Science for the Energy Challenge

Presented to
Friends of ORNL

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Oak Ridge, Tennessee
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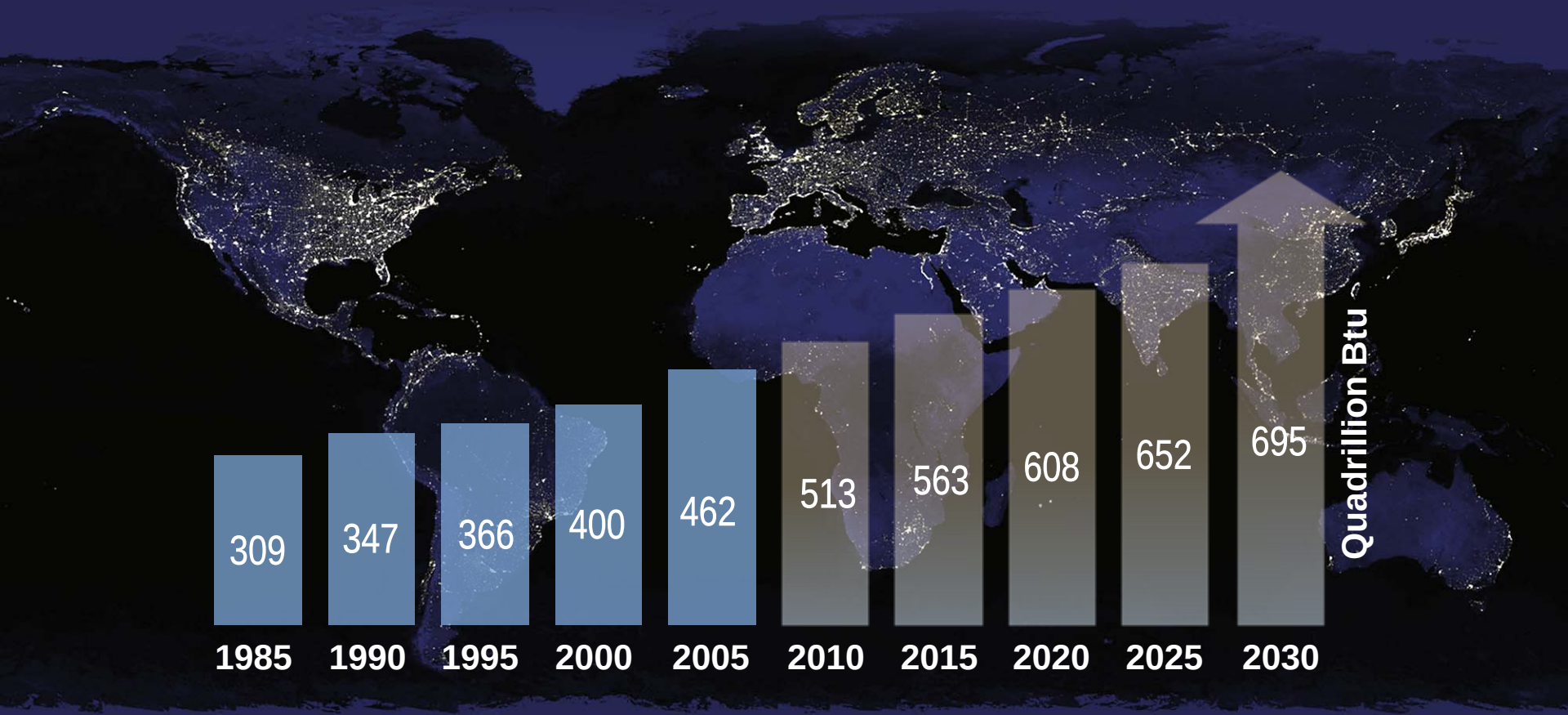
U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE U.S. DEPARTMENT OF ENERGY

World energy consumption is projected to increase by 50% from 2005 to 2030



Source: International Energy Outlook 2008, DOE/EIA-0484(2008),
Energy Information Administration, June 2008

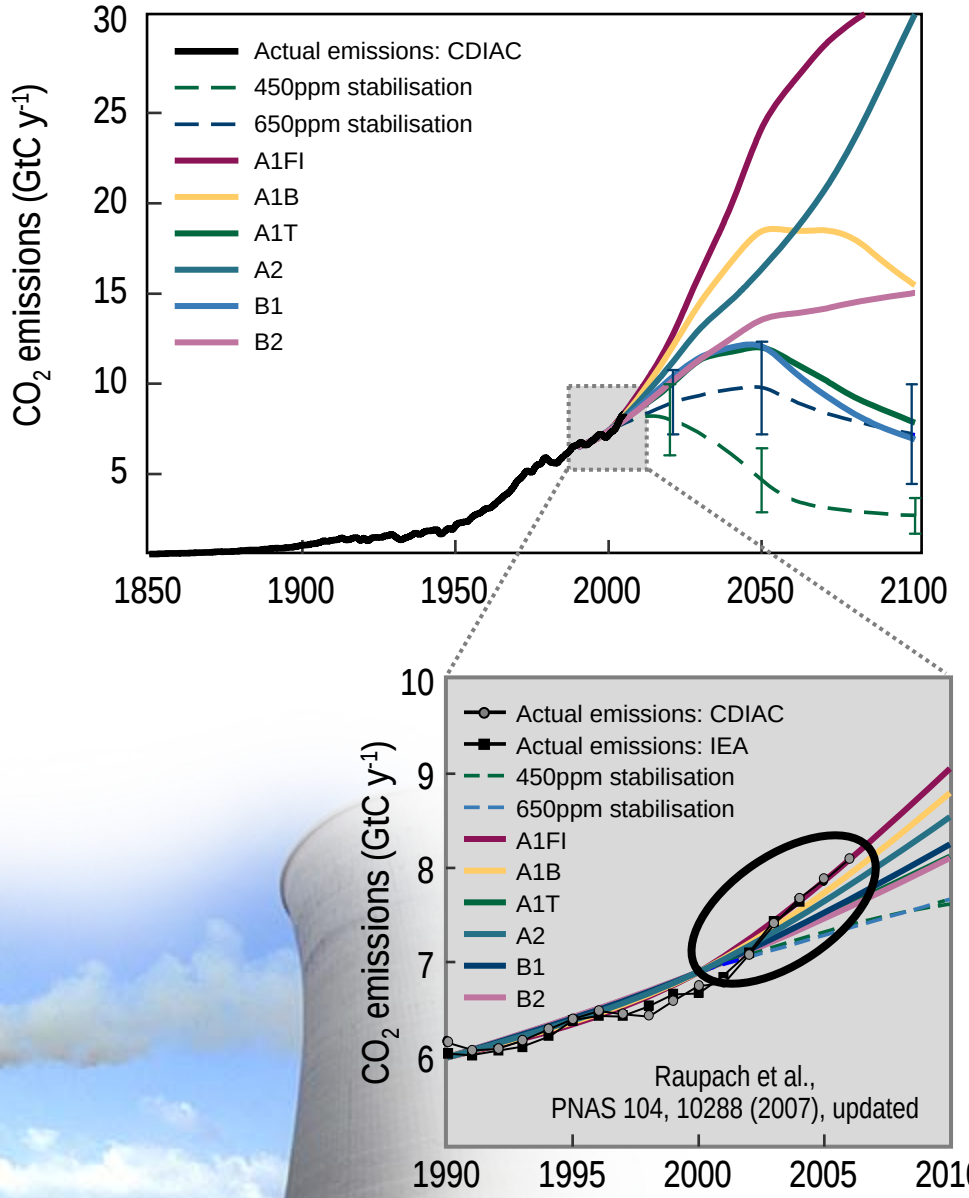
Energy and climate: Important issues for the new Administration

