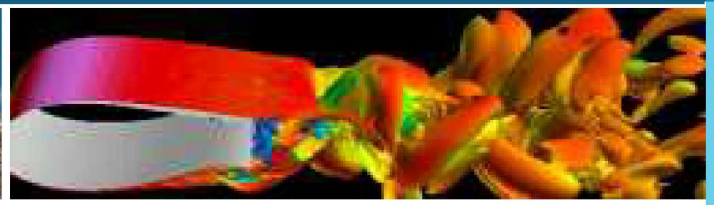
SAND2019-13490C

Sandia National Laboratories: Energy Programs, Research and Development



PRESENTED BY

Peter H. Kobos, Ph.D.

Manager, Water Power Technologies Program

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

Energy Program Areas & Approach

Energy Program Areas

- Renewables
- Grid Energy Storage
- Fossil
- Nuclear
- Hydrogen
- Biofuels
- Transportation
- Analysis

Approach

- De-risk low Technology Readiness Level (TRL) technologies
- Test & Verify Technologies (components, systems)
- Teaming with Technology Standards Institutions
- Partner with Industry
- Energy Security and Resilience

Sandia's Energy Programs Have Grown from Our Core Capabilities

Safe Nuclea
Waste Disp

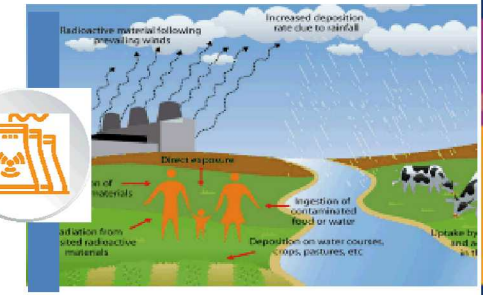
Solar Towe

Water
Distributio
Systems

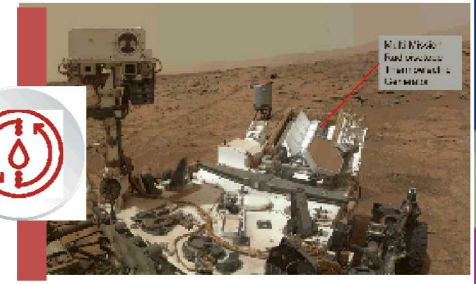
Energy Sto
Integration

Borehole
Integrity

Off-Site
quences of
Radioactive
mospheric
e Modeling

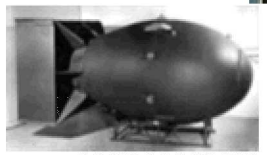


Safety
Analysis
of MARS
2020



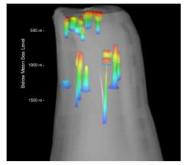
Advanced
aterials for
y Efficiency

Sandia's Energy Program Dates to the 70'S



BORN A NUCLEAR WEAPONS ENGINEERING LABORATORY WITH DEEP SCIENCE AND ENGINEERING COMPETENCIES

ENERGY CRISIS OF THE 1970S SPAWNED THE BEGINNING OF SIGNIFICANT ENERGY WORK

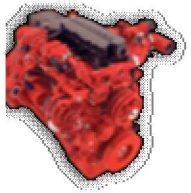


STRATEGIC PETROLEUM RESERVE

SYNTHETIC DIAMOND DRILL BIT

WASTE ISOLATION PILOT PLANT (WIPP) EVALUATION

NUCLEAR REACTOR SAFETY & RELIABILITY



CRF & CUMMINS PARTNERSHIP

JOINT BIOENERGY INSTITUTE

SCALED WIND FARM TECHNOLOGY (SWIFT) FACILITY COMMISSIONED

CRUDE OIL CHARACTERIZATION RESEARCH STUDY

3-D PRINTING, ADDITIVE MANUFACTURING, AND PROCESSES TO CREATE MOLDS FOR WIND TURBINE BLADES.

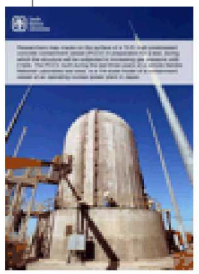
1950s | 1960s | 1970s | 1980s | 1990s | 2000-2010 | 2010-2018

OUR CORE NW COMPETENCIES ENABLED US TO TAKE ON ADDITIONAL LARGE NATIONAL SECURITY CHALLENGES

SOLAR TOWER OPENS

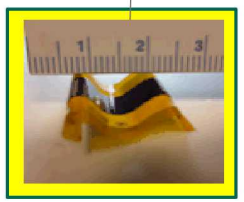
BATTERY SAFETY & RELIABILITY PROGRAM

COMBUSTIONS RESEARCH FACILITY (CRF) OPENS



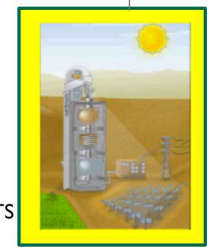
MELCOR COMPUTER CODE RELEASED

IDENTIFIED AS LEAD LAB FOR YUCCA MOUNTAIN



MICROSYSTEM-ENABLED PHOTOVOLTAICS

LARGE-SCALE POOL FIRE TESTS OF LIQUEFIED NATURAL GAS (LNG) ON WATER



HIGH TEMPERATURE FALLING-PARTICLE SOLAR RECEIVER

200% IMPROVEMENT IN ENERGY CAPTURE FROM WECS THROUGH ADVANCED CONTROLS

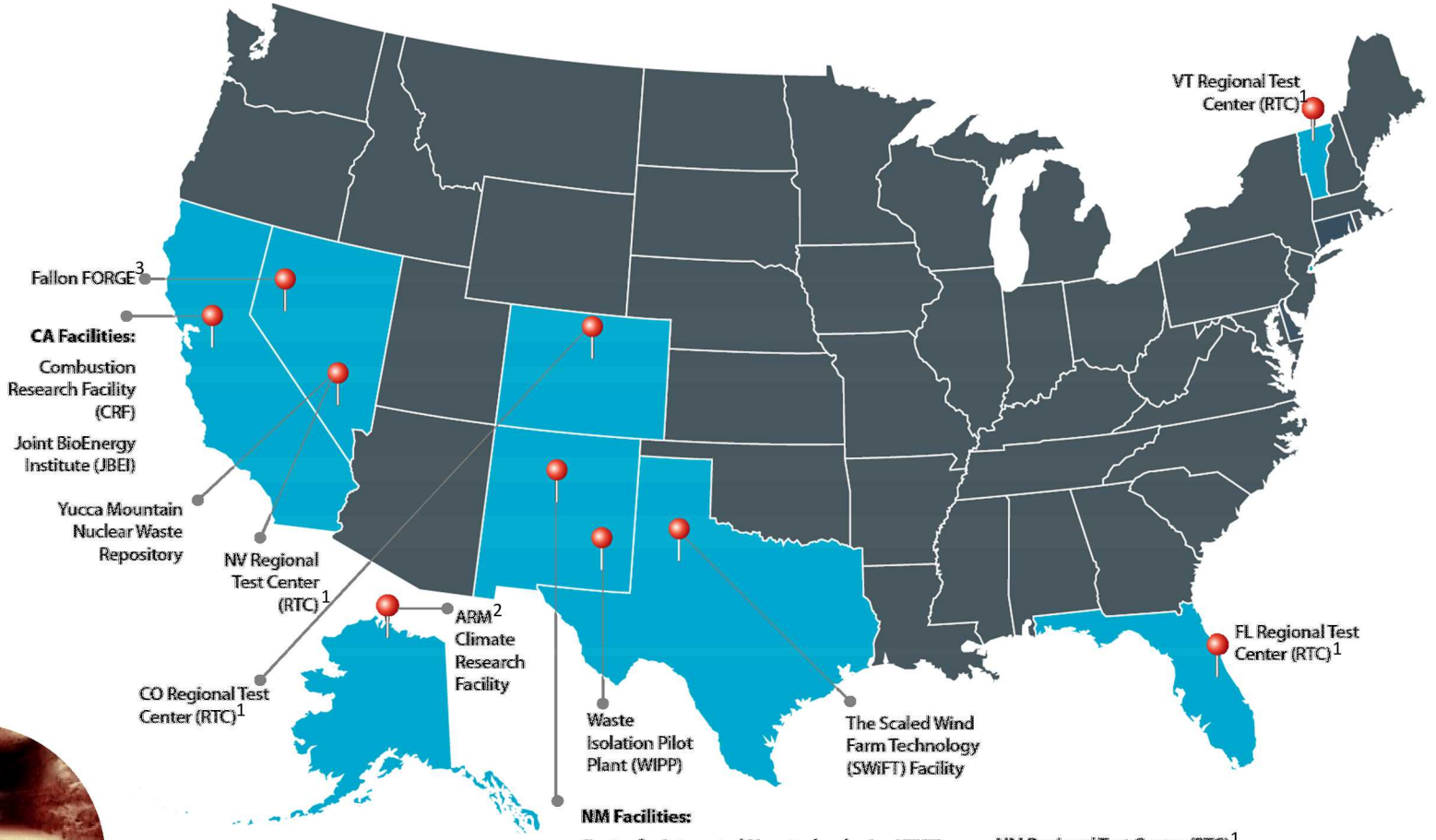
PV REGIONAL TEST CENTERS ESTABLISHED

Our Energy Facilities

FORGE

Brayton Cycle Lab

Waste Isolation Pilot Plant (WIPP)



