What Does It Take to Address the Nation's Energy Challenges

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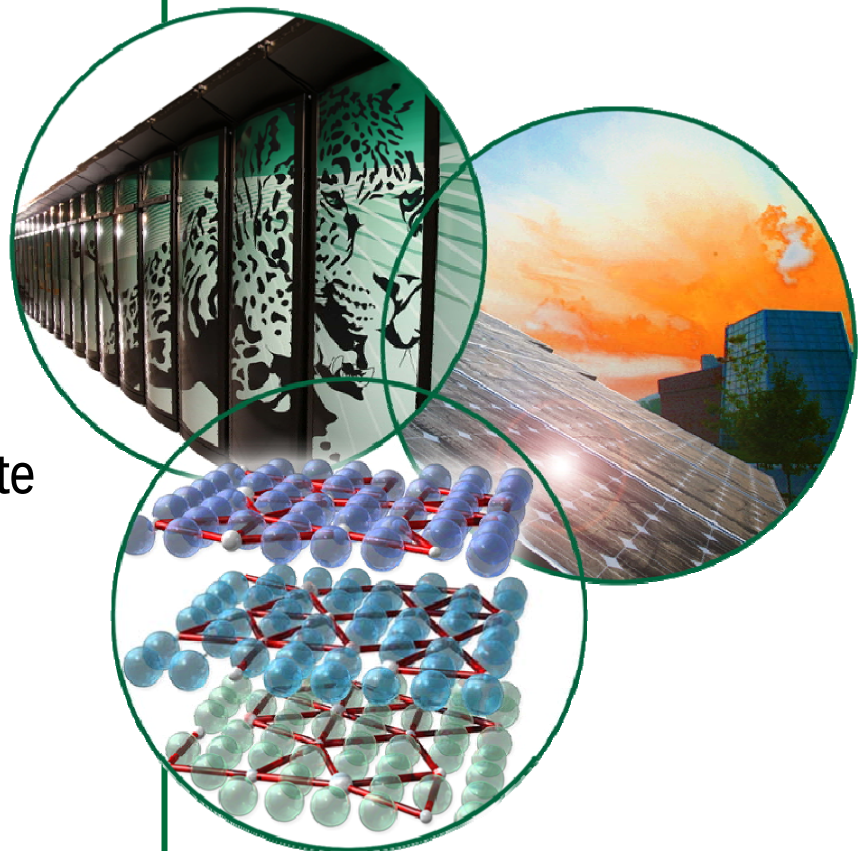
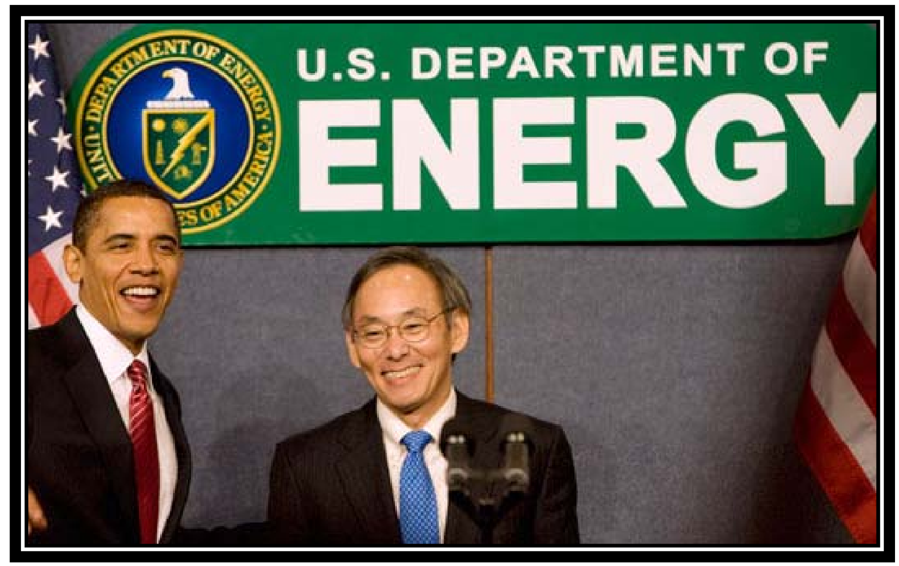


