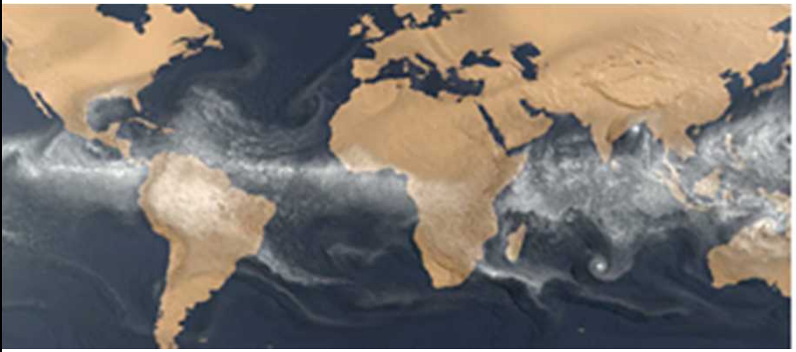
SAND2016-8332C

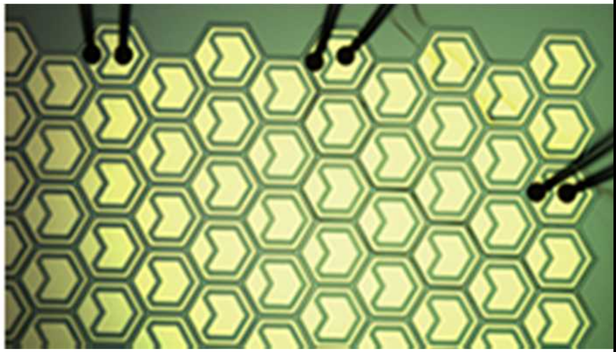
Exceptional service in the national interest

Sandia National Laboratories

Twitter: @SandiaEnergy

Website: energy.sandia.gov





Toward A Secure and Sustainable Energy Future

Juan Torres

Deputy to the Vice President

Energy and Climate Programs

U.S. DEPARTMENT OF ENERGY

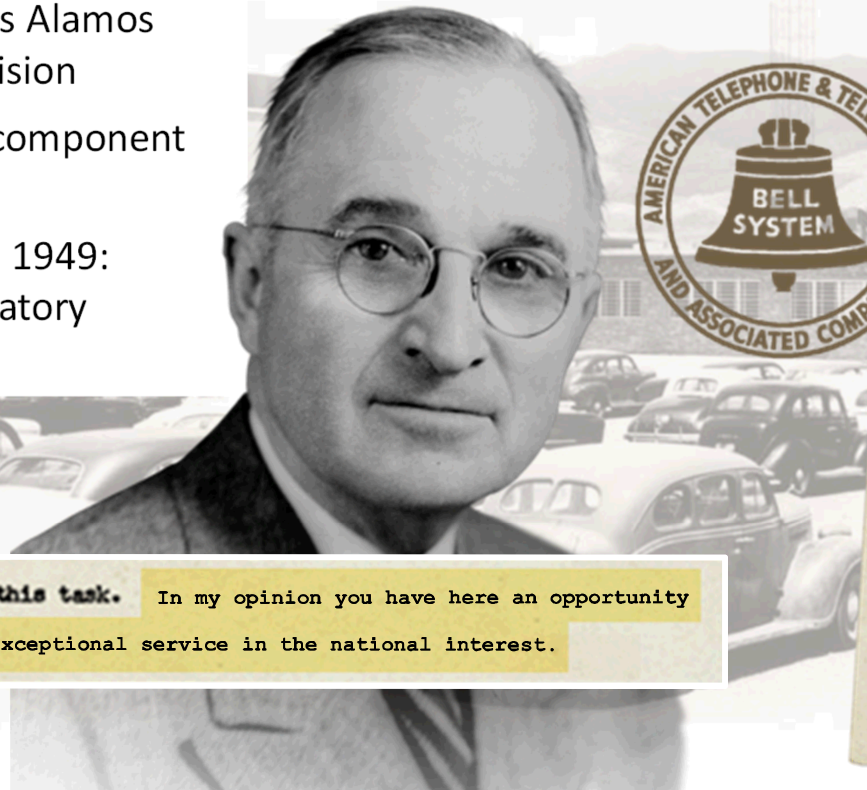
NNSA National Nuclear Security Administration

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. SAND2016-0090 PE

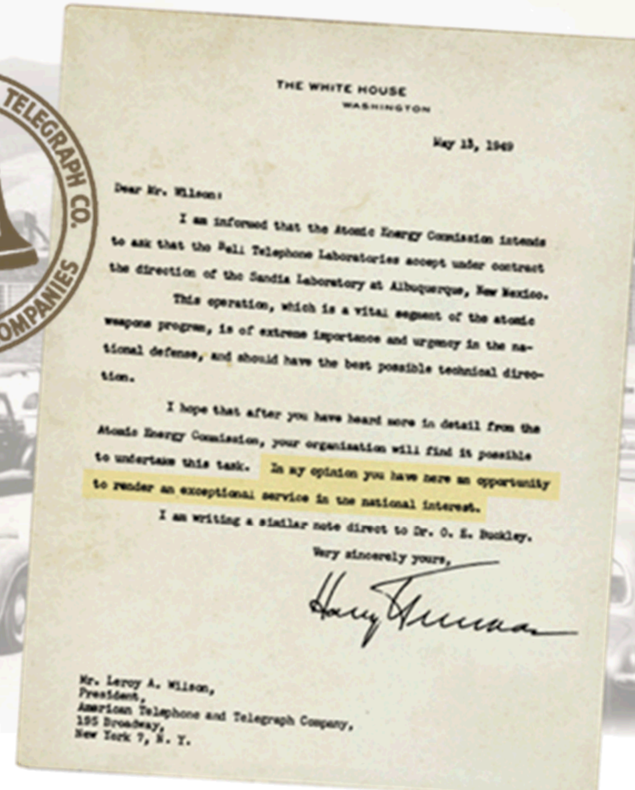
Sandia's History

Exceptional service in the national interest

- July 1945: Los Alamos creates Z Division
- Nonnuclear component engineering
- November 1, 1949: Sandia Laboratory established



to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.



THE WHITE HOUSE
WASHINGTON

May 13, 1949

Dear Mr. Wilson:

I am informed that the Atomic Energy Commission intends to ask that the Bell Telephone Laboratories accept under contract the direction of the Sandia Laboratory at Albuquerque, New Mexico.

This operation, which is a vital segment of the atomic weapons program, is of extreme importance and urgency in the national defense, and should have the best possible technical direction.

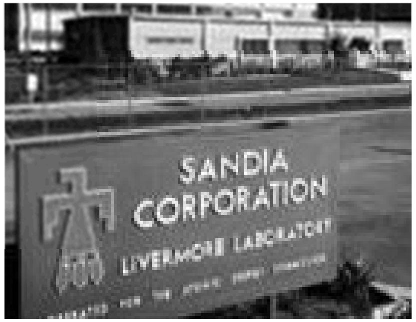
I hope that after you have heard more in detail from the Atomic Energy Commission, your organization will find it possible to undertake this task. In my opinion you have here an opportunity to render an exceptional service in the national interest.

I am writing a similar note direct to Dr. O. E. Buckley.

Very sincerely yours,

Harry Truman

Mr. Leroy A. Wilson,
President,
American Telephone and Telegraph Company,
195 Broadway,
New York 7, N. Y.



Sandia Sites

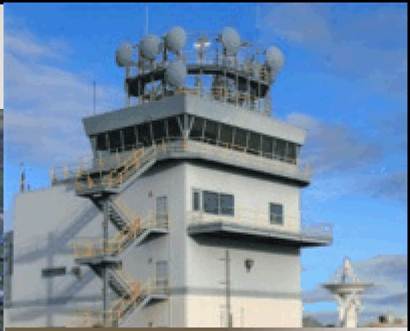
Albuquerque, New Mexico

Livermore, California

Kauai, Hawaii

Waste Isolation Pilot Plant, Carlsbad, New Mexico

Pantex Plant, Amarillo, Texas



Tonopah, Nevada

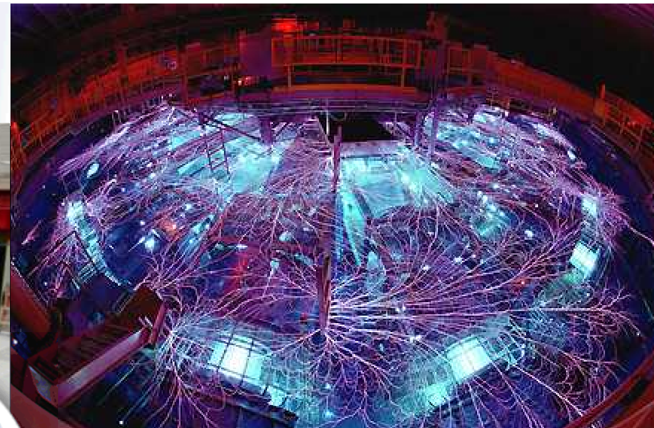
Sandia's Missions

Sandia National Laboratories

Our Research Framework

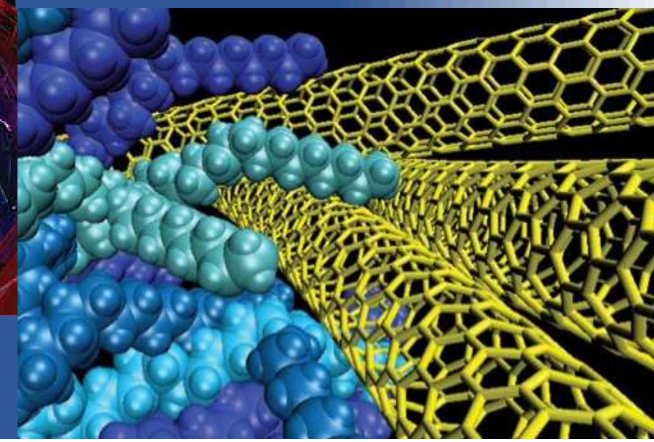
Strong research foundations play a differentiating role in our mission delivery