NM Facilities:

- Center for Integrated Nanotechnologies (CINT)
- Distributed Energy Technologies Lab (DETL)
- Photovoltaic Systems Evaluation Lab (PSEL)
- Control & Optimization of Networked Energy Technologies (CONET)
- Battery Abuse Testing Laboratory (BATLab)
- NM Regional Test Center (RTC)[1]
- National Solar Thermal Test Facility (NSTTF)
- Geomechanics Lab
- Brayton Cycle Lab
- National Infrastructure Simulation & Analysis Center (NISAC)

National Solar Thermal Test Facility (NSTTF)

Geomechanics Lab

The Scaled Wind Farm Technology (SWiFT) Facility

ARM Climate Research Facility

[1] Regional Test Centers (RTCs) provide high fidelity testbeds for US solar companies to evaluate their technologies in varied climates.
[2] The Arctic Radiation Measurement (ARM) Climate Research Facility supports climate modeling, search & rescue operations, and other national security work.
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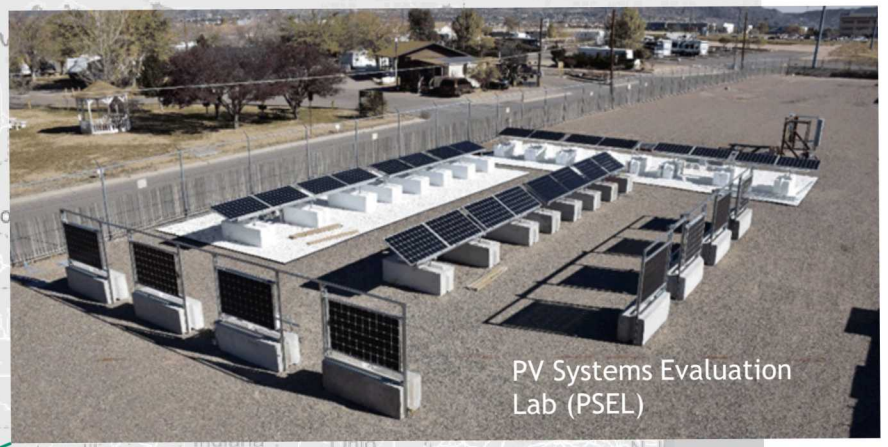
Unique Large-Scale Renewable Energy Facilities: NSTTF, PSEL and SWIFT

National Solar Thermal Test Facility (NSTTF)



PV Systems Evaluation Lab (PSEL)

Scaled Wind Farm Technology (SWIFT)

Our National Impact

PDC Drill Bits

Sandia contributed to the development of polycrystalline diamond compact (PDC) bits, one of the most important material advances for drilling tools in recent years. PDCs have allowed for the significant increase in shale oil production

Improving WECs

Sandia developed and integrated advanced controls algorithms for Wave Energy Converters (WEC): this increased experimental WEC output by 200-300%.

Wind Turbine Blade Manufacturing

Sandia worked with TPI to reduce the time required to manufacture blades and reduce the scrap rate which made it economical to manufacture blades in the US.

PV Systems Evaluation Lab (PSEL)

Researchers at PSEL have accelerated the adoption of new PV technologies by providing highly accurate, comprehensive performance characterization of cells, modules, arrays, and balance of system components in real world scenarios.

Every commercial CSP power-tower plant in the world has used technologies developed and tested at the National Solar Thermal Test Facility (NSTTF)

Recent R&D 100 Awards

2017: Sandia's Microgrid Design Toolkit

2016: Falling Particle Receiver for Concentrated Solar Energy

2015: New High Voltage Switch (SNL & United Silicon Carbide, Inc.)

2013: Solar Glare Analysis Tool (SGHAT)

2012: Microsystems Enabled Photovoltaics

Renewables: Floating Offshore Wind Energy

Floating offshore wind plants

- More components than land-based machines

Turbine costs

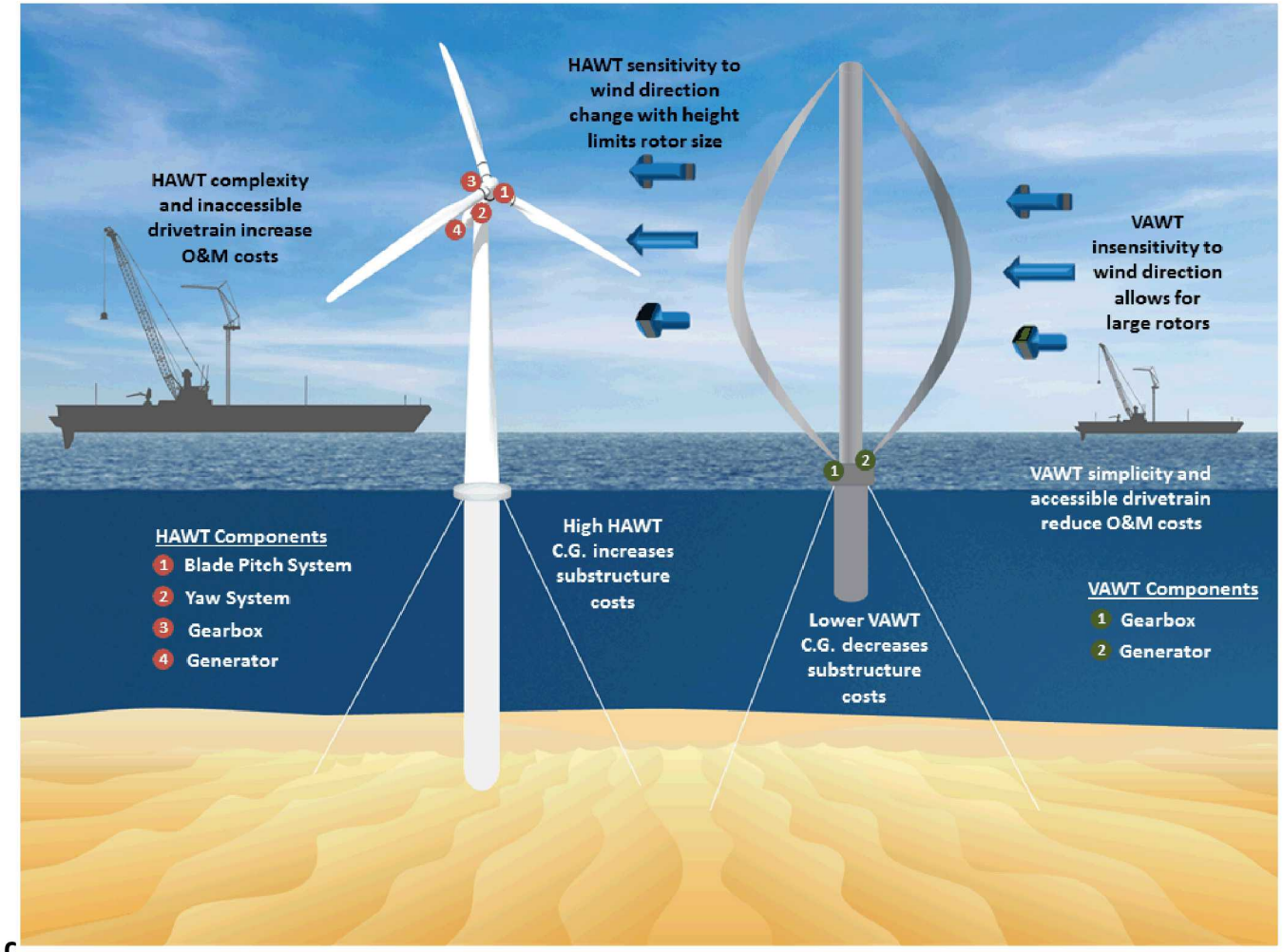
- 65% of wind plant costs for land-based sites compared to around 20% for floating offshore sites

