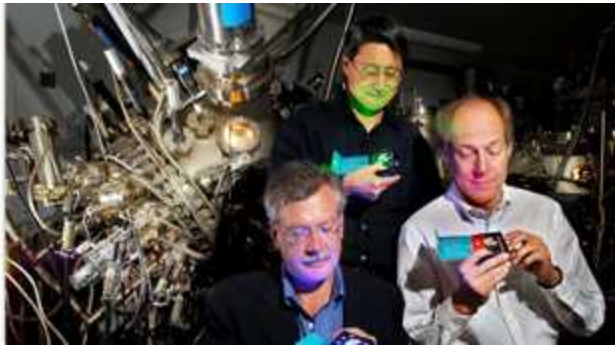
SAND2013-8703C

Exceptional service in the national interest

Sandia National Laboratories

energy.sandia.gov





Renewable Energy Program Overview

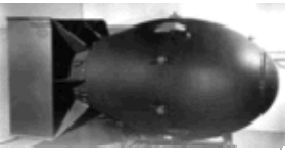
25 June 2013

http://energy.sandia.gov

U.S. DEPARTMENT OF ENERGY | NNSA National Nuclear Security Administration

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.

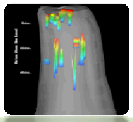
History of Sandia Energy Programs



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



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

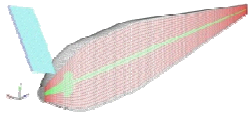
METAL HYDRIDE CENTER OF EXCELLENCE

Advent Solar

Energy Policy Act of 2005

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

Joint BioEnergy Institute



Water Power Program

1950 | 1960 | 1970 | 1980 | 1990 | 2000 | 2007 | 2009 | 2010

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

Vertical axis wind turbine

NRC cask certification studies & core melt studies

Solar Tower opens

CRF opens to researchers

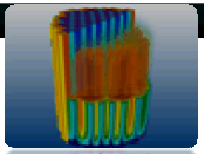
Distributed Energy Technology Laboratory (DETL) to integrate emerging energy technologies into new and existing electricity infrastructures

Power grid reliability study

SunCatcher™ partnership with Stirling Energy Systems

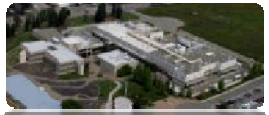
Sunshine to Petrol Pilot Test

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



Consortium for Advanced Simulation of Light Water Reactors (CASL)

