U.S. DEPARTMENT OF ENERGY | Office of Science

Science Opportunities in Infrastructure Security

NNSA LDRD 2009 Tri-Lab Symposium

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U.S. Department of Energy

DOE's Office of Science

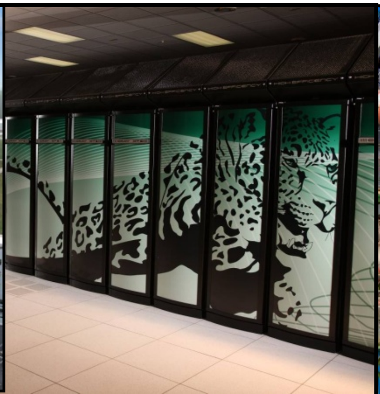
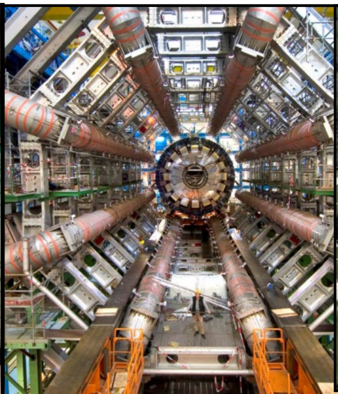
The Office of Science is one of the nation's largest supporters of peer-reviewed basic research, providing 40% of Federal support in the physical sciences and supporting ~25,000 Ph.D.s, graduate students, undergraduates, engineers, and support staff at more than 300 universities and at all 17 DOE laboratories.

Three themes describe the work supported by the Office of Science:
- **Science for discovery**
- **Science for national need**
- **National scientific user facilities, the 21st century tools of science**

Discover new science that can change both the way we view the world and how we live in it

User Facilities

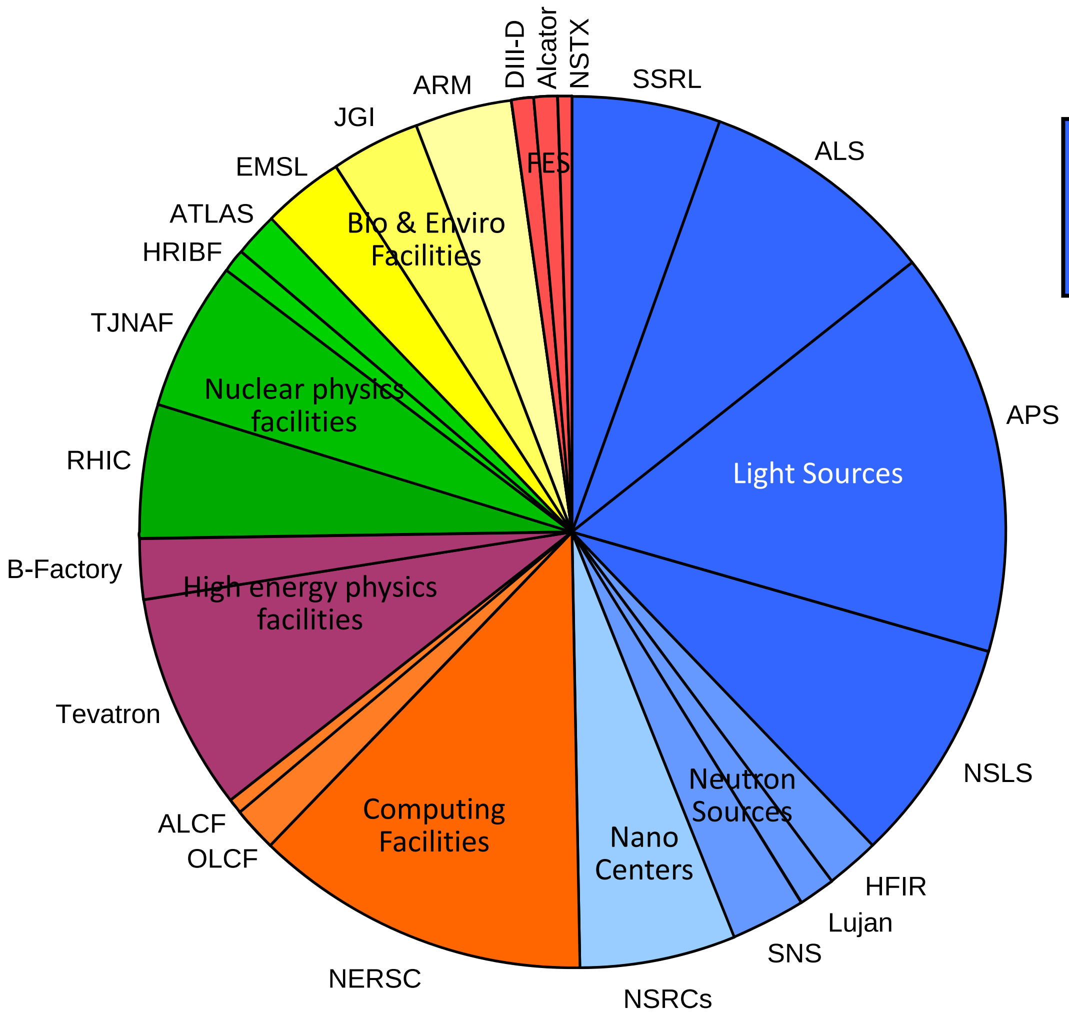
- Advanced **computational resources** – terascale to petascale computing and networks for open science
- Four **synchrotron light sources**, and two next-generation light sources in construction
- Three **neutron sources** for scattering
- **Particle accelerators/colliders/detectors** for high energy and nuclear physics
- **Fusion/plasma facilities**, including **ITER** which seeks to demonstrate a burning plasma
- Five **Nanoscale Science Research Centers** – capabilities for fabrication and characterization of materials at the nanoscale
- **Joint Genome Institute** for rapid whole genome sequencing
- **Environmental Molecular Science Laboratory** – experimental and computational resources for environmental molecular sciences
- **Atmospheric and Environmental Facilities** – capabilities for cloud and aerosol measurement and for carbon cycling measurements

Distribution of Users by Facility

Breakdown by facility of ~25,000 users in FY 2010

~25,000 users at the facilities in FY 2010: ~1/2 from universities; ~1/3 from national labs; and the remainder from industry, other agencies, and international entities.



FY 2010 funding for the light sources is $258M, ~17% of the total funding for the operating facilities.

Training the Next Generation of Scientists and Engineers

The Department of Energy has >50 year history of training scientists, mathematicians, and engineers through research grants, the DOE national laboratories, and targeted education programs.

- In FY 2008, more than 300,000 K-12 students; 21,000 educators; 3,000 graduate students; and 4,200 undergraduate students participated in opportunities at the DOE labs, funded by DOE and other federal and non-federal sources.
- SC will support over 4,400 graduate students and 2,700 post docs in FY 2009.
- In FY 2009, the Office of Workforce Development for Teachers and Scientists will support ~550 undergraduates in research internships at the DOE laboratories (and 1,175 in FY 2010 request) and ~280 K-16 educators.
- The DOE National Science Bowl attracts ~22,000 high school and middle school students every year.
- With ARRA funds and the FY 2010 request, SC initiated the DOE SC Graduate Fellowship Program, supporting over 160 graduate students in fields important to SC missions.
- SC proposes to increase the Graduate Fellowship Program to support approximately 400 graduate students in the out-years.