Platform costs

- largest single contributor to LCOE

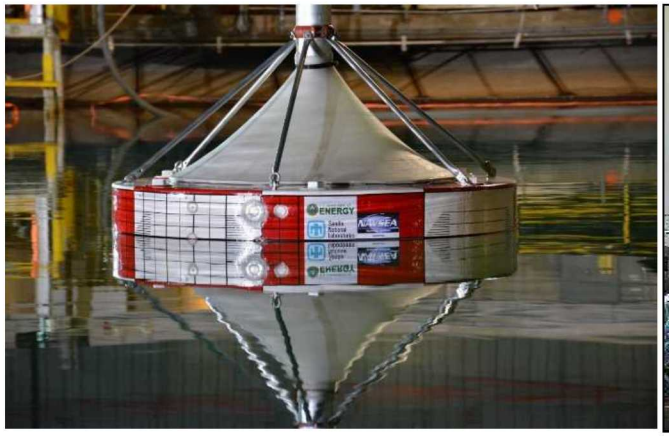
Vertical-axis wind turbines (VAWT)

- Lower center of gravity, reducing platform costs
- Improved efficiency over HAWTs at multi-MW scales
- Reduced O&M costs via reduced active components, platform-level placement of drivetrain



Renewables: Water Power Technologies

Water Power Device Testing & Robotics: Advanced Dynamics & Controls testing w/DOD, DOE, others

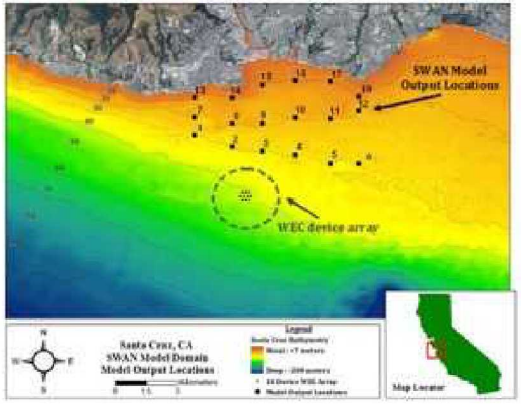


MASK Wave Basin Tests:
Increased power absorption by 200%+

Power Take Off Design & Testing

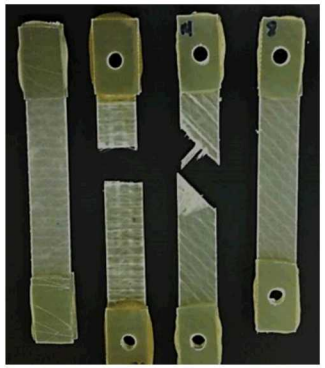
Mobile Lab Capability:
Software & Hardware Device Co-Design & Testing
Demo Video: https://youtu.be/lQgPLUfttN8

Deployment Support



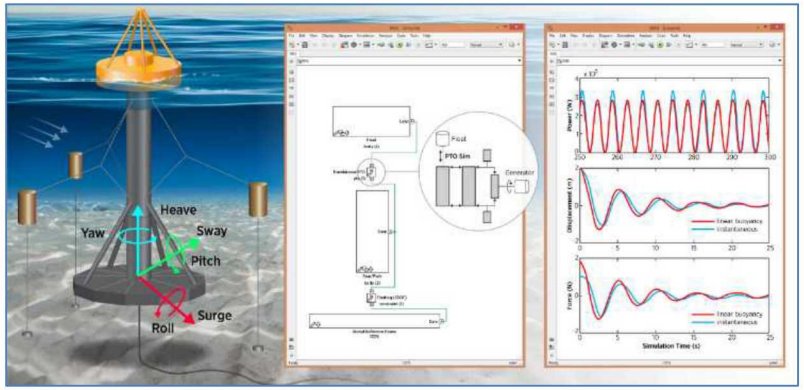
Device Array

Materials Testing *SNL, PNNL, NREL*



Lab & Field Testing

Design *SNL & NREL Partnership*

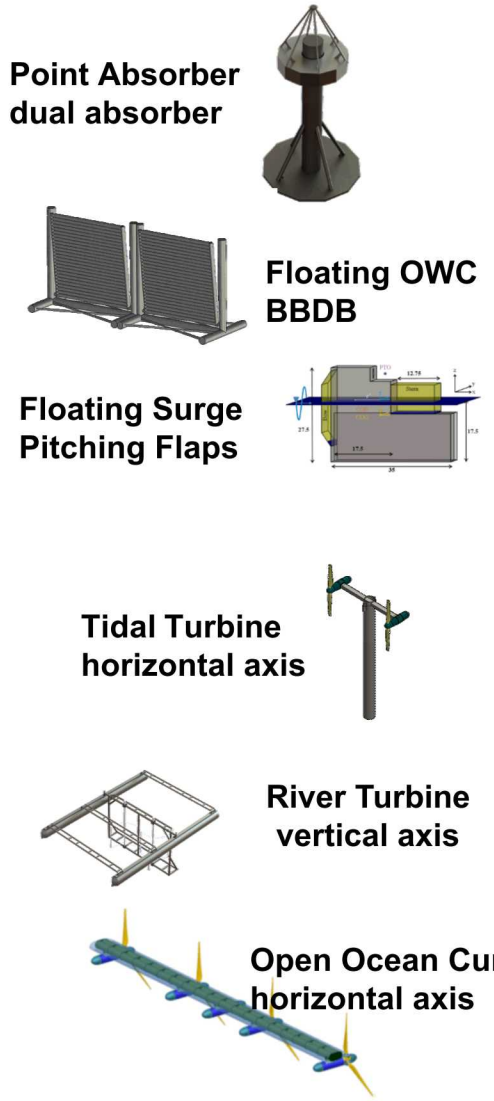


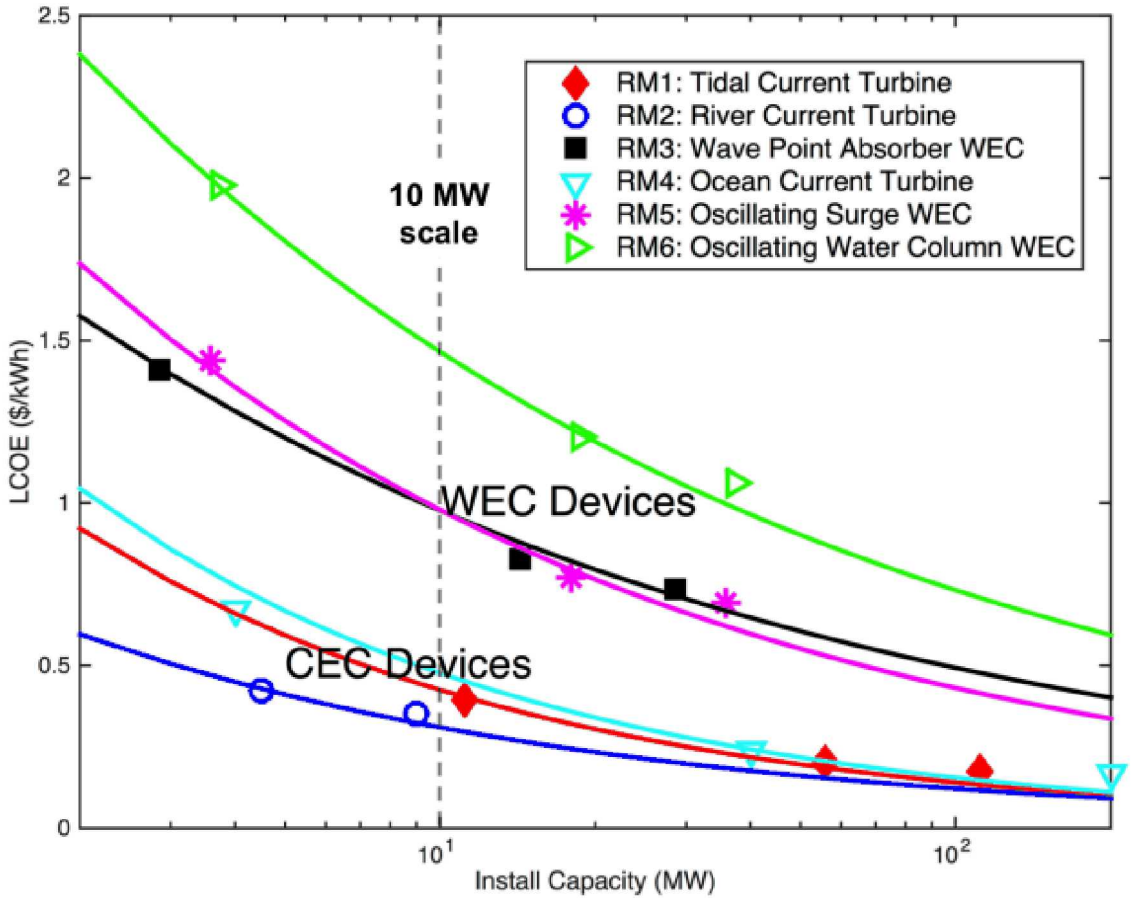
Software

Renewables: Water Power Reference Model

10 MW Installed Capacity

- Wave Energy Converters (WECs)
  - ≈ $0.98-1.53/kWh
  - At 10 MW structural mass is the largest contributor to LCOE.
- Current Energy Converters (CECs)
  - ≈ $0.31-0.45/kWh
  - Varying resource conditions impact installation, permitting, capacity factors, etc.