Computing & Information Sciences

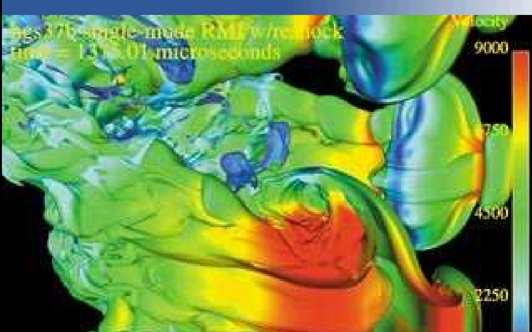


Radiation Effects & High Energy Density Science

Materials Sciences

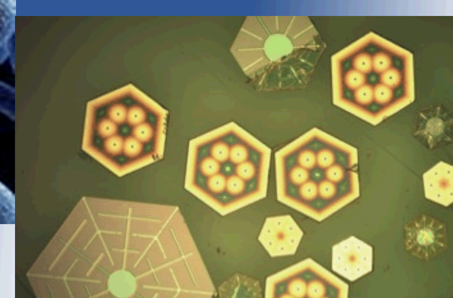


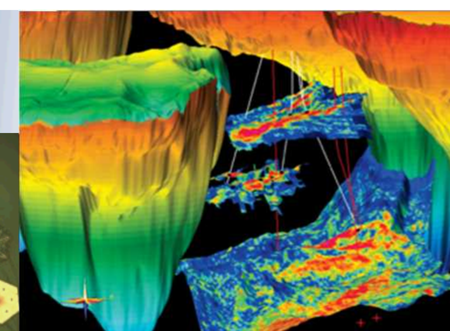
Engineering Sciences



Bioscience

Nanodevices & Microsystems





Geoscience

The National Labs Are Making an Impact on the Nation's Energy Future

Office of Science Laboratories

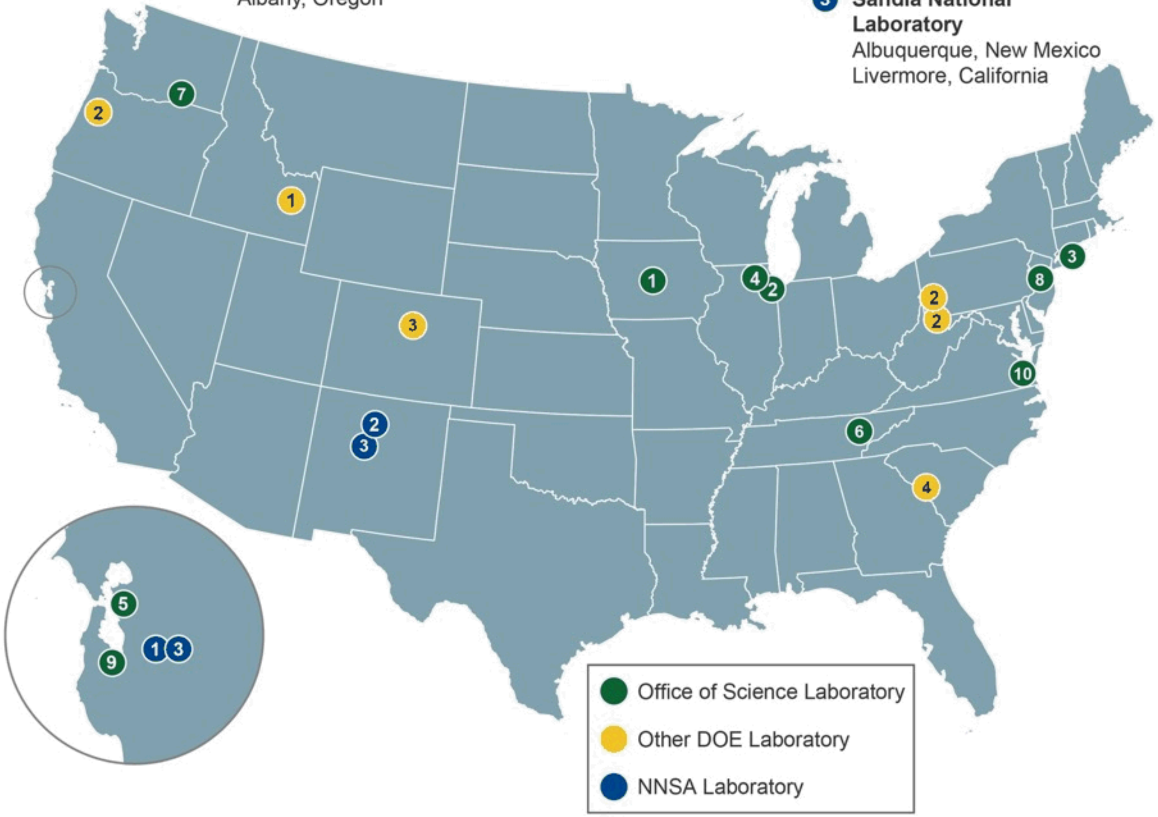
1. **Ames Laboratory**
   Ames, Iowa
2. **Argonne National Laboratory**
   Argonne, Illinois
3. **Brookhaven National Laboratory**
   Upton, New York
4. **Fermi National Accelerator Laboratory**
   Batavia, Illinois
5. **Lawrence Berkeley National Laboratory**
   Berkeley, California
6. **Oak Ridge National Laboratory**
   Oak Ridge, Tennessee
7. **Pacific Northwest National Laboratory**
   Richland, Washington
8. **Princeton Plasma Physics Laboratory**
   Princeton, New Jersey
9. **SLAC National Accelerator Laboratory**
   Menlo Park, California
10. **Thomas Jefferson National Accelerator Facility**
    Newport News, Virginia

Other DOE Laboratories

1. **Idaho National Laboratory**
   Idaho Falls, Idaho
2. **National Energy Technology Laboratory**
   Morgantown, West Virginia
   Pittsburgh, Pennsylvania
   Albany, Oregon
3. **National Renewable Energy Laboratory**
   Golden, Colorado
4. **Savannah River National Laboratory**
   Aiken, South Carolina

NNSA Laboratories

1. **Lawrence Livermore National Laboratory**
   Livermore, California
2. **Los Alamos National Laboratory**
   Los Alamos, New Mexico
3. **Sandia National Laboratory**
   Albuquerque, New Mexico
   Livermore, California



Sandia Addresses Energy Challenges

Sandia National Laboratories

1970s
Multiprogram laboratory
Energy crisis

1980s
Missile defense work
Cold War

1990s
Post–Cold War transition
Stockpile stewardship

2000s
START
Post 9/11
National security

2010s
LEPs
Cyber, biosecurity proliferation
Evolving national security challenges

- Solar
- Nuclear
- Fossil
- Geothermal
- Wind
- Combustion
- Nuclear Waste

- Atmospheric Monitoring
- Water & Energy
- Grid
- Biomass
- Energy Cyber

Clean Energy & Climate Sustainability: Defining Challenges of Our Time

We want energy to be:

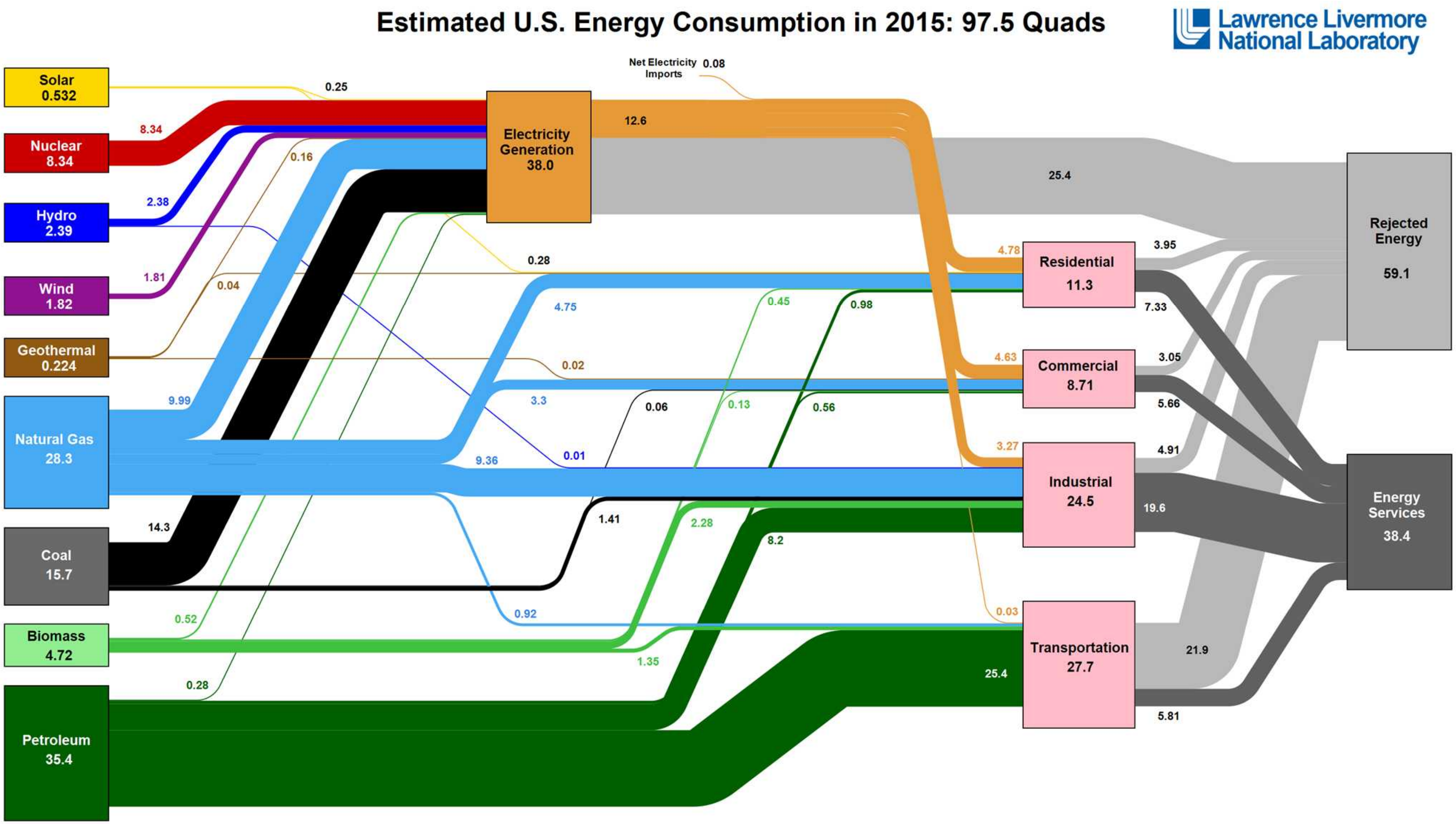
✓ Affordable
- Low cost per unit of energy
- Price Volatility: stable or fluctuating