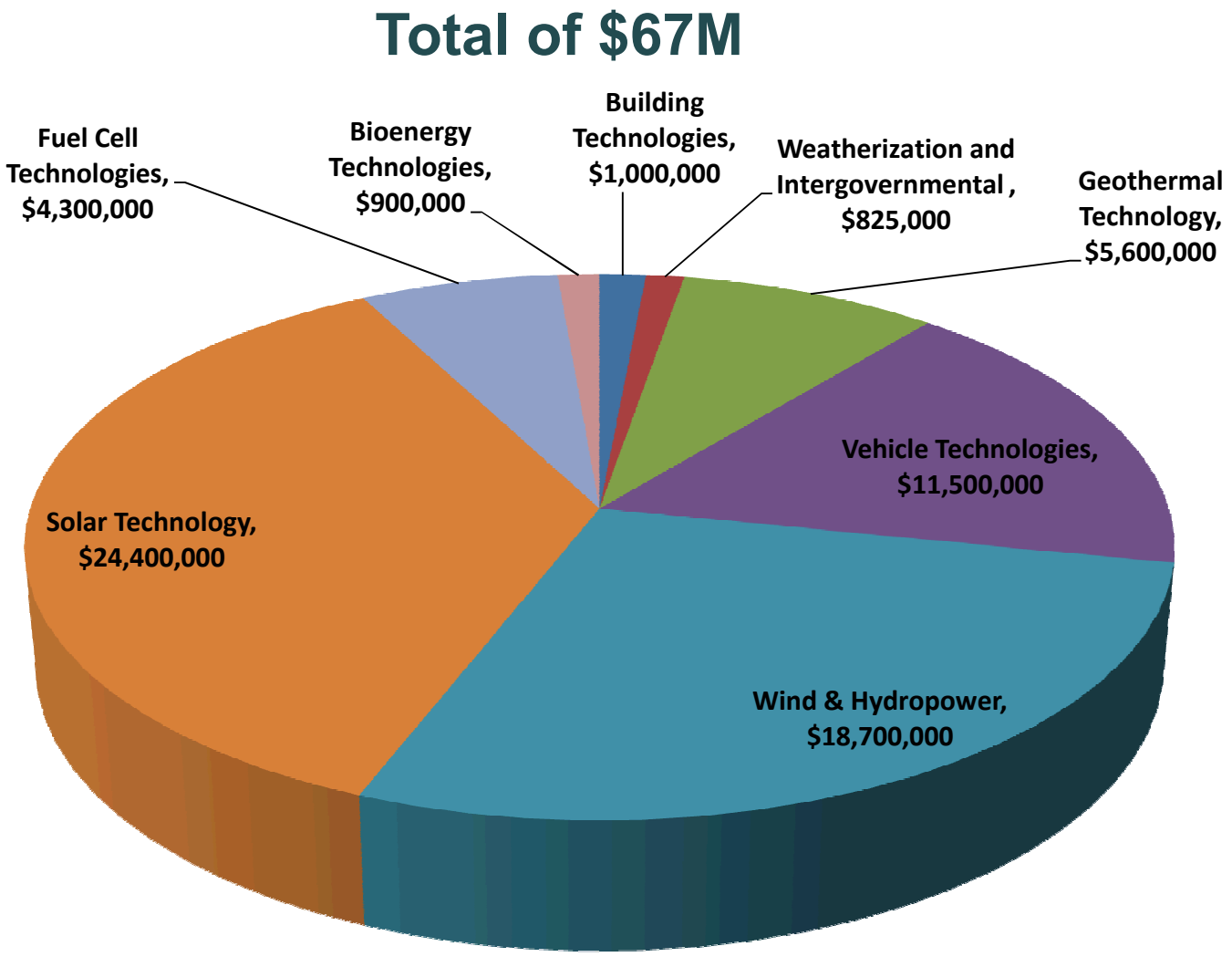
Climate study uncertainties to economies



Combustion Research Computation and Visualization (CRCV) opens

FY12 EERE Investments in Sandia

Sandia National Laboratories



Sandia Already Has Several RE Collaborations in California

- CEC: Development of test protocols for advanced PV inverters
- CA Solar Initiative (CPUC): Supporting EPRI on development of new distribution models and screens
- CAISO: application of stochastic unit commitment algorithms
- SMUD: solar resource forecasting validation methodologies
- Solar industry collaborations:
  - CRADAs with industry leaders and startups (SunPower, Cool Earth Solar)
  - Demonstration collaborations at Livermore Valley Open Campus
- Ormat/US Navy – lower cost development of geothermal wells