Technology Build out will help verify Cost reductions

Source: Neary et al., 2014, 2016, 2017

Grid Energy Storage

Energy Storage Safety and Reliability

- Cell and module level safety test and analysis.
- Engineered safety of large systems.
- Predictive models for ES safety.
- Storage safety standards and protocols.

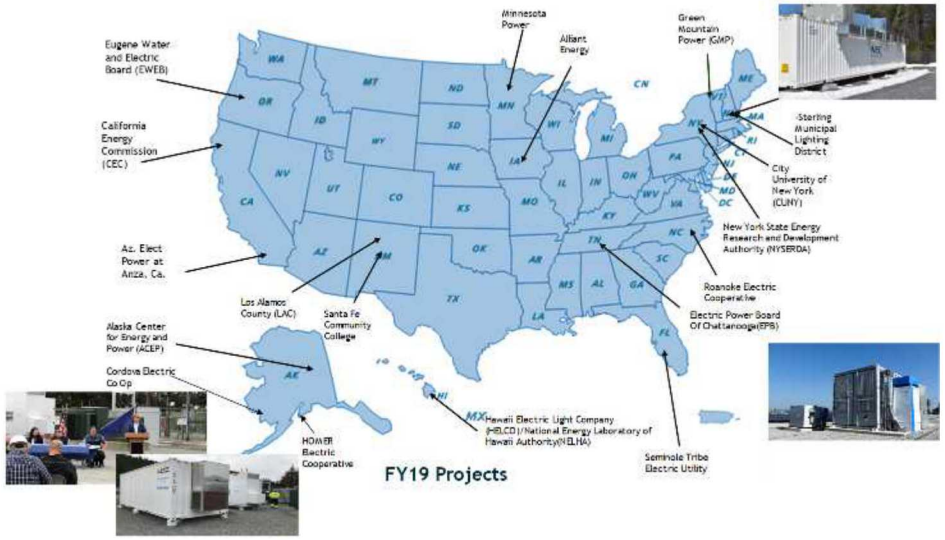
Power Electronics and Power Converters

- Reduce cost/kW (PCS accounts for 20-60% of capital cost)
- Increase reliability (Downtime is $$)
- Increase efficiency (Loss is $$)
- Enhance control over power flow in ESS

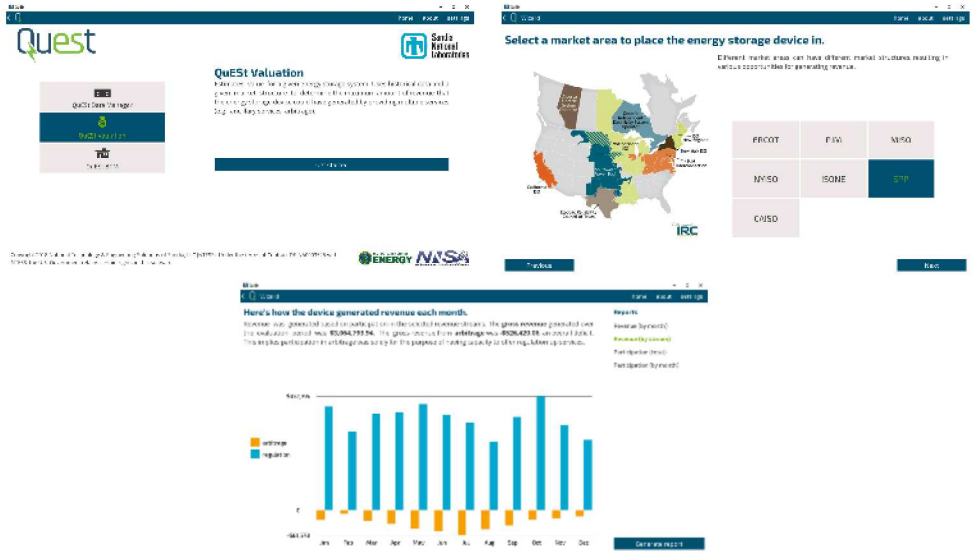
Energy Storage Analytics and Controls

- Developing analytics and controls for integration of utility class storage systems.
- Software tools for optimal use of energy storage across the electricity infrastructure.
- Standards development.
- Engineering analysis for demo projects

Energy Storage Demonstration Projects



Quest Open-source, Python-based Energy Storage Analysis Suite



Sandia Grid Modernization

1980s

Distributed Energy Technology Laboratory (DETL) opens

Sandia designs first battery test facility hosted by PSE&G in NJ

Lead Center for the Exploratory Battery Technology Development and Testing Project

1990/2000s

Interconnected PV systems work begins

US Infrastructure Assurance Strategic Roadmaps

DOE designates Sandia as US Rep to IEC TC57, (standards for information exchange for power systems)

2003/04

U.S. DEPARTMENT OF ENERGY | Electricity Delivery & Energy Reliability

DOE/OE Established

National SCADA Test Bed (NSTB) established

IEEE 1547: *Standard for Interconnecting Distributed Resources with Electric Power Systems*

DOE/EPRI Electricity Storage Handbook Published

Report of the Commission to Assess the Threat to the United States from Electromagnetic Pulse (EMP) Attack

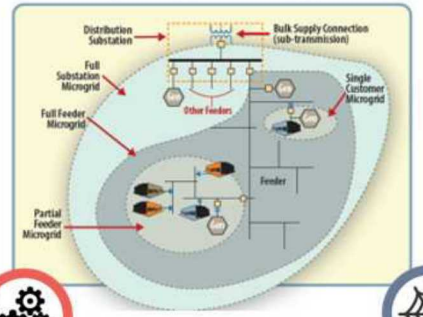
Common Vulnerabilities in Critical Infrastructure Control Systems

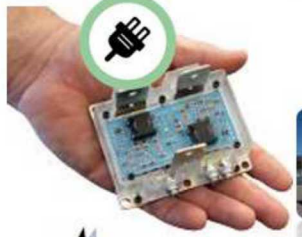
2008

ESM work begins-LDRD

2009

Energy Surety Microgrid (ESM™) Methodology





SiCPower Module

ARRA-funded reconfiguration of DETL to enable high penetration experimentation on distributed generation

2010

Smart Power Infrastructure Demonstration for Energy Reliability and Security (SPIDERS) established

R&D100: Micro Power Source

Energy Storage Test Pad established as the first facility to test 1MW class storage systems at a national lab

2011

Enabling Secure, Scalable Microgrids with High Penetration Renewables Grand Challenge

SSM SECURE SCALABLE MICROGRIDS It's the end of the grid as we know it

R&D100 Award Winners:
-Ultra-high-voltage Silicon Carbide Thyristor
-The Demand Response Inverter

2013

Sandia develops the DOE/SNL Global Energy Storage Database

2014

Grid Modernization Continuum established & Sandia participates in 29 GMLC projects

