Technology Group and other advanced Sandia capabilities/facilities

RESEARCH IMPACT



Geothermal Research Lab



UNIQUE CAPABILITIES

The geothermal research laboratory designs, tests and analyzes field deployment downhole tools for operation in high-temperature, high-pressure environments coupling research and development with practical applications.

NATIONAL VALUE

- A unique national resource for the development and testing of well construction systems in harsh environments
- Over 35 years of continuous effort supporting the advancement of well construction technologies



RESEARCH IMPACT

| | |
|--------------------------|----------------|
| • DOE | Downhole |
| • DOD - DARPA | • US Synthetic |
| • CDC - NIOSH | • Numa |
| • Other Federal Agencies | • Security DBS |
| • GE Global Research | • Draka |
| • Atlas Copco | Cableteq |
| • NOV | • MagiQ |



- Hard-rock drilling facility to support testing of rock cutting materials, bits and downhole tools with active control through a drilling dynamics simulator.
- Dynamometer test stand for evaluation of drilling tool power
- Instrumented test rigs for down-the-hole-hammer evaluation
- Component fabrication facilities and test equipment for development of high-temperature electronics, electromechanical and optical fiber based equipment.
- Environmental test systems (ovens, furnaces, pressure vessels, shakers) for component evaluation and testing of high-temperature systems and components



LDRD INVESTMENTS

A collage of images representing various energy and technology sectors. It includes a wind turbine, a water droplet with a rainbow reflection, a complex electrical substation with multiple power lines and insulators, a large industrial facility with tall cooling towers emitting steam, and a modern electric vehicle. The images are overlaid with a green and blue circular motion graphic in the bottom right corner.

Highly Leveraged Investments

- “Grand Challenge” and leading LDRDs
 - Solar fuels - \$14M (five years), completed in FY11
 - Scalable Secure Microgrids - \$11M (three years), completed in FY13
 - Microsystems enabled PV - \$10M (three years), completing in FY15
- Office of Science
 - Center for Integrated Nanoscience Technology - \$11M in FY11
 - <http://cint.lanl.gov/>
 - Joint Bioenergy Institute - \$5M in FY11
 - <http://www.jbei.org/>
 - Combustion Research Center - \$10M in FY11
 - <http://crf.sandia.gov/>
- DOE OE Energy Storage and Transmission
 - Research, Development and Deployment Analytics

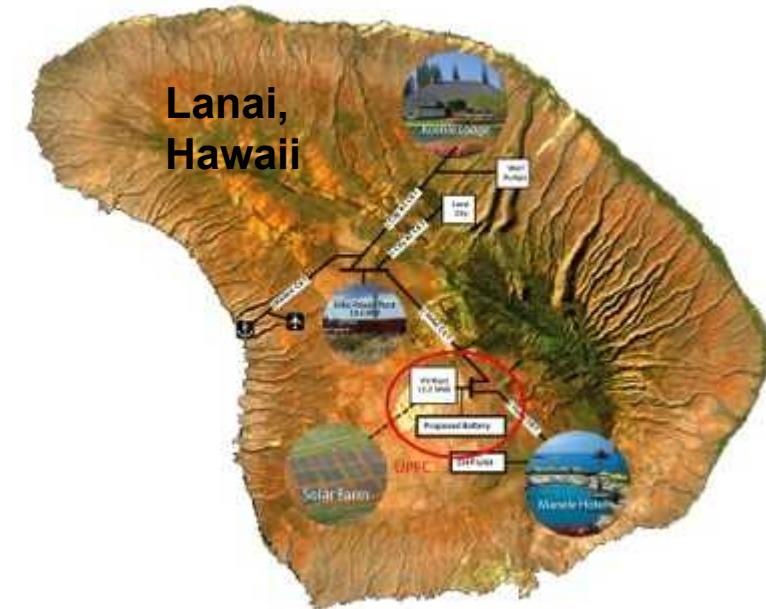
Enabling Secure Scalable Microgrids with High Penetration Renewables



Grand Challenge Laboratory Directed Research and Development



- SNL is unlocking microgrid application space through ground breaking nonlinear control theory, informatics, and innovation.
- Tools are being developed for networked microgrids spanning from conventional to 100% stochastic generation.
- Potential impact
 - Unlimited use of renewable sources
 - Reduction in centralized fossil fuel based sources
 - Self-healing, self-adapting architectures
 - Microgrids as building blocks for larger systems



Construction of the SSM test bed

Sunshine to Petrol (S2P)

Producing Drop-In Fuels

UNIQUE CAPABILITIES

- Sandia is uniquely capable in concentrating solar, materials development, systems engineering, and computing to develop reactors, high-temperature metal oxide chemistry, and balance of systems efficiencies, cost, and cost-driver analysis.

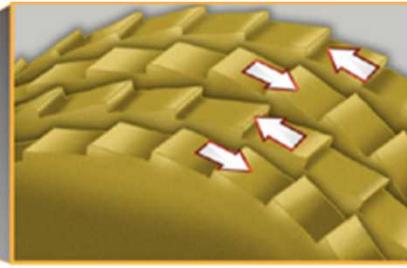
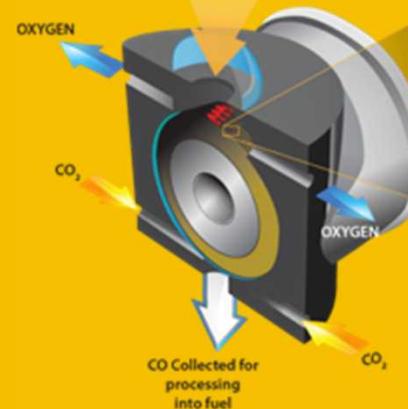
KEY PARTNERSHIPS

- Sandia's internal Grand Challenge investment (\$14M/5 years)
- BP, Solar Fuels Alliance

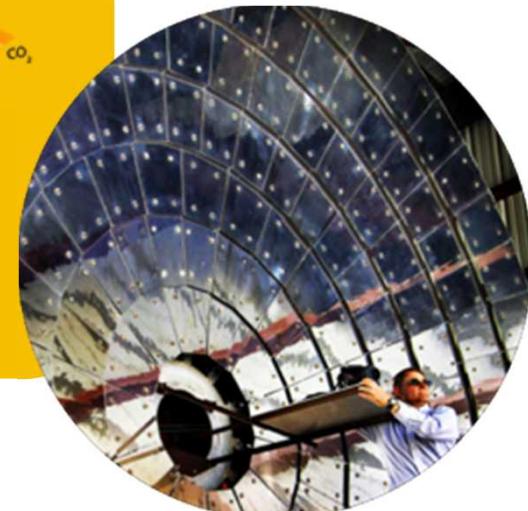


CURRENT WORK

- A concentrating solar-driven thermochemical heat engine to convert CO₂ and H₂O to SynGas – a flexible and established precursor to gasoline, jet fuel, diesel, and chemical components.
- With biofuels, S2P balances the national research portfolio in alternative transportation fuels.



Alternate discs
rotate in opposite
directions



Solar Glitter

A Microsystem-Enabled PV Concept



GOAL

To develop advanced solar technologies and systems that will provide the US industry with a competitive advantage worldwide in delivering solar electricity at less than 10 cents per kWhr.



Flexible
PV Modules



MOTIVATION

Double the efficiency and half the cost of conventional PV systems:

- high efficiency (*cell level* >50%, *system level* >40%)
- reduced cost (module cost of ~\$0.5/Watt_{peak}, system cost of 2-3/Watt_{peak}).



Thin PV Cells