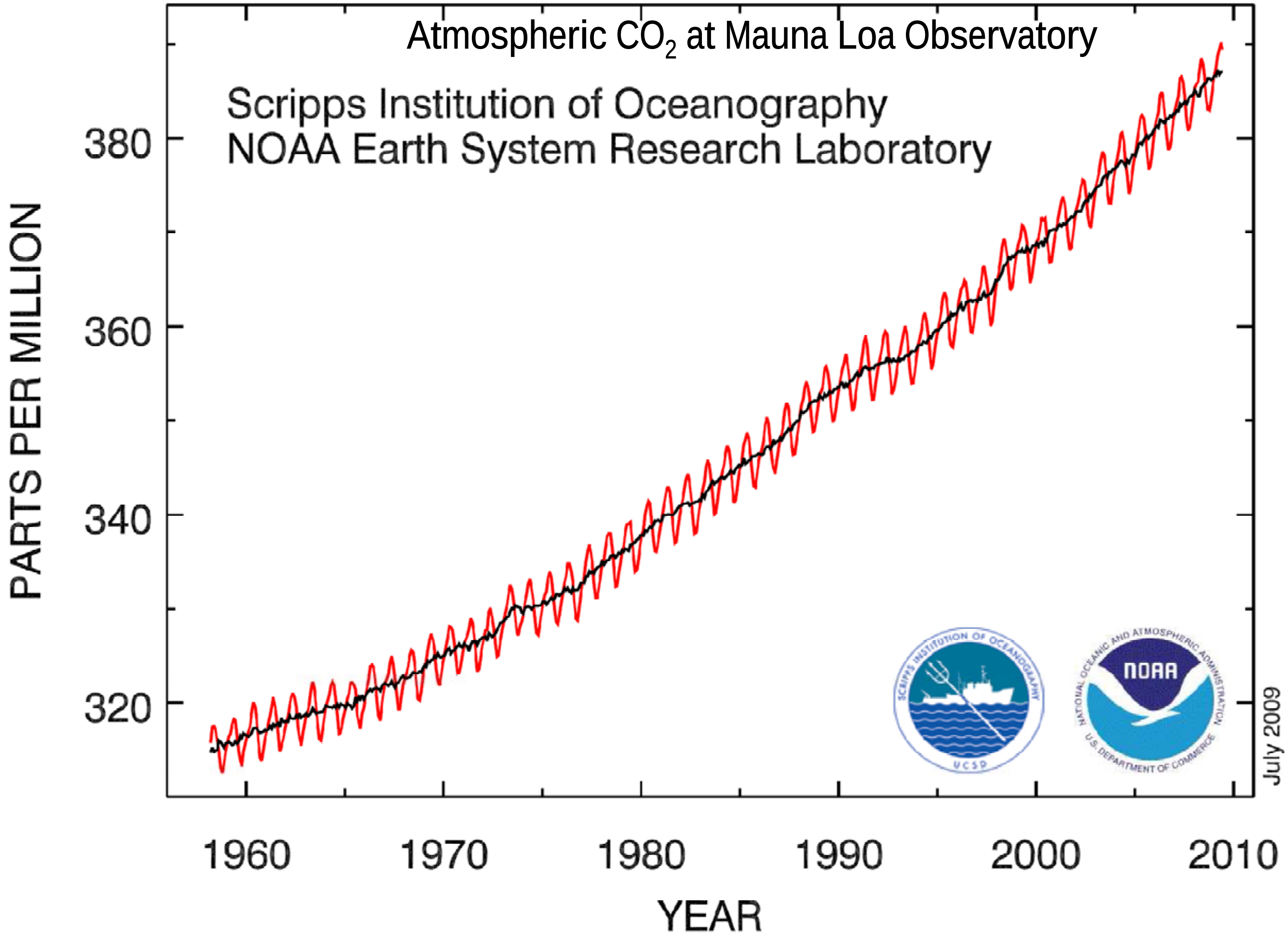
Early Career Research Program

The Department of Energy is now accepting proposals for the DOE Office of Science Early Career Research Program to support the research of outstanding scientists early in their careers.

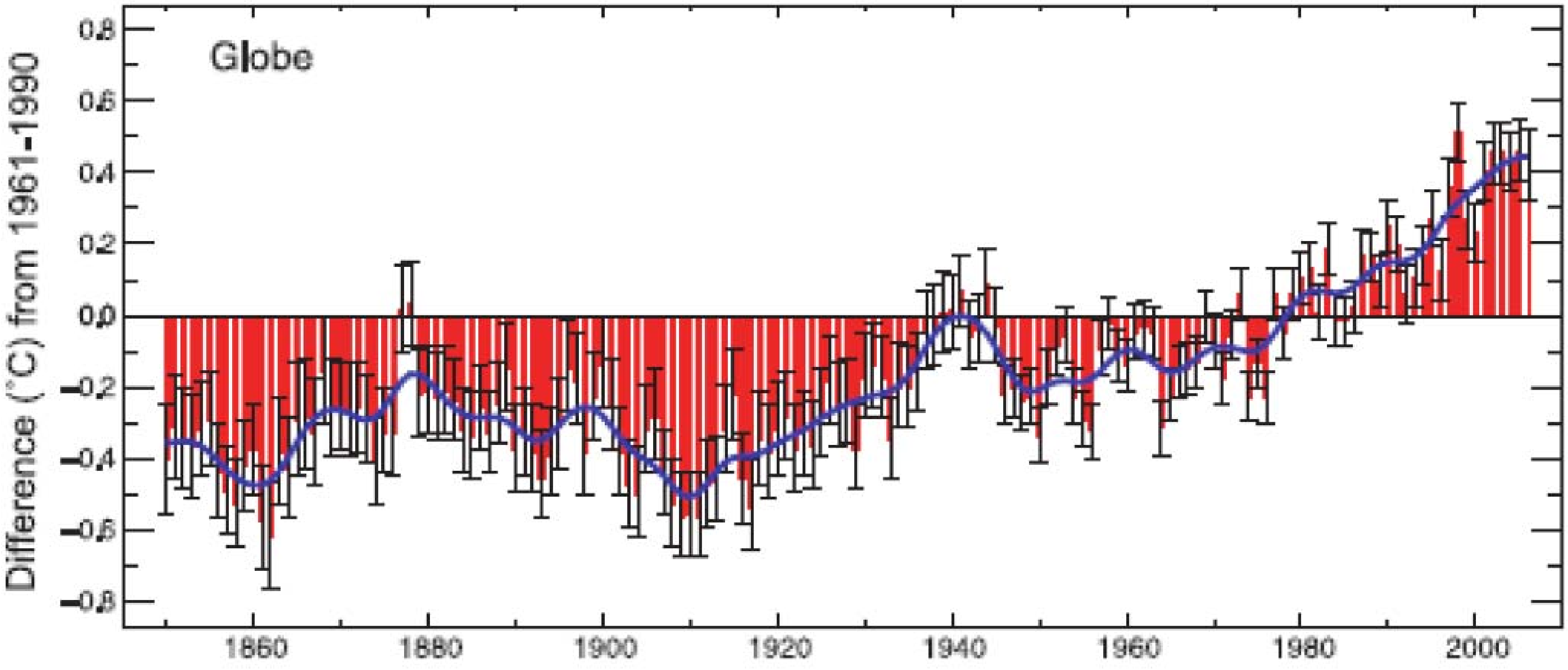
Purpose: To support the development of individual research programs of outstanding scientists early in their careers and to stimulate research careers in the disciplines supported by the Office of Science.

The future of mankind depends on how we handle energy use, CO_2, and population growth in this century.