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

2015

2015 R&D 100 WINNER

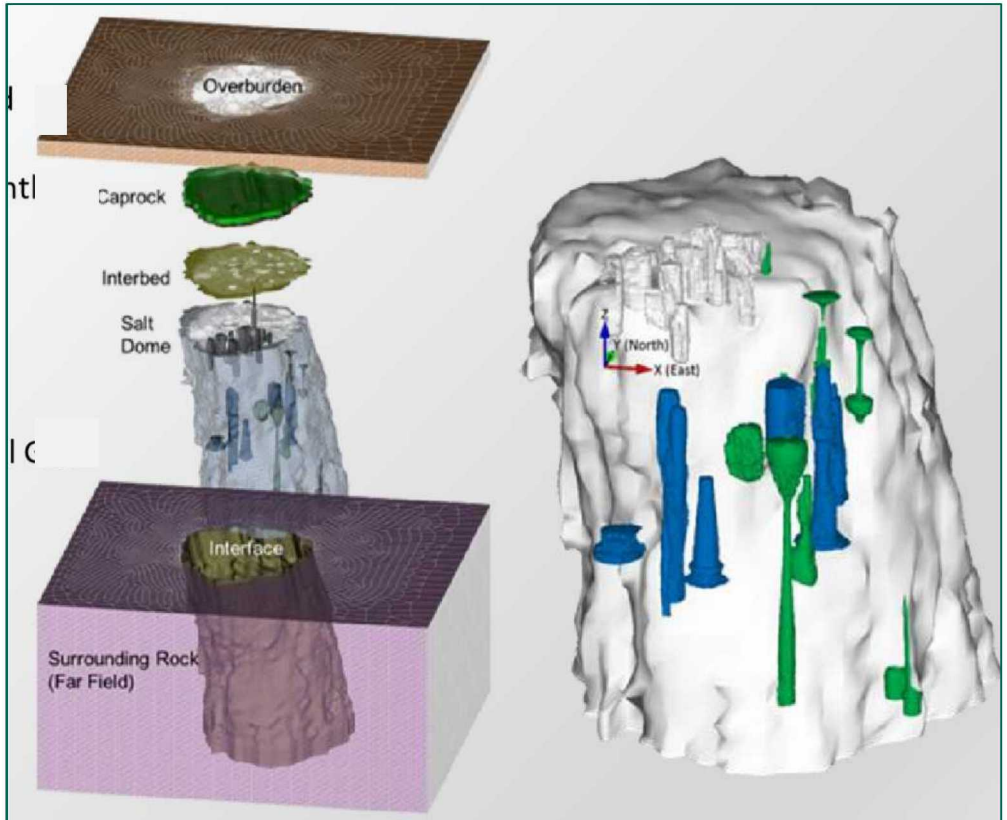
Sandia and United Silicon Carbide, Inc., create new high voltage switch

SIRFN established as Annex 5 of ISGAN

Microgrid Design Toolkit available

Fossil Energy

U.S. Strategic Petroleum Reserve (SPR)

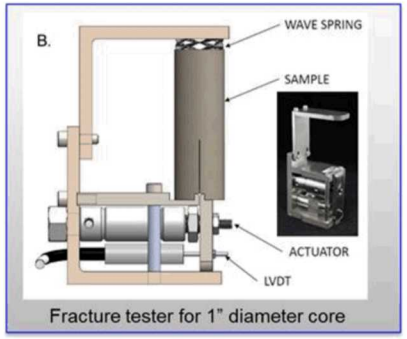


SPR Bayou Choctaw salt dome 3D rendering and accompanying geomechanical model

Clean Coal and Carbon Management Carbon Storage and Sequestration

Geomechanics of CO_2 Reservoir Seals

An in-situ fracture tester was developed to examine the effects of CO_2 injection on Caprock integrity by measuring the effects of different solutions and their concentrations on fracture velocities.



Fracture tester for 1" diameter core

SWP: Southwest Regional Partnership on Carbon Sequestration

SWP has completed an initial characterization of the potential to store CO_2 in geologic formations and a validation of the most promising storage opportunities. Current work is underway at the Farnsworth Unit, Texas, enhanced oil recovery site using CO_2 captured from ethanol and fertilizer plants that is injected into the underground oil reservoir.

Chemical-Mechanical Effects on Fracture

This work focuses on developing a fundamental atomistic-level understanding of the chemical-mechanical processes that control subcritical cracks in low-permeability geomaterials. This links atomic-scale insight to macroscale observables, with applications to fracking as well as deep geologic disposal of CO_2. Work sponsored by SNL LDRD program.

Phoenix Series Large Scale LNG Pool Fire Experiments

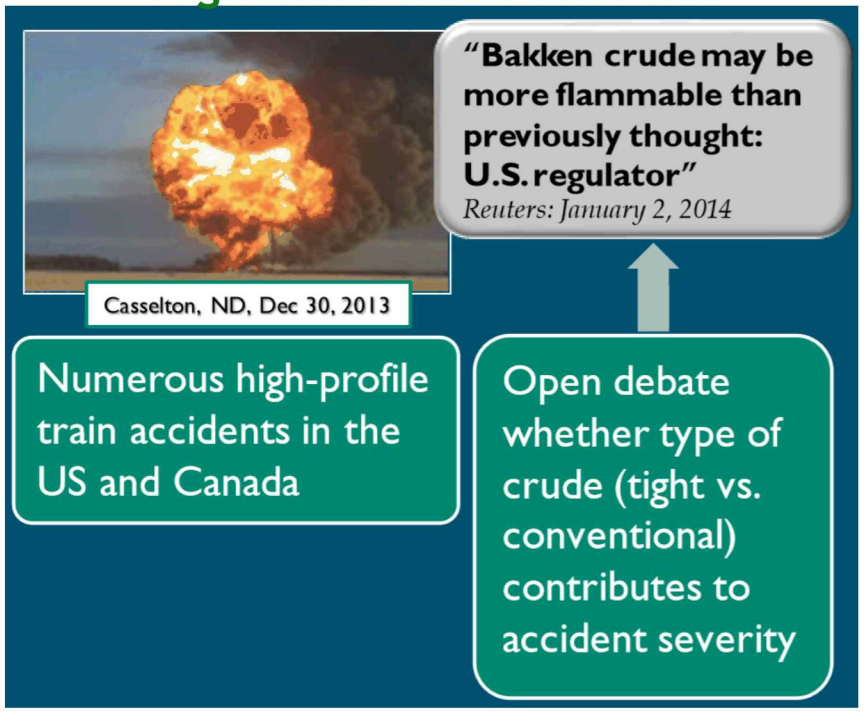
Blanchat, T., SAND2011-4850C

Fossil Energy

Crude Oil Characterization Research Study

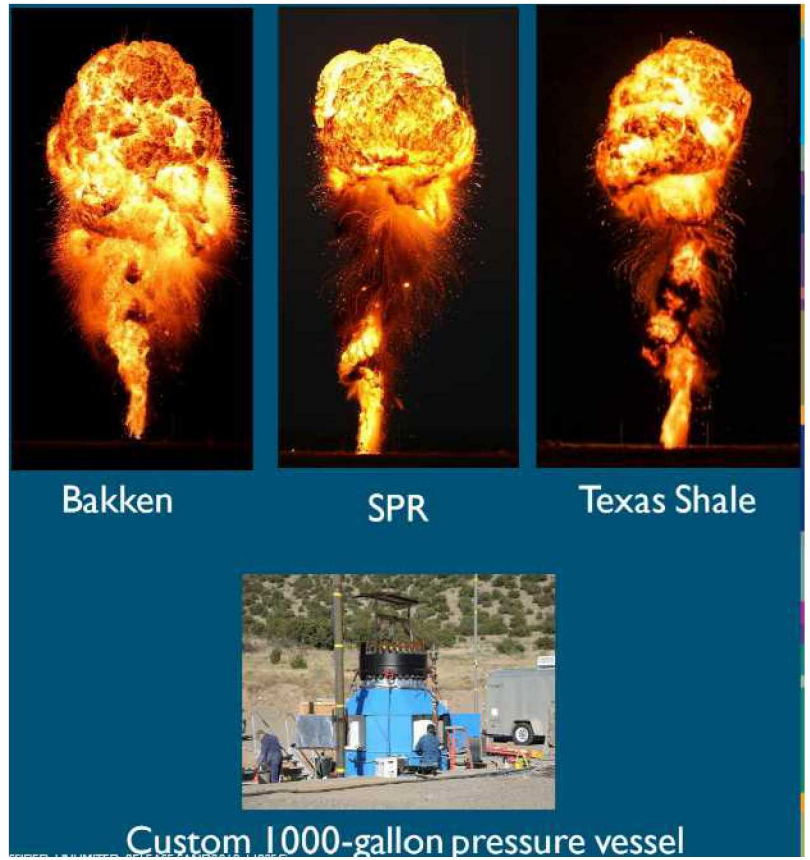
- Objective: Evaluate whether crude oils currently transported in North America, including those produced from "tight" formation exhibit:
  - physical or chemical properties that are distinct from conventional crudes
  - how these properties affect parameters required to assess thermal hazard distances