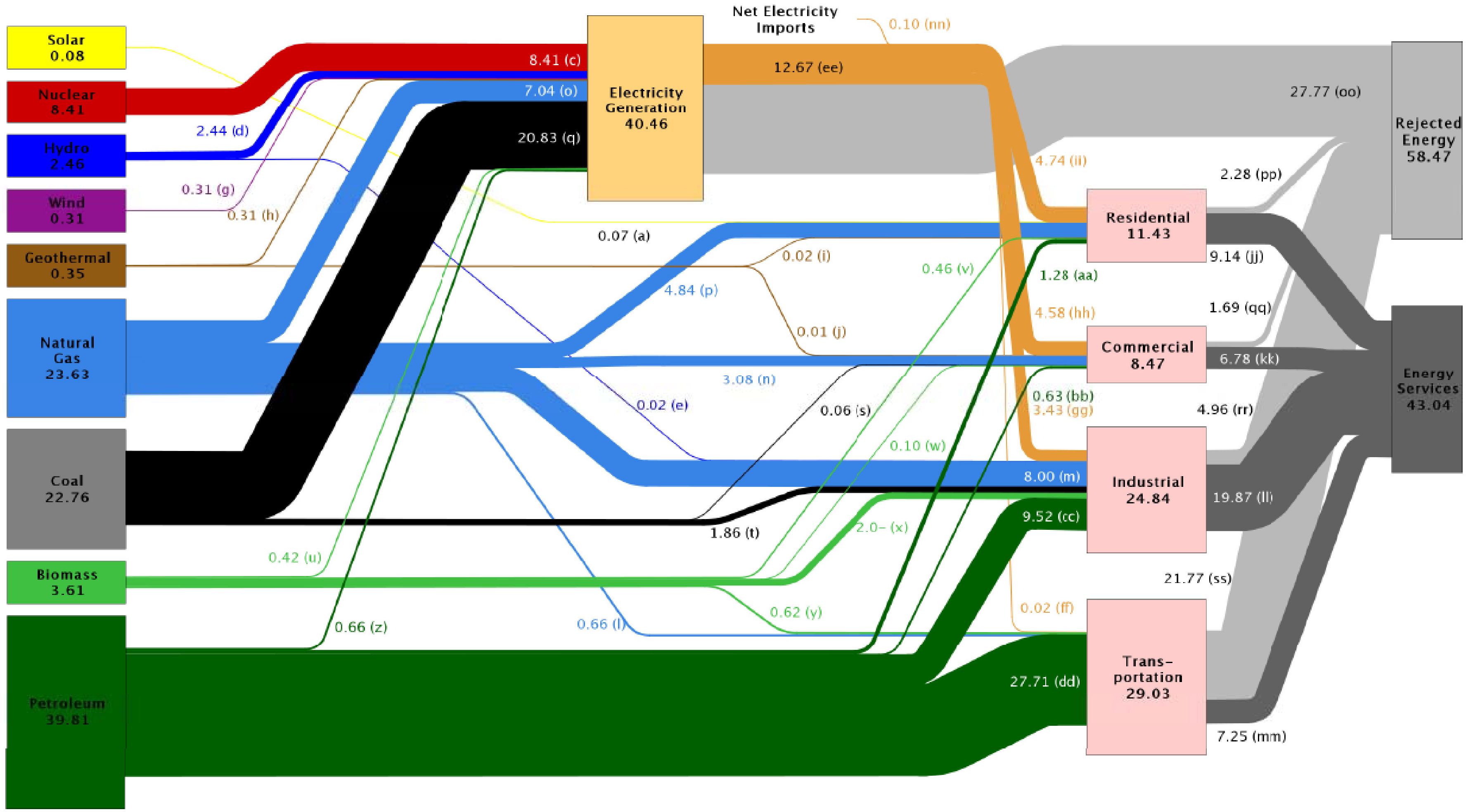
White House goals on energy future

- 80% reduction in greenhouse gas emissions by 2050
- 25% electricity from renewables by 2015
- Save more oil than imported from OPEC by 2019
- Deploy 1M plug-in hybrid cars by 2015
- Develop and deploy clean coal technology
- Weatherize 1M homes annually