Modern CO2 Concentrations are Increasing

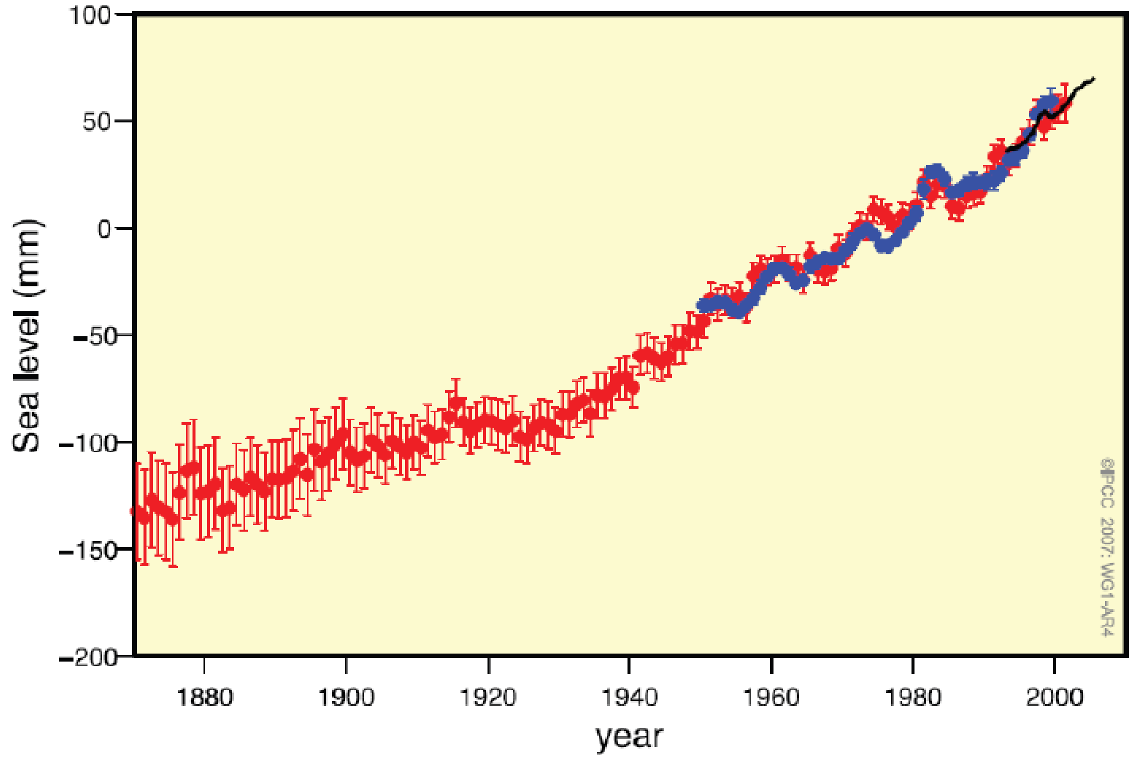


Temperature Record (1850-2006)*



*Intergovernmental Panel on Climate Change 2007 assessment

Rise in Global Sea Level*



Past 2000 years:	0.0 - .02 mm/year
1870 – 1890:	0.6 mm/year
1990 – 2008:	3.0mm/year (including recent satellite data)

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*Intergovernmental Panel on Climate Change 2007 assessment

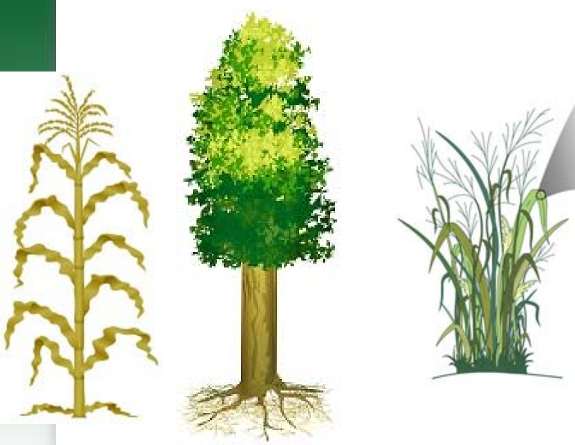
Opportunities for Transportation Fuels

- Feedstock grasses such as Miscanthus can be energy crops
- 15x more ethanol / acre than corn
- 25 M acres of energy crops, plus agricultural and urban wastes could produce up to 25% of current U.S. consumption of gasoline

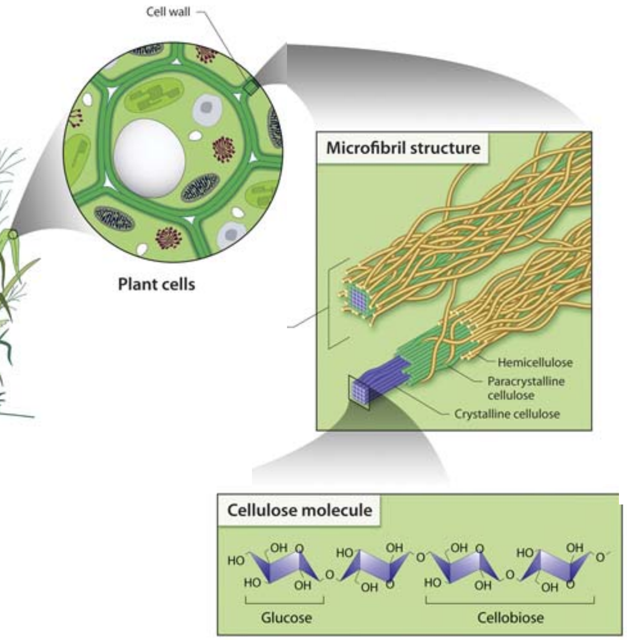
Opportunities for Transportation Fuels

Imagine: Development of local biofuels infrastructure from regional plants and feedstock crops

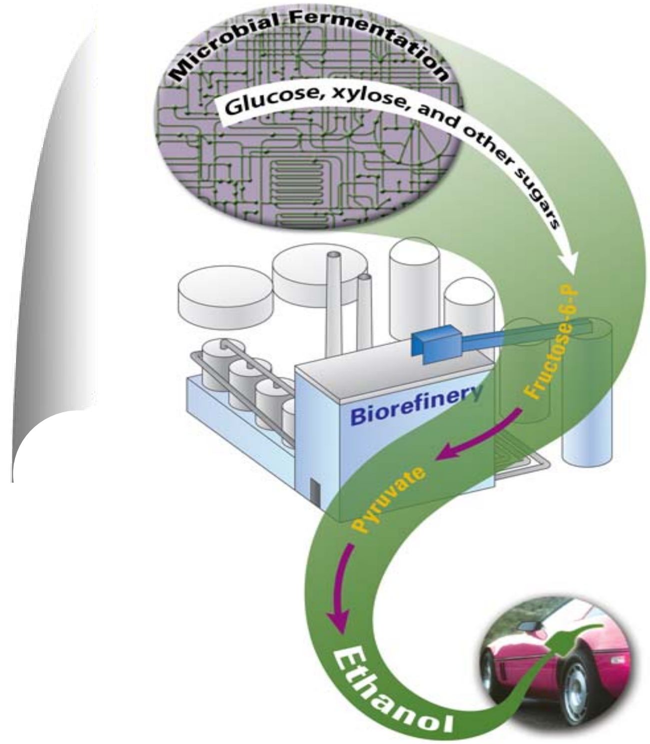
Lignocellulose → *Sugars/Metabolites* → *Biofuels*



- Local agricultural waste and regional feedstock crops optimized to climate and minimal inputs



- Biochemical, thermochemical, and/or catalytic processing of plants to sugars, lipids, and other metabolites