Crude transport by rail poses risks recognized by US & Canadian regulators & stakeholders



Thermal Hazard Distances

Pool Fire and Fireball Tests (For Comparative Purposes only)



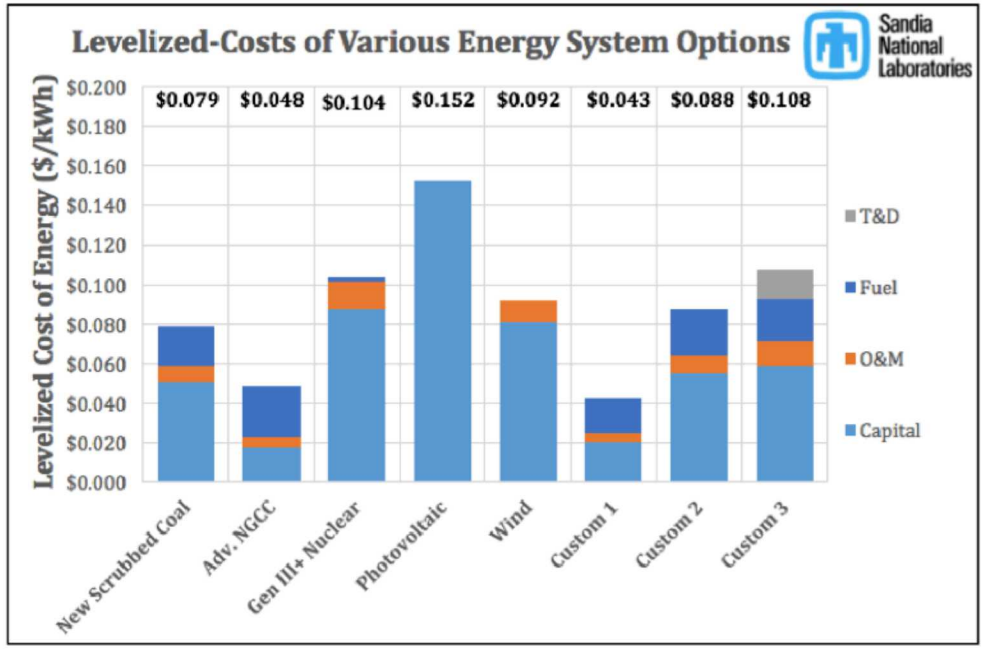
Lord, D., SAND2019-11605C; Luketa, A., SAND2019-11825C.

Nuclear Energy / Clean Coal / Energy

Brayton Cycle

Sandia has been developing the Supercritical Carbon Dioxide (sCo2) Closed Brayton Cycle. Brayton Cycles can achieve higher energy conversion efficiencies at 1/10th the cost of comparable steam Rankine cycles. The technology is being demonstrated in the Nuclear Energy Systems laboratory/Brayton lab.

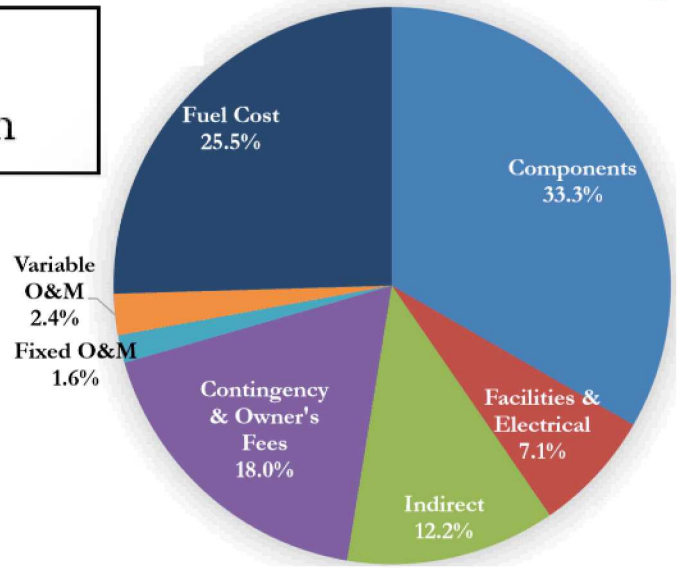
An Integrated Techno-economic Modeling Tool for sCO_2 Brayton Cycles



Drennen and Lance, 2019, SAND2019-8738.

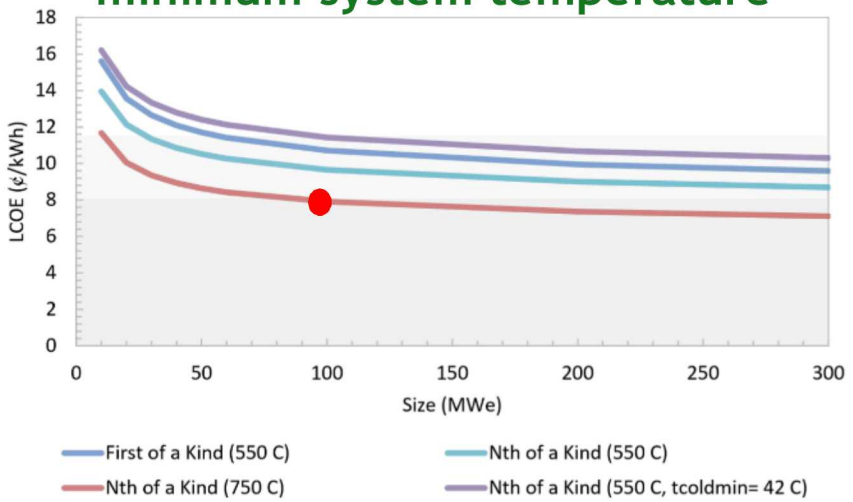
Estimated LCOE for an n^{th}-of-a-kind, 100 Mw_e RCBC w/dry cooling

LCOE:
0.083$/kWh



Leveraging NETL Expertise & Approaches

LCOE as a function of plant size, turbine inlet temperature, & minimum system temperature



Hydrogen: Research in Materials, Safety, Costs

Materials – for hydrogen production, storage and utilization

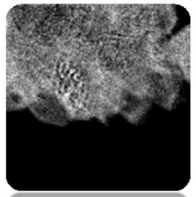
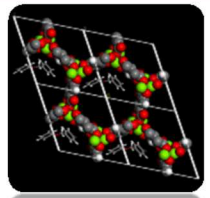
Safety – risk analysis and the creation of risk-informed standards

Hydrogen Production from Renewables

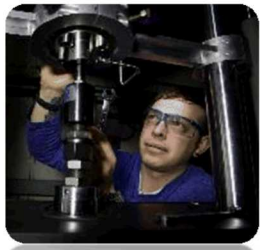

Advanced water-splitting materials and technologies for large-scale H_2 production

Hydrogen Storage Materials and Solutions

Discovering the behavior and performance of solid storage materials


Hydrogen-Materials Compatibility

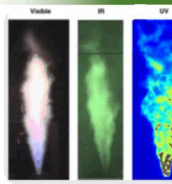


Low-cost, hydrogen-compatible materials and the science basis for their qualification

Fuel Cells

Membrane systems for enhanced electrochemical performance

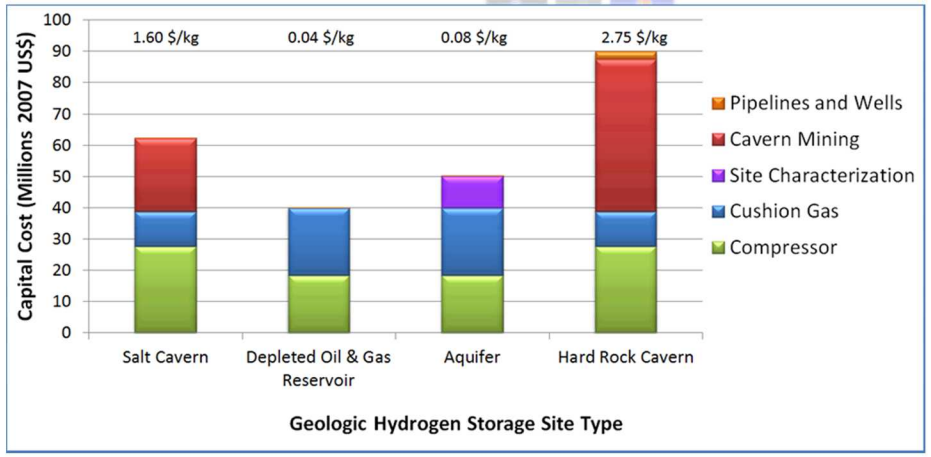
Hydrogen Fueling Infrastructure



H_2 release behavior and risk assessment to define the safety envelope for storage & delivery