Estimated U.S. Energy Use in 2007: ~101.5 Quads

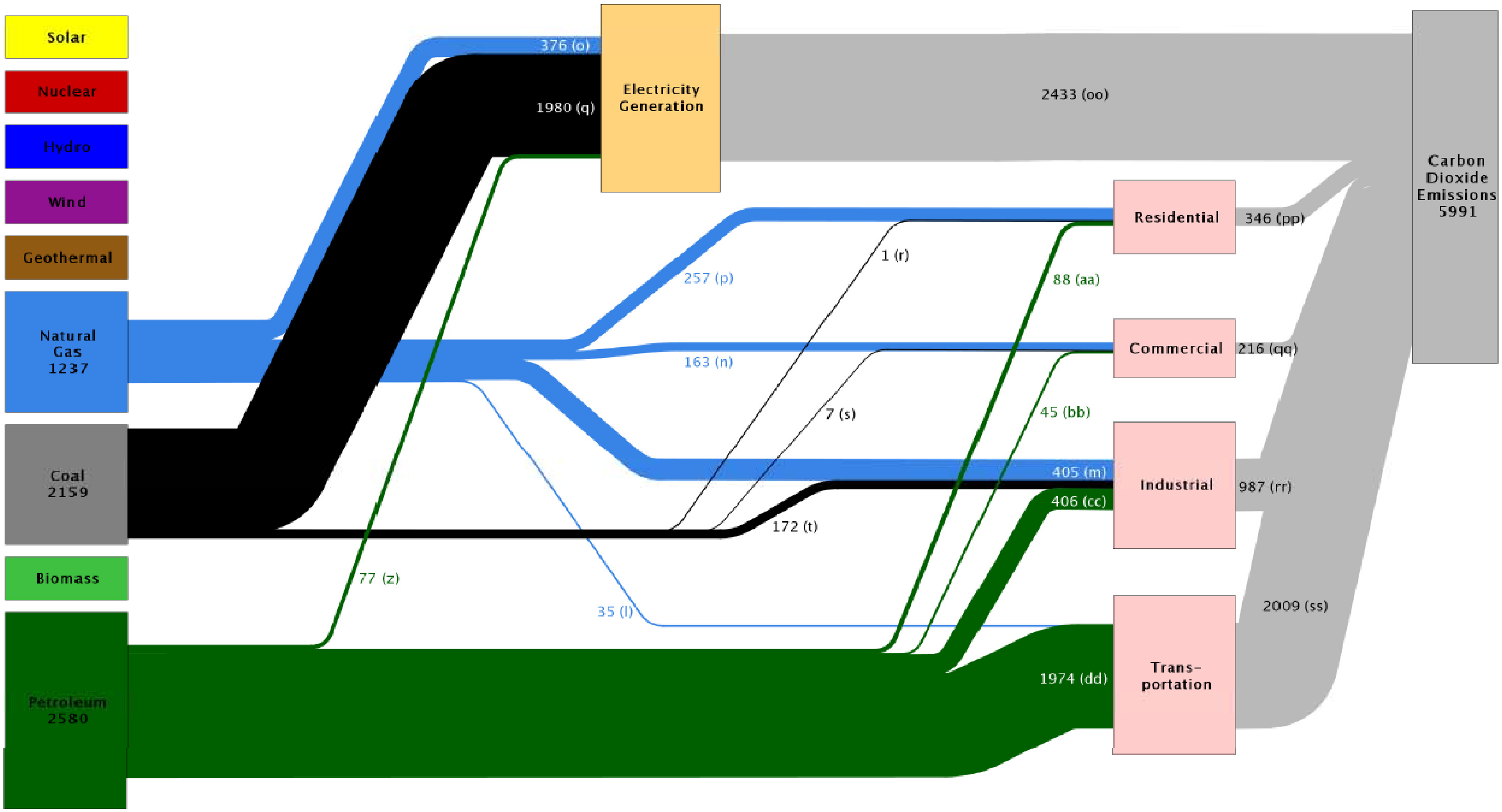
Lawrence Livermore National Laboratory



Source: LLNL 2008. Data is based on DOE/EIA-0384(2007), June 2008. 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 flows for non-thermal resources (i.e., hydro, wind and solar) 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 80% for the residential, commercial and industrial sectors, and as 25% for the transportation sector. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

Estimated U.S. Carbon Dioxide Emissions in 2007: ~5991 Million Metric Tons

Lawrence Livermore National Laboratory



Source: LLNL 2009. Data is based on DOE/EIA-0384(2008), June 2009. 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 embodied in industrial and commercial products such as plastics is not shown. The flow of petroleum to electricity production includes both petroleum fuels and the plastics component of municipal solid waste. The combustion of biologically derived fuels is assumed to have zero net carbon emissions – lifecycle emissions associated with biofuels are accounted for in the Industrial and Commercial sectors. Totals may not equal sum of components due to independent rounding. LLNL-MI-411167

EIA assumes 1%/yr. growth in energy demand*(Quads)

	2007	2015	2019	2050	Δ
Total Energy	101.50	109.9	114.4	155.0	
Electricity	40.46	43.8	46.0	62.0	
Residential	11.40	12.4	12.9	17.5	6.1
Commercial	8.50	9.2	12.1	13.0	4.5
Industrial	24.80	26.9	28.0	38.0	13.2
Total Petroleum	39.81	43.0	45.0	61.0	
Imported Petroleum	22.60	25.8	27.8	43.8	
Domestic Production+	17.20	17.2	17.2	17.2	
Transportation	29.03	31.4	33.0	45.0	

*Key question is the fidelity of a 1% demand growth through 2050.
+Unlikely that domestic production remains constant.