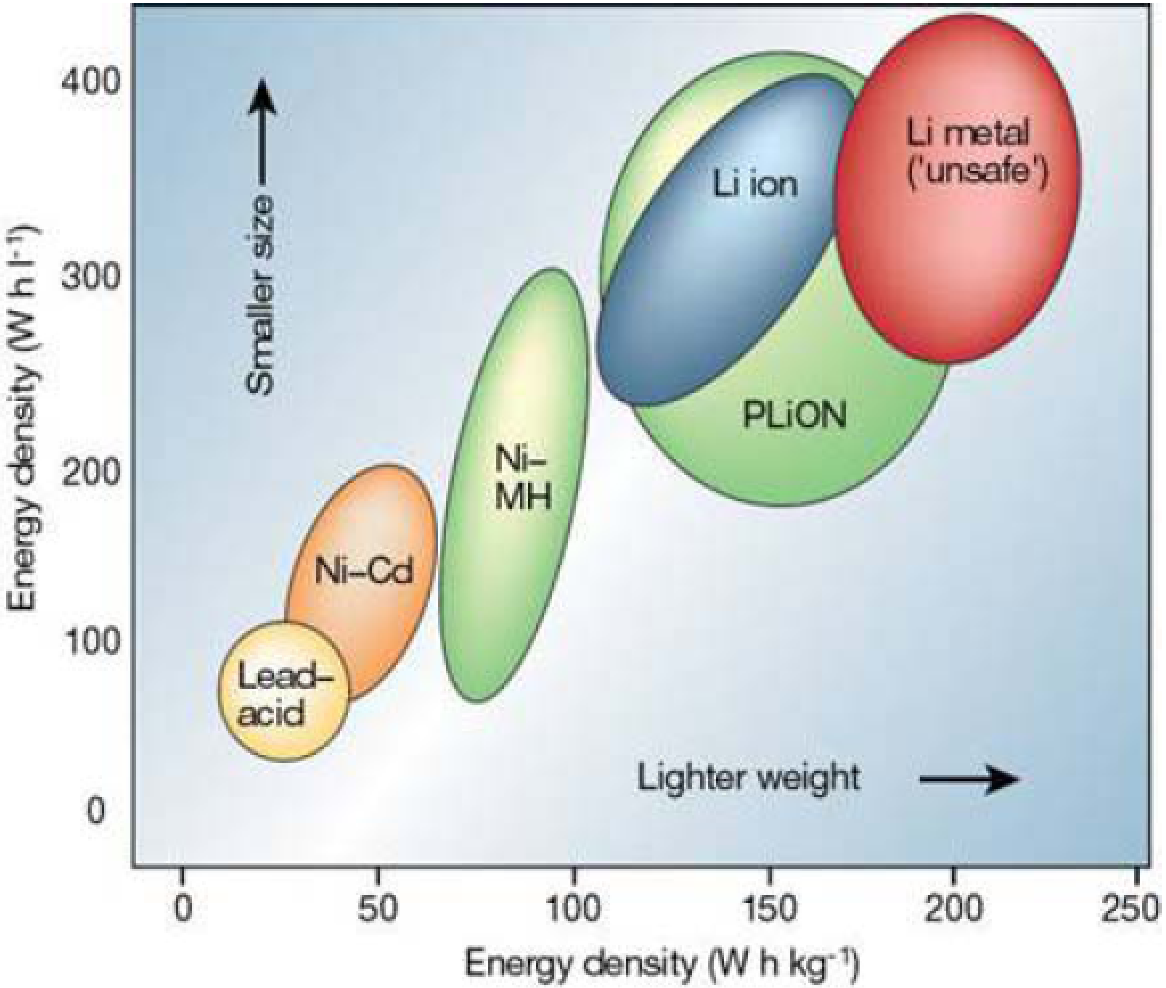


- Biological, thermochemical, and/or catalytic synthesis of biofuels that meet national standards.