New Energy for America

- Tackle climate change: Implement an economy-wide cap-and-trade system to reduce GHG emissions to 80% below 1990 levels by 2050
- Invest to reduce our dependence on foreign oil and accelerate deployment of low-carbon technologies
  - $150B over 10 years for plug-in hybrid electric cars, renewables, energy efficiency, clean coal technology, biofuels, digital grid
  - $1B/year to create “clean technology centers” and train clean energy workforce
- Make our cars, trucks, and SUVs fuel efficient
  - Raise fuel economy standards 4% per year
  - Put 1 million plug-in electric vehicles on the road by 2015
- Promote the supply of domestic energy: Responsible production of oil and natural gas
- Diversify our energy sources
  - Require ≥10% of electricity from renewables by 2012
  - Develop and deploy clean coal technology
  - Safe and secure nuclear energy
- Commit to efficiency improvements

Human activity is affecting global climate

- Atmospheric CO_2 concentrations are increasing rapidly
  - 1990–1999: +1.5 ppm per year
  - 2000–2007: +2.0 ppm per year
  - 2007: +2.2 ppm per year
- Three processes are contributing to this increase:
  - Growth in world economy
  - Increase in carbon intensity
  - Decline in efficiency of CO_2 sinks on land and in oceans
- Climate forcing is both stronger than expected and sooner than expected



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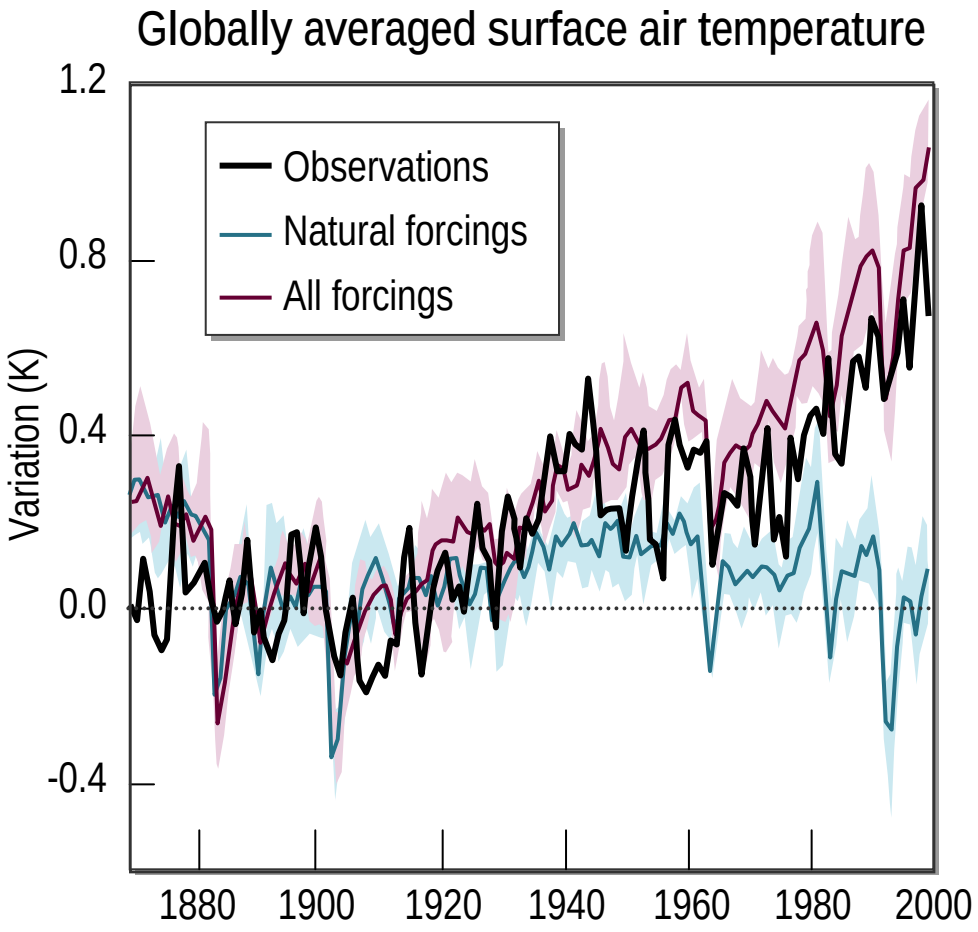
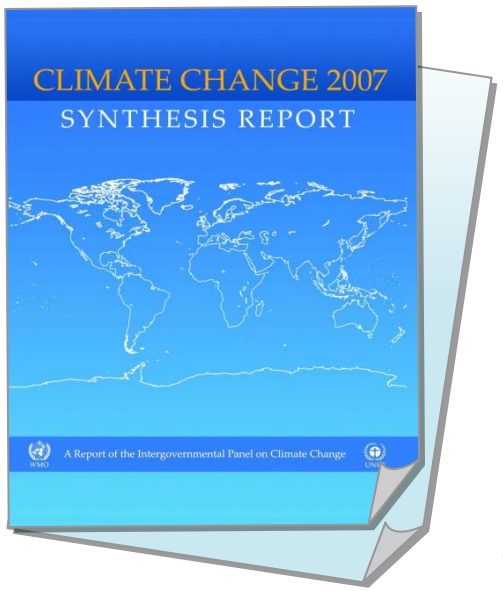
IPCC 2007: “Warming of the climate system is unequivocal”