Photovoltaics & Distributed Systems

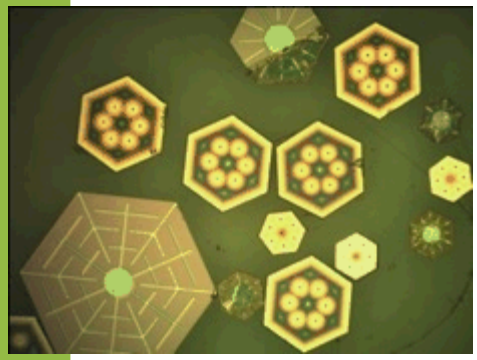
Sandia National Laboratories

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

Sandia National Laboratories

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

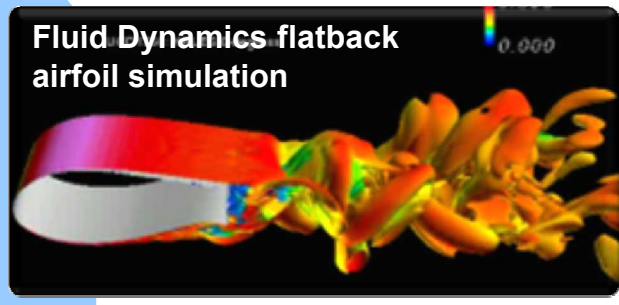
csp.sandia.gov

Wind Program

Sandia National Laboratories

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



COLLABORITIVE 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

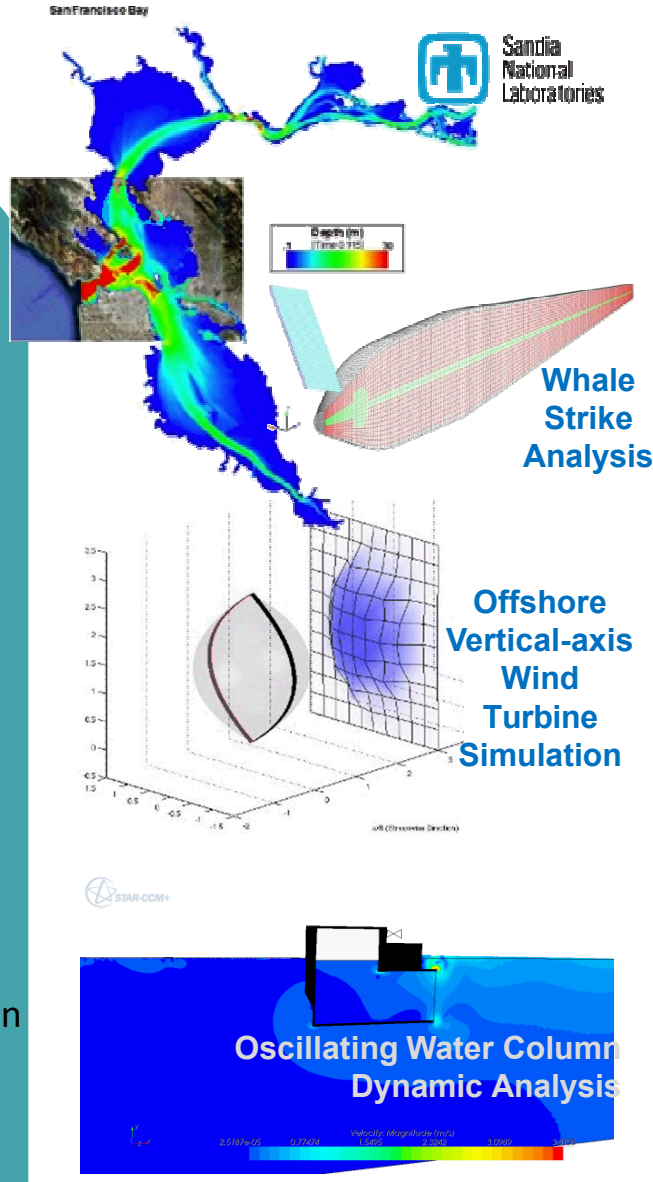
- SEAWOLF laboratory/field oscillatory-flow sediment transport testing
- MHK-capable environmental circulation and performance code (SNL-EFDC)
- Renewables-appropriate composite structural materials and anti-biofouling coatings test facilities
- Sandia Lake Facility – TRL 6 appropriate for wave testing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

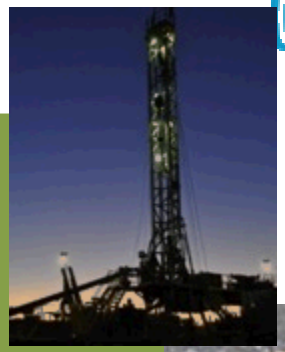
IMPACT EXAMPLES

- 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.