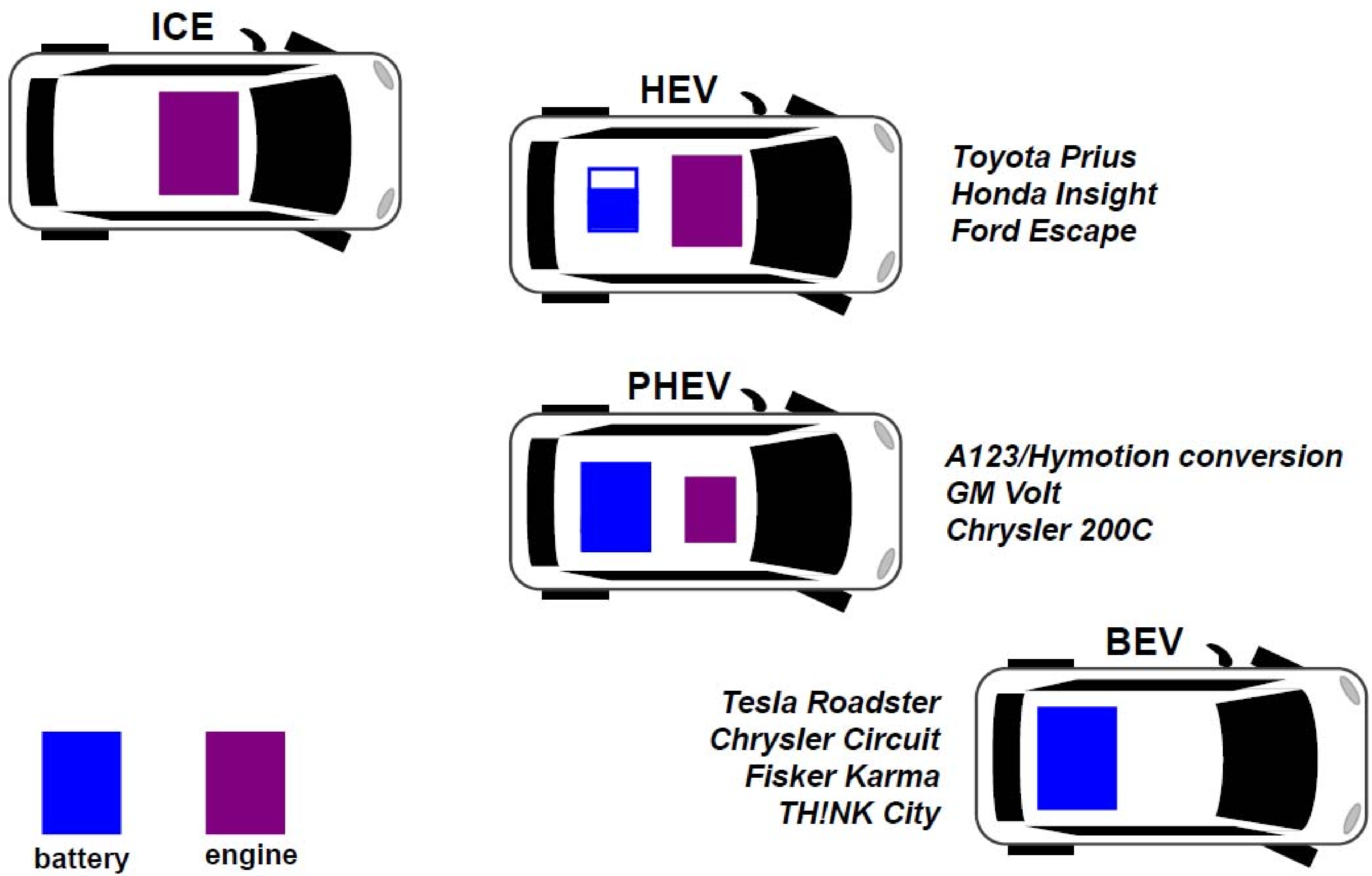
Opportunities in Energy Storage

Comparison of Energy Densities for Rechargeable Systems

Volumetric & Gravimetric Energy Density



Progress in Vehicular Energy Storage



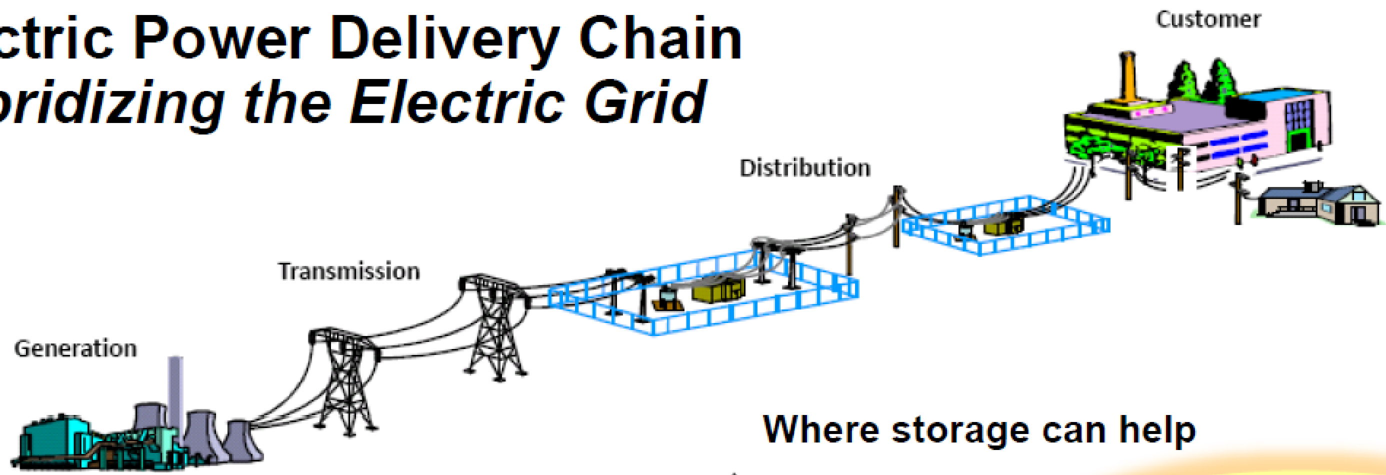
Why Science Breakthroughs are Needed for Transportation Storage

	Range (miles) x 300 Wh/mile / 0.8 (20% reserve capacity)	=	15 kWh for 40 mile PHEV	*Energy*
		=	75 kWh for 200 mile BEV	
Typical of current Li-ion	÷ 110 Wh/kg	=	136 kg for 40 mile PHEV	*Mass (too heavy!)*
		=	681 kg for 200 mile BEV	
	÷ 220 Wh/L	=	68 L for 40 mile PHEV	*Volume (too big!)*
		=	341 L for 200 mile BEV (12 cu ft)	
Target cost	x US$0.50/Wh	=	US$7500 for 40 mile PHEV	*Cost (too expensive!)*
	~Similar cost to Na-S	=	US$37,500 for 200 mile BEV	

Not to mention that charging a 75 kWh pack in 1h takes 75 kW; in 5 min takes 900 kW…..

Progress Is Needed in the Electric Grid

Electric Power Delivery Chain
Hybridizing the Electric Grid



US: 3% renewables

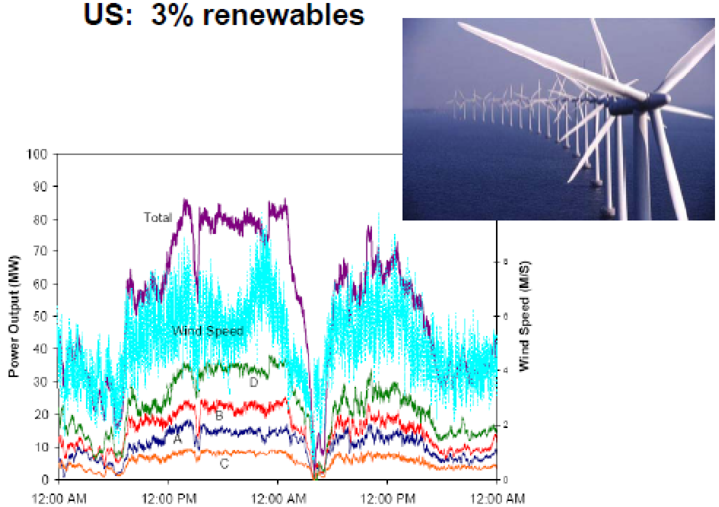
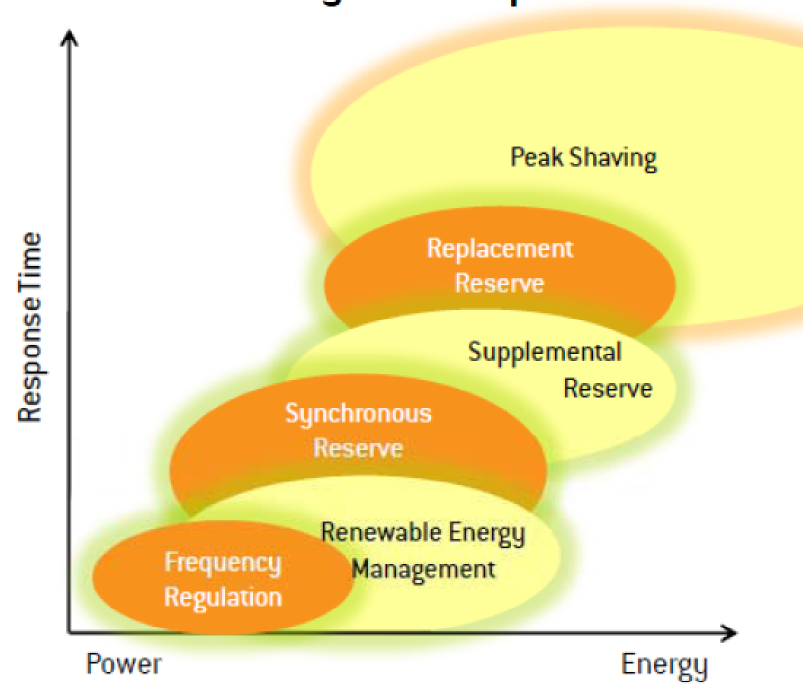