Technologies for Non-Vehicle Applications

Marine and rail applications

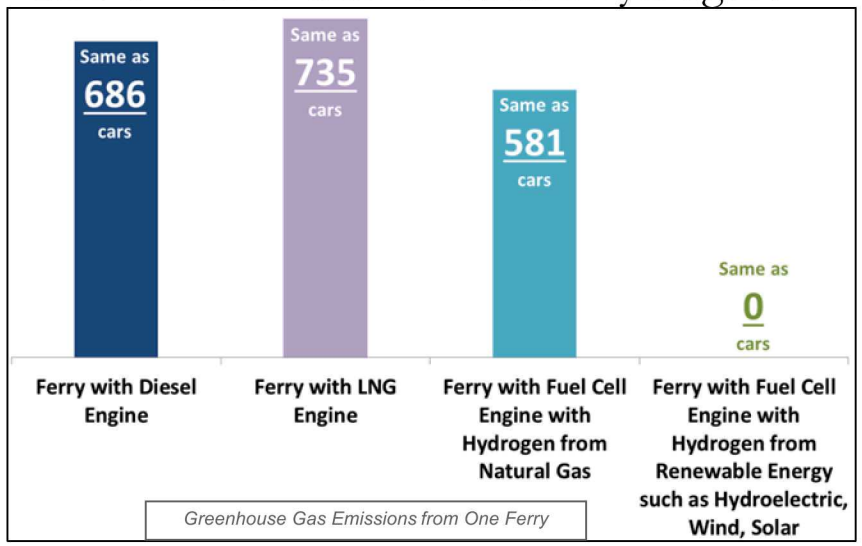



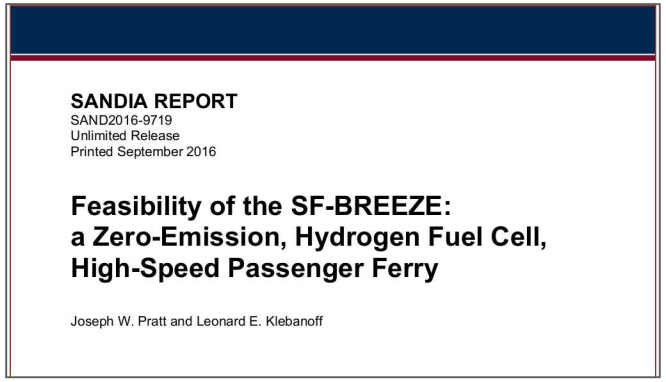
Hydrogen

Feasibility of Hydrogen Fuel Cell-Powered Maritime Vessels

- Are hydrogen powered marine vessels feasible considering technical, economic and regulatory factors?

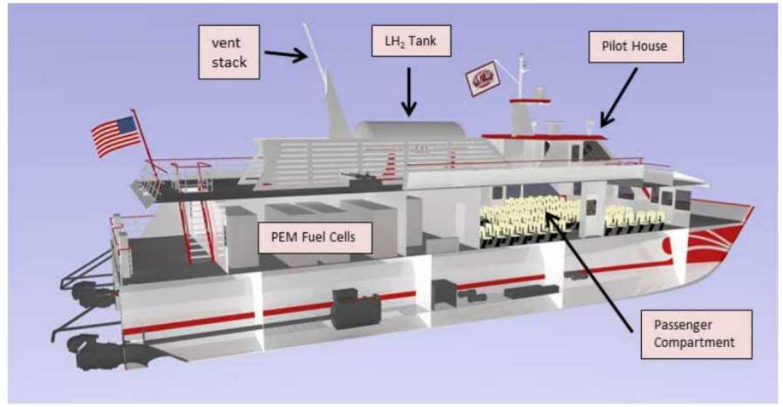
- SF-BREEZE high-speed passenger ferry
  - Catamaran design has similar capacity to existing ferry service.
  - Analysis shows modest emissions reduction with SMR-produced hydrogen, zero emission with renewable hydrogen.



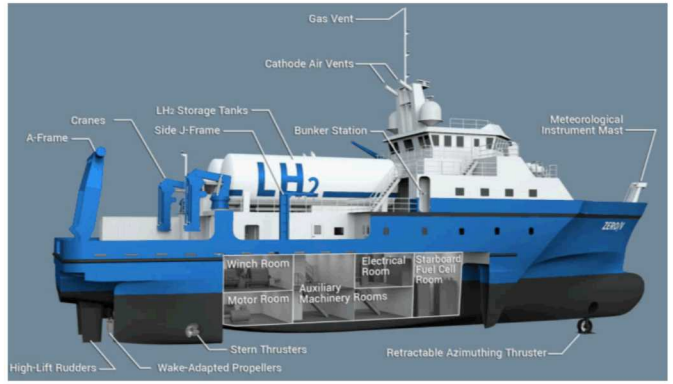

SANDIA REPORT
SAND2016-9719
Unlimited Release
Printed September 2016

Feasibility of the SF-BREEZE: a Zero-Emission, Hydrogen Fuel Cell, High-Speed Passenger Ferry

Joseph W. Pratt and Leonard E. Klebanoff



- Zero-V coastal research vessel
  - Feasibility was found for a vessel able to perform 14 Scripps science missions with a 2,400 nautical mile range.



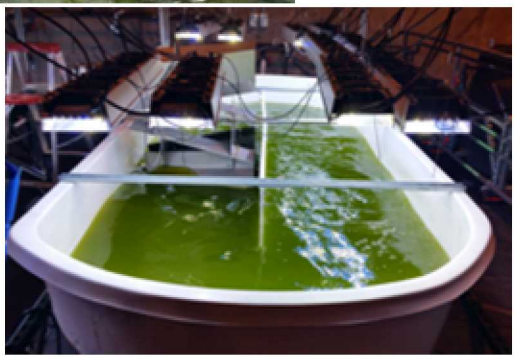
Biofuels

Algae

Sandia is achieving success and recognition in three specific areas:

- Turf Algae
  - Robust polycultures grown on polymer mats to treat ag runoff and other nutrient-loaded surface water, and to produce algal biomass for energy / fuel / feed applications.
- The “Crash Lab”
  - Understand causes of pond crashes in algal monoculture systems
  - Develop response & prevention strategies
- Genomics
  - Leveraging expertise & capabilities to develop advanced, more productive strains of algae and cyanobacteria.


Turf algae



Biofuels & Bioproducts:

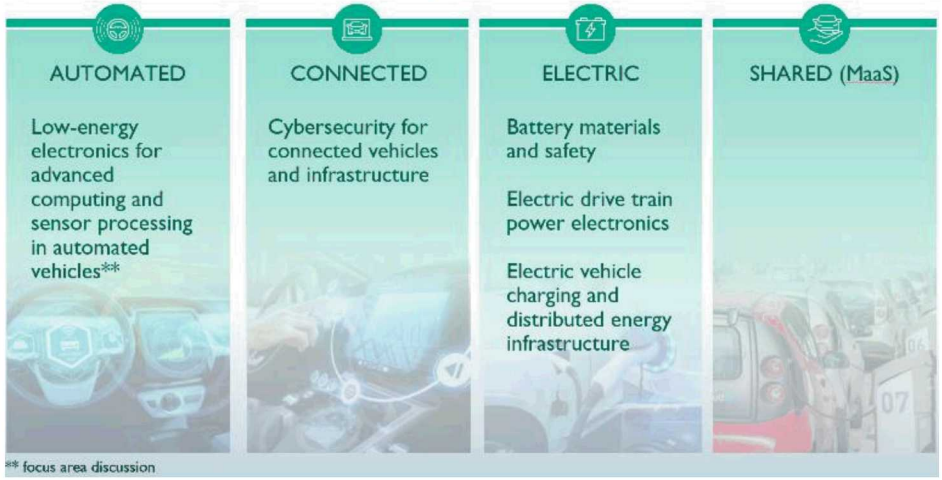
- Genomics / Metabolomics / Microbiomics
- Algae – Attached “Turf” Algae & Algal Pond Stability
- Discovery Tools
  - imaging, novel sensors, micro-fluidics, field-test sites, relationships, etc.
- Biomass (pre-) Treatment & Fermentation