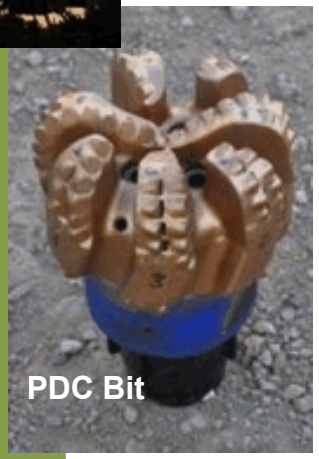
Geothermal Program

Sandia National Laboratories



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 H_2 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

Vehicles Program

Sandia National Laboratories

UNIQUE CAPABILITIES

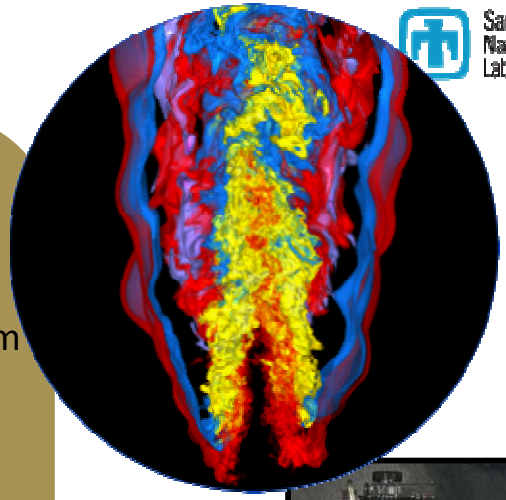
- Combustion Research Facility basic and applied research to improve and control combustion processes
- High performance computers including a 5000 core, 50 teraflop system
- Advanced optical and laser based diagnostics
- High fidelity combustion simulation tools
- Battery Abuse and Testing Laboratory (BATLab) reliability and safety research including abuse of capacitors, cells, batteries, and systems from milliwatthours to kilowatt-hours.

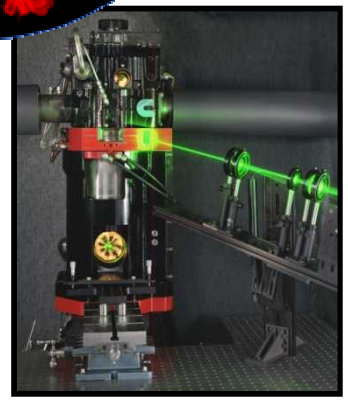
COLLABORATIVE PROJECTS

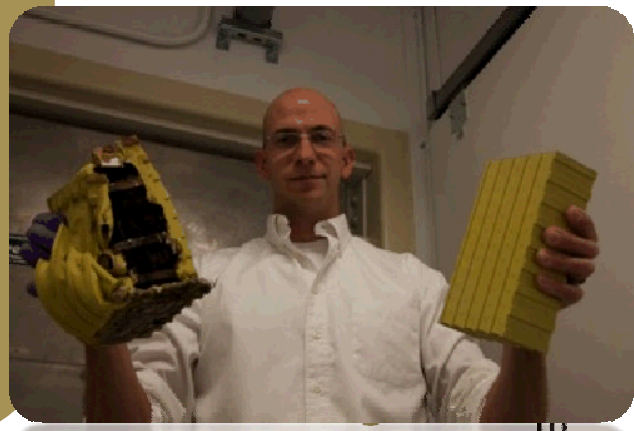
- Ford, GM, Detroit Diesel, Caterpillar, John Deere, Cummins, Chrysler, Mack, ConocoPhillips, ExxonMobil, Chevron, BP, Shell, Volvo, GE, Navistar
- International collaborators (Europe, China, Japan)
- Hundreds of visiting collaborators to the CRF and BATLab each year

IMPACT EXAMPLES

- Every modern vehicle on the road today is cleaner and more efficient due to CRF collaborative work
- Facilitating the deployment of safe and responsible energy storage solutions for the emerging EV market







Biomass Program

Sandia National Laboratories

UNIQUE CAPABILITIES

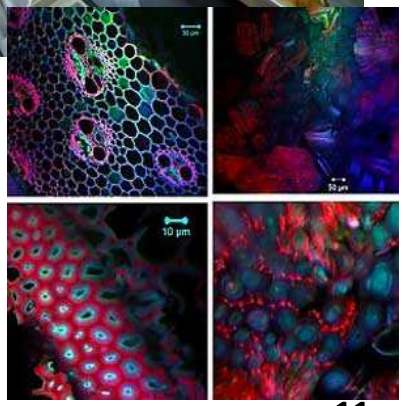
- SNL has unique capabilities at the Combustion Research Facility for the science of advanced biofuel combustion
- SNL has unique expertise in multi-spectral imaging, microsystems, and diagnostics for the analysis of biomass conversion
- SNL has unique expertise in ionic liquids and biomass pretreatment