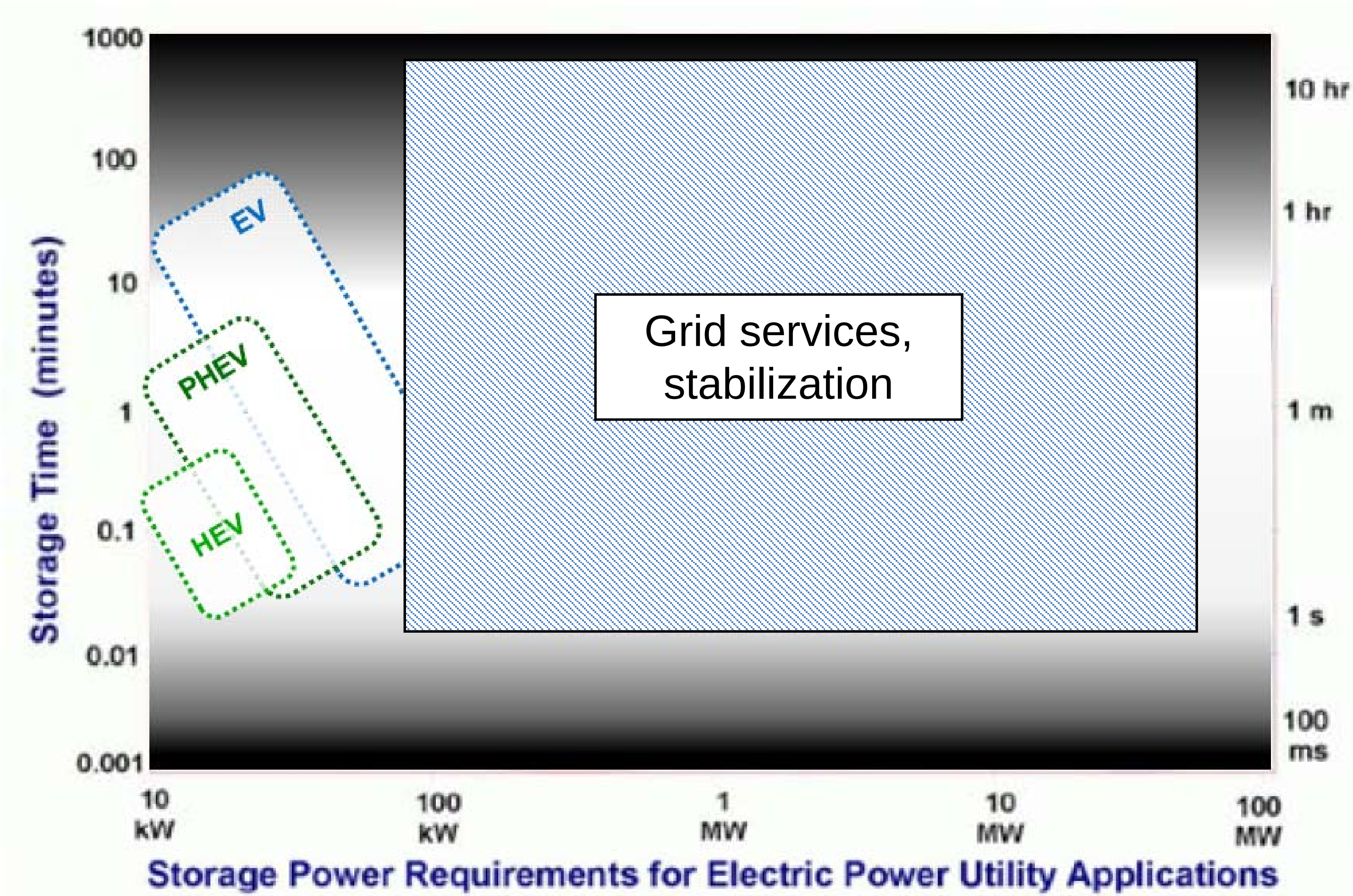
Fig. 8. Two days of output and wind speed from a four-section midwestern wind plant.

Wind and Solar are Intermittent Sources (not "dispatchable")

Where storage can help



Grid Storage Requirements Needs to Scale to Megawatt Levels



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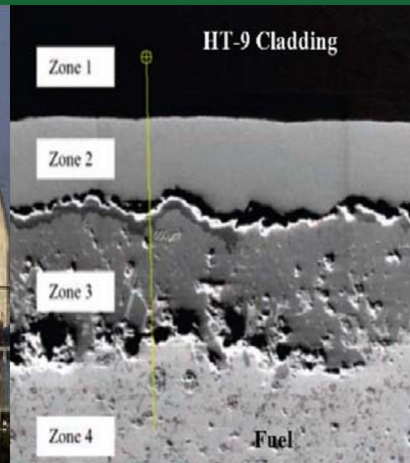
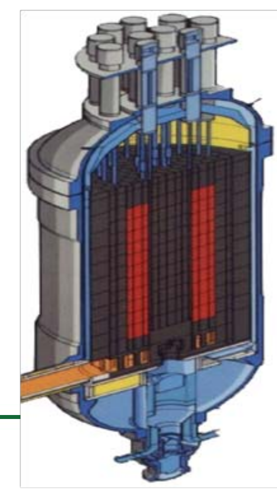
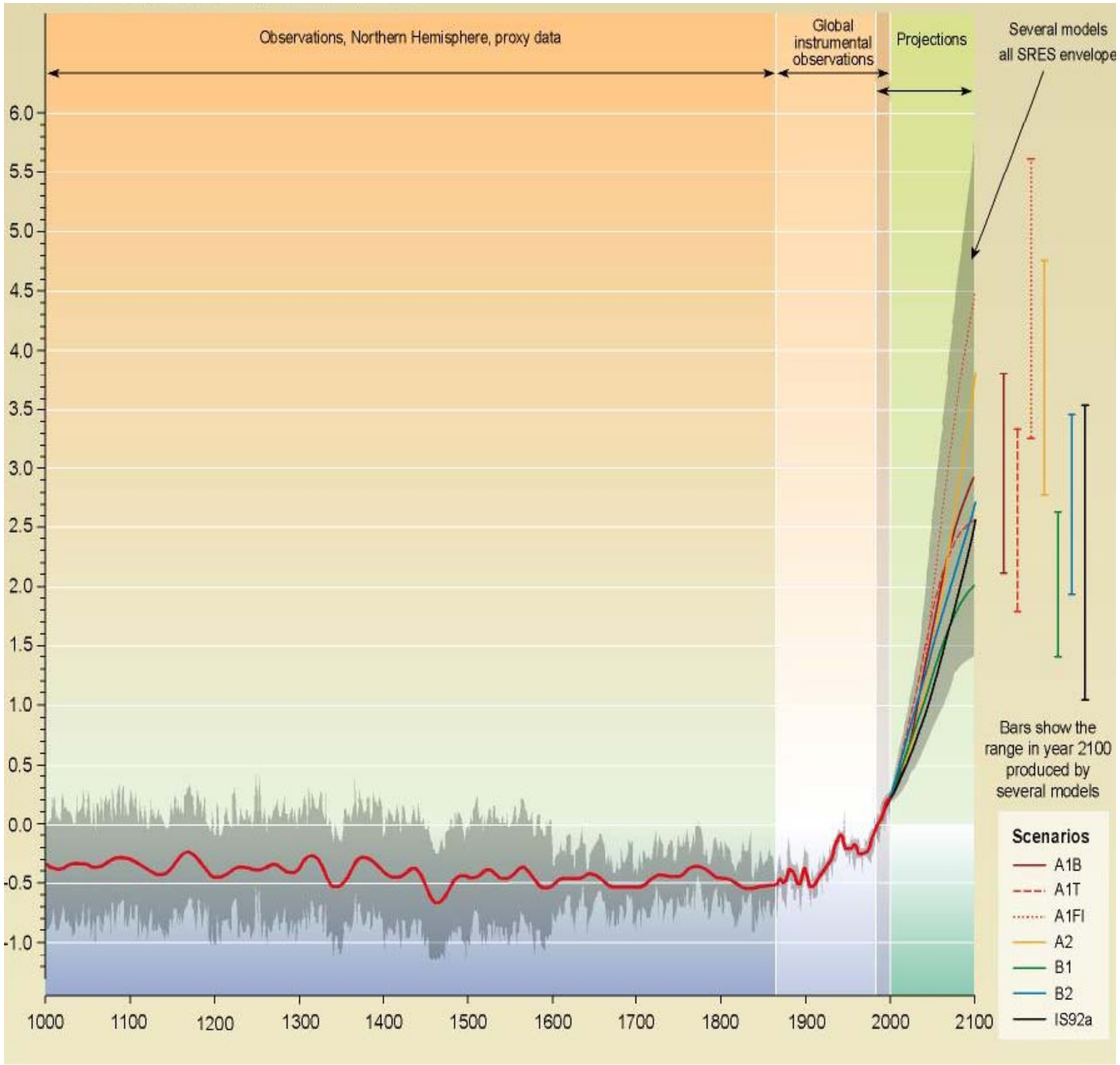
Opportunities in Nuclear Energy