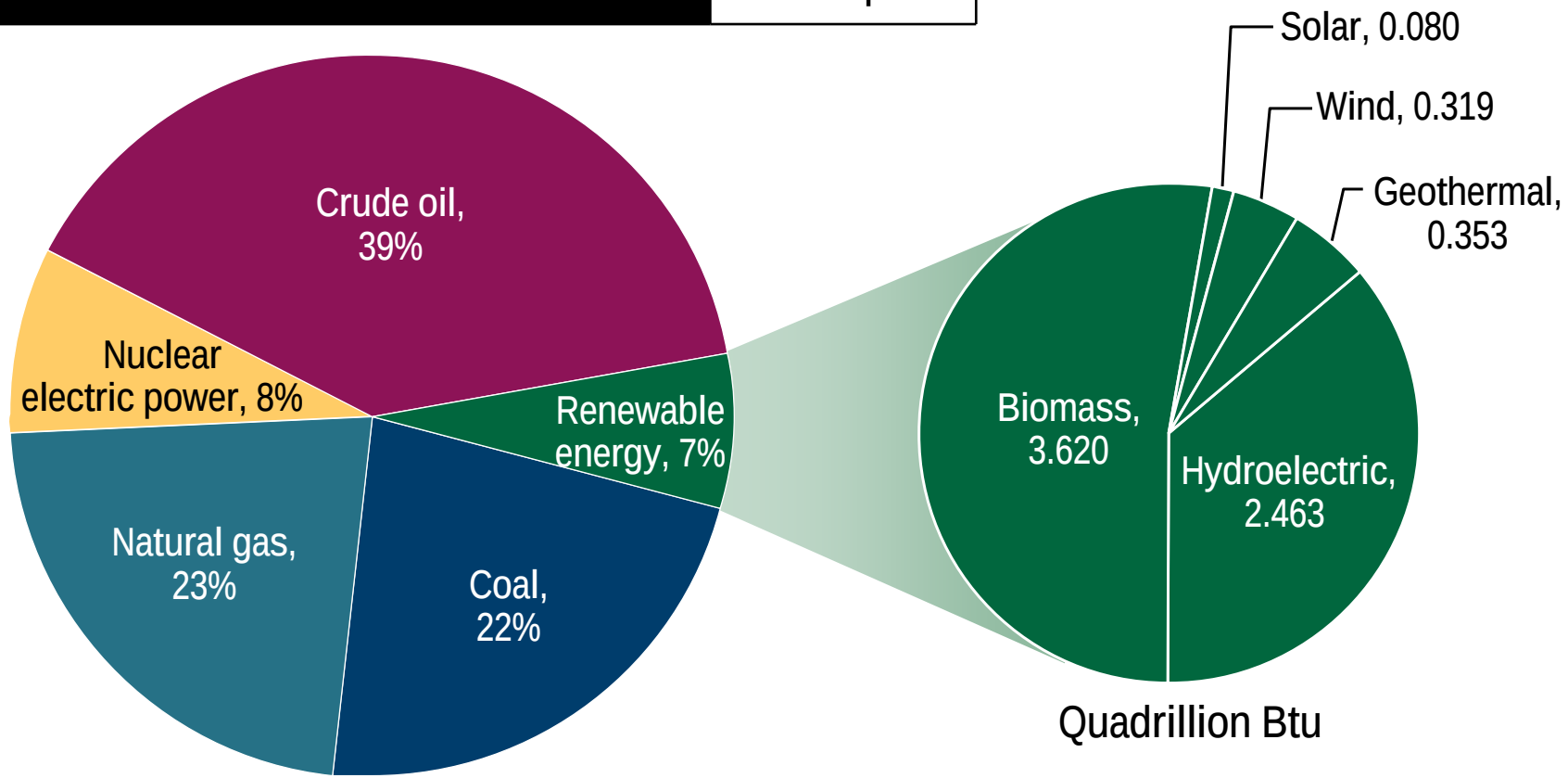


- Global atmospheric concentrations of greenhouse gases have increased markedly as a result of human activities since 1750
- Most of the observed increase in global average temperature since the mid-20th century is very likely due to increased greenhouse gas concentrations