COLLABORATIVE PROJECTS

- JBEI/LBNL – advanced biofuels through synthetic biology
- INL – mixed biomass feedstocks
- US-China Clean Energy Research Center
- GE – lifecycle analysis and testing of advanced biofuels
- Lockheed Martin – thermochemical conversion of biomass
- DSM – enzyme engineering and cocktail design
- Arizona State University /NREL/Sapphire – algal biofuels
- Montana State University – endophytic fungi

IMPACT EXAMPLES

- Development of a pretreatment process that requires 1/10th the enzyme loading compared to other technologies
- Advanced biomass pretreatments based on ionic liquids
- Development of thermostable enzyme cocktails
- Synthetic biology of fungi
- Co-evolution of advanced biofuels and engines (with the CRF)
- Algal biofuels (EERE: ATP3, SABC, Nutrient Recycle)



Hydrogen/Fuel Cells Program

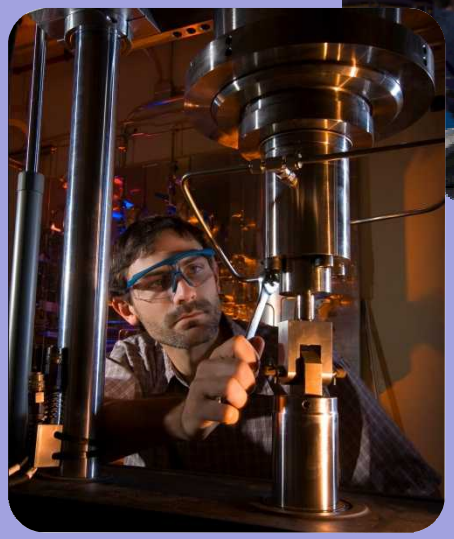
Sandia National Laboratories

Providing the science and engineering depth to accelerate the deployment of clean and efficient hydrogen and fuel cell technologies

UNIQUE CAPABILITIES

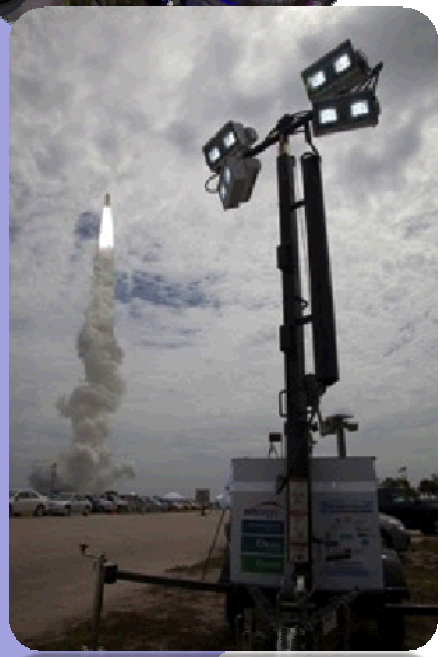
- We design and deliver hydrogen systems that are absolutely safe, secure, and reliable
- 50 years of experience in H_2 S&T
- H_2 effects in materials, components
- Hydrogen systems engineering

Ciri Center for Infrastructure Research and Innovation



COLLABORATIVE PROJECTS

- NREL - Data collection for risk analysis
- NIST – Materials qualification
- Norris Cylinder, Plug Power – Tank research
- SAE, CSA, ASME, ISO – Standards
- Univ. of Illinois – Structural materials
- Univ. of Colorado – Solar H_2 Production



IMPACT EXAMPLES

- Leadership of the Metal Hydride Center of Excellence
- We develop the basis for meaningful codes and standards
- Public/private consortia to develop and deploy hydrogen systems
- International Institute of Carbon-Neutral Energy Research (I^2CNER)
- Leadership of global hydrogen resource assessments