✓ Available
- Access substantial resources

✓ Reliable
- Intermittent: source consistent, or variable?
- Safe: natural/human causes

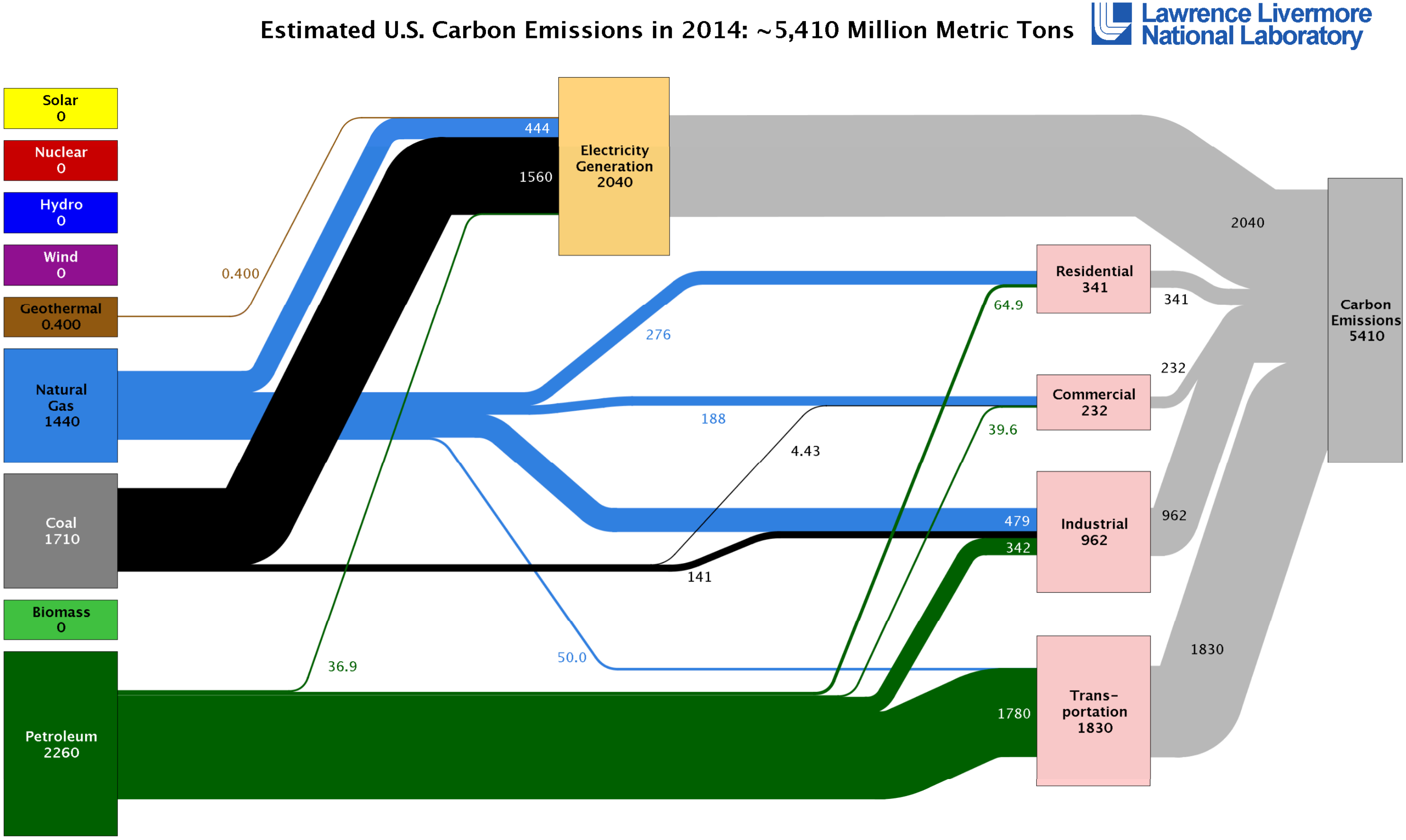
✓ Sustainable
- Clean: atmospheric and air emission
- Dense: land footprint
- Dry: fresh water use/risk

US Energy, 2015



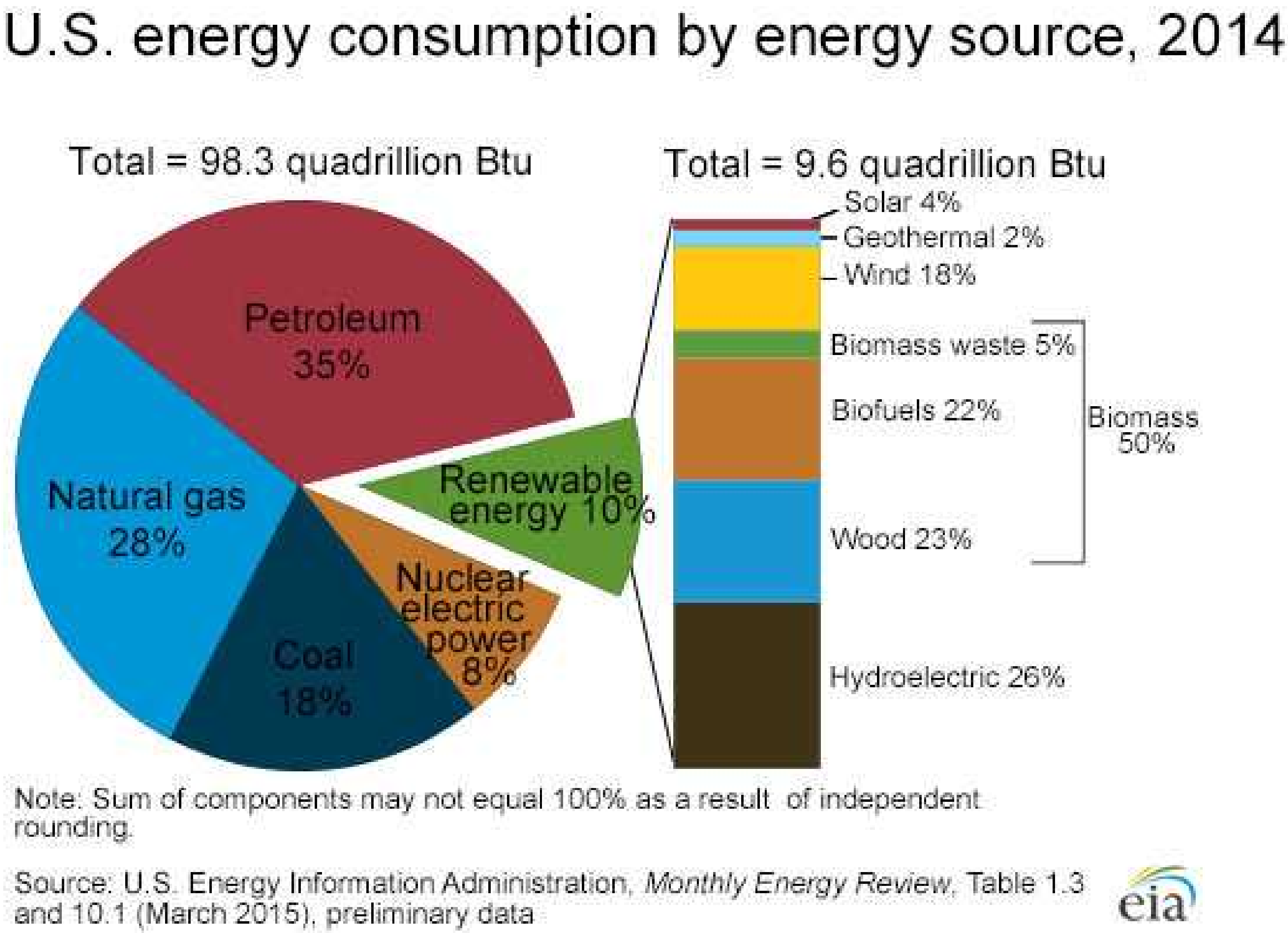
Source: LLNL March, 2016. Data is based on DOE/EIA MER (2015). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Distributed electricity represents only retail electricity sales and does not include self-generation. EIA reports consumption of renewable resources (i.e., hydro, wind, geothermal and solar) for electricity in BTU-equivalent values by assuming a typical fossil fuel plant heat rate. The efficiency of electricity production is calculated as the total retail electricity delivered divided by the primary energy input into electricity generation. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Totals may not equal sum of components due to independent Rounding. LLNL-MI-410527