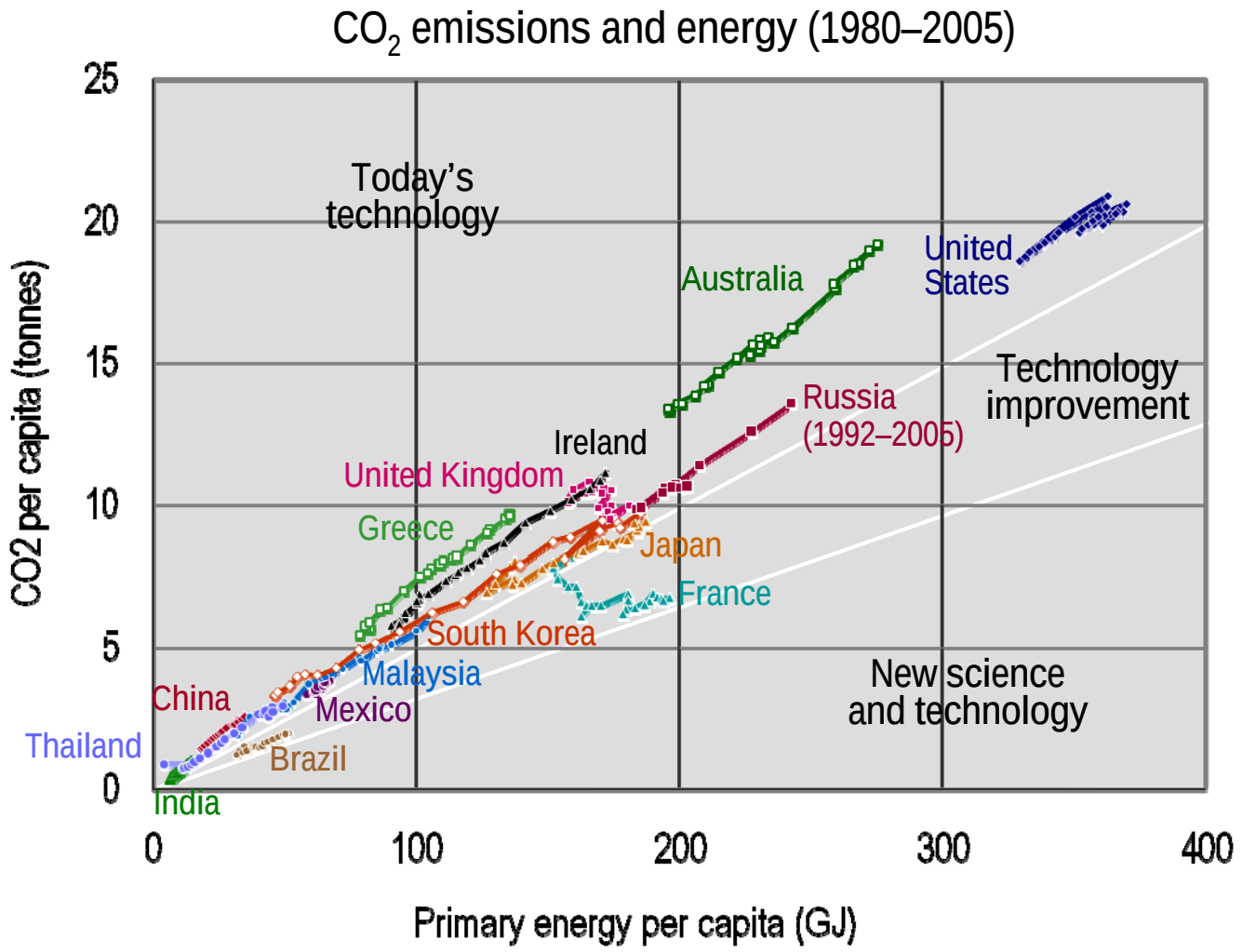


Fossil fuels are still the source of most of the nation's energy

Total U.S. energy consumption, 2006	~102 quads
Nonfossil sources	~15 quads



We can break the connection between energy use and CO_2 emissions



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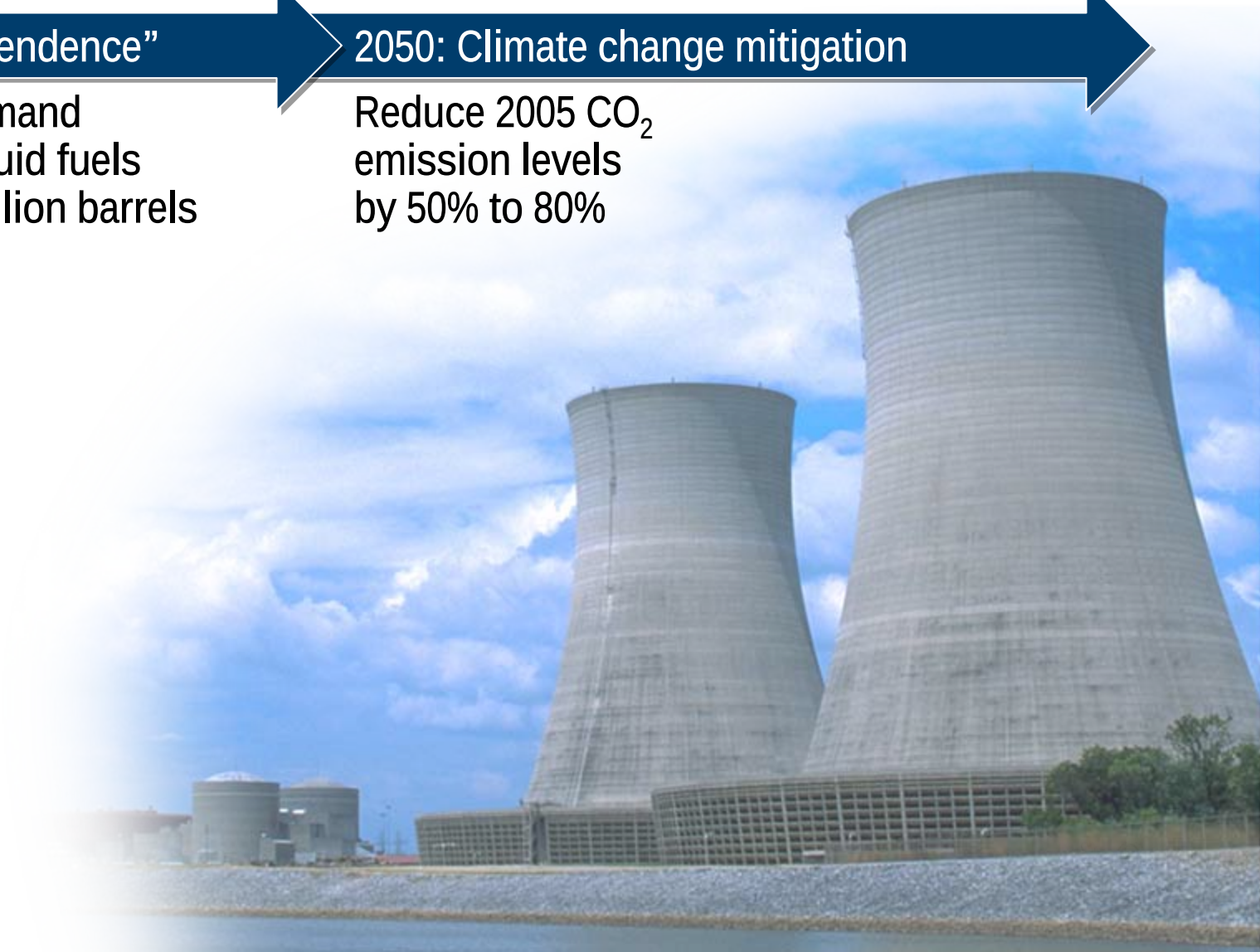
Energy assurance:
Meeting our energy needs in an economically and environmentally responsible way

2030: Oil "independence"

Decrease oil demand and increase liquid fuels to replace 11 million barrels of oil per day