DOE Secretary’s Achievement Award
Pretreatment & Process Development Team

Transportation

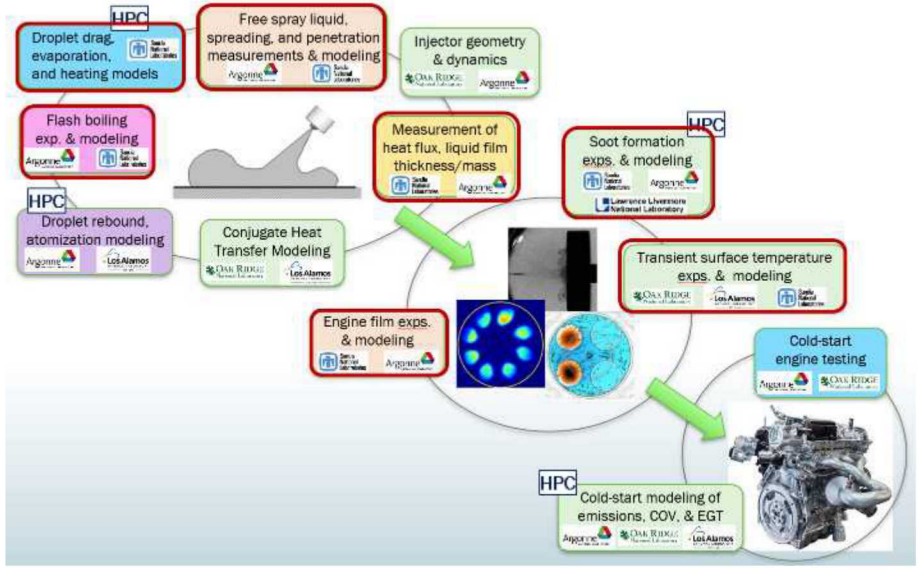
Co-Optimization of Fuels and Engines

On-Road Transportation Trends



Battery Safety and Extreme Fast Charging

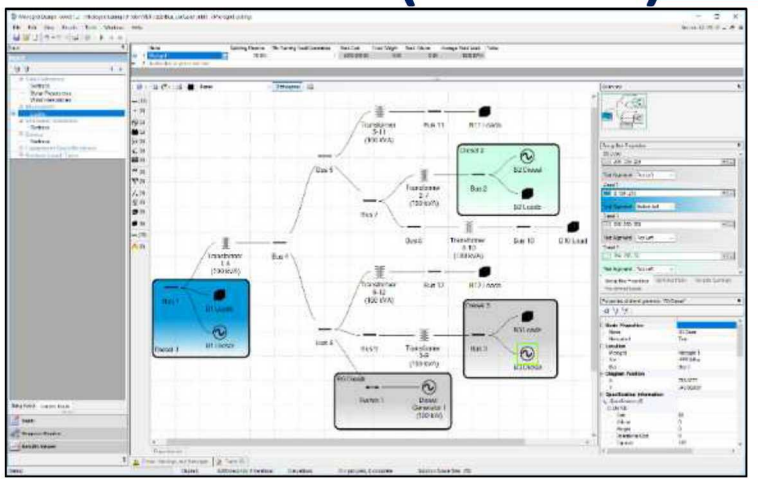
Fundamental Model Development Supported by High Performance Computing - Multiple National Labs

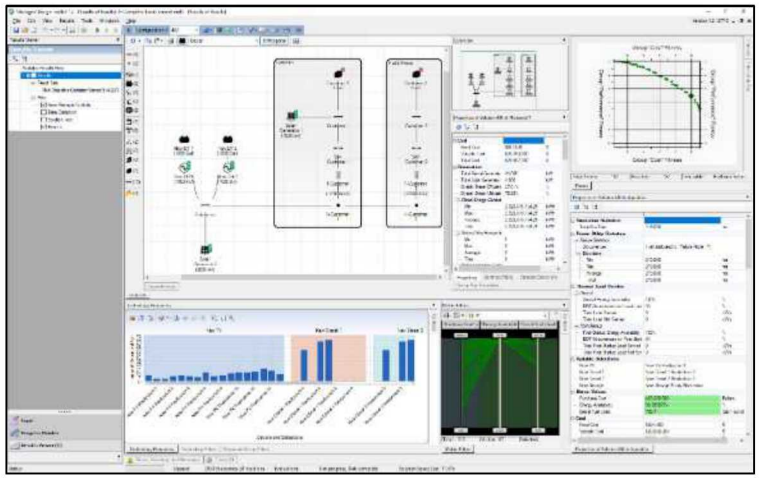


Analysis: Sandia's Microgrid Design Toolkit (MDT)

- Produces a Pareto frontier:
  - Efficient alternative Microgrid designs and visualizations
  - To help a designer understand system trade-offs.
- Unique capability to:
  - Optimize topology, generation, and asset sizes
  - Over multiple measures of performance.
- Toolkit Attributes allow for optimized scenarios focusing on:

Performance | Reliability | Operations | Renewables | Service





History

SPIDERS (2011)

v1.0 Publicly Released (2016)

Use for GMLC and Others (2017-*)

DOE OE Funding (2014)

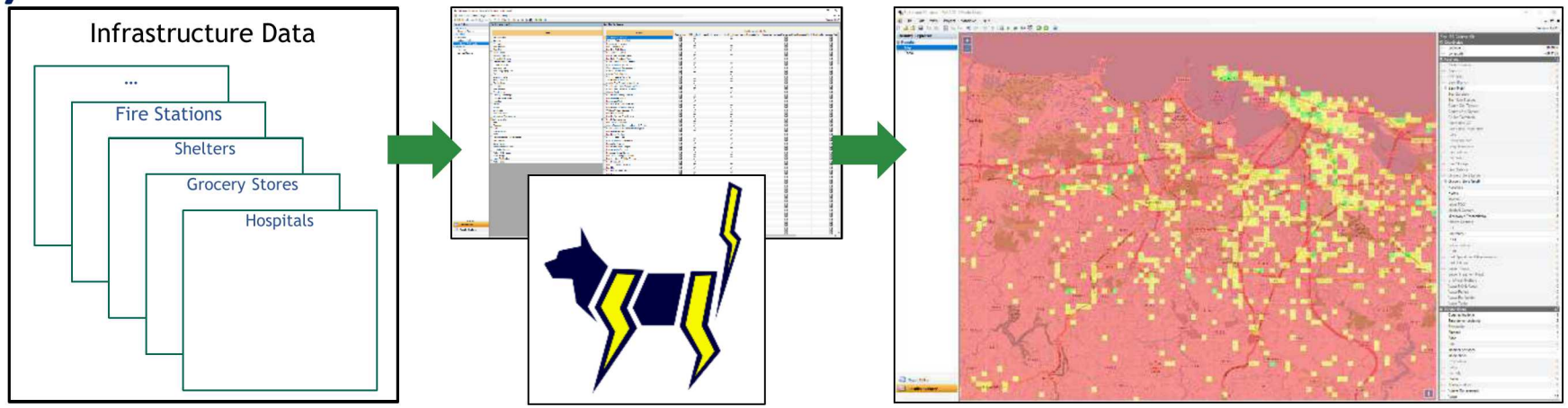
USMC SYSCOM Funding (2016)

R&D 100 Award (2017)

http://www.energy.gov/oe/services/technology-development/smart-grid/role-microgrids-helping-advance-nation-s-energy-syst-0

Analysis: Resilience Node Cluster Analysis Tool (ReNCAT) 1.0

Determines Potential Microgrid locations



- ReNCAT takes infrastructure data and determines potential microgrid locations in an urban area based on high-density clusters of critical services subject to design basis threats (DBTs)
- Users can include any number of infrastructure sectors and threats, and may specify both the desired area size for microgrids and the minimum service level required
- ReNCAT displays results in report form and as a color-coded interactive map showing potential locations & service levels

- ReNCAT has been used to suggest portfolios of microgrids for the city of New Orleans and the island of Puerto Rico
- Version 1.0 is in the final stages of the copyright process and will be available for use by U.S. entities
- Version 2.0 is under development and will utilize optimization to locate potential microgrids that best serve the community based on the distribution system layout, population location, asset services/service levels, and cost

Summary

- Sandia works across all major energy carrier types & select infrastructure
  - Renewables, Grid Energy Storage, Fossil, Nuclear, Hydrogen, Biofuels, Transportation, Analysis
- Sandia partners with other National Labs and Industry Partners to ensure relevance
  - Analysis capabilities, Technology Integration to existing Infrastructure

Thank You