US Carbon Emissions, 2014

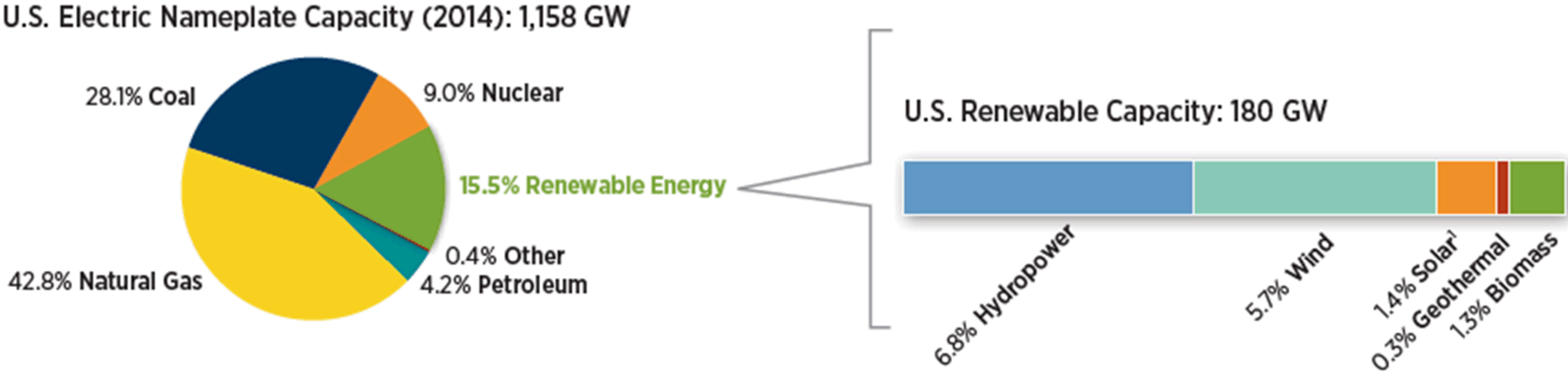


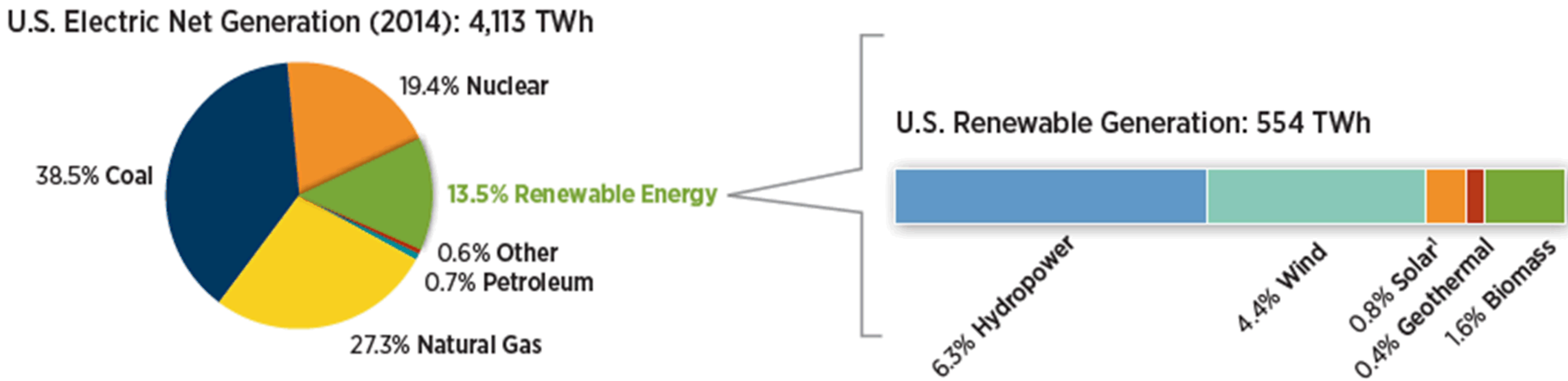
Source: LLNL 2015. Data is based on DOE/EIA-0035(2015-03), March, 2015. If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. Carbon emissions are attributed to their physical source, and are not allocated to end use for electricity consumption in the residential, commercial, industrial and transportation sectors. Petroleum consumption in the electric power sector includes the non-renewable portion of municipal solid waste. Combusition of biologically derived fuels is assumed to have zero net carbon emissions – the lifecycle emissions associated with producing biofuels are included in commercial and industrial emissions. Totals may not equal sum of components due to independent rounding errors. LLNL-MI-410527

All of the Above Energy Mix



U.S. Electricity Nameplate Capacity & Generation



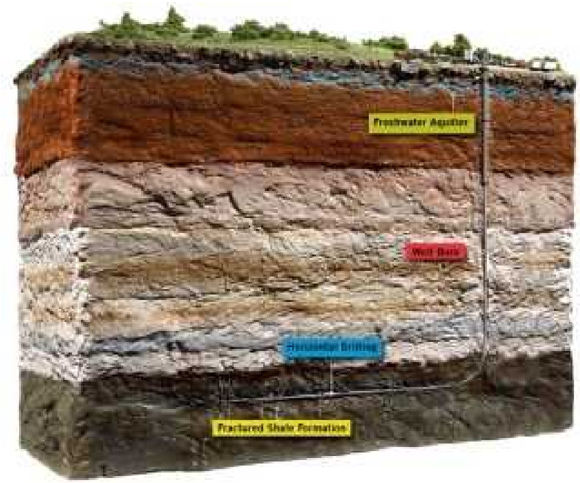


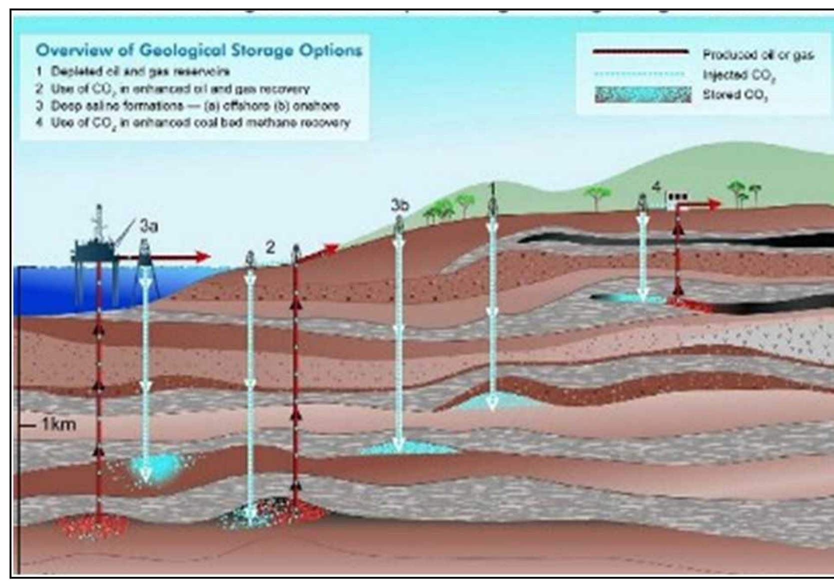
Sources: EIA, Solar Energy Industries Association (SEIA)/GTM Research (GTM)
Other includes pumped storage, batteries, chemicals, hydrogen, pitch, purchased steam, sulfur, tire-derived fuels, and miscellaneous technologies.
Totals and percentages may not correspond due to rounding.
1 Grid-connected only. Solar generation assumes a 25% capacity factor for CSP and an 18% capacity factor for PV. A de-rate factor of 77% has been applied to convert PV Installed Nameplate Capacity from MWdc to MWac.

Source: NREL 2013 Data Book

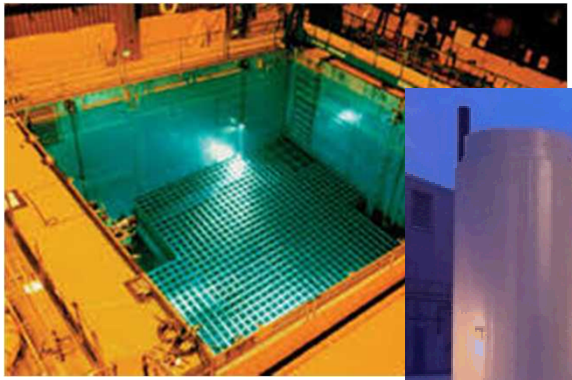
Current Landscape: More Than 80% of our Energy Comes from the Subsurface

- Oil, Gas, Coal
  - Low Oil and Gas Prices
- Huge intact infrastructure for fuel and electricity production
- Increase in Natural Gas usage over time (electricity)
- Environmental effects
  - Methane leakage
  - Carbon sequestration?





Nuclear

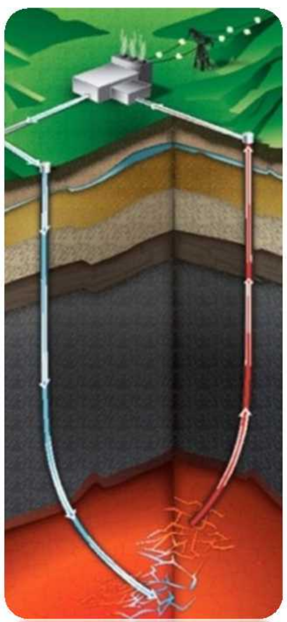


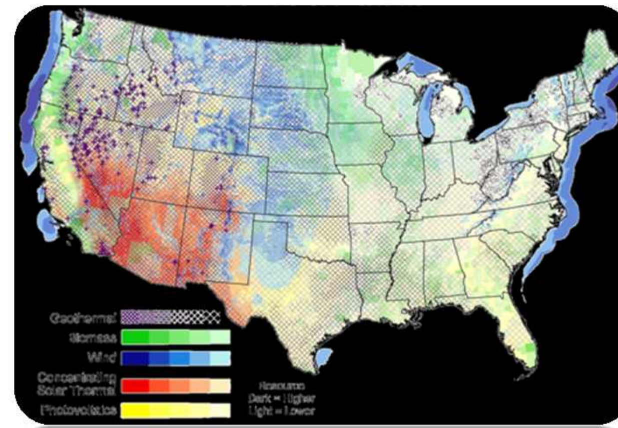
- Low-carbon, baseload power with high capacity factor
  - (> 90%, 2013-2015)
- ~20% of US electricity
- > 100 new units planned or under construction; 37 in China and 8 in US
- 14 completed and announced reactor closures this decade in the US
- Why? Economics (High capital cost, low natural gas prices), waste disposal

Renewables

Market Penetration Increasing; Issues Remain

- Solar and wind intermittency issues require storage solutions for baseload power
- Geothermal is a small player; provides baseload. EGS needed for impact
- Marine hydrokinetics - early development
- Wind: high nameplate, lower capacity factor
- Offshore wind is gaining US attention