2050: Climate change mitigation

Reduce 2005 CO_2 emission levels by 50% to 80%

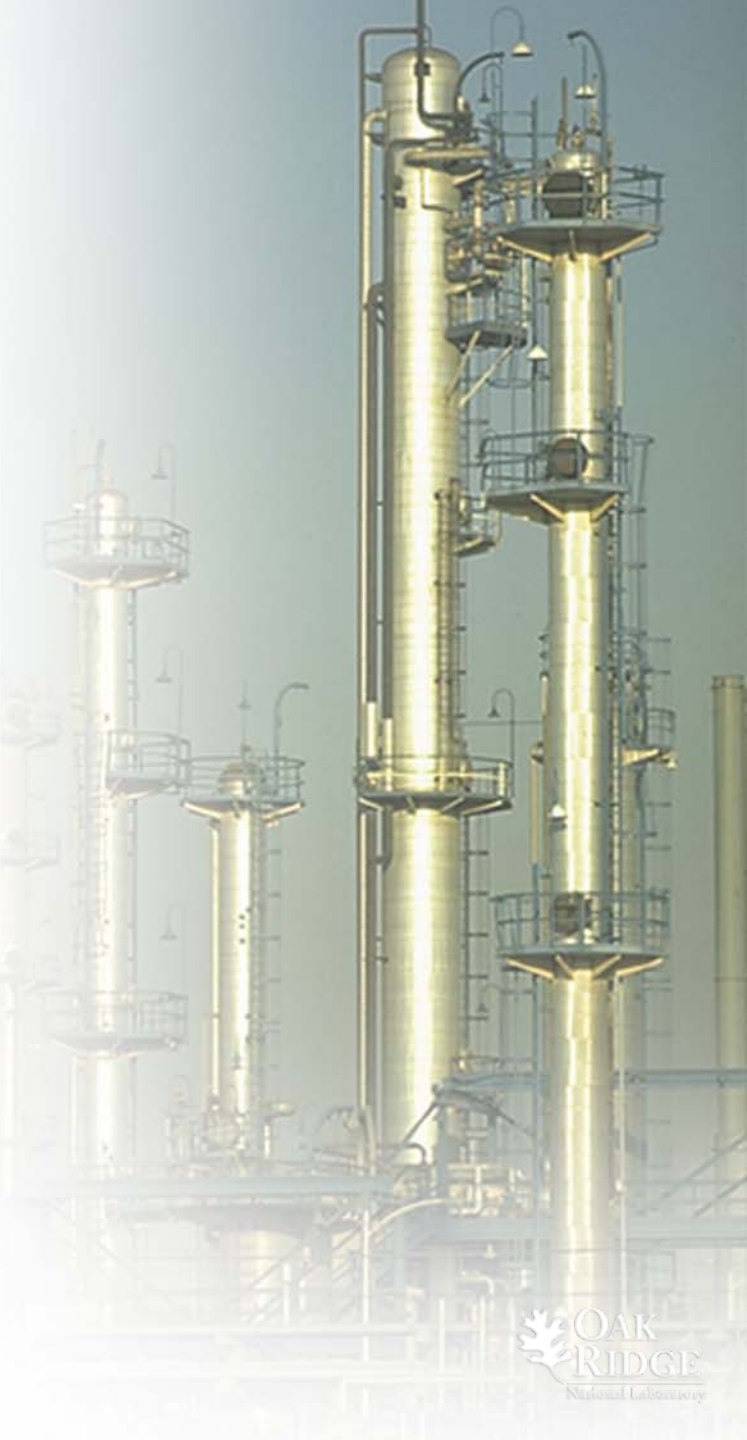


Making the United States "oil independent"

Oil dependence	Oil independence
• Primarily an economic problem with vital national security implications • Causes: – Use of market power by oil-producing states – Importance of oil to the economy – Lack of economical substitutes for oil	• Not eliminating the use of oil • Not cutting out oil imports • Attaining a state in which the U.S. is "not subject to restraining or directing influence by others" as a consequence of our need for oil

Oil independence:
Setting a measurable goal

Qualitative	Quantitative
For all conceivable world oil market conditions, the costs of oil dependence to the economy will be so small that they have no effect on economic, military, or foreign policy	The estimated total economic costs of oil dependence in any year will be less than 1% of GDP with 95% probability by 2030



Carbon management: Reducing emissions of CO_2

- Roughly one-third of U.S. carbon emissions come from power plants and other large point sources
- Carbon capture and storage technologies:
  - Help to meet growing U.S. power needs through environmentally responsible use of coal
  - Can be readily transferred to other nations
- Work is needed to:
  - Develop cost-effective CO_2 capture and separation processes
  - Understand CO_2 sequestration in geological formations
  - Improve the full life-cycle carbon uptake of terrestrial ecosystems
  - Explore advanced chemical, biological, and decarbonization concepts

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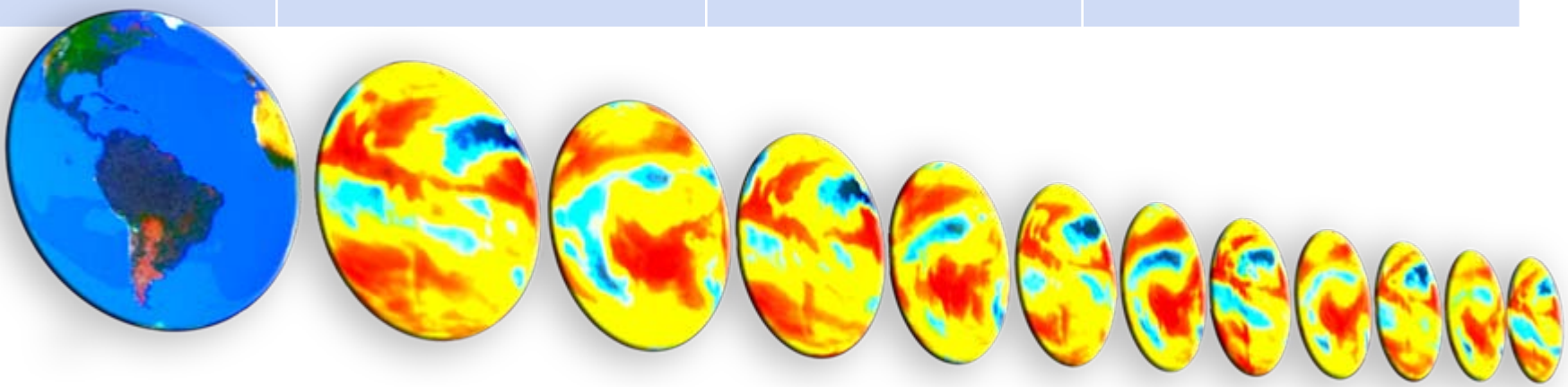
CO_2 stabilization: Mitigation efforts over the next few decades will be key

CO_2 stabilization level	Global mean temperature increase	Year in which CO_2 needs to peak	Global sea level rise above preindustrial
445–490 ppm	2.0–2.4°C	2000–2015	0.4–1.4 m
490–535 ppm	2.4–2.8°C	2000–2020	0.5–1.7 m
535–590 ppm	2.8–3.2°C	2010–2030	0.6–1.9 m
590–710 ppm	3.2–4.0°C	2020–2060	0.6–2.4 m