What must happen to achieve 25% RPS?

2015	=	44 quads of demand
		11 quads from renewables

Today

• Hydro/Geo	2.81 (no measurable growth)
• Solar	.08
• Wind	.31 quads
Total	3.20 quads
• Supply Growth	7.80 quads (20 x growth of solar and wind)

Barriers:

1. Cost (capital and operating)
2. Energy storage
3. Manufacturing capacity
4. Industry

What must happen to "save more oil than imported from OPEC by 2019"

	2019
Total Petroleum	45 quads
Imported OPEC	14+
Imported Other	13+
Domestic	17

Therefore the goal is to save 14 quads of Oil consumption (~5M bbl/day reduction And represents ½ of transportation)

Reference: 9M/bbl/day gasoline today

Vehicles

LD cars	135M registrations	9M bbl/day gasoline
LD trucks	101M registrations	
HD single axle	7M registrations	
HD combo	2.2M registrations	

Barriers

- Vehicle efficiency (convert to diesel)
- Batteries
- Light weight (composites)
- Power electronics
- Vehicle – infrastructure integration
- Electrification

What must happen to reduce greenhouse gas by 80% by 2050

- CO_2 today 6000 Mmt/yr.
- CO_2 2050 1200 Mmt/yr.

Assume	Additional non-GHG electricity (quads)
– Residential – no GHG growth	6.1
– Commercial – no GHG growth	4.5
– Industrial – no GHG growth	13.2
	23.8
– Traditional electricity	62.0
	85.8
• Transportation	14.0
• Behavior adjusted electricity demand	99.8

Energy profile of 2050

	Quads	CO_2 Emissions (1200M mt/yr. goal)
Electricity (100 quads) Renewables Fossil Nuclear	25 75	?
Residential (17.5 quads) Electricity Fossil	12.2 5.3	346
Commercial (13.0 quads) Electricity Fossil	9.3 3.7	216
Industrial (38.0 quads) Electricity Fossil	20.5 17.5	986
Transportation (45.0 quads) Electricity Fossil	14.0 31.0	2145

Summary of the energy challenge in meeting administration goals

1. Energy efficiency essential to all sectors
2. Growth in renewables to achieve 25% extremely challenging
3. Climate change R&D essential to understanding magnitude of the challenge: Impacts
4. Mobility: A new paradigm is required, electrification
5. Nuclear energy must grow substantially
6. Coal: CCS must succeed
7. Grid: A new paradigm is required
8. Biomass: Becomes the new feedstock for liquid fuels/chemicals