Building Technologies Program

Sandia National Laboratories

UNIQUE CAPABILITIES

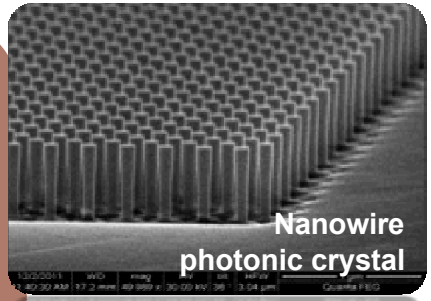
- Lead laboratory for the Office of Science solid-state lighting Energy Frontier Research Center (EFRC)
- Semiconductor growth, processing, and characterization equipment in Microsystems and Engineering Sciences Applications (MESA), the world's largest government investment in semiconductor facilities
- Platform development technology for application of the Sandia cooler in the HVAC area

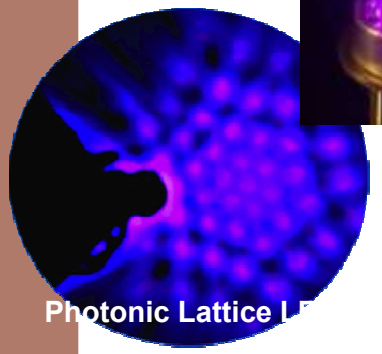
COLLABORATIVE PROJECTS

- Veeco – semiconductor growth reactor design, modeling, and sensors
- Philips – measurement of LED defect densities and locations
- Applied Materials – novel substrates
- RPI – fundamental mechanisms of LED efficiency droop at high currents
- Corning – lasers for lighting

IMPACT EXAMPLES

- 2012 R&D 100 Award- Sandia Cooler
- III-V semiconductor materials for enhanced LED efficiency
- Research on quantum dots as rare-earth-free phosphor replacements
- Design of advanced growth reactors to lower costs of LED growth





Energy Storage Program

Sandia National Laboratories

UNIQUE CAPABILITIES

- 1 MW Energy Storage Test Pad
- Energy Storage Analysis Laboratory
- Over 3 decades of leadership and experience to DOE/OE ESSP
- Cradle-to-grave responsibility for all power sources for DOE defense programs

KEY INDUSTRY PROJECTS

- Demo projects with NYSERDA & CEC
- Development of electrical energy storage metrics and market structures
- Development of high-temp power electronics
- ARRA energy storage demo: PNM Prosperity Project
- R&D 100 Awards
  - 2011 Ultra-high-voltage Silicon Carbide (SiC) Thyristor
  - 2009 High-Temperature SiC Power Module
  - 2003 Emitter Turn-Off Thyristor
  - 2003 Fiber-Optic Electrical Current and Temperature Transducer

CURRENT WORK

Research: Redox flow, Sodium based, Lithium-ion and Advanced lead-acid batteries; Compressed air energy storage; Flywheel storage

Demonstrations/deployments: 16 ARRA; State Energy Agency Support; Energy Surety Microgrids; Hawaii Clean Energy

Systems analysis: Impact Assessments; Market Design studies; Cost Modeling; Codes and Standards

KEY FACILITIES SUPPORTING RENEWABLES RESEARCH @ SANDIA

National Solar Thermal Test Facility (NSTTF)

Sandia National Laboratories

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)

Sandia National Laboratories

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

Distributed Energy Technologies Laboratory (DETL)