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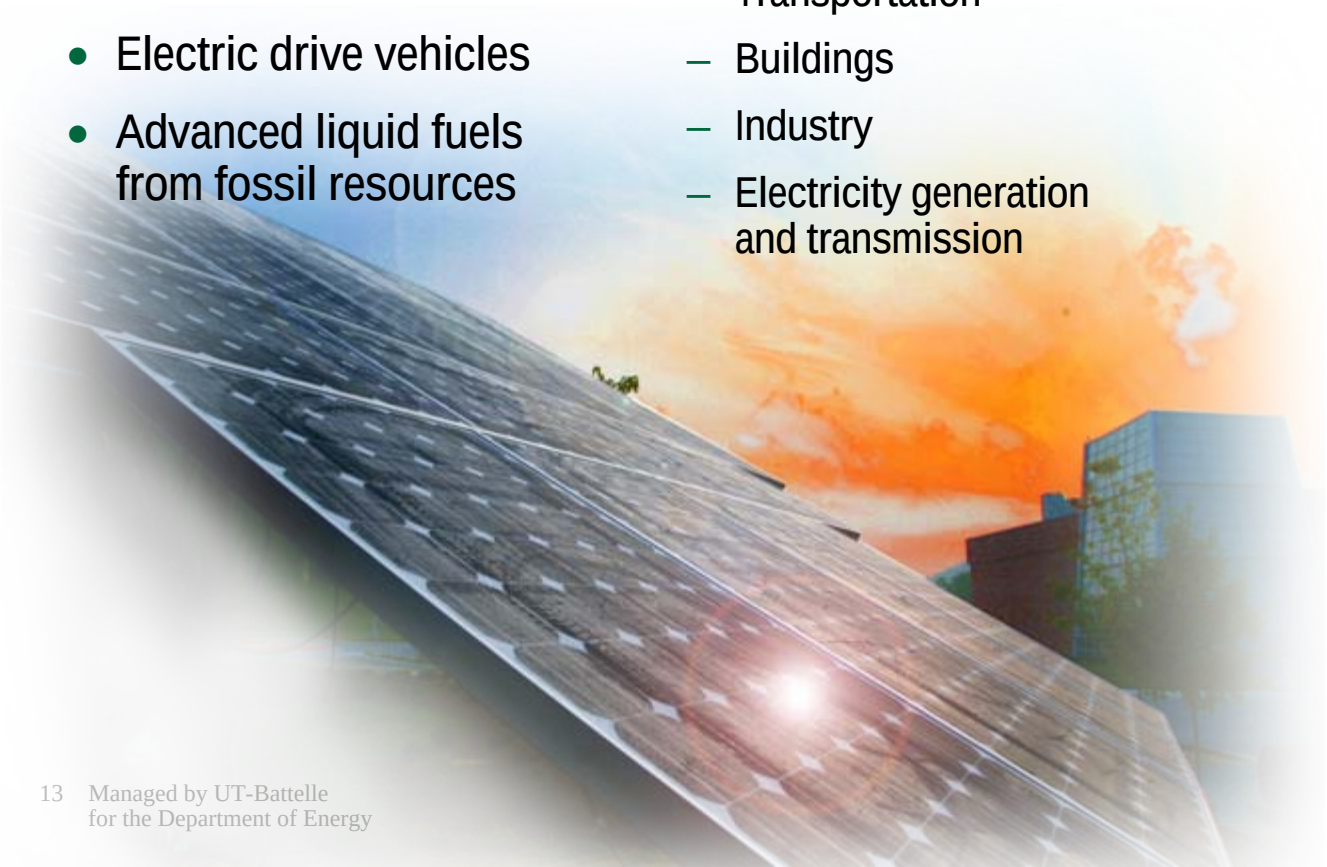
Meeting our energy assurance goals: Essential energy technologies

- Nuclear power
- Wind
- Solar
- Biofuels
- Electric drive vehicles
- Advanced liquid fuels from fossil resources
- Carbon capture and storage
- Major improvements in energy efficiency for:
  - Transportation
  - Buildings
  - Industry
  - Electricity generation and transmission

Major advances in basic science and supporting technology will be required to ensure success



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ORNL has an extraordinary set of assets for tackling the energy challenge

- World-leading neutron science capability
- World's most powerful open scientific computing complex
- Nation's largest and best integrated basic and applied materials research program
- One of 3 DOE Bioenergy Research Centers
- Deploying our S&T assets to deliver solutions for energy efficiency and transmission
- Leadership of the U.S. ITER project
- Nuclear science and technology for advanced fuel cycles and nonproliferation

Our challenge:
Use these assets to deliver results that are significant on regional, national, and international scales

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Leading the development of ultrascale scientific computing

- **Leadership Computing Facility:**
  - **World's most powerful scientific computing facility**
  - **Jaguar operating at 1.64 petaflops**
  - **Exascale system within the next decade**
  - **Focus on computationally intensive projects of large scale and high scientific impact**
- **With the University of Tennessee, developing a second petascale computer for the National Science Foundation**

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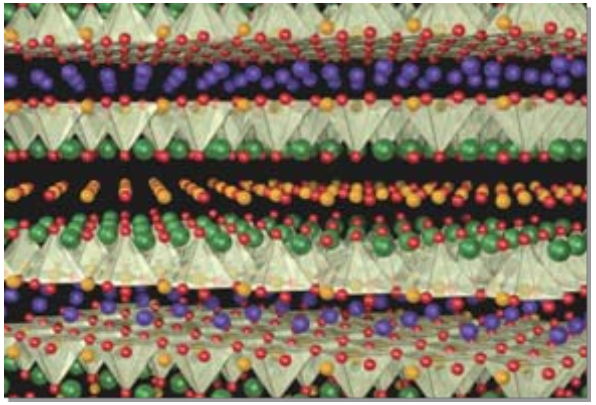
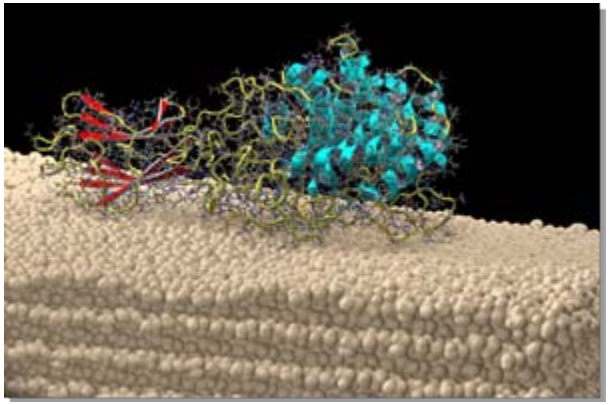
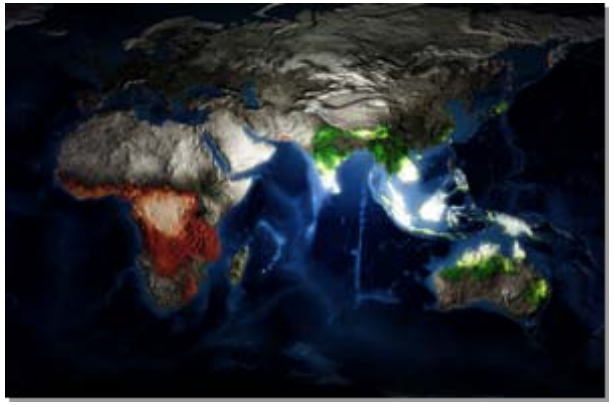
Simulation and modeling will have dramatic impacts on energy security