Oil independence really means sustainable mobility

Scientific Discovery | **Modeling & Simulation** | **Technology Innovation**

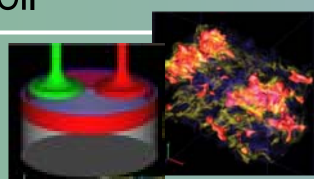
Alternative Fuel Sources


Unconventional Oil

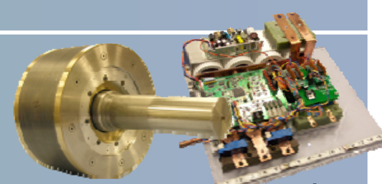

Bio-based fuels


Electrification

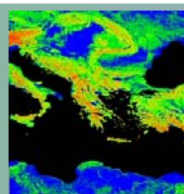
Efficient Vehicle Technology


High-efficiency clean combustion


Advanced Materials


Energy recovery and management

Optimized Infrastructure


Geospatial Information Systems

Intelligent Vehicles & Infrastructure, Driver Interface

Integrated Solutions

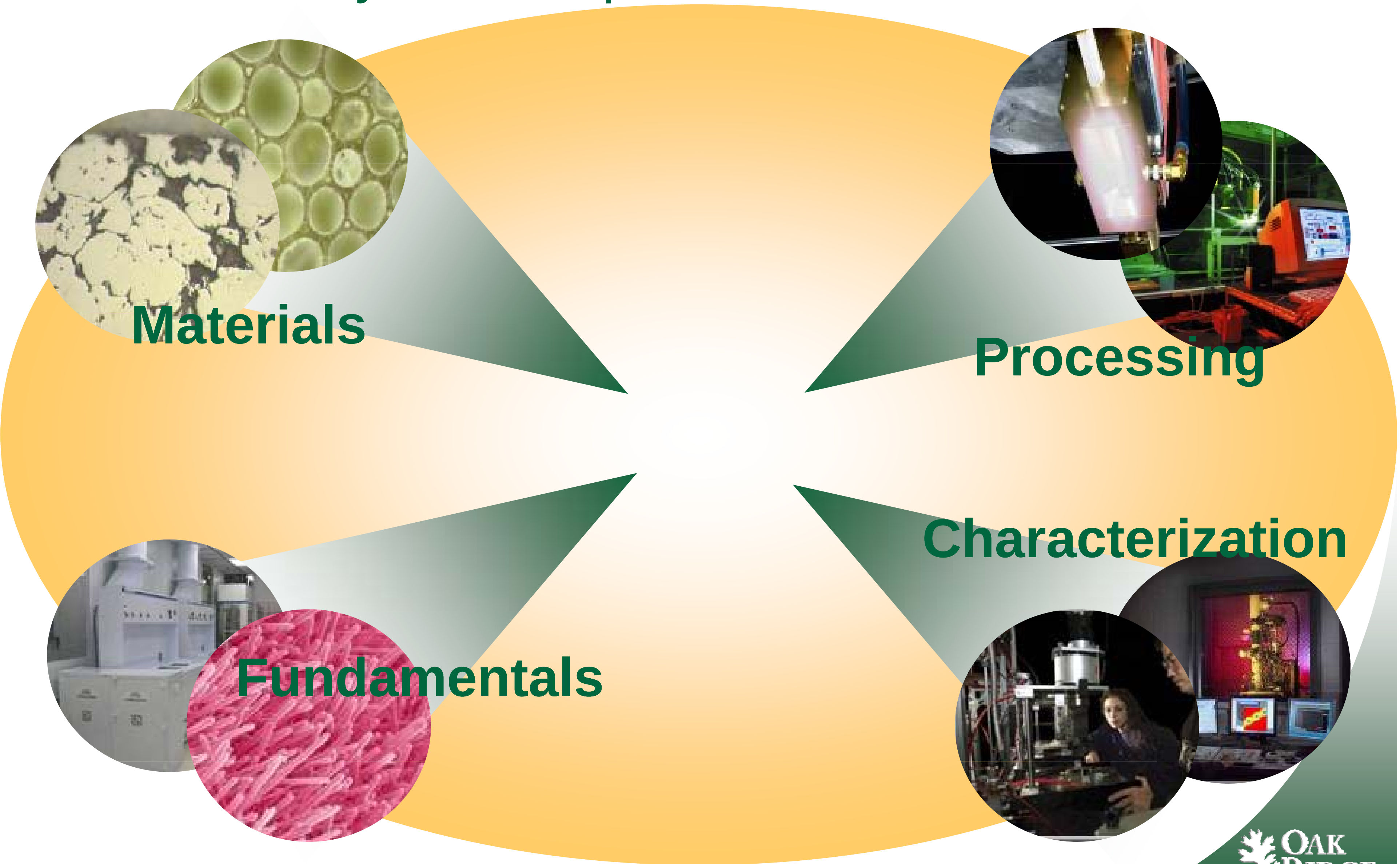
Objectives

- >100 MPGe Vehicles
- Compatible with Domestic Source Fuels
- Highly Intelligent, Adaptive Vehicles & Infrastructure