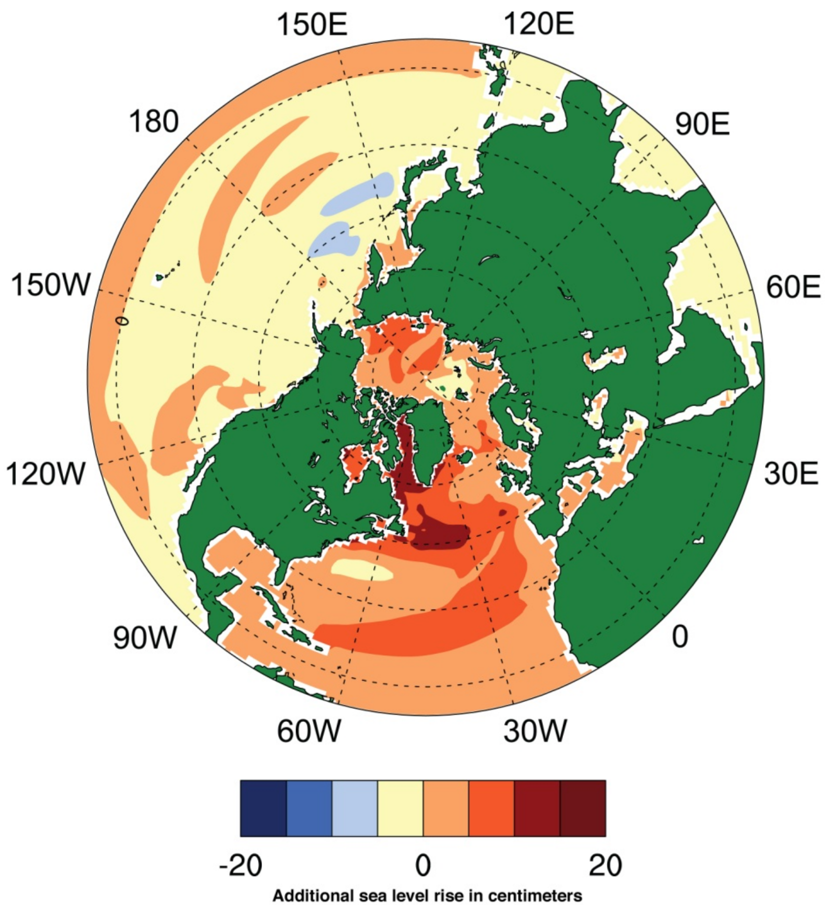
- **Qualification of advanced fuels – use of simulations**
- **Separations, reprocessing, and waste forms**
- **Proliferation resistant fuels and waste forms**
- **Safety**
- **Risk methodologies**
- **Fusion and Fission/fusion concepts**



Current Climate Models Predict a Range of Surface Temperatures by 2100



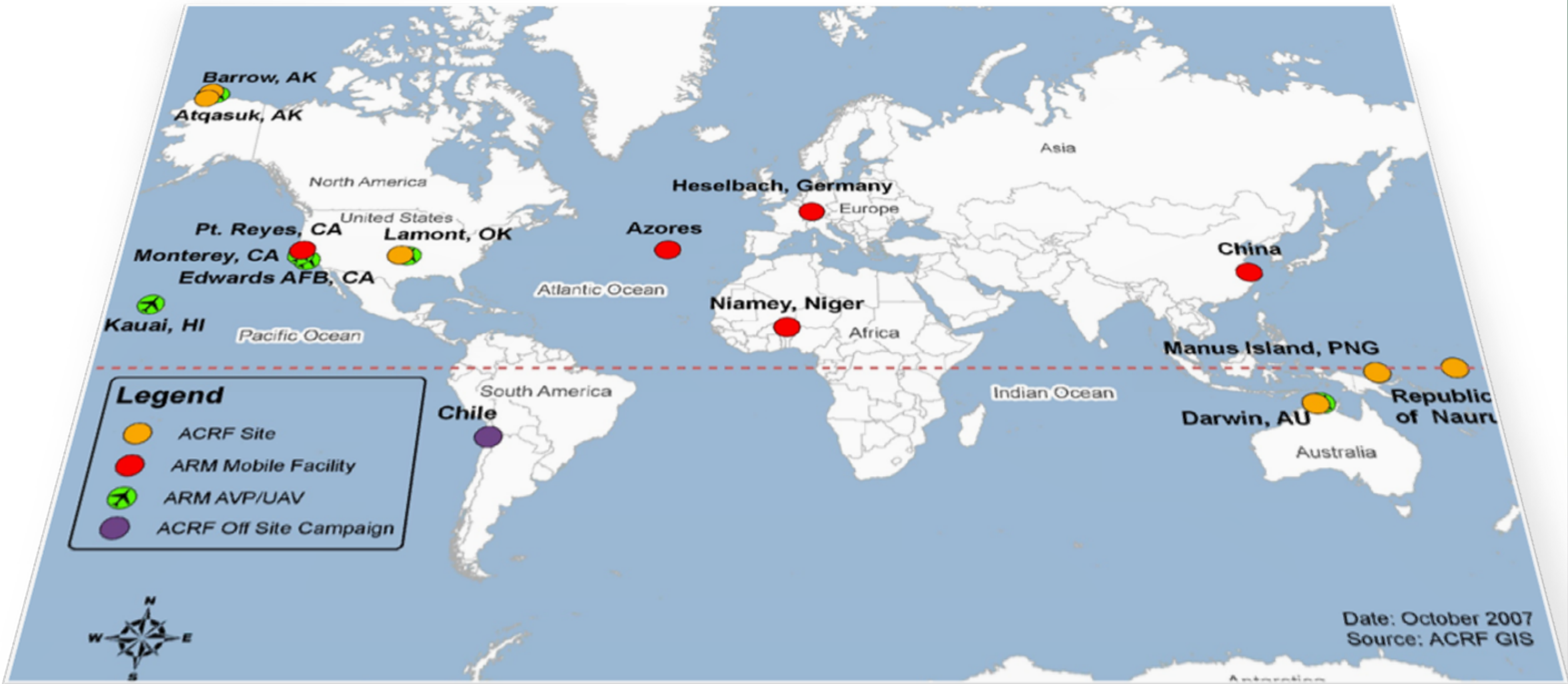
Major Uncertainties in Climate Change



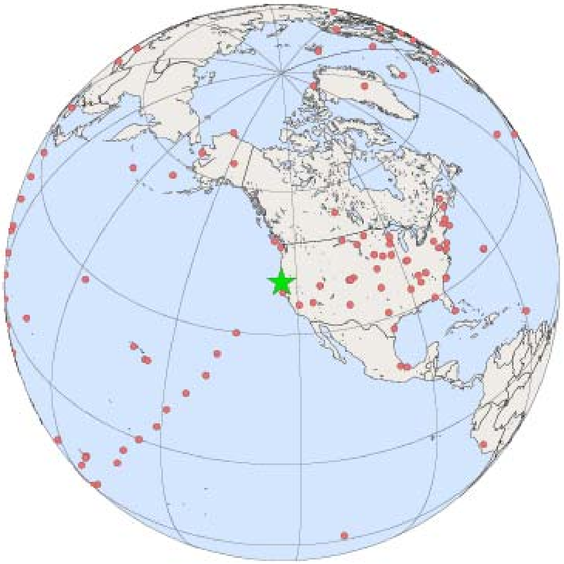
Modeling the impacts of climate change
Sea level rise modeled with the
Community Climate System Model