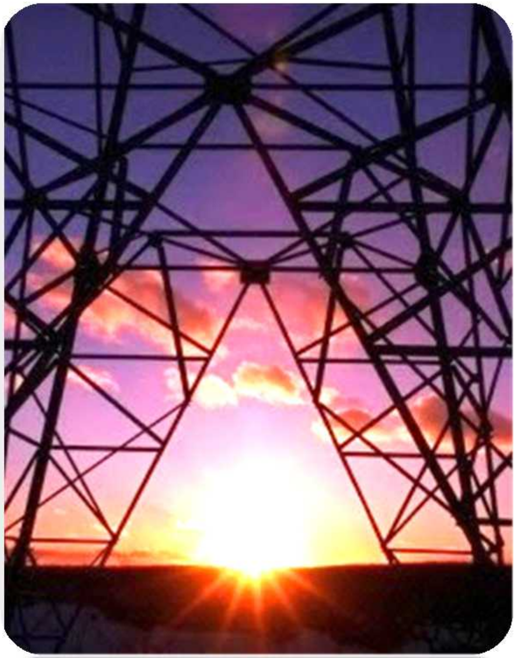


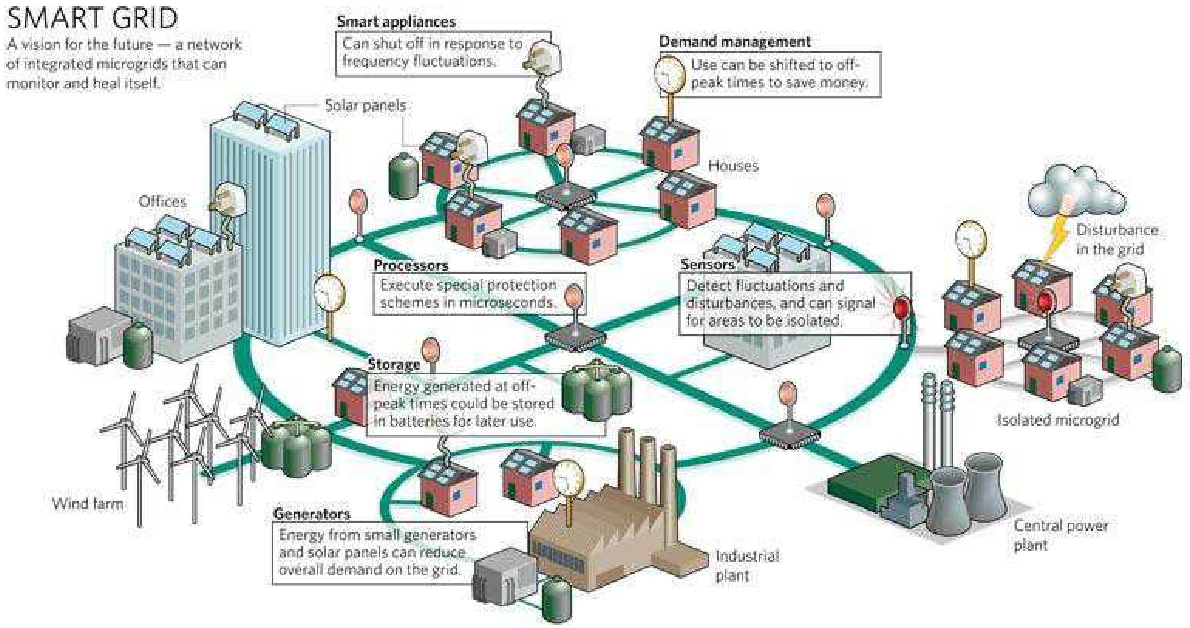


The Electric Grid

Grid Modernization

- Aging Infrastructure
- Renewables integration – changing supply mix and need for storage
- Microgrids
- Reliability and Extreme Events
- Security





Sandia National Laboratories

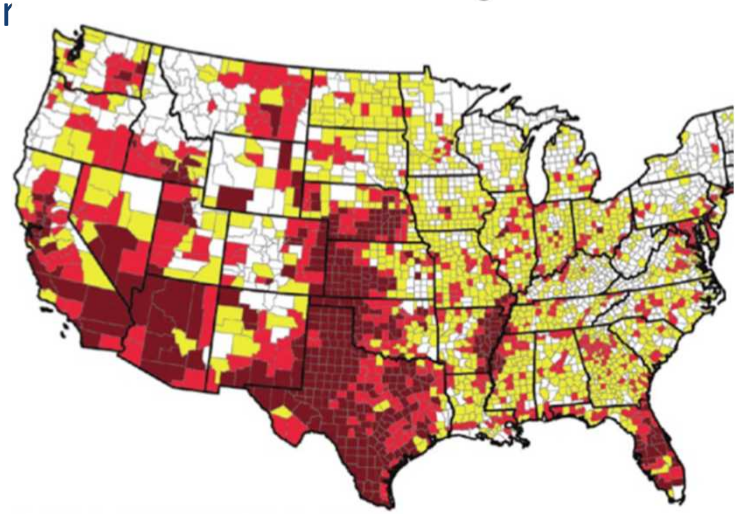
Transportation Options

- Natural gas: more likely for heavy duty vehicles
- Hydrogen Fuel cells
- Electric
- Biofuels

Climate, Energy, and Water

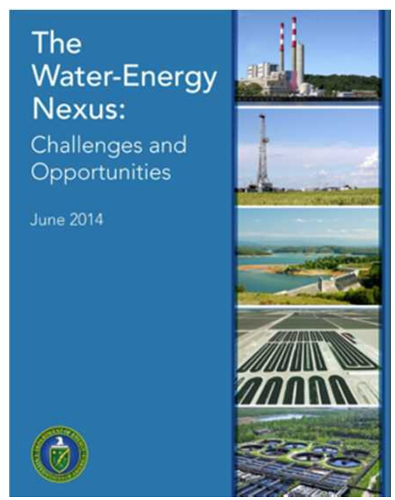
- 2016 expected to be warmest year on record
- Warmer temperatures require more electricity for cooling
- Generating electricity requires large amounts of water withdrawal for cooling: reduce water use for energy
- Pumping water in arid lands requires large amounts of energy: reduce energy use for water
- Address environmental impacts of energy development on water resources

Climate Change Effects

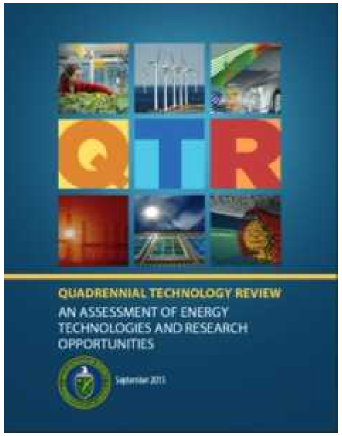


Water Supply Sustainability Risk Index (2050)

- Extreme (412)
- High (608)
- Moderate (1192)
- Low (929)



What Can/Should a National Lab Do?



DOE mission in energy:

- Secure and Resilient
- Economic Competitive
- Environmentally Responsible (QTR)

Lab Elements:

- Foundational Research
- New Technologies
- Integrate to understand systems behavior
- Reduce key technical uncertainties
- Provide unbiased technical information
- With a broad multidisciplinary capability base



Sandia National Laboratories

ENERGY & CLIMATE PROGRAM

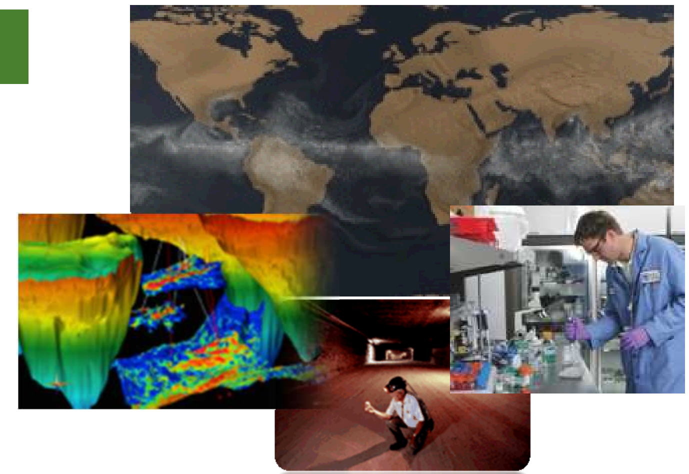
Sandia's Energy & Climate Program

Energy Research

Chemical, Geological, Biological, Materials, Computational, and Nano Sciences

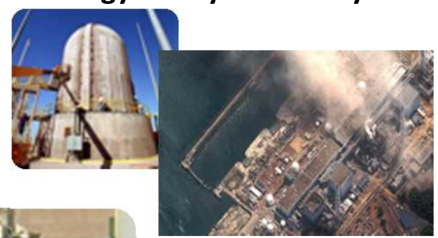
Climate & Engineered Earth Systems

Measurement & Modeling, Energy & Water, Fossil Energy, Biofuels, DOE Managed Nuclear Waste



Nuclear Energy & Fuel Cycle

Commercial Nuclear Power Generation, Nuclear Energy Safety & Security



Renewable Systems & Energy Infrastructure

Renewable Energy, Energy Efficiency, and Grid Modernization

Transportation Energy & Systems

Vehicle Technologies, Biomass, Fuel Cells & Hydrogen Technology

Examples of Sandia's impact

Core, dynamic, and rapid response

Core: Long term research that solves the nation's immense prob

- **Drilling technologies, nuclear reactor safety, nuclear waste disposal, and Strategic Petroleum Reserve**

Dynamic: Addressing current nation Needs on a 5-10 year timeframe

- **Efficient engines, wind energy, and solid-state lighting**

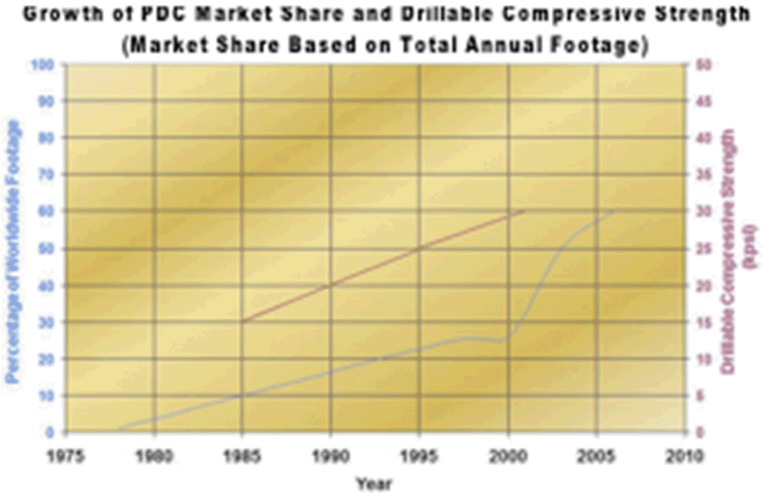
Rapid Response: Quick mobilization of expertise for urgent national need