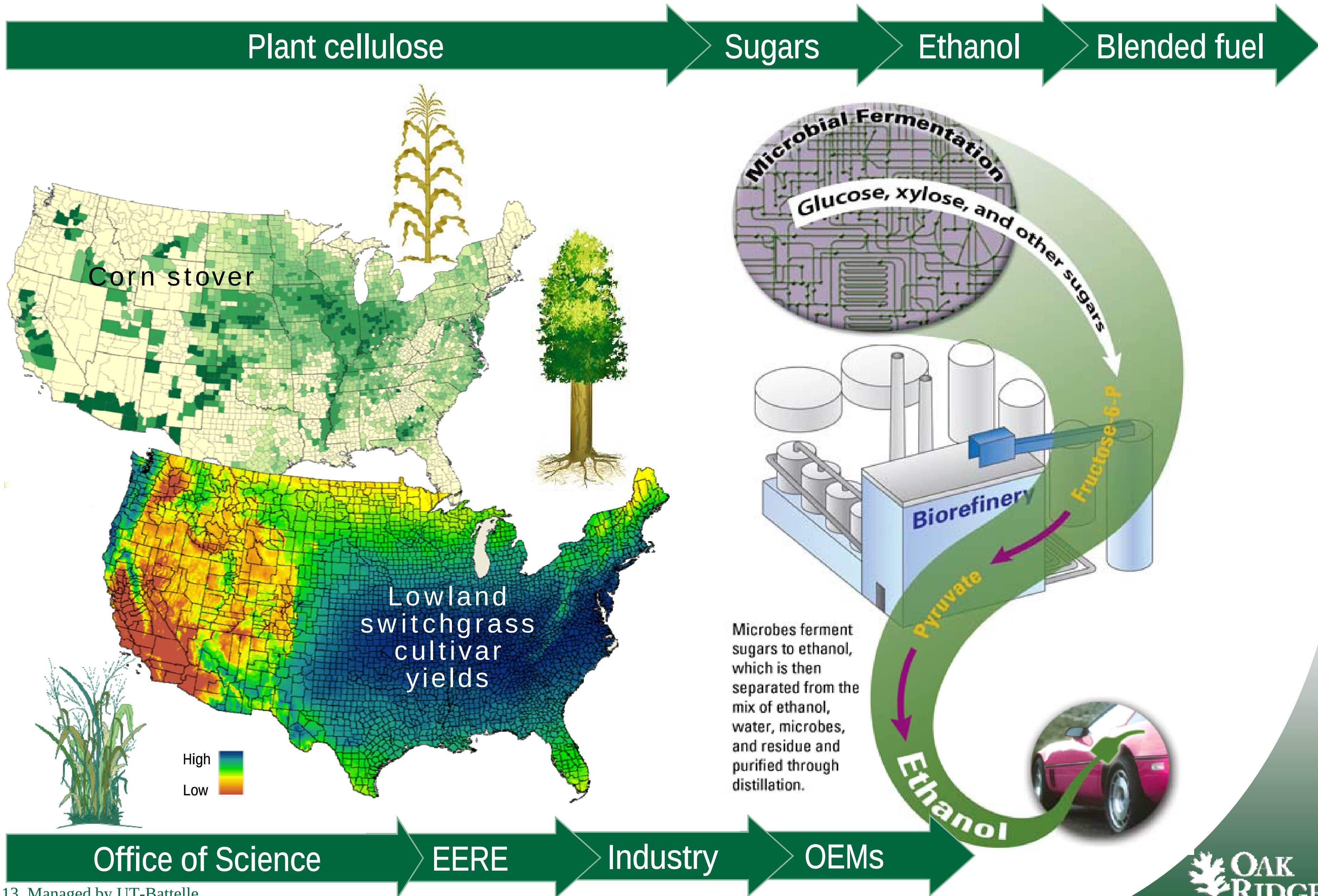
Attributes of Pathways

- Improved Mobility
- Competitive and Affordable
- Safe and Secure
- Clean and Sustainable

Materials and processing thrust for U.S. battery developers and automakers



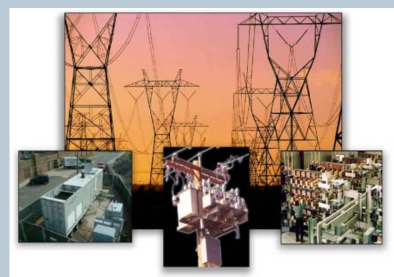
Biomass to biofuel transformation



Research development & deployment can transform the electric grid

Energy Storage & Power Electronics

- **Transform the grid through storage and power flow control**
- **Reliability and low cost devices are needed**



- **Materials research will play a key role in advancing the technologies**

Distributed Systems Integration

- **Deployment of distributed systems expected to double in 20 years**
- **Voltage support from clean, distributed sources**
- **Penetration impact & analysis needed**

Grid Visualization and Controls

- **Wide-area situational awareness**
- **Real-time status of transmission lines**
- **Energy interdependency and extreme contingency analyses needed**

Smart Grid Technology Deployment

- **Upgrading the grid to make it intelligent and interactive**
- **Systems integration and cost benefit analyses are needed**

Buildings: Partner to develop deep-savings components to enable zero-energy, demand-responsive buildings

Residential-house energy savings:
70% use;
80% peak periods

Integration of ORNL and emerging technologies from partners

LENNOX Whirlpool GE ClimateMaster

Embedded intelligence in buildings

Integrate intelligent buildings with renewables, DG/CHP, smart grid, and PHEVs

Develop transformational energy saving cooling, heating, and humidity control technologies

Multi-functional envelope/partition materials and structures

Enable near zero energy commercial buildings by 2025

Development and deployment of new technologies to reduce energy consumption by 75%

Buildings technology

Buildings Technology Center: Over 300 tests for industry of building envelope systems

There will be a number of areas for R&D in Solar Technologies

Photovoltaic

- **Increasing the efficiency of thin film systems**
- **Next generation organic and organic/inorganic hybrids**
- **New processing methods for current silicon and thin film PV material systems**