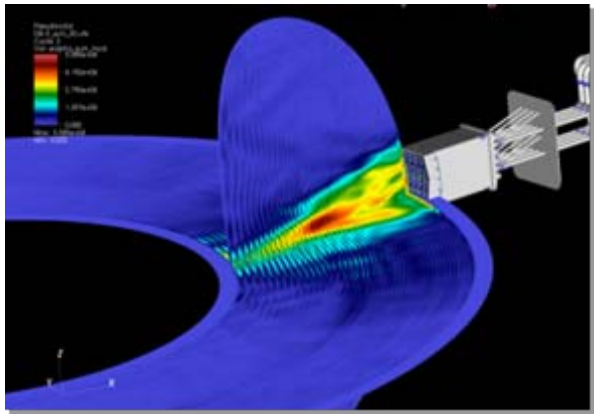
Nanostructure of high-T_c superconducting cuprates



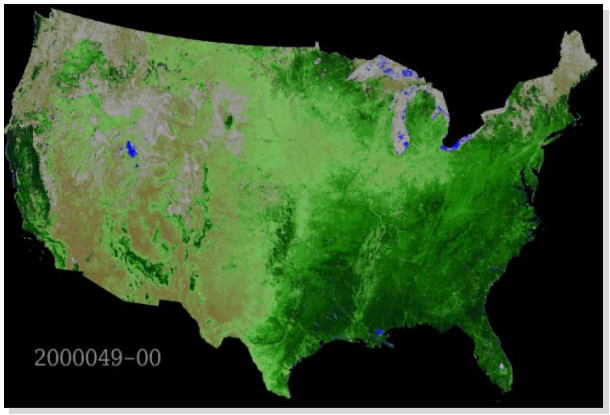
Protein structure and function for bioenergy



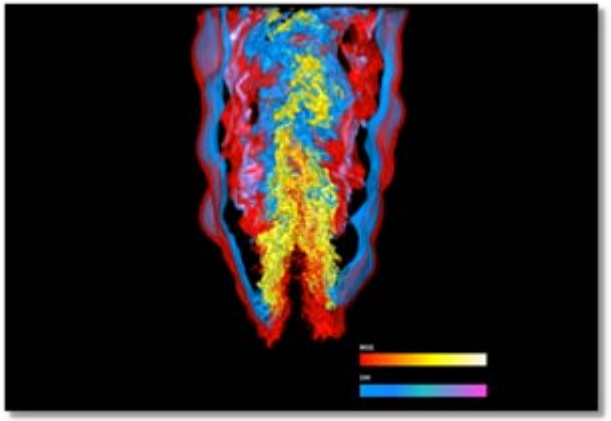
Climate codes for global, dynamic CO_2 exploration



Fusion energy: 3D plasma simulations for ITER



Bioresource modeling and monitoring



Combustion: 3-D simulations of flame

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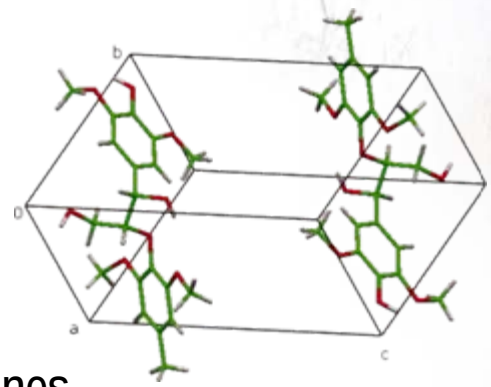
Bioscience to bioenergy

- BioEnergy Science Center is in operation, headquartered at UT-ORNL Joint Institute for Biological Sciences
- We are using our resources in neutrons and computing to understand molecular dynamics for bioenergy
  - Computational simulation of lignin aids in understanding biodegradability of lignocellulose
  - Neutron scattering reveals details of biomembranes, molecular machines, and biomolecular hydration
- We are partners in the Tennessee Biofuels Initiative
- We have launched a crosscutting LDRD initiative: S&T for Sustainable Bioenergy



Our transportation R&D addresses national imperatives

- Collaboration with NREL supports Presidential "20 in 10" initiative and related Energy Independence Security Act (EISA) actions
  - Generating and analyzing data on use of intermediate ethanol fuel blends in non-flexfuel fleet
  - Drafted report to Congress on optimized E85 vehicles
- Low-cost carbon fiber technologies: Gaining commercialization momentum
  - Significant industry partnership in negotiation
  - Fall 2008 workshop: Suppliers, manufacturers, and end users
- Energy storage: Targeted growth area
  - Projected ORNL budget growth, FY08 to FY09: 120%
  - Focus on Li-ion battery materials and processing
- USAutoPARTS: Partnership with automotive suppliers and State of Michigan for precompetitive, collaborative R&D

USAutoPARTs

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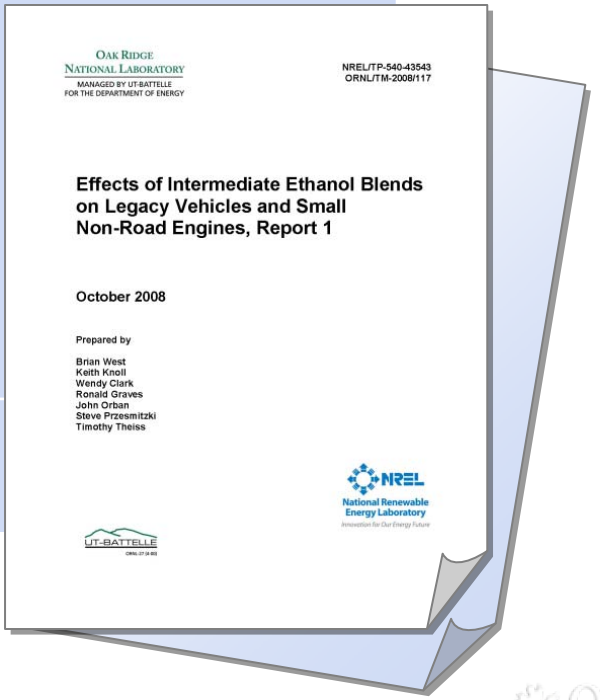
We are partnering with industry to meet national goals for use of renewable fuels