- **Aliso Canyon, Fukushima, and Deepwater Horizon**

Polycrystalline Diamond Compact (PDC) Drill Bit

Work began in the early 1980's when DOE started with Geothermal Program with the goal of improving PDC performance

- PDC bits save industry $billions annually
- ~ 2/3 of world footage today
- PDC bits now a ~ $1.5 billion industry
- Catalyzed a major industry
- Used to drill most of the long horizontal wells used for fracking



Fundamental work at Sandia:

- Finite Element Modeling analyses
- Bonding
- Cutter tests CRADAs
- Bit design / analysis
- Lab / field testing

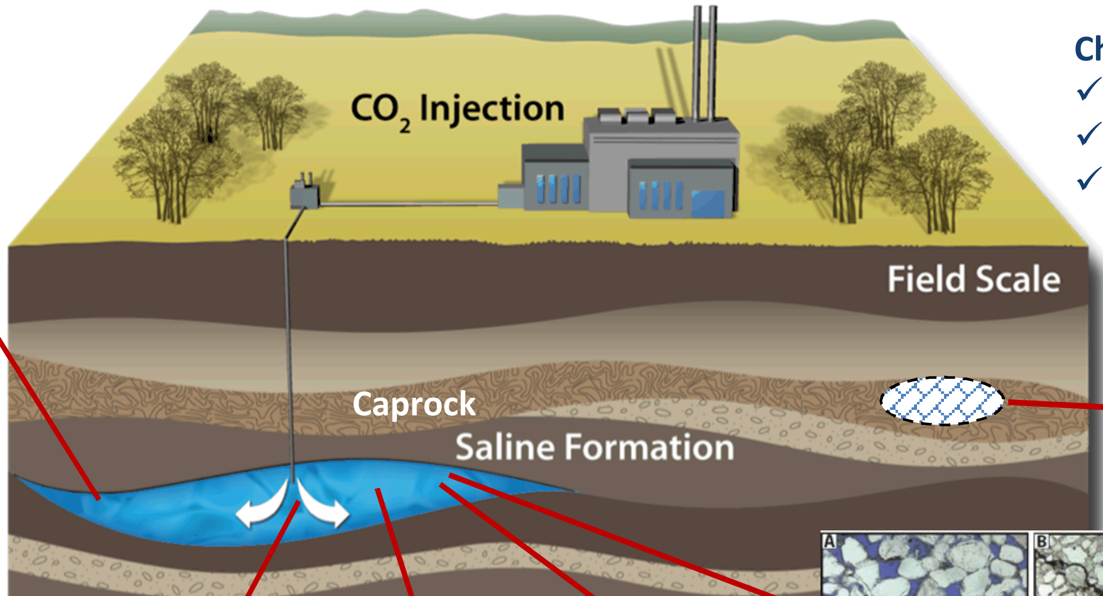
Center for Frontiers of Subsurface Energy Security (CFSES)

A DOE Energy Frontier Research Center and partnership between Sandia and UT-Austin

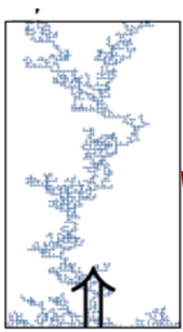
Goal: To understand and control emergent behavior arising from coupled physics and chemistry of geologic CO_2 storage in heterogeneous geomaterials.

Challenges:

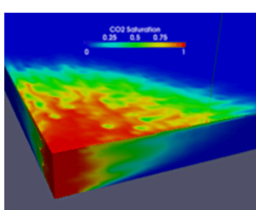
- ✓ Sustain large storage rates
- ✓ Use pore space efficiently
- ✓ Control emergent behavior



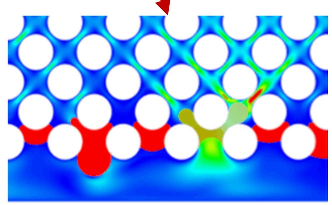
Caprock jointing & fracture flow



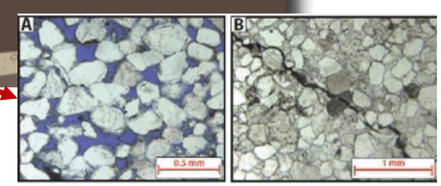
Capillary & buoyancy controlled CO_2 migration



Pressure & buoyancy driven flow



Capillary trapping

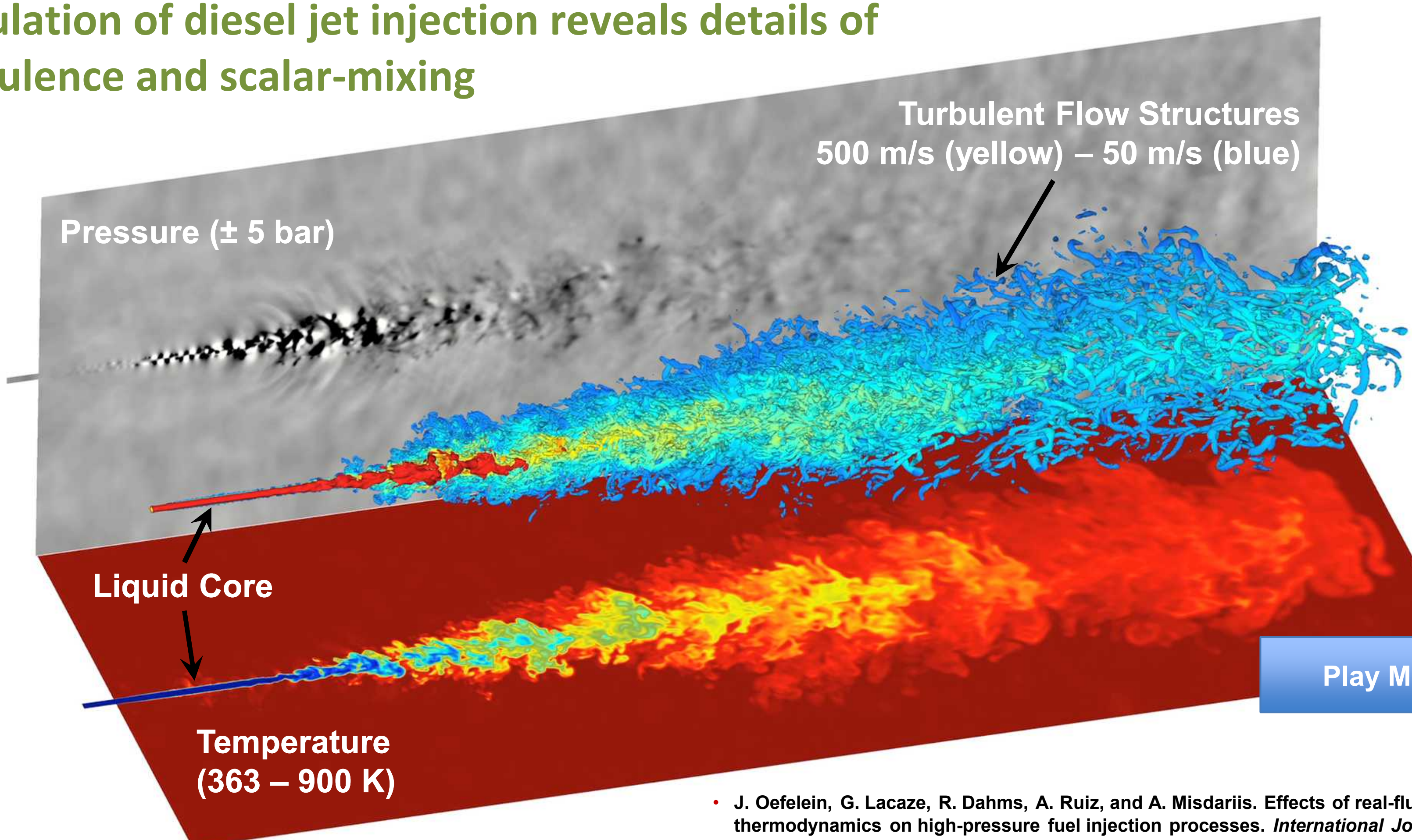


Precipitation / dissolution

Mineral trapping

Combustion Modeling at the Combustion Research Facility (CRF)

Simulation of diesel jet injection reveals details of turbulence and scalar-mixing