Concentrated Solar

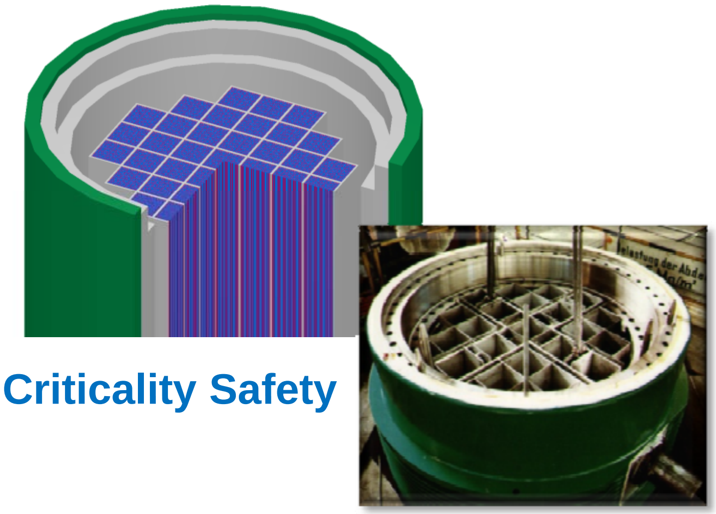
- **Increase efficiency and reduce costs of the concentrators**
- **Decrease manufacturing costs and increase reliability of collectors and mirrors**
- **Develop thermal energy storage and heat transfer technologies**

Grid Integration

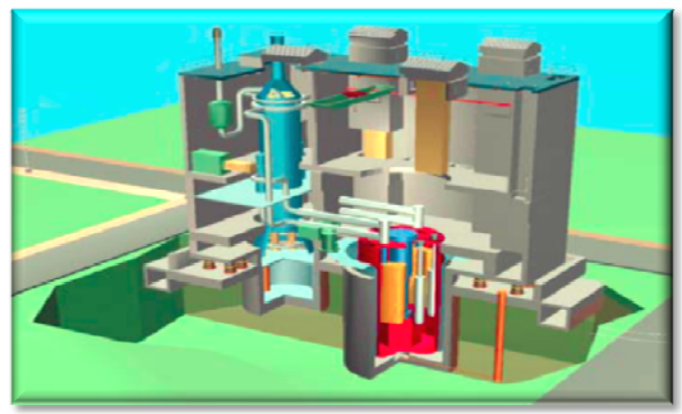
- **Reliability and cost of power electronics**

Nuclear Science and Technology Division
Nuclear Systems Analysis, Design, and Safety

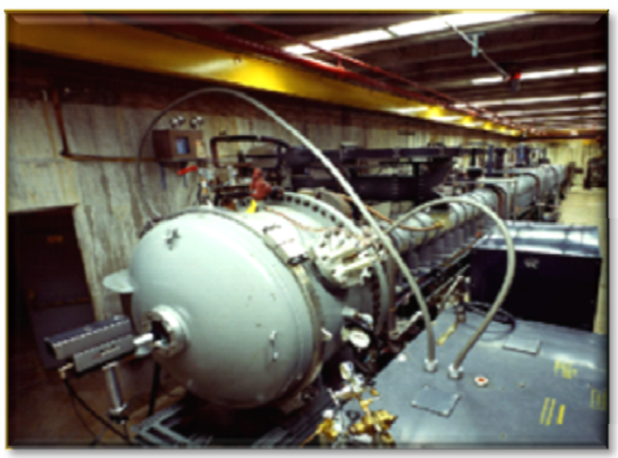
- **Nuclear computational methods and data**
- **Advanced reactor systems and controls**
- **Reactor and facility safety**
- **Radiation transport and reactor physics**
- **Criticality safety**
- **Nuclear data**
- **Material irradiation experiments**
- **Thermal hydraulic analysis and experiments**