Sandia National Laboratories

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

Sandia National Laboratories

UNIQUE CAPABILITIES

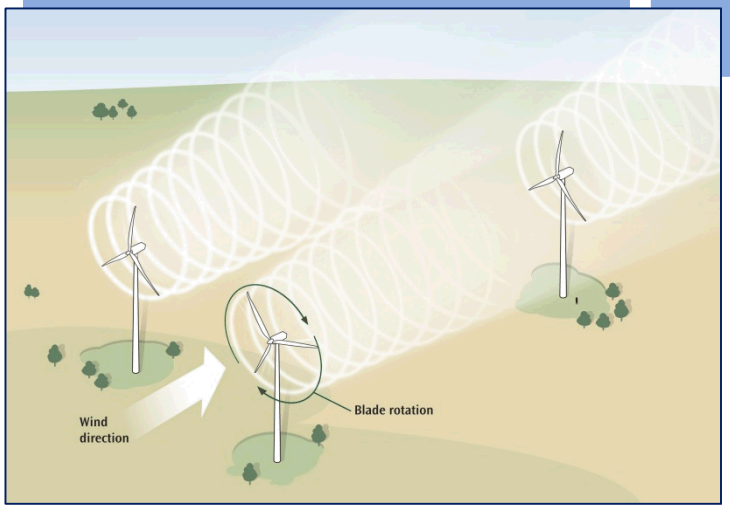
- 1st facility in the world to specifically study wind farm wakes and their interaction with wind turbines
- Highest category wind class, with average winds of 17 mph (7.5 m/s) directly from the South
- Scaled research turbines (Vestas model V27) allow for rapid technology development at ~1/20th the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



Lake Test Facility

Sandia National Laboratories

UNIQUE CAPABILITIES

The Lake Test facility is the only test facility of its kind with a large surface area and 15 m depth and infrastructure to support full scale hydrokinetic equipment equipped with instrumentation and data analysis.

NATIONAL VALUE

- With a wave making modification, this would be the largest controlled test capability in the world
- Would be the only test capability to test fully operational wave energy devices in the world
- Preliminary US Testing Needs assessment for MHK development shows this potential capability is a major gap

RESEARCH IMPACT

- CTD, Inc.
- General Power Associates
- Resolute Marine
- Columbia Power Technologies
- Wave Energy Technology
- Ecomerit
- Straumekraft AS
- OPT

Combustion Research Facility

Sandia National Laboratories

An Office of Science Collaborative Research Facility dedicated to energy science and technology for the 21st century

Essentially every modern vehicle on the road today is cleaner and more efficient due to CRF collaborative work.

- 82,000-square-foot office and lab facility at Livermore Valley Open Campus
- 36 highly specialized labs
  - Laser-based diagnostics
  - Combustible and toxic gas handling
  - Computer-controlled safety system
- New 8000 square-foot computational laboratory
- Co-sponsored by EERE and BES

ONGOING WORK

- Target combustion strategies:
  - Low temperature, clean combustion (e.g., homogenous charge compression ignition)
  - Advanced lean-burn gasoline engines
  - Advanced diesel combustion (e.g., high exhaust gas recirculation)
  - Alternative fuels (biofuels, natural gas, etc.)
- Next-gen diagnostics and computational tools

The most direct path to reduced dependence on foreign oil is increased vehicle efficiency and use of alternative fuels

CHRYSLER · GE · Lawrence Livermore National Laboratory · Shell Global Solutions · ExxonMobil · GM · Cummins · CATERPILLAR · Oak Ridge National Laboratory · ConocoPhillips · 21st Century Truck Partnership · Ford · Argonne · International · John Deere · NREL · Los Alamos · Chevron · bp · DETROIT DIESEL · VOLVO · USDRIVE

Battery Abuse Testing Lab (BatLab)

Sandia National Laboratories

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

EnerDel Lithium Power Systems, Dow, SK, A123 Systems, Air Products, Seeo, Quallion, Brookhaven National Laboratory, BASF The Chemical Company, Solvay, NREL National Renewable Energy Laboratory, Berkeley Lab, INL Idaho National Laboratory, Hitachi, Nissan, Argonne National Laboratory, Chrysler, Ford, GM