- Most U.S. gasoline contains up to 10% ethanol (E10)
- E85 can be used only in flexible-fuel vehicles (<3% of U.S. fleet)
- Test program to assess intermediate ethanol blends (up to E20)
  - Co-led by the biomass and vehicle technologies programs in DOE's Office of Energy Efficiency and Renewable Energy
  - Work conducted by ORNL, National Renewable Energy Laboratory, Battelle, U.S. Environmental Protection Agency, and industry partners
  - Examining effects of E10, E15, and E20 on late-model vehicles and small non-road engines

Effects of intermediate ethanol blends on vehicles: Initial results

Emissions and fuel economy	• Tailpipe emissions largely unaffected – CO emissions drop with increasing ethanol • Fuel economy decreased on volumetric basis (closely tracking fuel energy content)
Exhaust and catalyst temperature	• Catalyst temperatures unchanged or cooler • Higher exhaust temperatures in cars that ran less rich at full throttle – About half of vehicles tested
Operation and driveability	• No impact at 50°F or 75°F



We are partnering with industry to put our energy technologies to work

- Supporting DOE goals: Zero-energy homes by 2020, zero-energy buildings of all kinds by 2025
  - DOE Commercial Building Initiative, a public-private partnership
  - Zero Energy Building Research Alliance with Schaad and TVA: Building zero-energy houses in Oak Ridge
- Deploying our hybrid electric water heater technology through a CRADA with GE
- Working with Johnson Controls to reduce our energy use

ZEBRAlliance™
Zero Energy Building Research Alliance

We are partnering with industry to improve grid reliability

- Project Hydra
  - Makes use of DOE-funded expertise and facilities at ORNL
  - Goal: Install 300-m HTS cables and HTS fault current limiters in 2 Manhattan substations by 2010
  - Partners: DHS, ConEdison, industry

- VERDE: Visualizing Energy Resources Dynamically on Earth
  - Developing tools for wide area situational understanding of the electric grid
  - Partners: TVA, Entergy, Southern Co., FRCC, ERCOT, SCANA, PJM, . . .

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We are part of the nuclear renaissance

- We are a key provider for DOE-NE
  - Advanced gas reactor fuel fabrication
  - Coupled end-to-end (CETE) demonstration of advanced aqueous separations
  - Generation IV materials
  - Isotope production
  - Radioisotope power sources
  - Modeling and simulation
- USEC CRADA has been renewed
- We have joined the SUNRISE consortium for nuclear science and energy education
- Our Safeguards Laboratory is a national user facility

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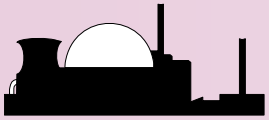
Coupled End-to-End Demonstration (CETE)

R&D to reduce the need for long-term spent fuel storage

Current once-through fuel cycle



Spent nuclear fuel to permanent geologic repository

CETE-enabled closed fuel cycle

Voloxidation

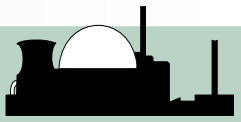
Cladding hulls	Zr reuse, or stored as low-activity waste form

Solvent extraction

FPEX	Cs/Sr (ceramic or glass) to geologic repository storage
TALSPEAK	Fission products (glass or metal) to geologic repository storage
TRUEX	Am/Cm transmutation targets
UREX	U/Pu/Np fuel product and U reuse, or stored as LLW

Pellet preparation

~480 fuel pellets	Fuel for power reactor

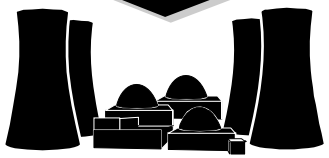


Overall mass balance

Cs/Sr	0.2 kg
Fission products + ~1 kg cladding	~1.8 kg
Fuel and targets	1 kg
Recycled cladding	~5 kg
LEU	18.0 kg

Recycled as reactor fuel

~24 kg



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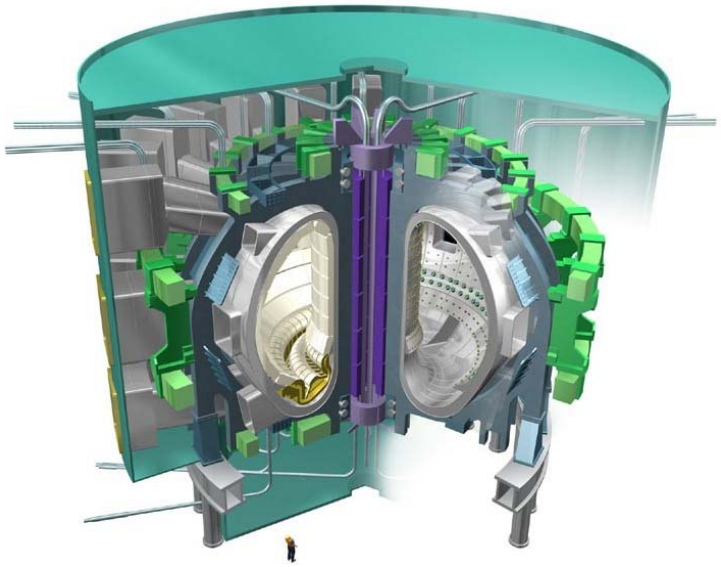
We are contributing to the international fusion program

- The U.S. team is making substantial contributions to the new ITER reference design despite a constrained budget
  - A National Academies report in July strongly endorsed U.S. participation in ITER
- ORNL supported design and operation of the ITER-Like Antenna for the Joint European Torus (JET) tokamak
- ORNL computing capabilities support fusion simulations for “ITER and beyond”



We are working to accelerate the rate of scientific breakthroughs needed to create advanced energy technologies

- Simple improvements in today's technologies will not meet requirements
- Technical barriers can be overcome only through high-risk/high-payoff research across a broad spectrum
  - Chemistry, physics, materials science, biology, engineering, nanoscience, computational science
- Interdisciplinary research is required
  - Fundamental science
  - Applied energy R&D
  - Increasing focus on integration of basic and applied research

Oak Ridge National Laboratory:
Meeting the challenges of the 21st century

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