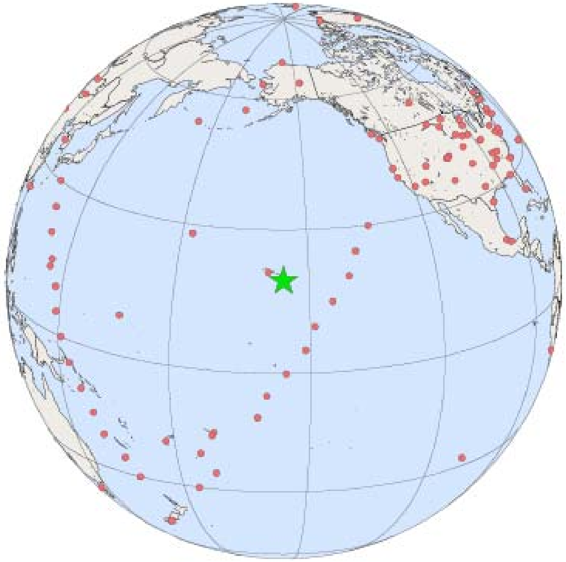
- Representation of **clouds**
- Direct and indirect effects of **aerosols**
- Interactions of the **carbon cycle**
- Impacts on **energy** production and use
- **Land-use** patterns

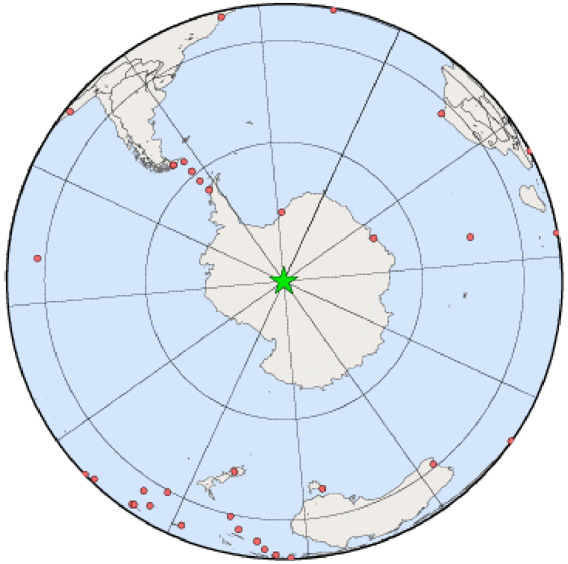
DOE Atmospheric Radiation Measurement Sites



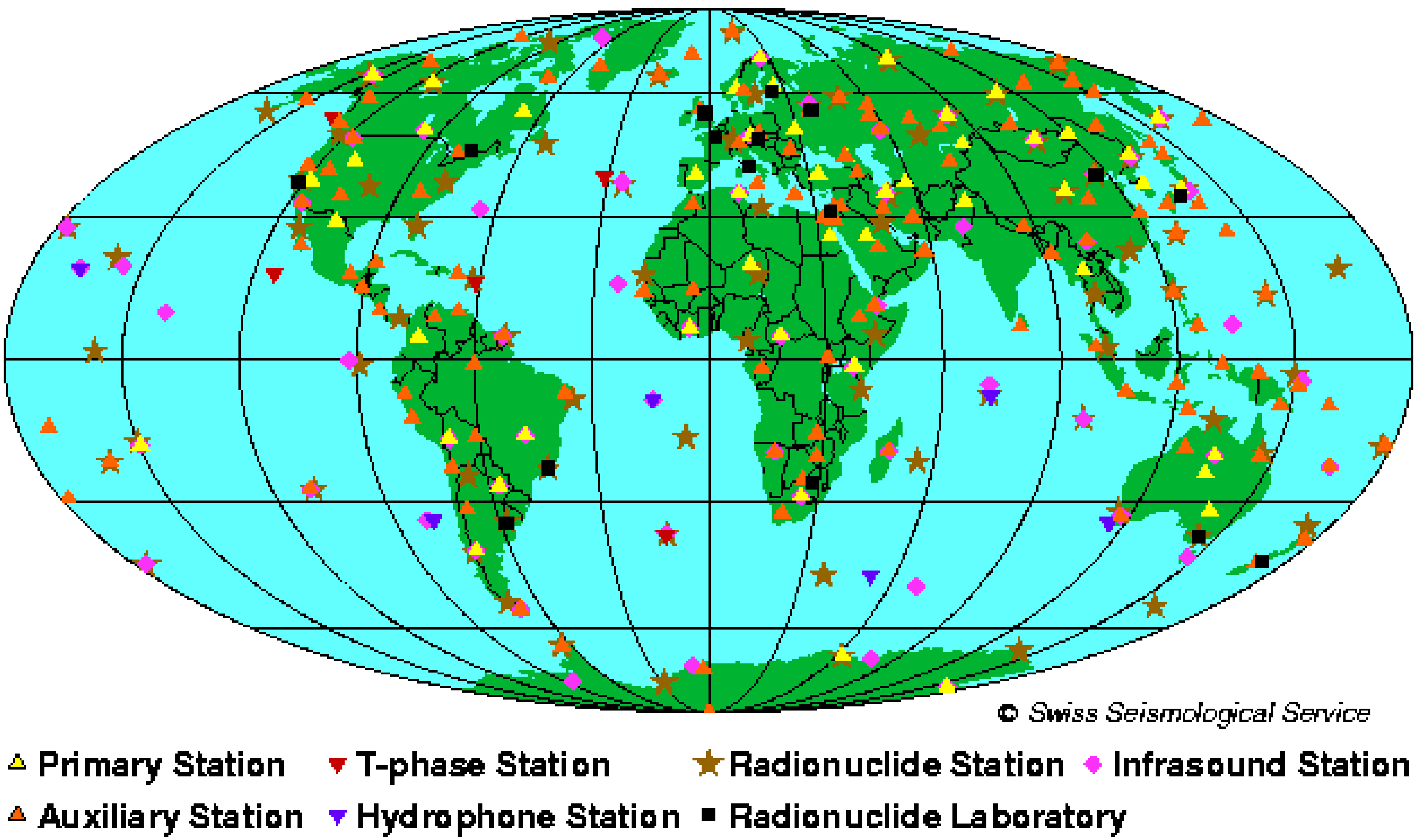
NOAA Global Monitoring Sites







CTBT Network of Integrated Monitoring Stations



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NOAA Global Data Collection

- **Aerosols**
- **Carbon Monoxide, Carbon Dioxide, and Methane**
- **Surface Ozone**
- **Ozone Soundings**
- **Water Vapor**
- **Station Meteorology**
- **Halocarbons and other Atmospheric Trace Species**
- **GMD Radiation**
- **SURFRAD**
- **Atmospheric Transport**

The Three SC Themes Impact Many Secretarial Priorities*

National Scientific User Facilities

Science for Discovery

Science for National Need

Science and Discovery: Invest in science to achieve transformational discoveries.

- Organize and focus on breakthrough science.
- Develop and nurture science and engineering talent.
- Coordinate DOE work across the department, across the government, and globally.

Clean, Secure Energy: Change the landscape of energy demand and supply.

- Drive energy efficiency to decrease energy use in homes, industry, and transportation.
- Develop and deploy clean, safe, low-carbon energy supplies.
- Enhance DOE's application areas through collaboration with its strengths in science.

Economic Prosperity: Create millions of green jobs and increase competitiveness.

- Reduce energy demand.
- Deploy cost-effective low-carbon clean energy technologies at scale.
- Promote the development of an efficient, "smart" electricity transmission and distribution network.
- Enable responsible domestic production of oil and natural gas.
- Create a green workforce.

Lower GHG Emissions: Position U.S. to lead on climate change policy, technology, and science.

- Provide science and technology inputs needed for global climate negotiations.
- Develop and deploy technology solutions domestically and globally.
- Advance climate science to understand better the human impact on the global environment.