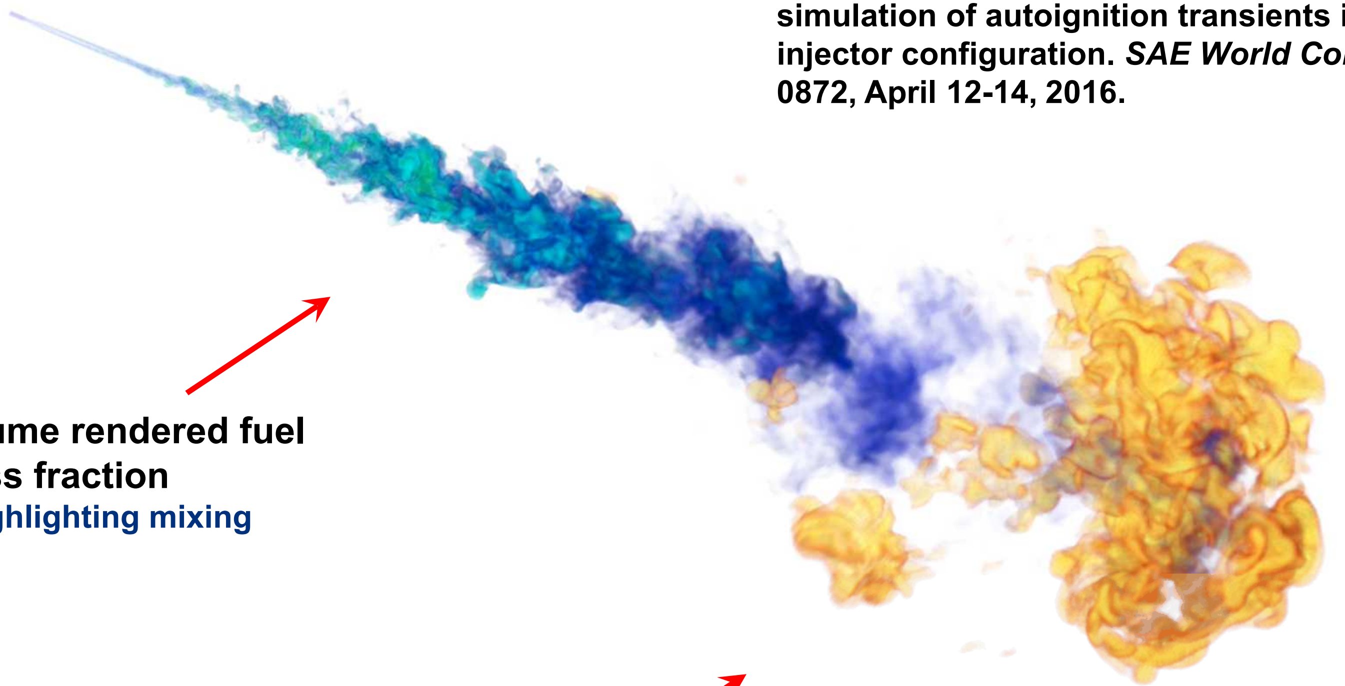


Play Movie

- J. Oefelein, G. Lacaze, R. Dahms, A. Ruiz, and A. Misdariis. Effects of real-fluid thermodynamics on high-pressure fuel injection processes. *International Journal of Engines*, 7(3):1–12, 2014.
- G. Lacaze, A. Misdariis, A. Ruiz, and J. C. Oefelein. Analysis of high-pressure diesel fuel injection processes using LES with real-fluid thermodynamics and transport. *Proceedings of the Combustion Institute*, 35:1603–1611, 2015.

CRF: Modeled Instantaneous Fluctuations Facilitate Formation of Ignition Kernels

L. Hakim, G. Lacaze, and J. C. Oefelein. Large eddy simulation of autoignition transients in a model Diesel injector configuration. *SAE World Congress*, Paper 2016-01-0872, April 12-14, 2016.



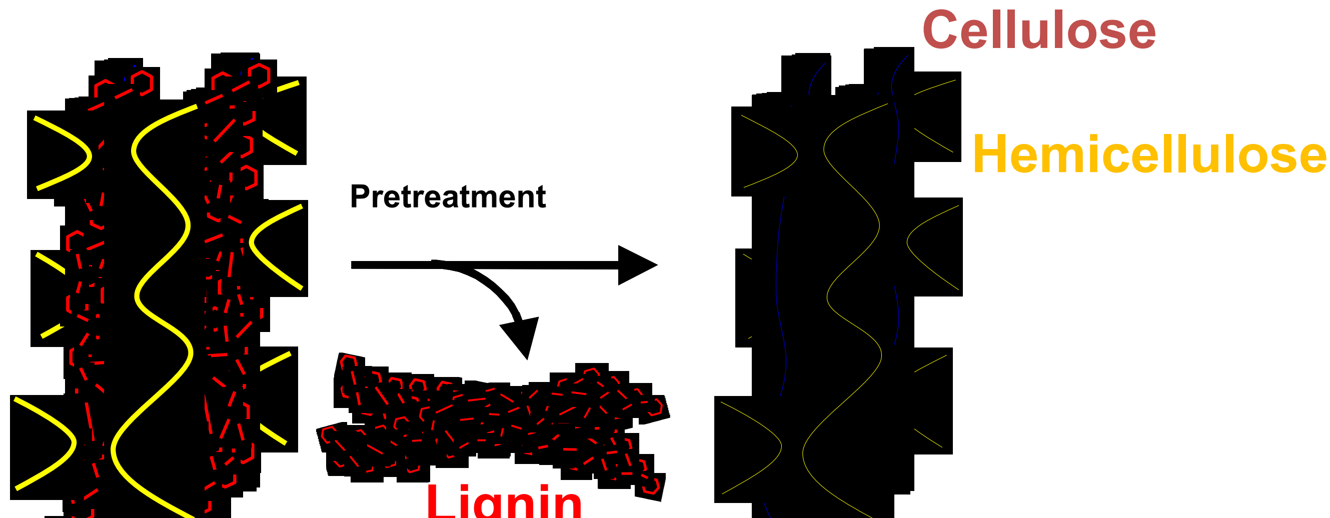
Volume rendered fuel mass fraction
- Highlighting mixing

Volume rendered temperature
- Highlighting ignition kernel development

Play Movie

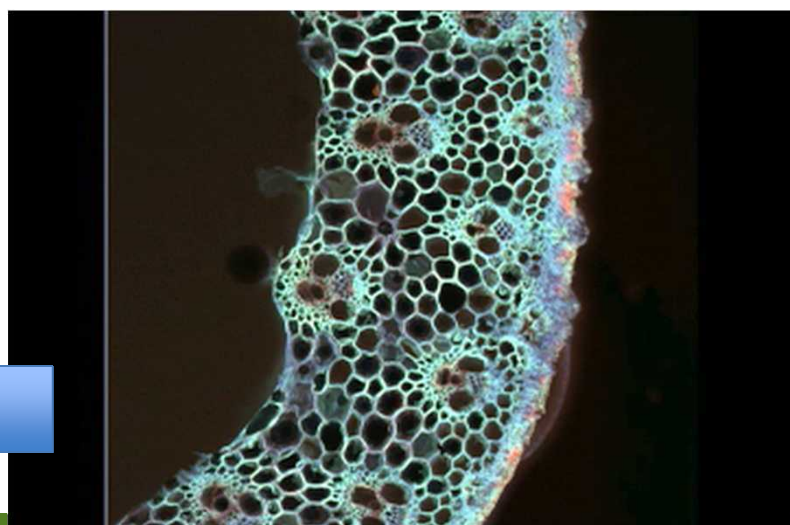
Ionic liquids Are Very Effective at Disrupting Biomass

Joint BioEnergy Institute



Switchgrass

Eucalyptus



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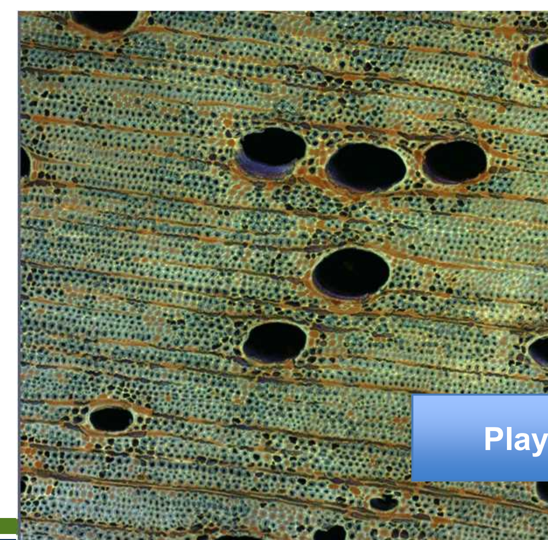
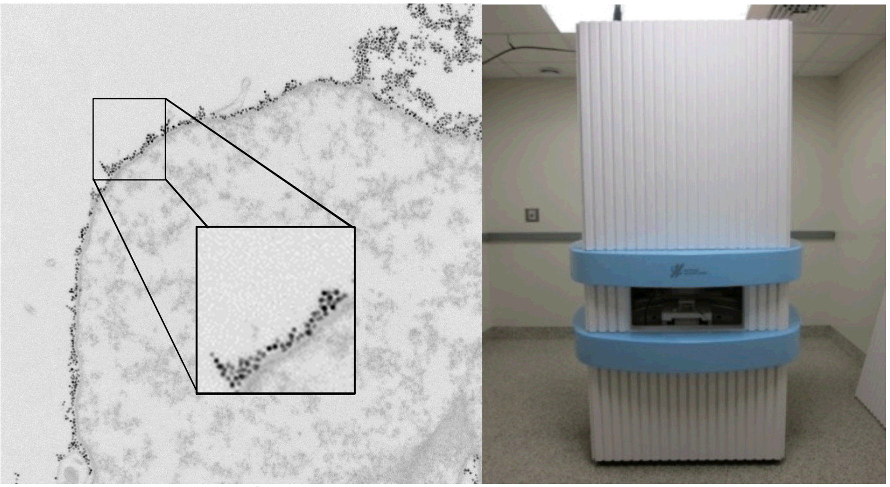


Play Movie

Center for Integrated Nanotechnology

Focused on understanding how to fabricate and integrate nanostructures to bridge length scales and impact the macroscopic world we live in.

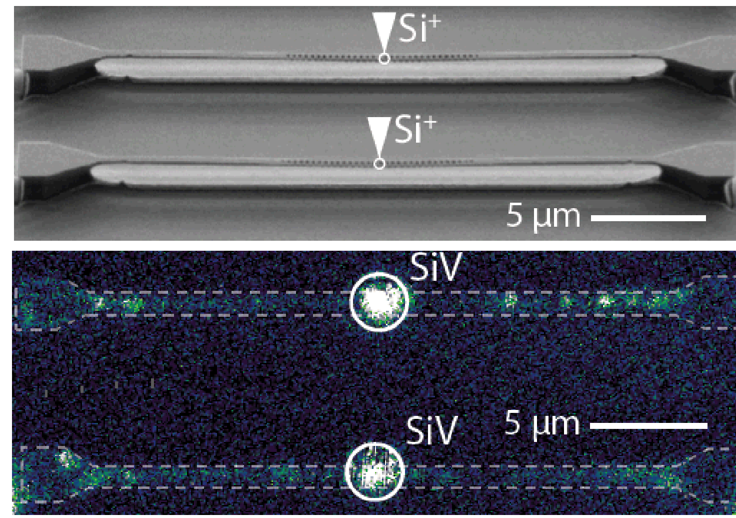


Detecting Cancer with Magnetic Nanoparticles

SENIOR SCIENTIFIC

Nanoparticles to detect by *Bacillus anthracis*

What are Nanostructures Good For?