Criticality Safety

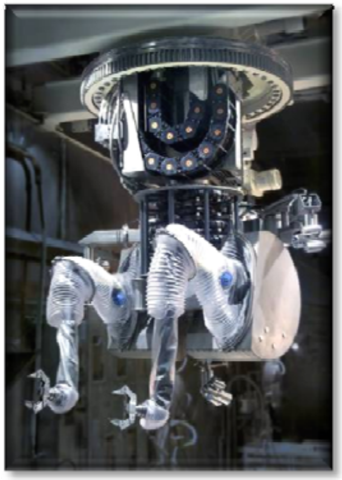


Advanced Reactor Systems



Nuclear Data Measurement

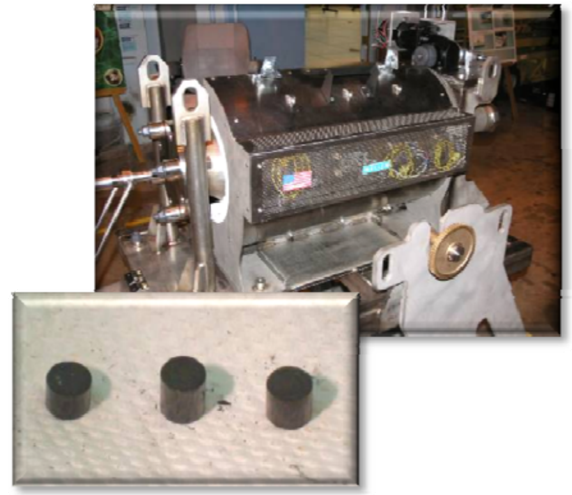
Nuclear Science and Technology Division
Fuels, Isotopes, and Nuclear Materials



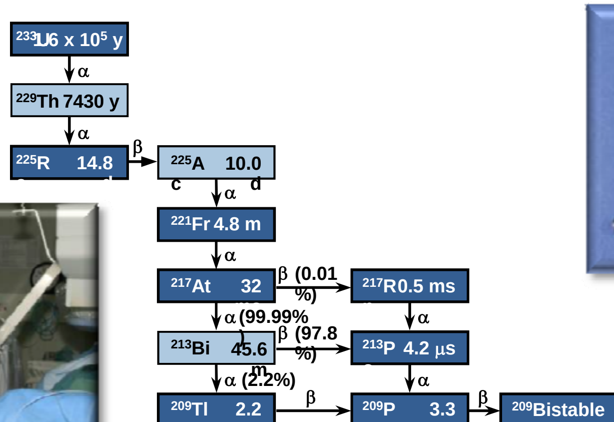
Robotics and Remote Handling

- **Used Nuclear Fuel Recycling**
- **Nuclear materials and waste processing development**
- **Robotics and remote handling**
- **Separation science and technology**
- **Medical isotope development**
- **Stable and radioactive isotopes**
- **Nuclear fuels**

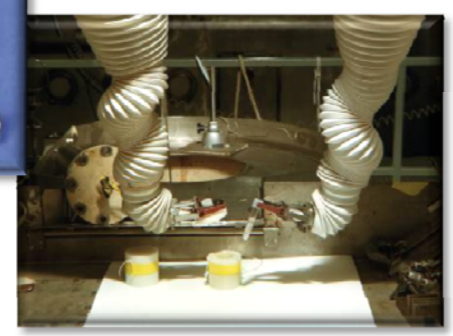
Used Nuclear Fuel Recycling



Medical Isotope Development



Californium-252 Production

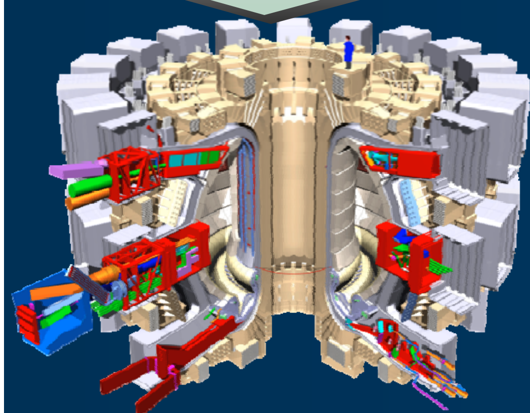


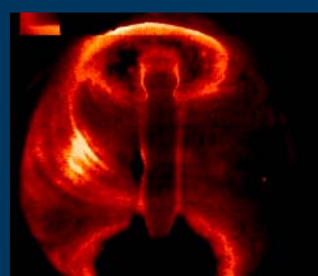
OAK RIDGE National Laboratory

Fusion energy:
Demonstrating the scientific and technological feasibility of *fusion energy*

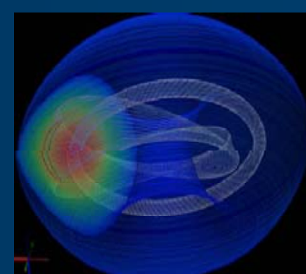
ITER → Science → DEMO

- **Manage U.S. ITER Project Office with excellence**
- **Conduct supporting burning plasma research and development**
- **Leverage our role in ITER construction to prepare for leadership in ITER experimental phase**





Plasma Experimentation



Modeling and Simulation

Enabling Technologies

Energy is the Apollo Project for the 21st century

1. **There is no single energy solution – we need it all**
2. **The energy challenges are daunting**
   - **Our economy demands on success**
3. **All solutions require new materials**
4. **Advanced manufacturing – a game changer**

The energy challenges require engineering solutions
Everyone needs to contribute to the solution