Geothermal Research Lab

Sandia National Laboratories

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

Sandia National Laboratories

LDRD

LABORATORY DIRECTED RESEARCH & DEVELOPMENT

LDRD INVESTMENTS

Highly Leveraged Investments

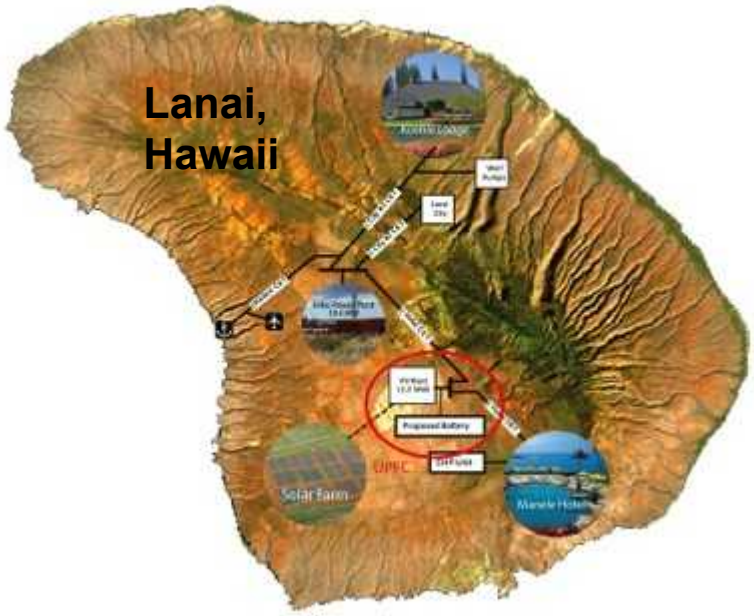
- "Grand Challenge" and leading LDRDs
  - Solar fuels - $14M (five years), completed in FY11
  - Renewables grid integration - $11M (three years), completing in FY13
  - Microsystems enabled PV - $10M (three years), completing in FY15
- Office of Science
  - Center for Integrated Nanoscience Technology - $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

Sandia National Laboratories

Grand Challenge Laboratory Directed Research and Development

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT



SSM SECURE SCALABLE MICROGRIDS

- 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

Sandia National Laboratories

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

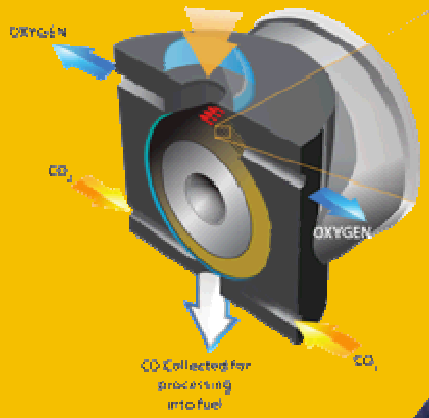
UNIQUE CAPABILITIES

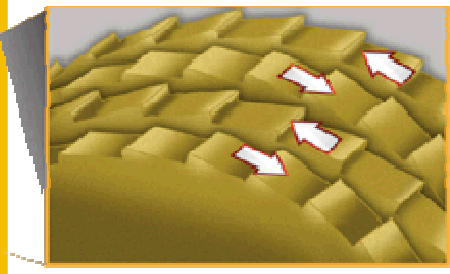
- Sandia is uniquely capable in concentrating solar, materials development, systems engineering, and computing to develop reactors, high-temperature metal oxide chemistry, and balance of systems efficiencies, cost, and cost-driver analysis.

KEY PARTNERSHIPS

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

S2P SUNSHINE TO PETROL





Alternate discs rotate in opposite directions

CURRENT WORK

- A concentrating solar-driven thermochemical heat engine to convert CO_2 and H_2O 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.

Sunlight + CO_2 + H_2O → Fuel + O_2

Solar Glitter

A Microsystem-Enabled PV Concept

Sandia National Laboratories

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Flexible
PV Modules

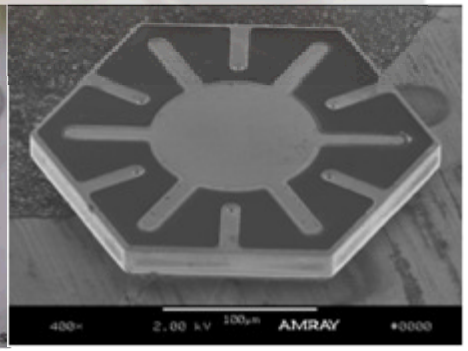
GOAL

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.

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