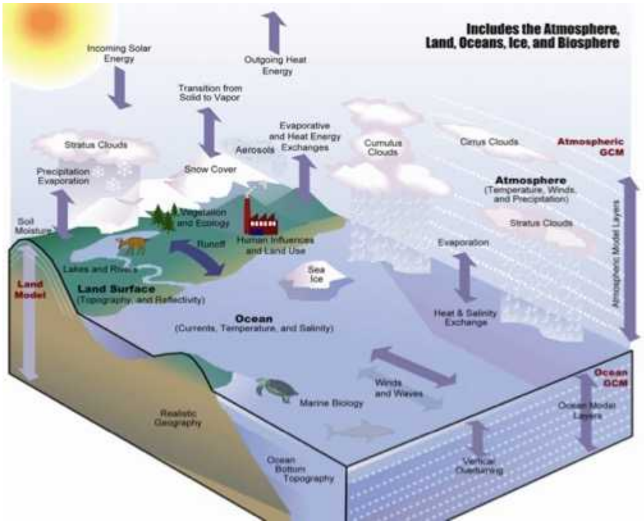
Switches that respond to a single photon

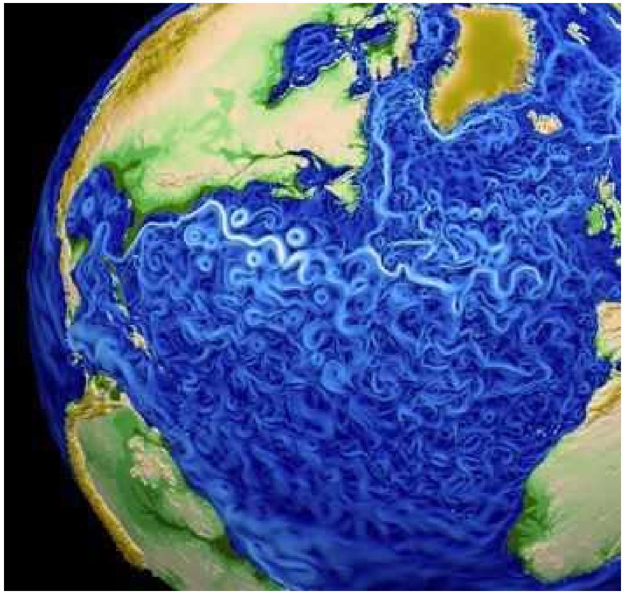
U.S. DEPARTMENT OF ENERGY | Office of Science

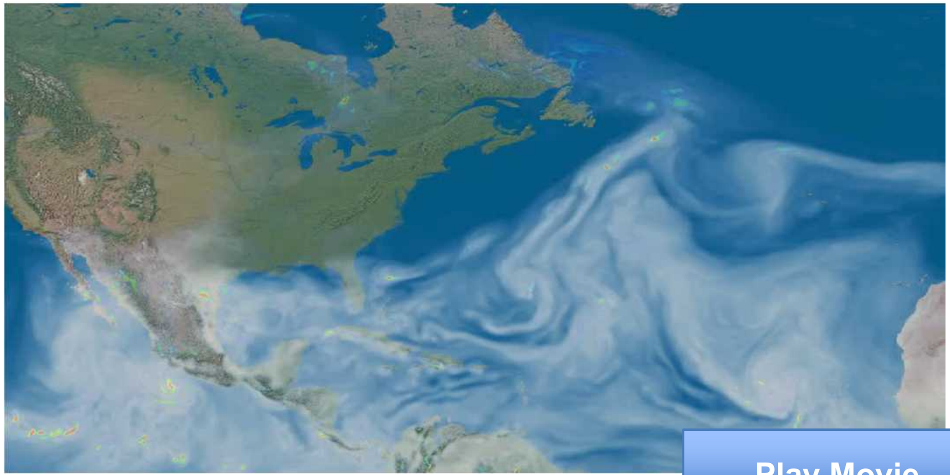
Los Alamos NATIONAL LABORATORY

Accelerated Climate Model for Energy (ACME)

- A DOE Earth System Model for DOE problems running on DOE computers
- 8 DOE labs, NCAR, Kitware and universities. Total ~45 FTEs spread over 100 staff
- Atmosphere, Land, Ocean and Ice component models
- Development driven by DOE-SC mission interests: Energy/water issues looking out 40 years
- Particular focus on ensuring ACME will run well on next generation DOE leadership computing facilities
- ACME is open source with public release of code & simulations







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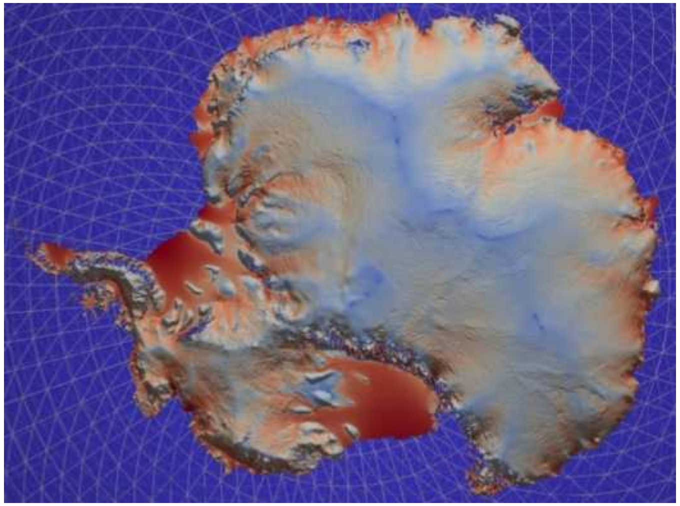
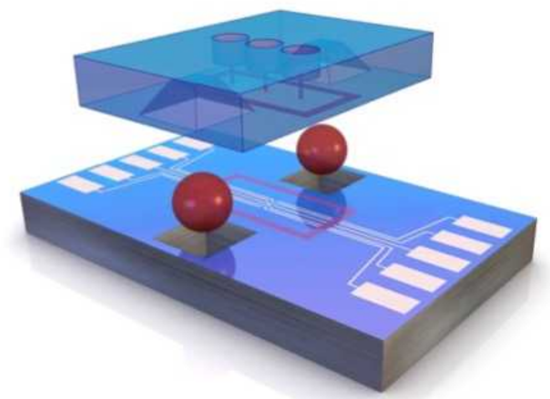
Ice Sheet Modeling



- FELIX (an Albany code) is being developed to model the evolution of the Greenland and Antarctic ice sheets, and will be the land ice component of ACME.
- The Albany team completed an unprecedented mesh convergence study for flows of the Greenland ice sheet, demonstrating accuracy, efficiency, and reliability for grids of over 1 billion unknowns.
- This required new algorithm advances -- algebraic multigrid for thin structures and hinged structures and high-performance implementation.
- The rapid optimization library (ROL) was used to solve large scale inversion for basal traction fields of Greenland and Antarctica ice sheets (~1.6M parameters, largest ice sheet inversions ever!)
- Fields will be used as initial conditions in ACME simulations and as mean fields for UQ.

Nano-Engineering Faster Batteries

CINT's Electrochemical TEM Platform



Why can't we charge our Li-ion batteries faster?- We need to move Li ions faster between electrodes

What is happening to the electrodes that is causing failure? If you move ions too fast, it can destroy the electrode

Structural information can be obtained at the atomic-to-micron scale of battery components during cycling

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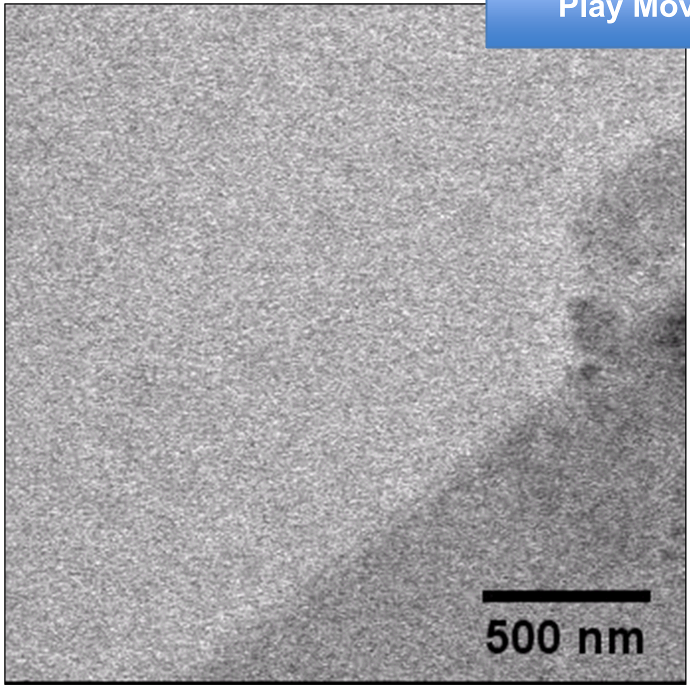

Video of Li deposition and stripping on the nanoscale

- [If we get Li metal electrodes to cycle safely, we can use them for higher energy density, therefore you can charge your phone 3x faster]

- Real-time observation of Li transport pathways from the electrode surface
  - 1st observation of Li transport pathways in a working battery from an individual Li grain
  - Use this knowledge to build structures for optimization of Li transport [will also aide in charging your cell phone faster]

Advanced Wave Energy Converter (WEC)

In partnership with the US Navy, Sandia conducted the tests at the maneuvering and sea-keeping (MASK) basin at the Naval Surface Warfare Center's Carderock Division (NSWCCD) in Bethesda, Maryland.

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- **The WEC tested, at 1:17 scale, is among the largest scale models ever tested in a wave tank, Sandia Labs informed.**
- **The test program focused on model validation and system identification, producing high-quality data for control design of WECs.**

Falling Particle Receiver

Thank You!

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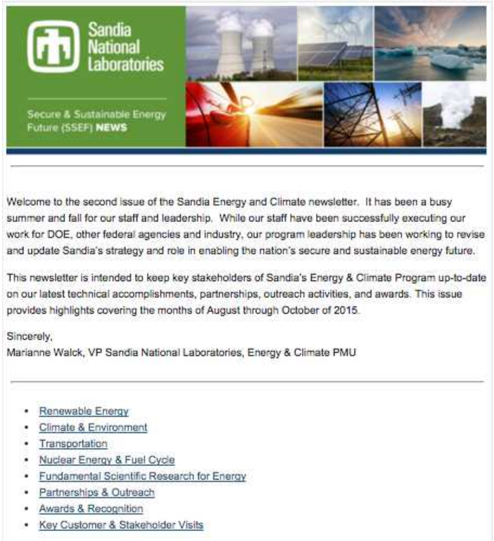

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