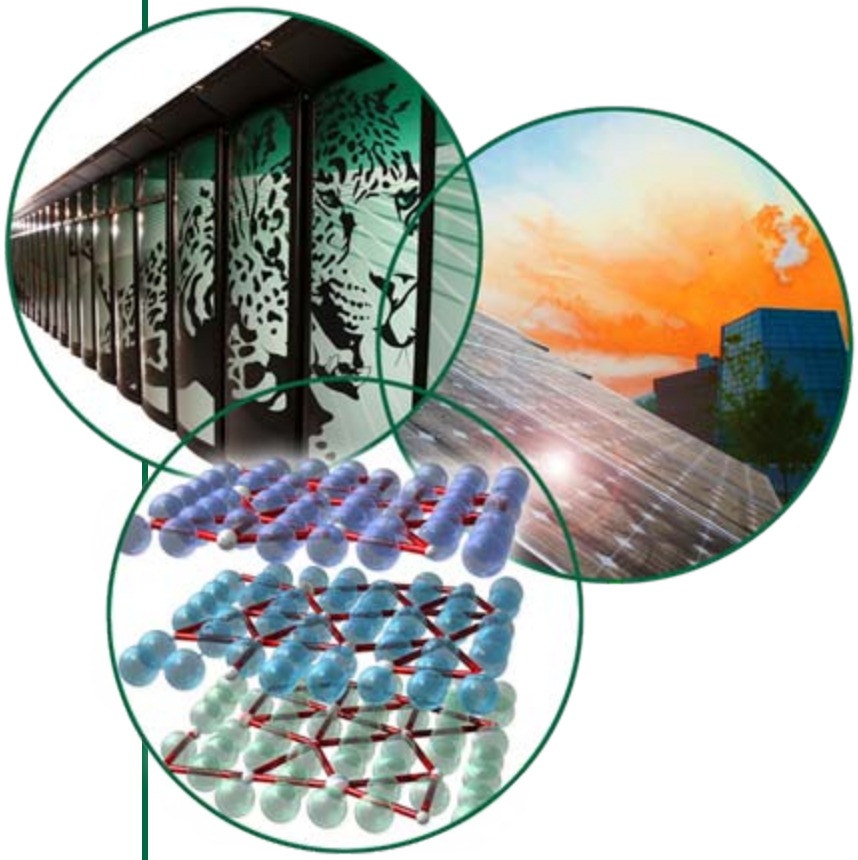
Virtualizing Infrastructure



Presentation to:
Fall Creek Falls Conference

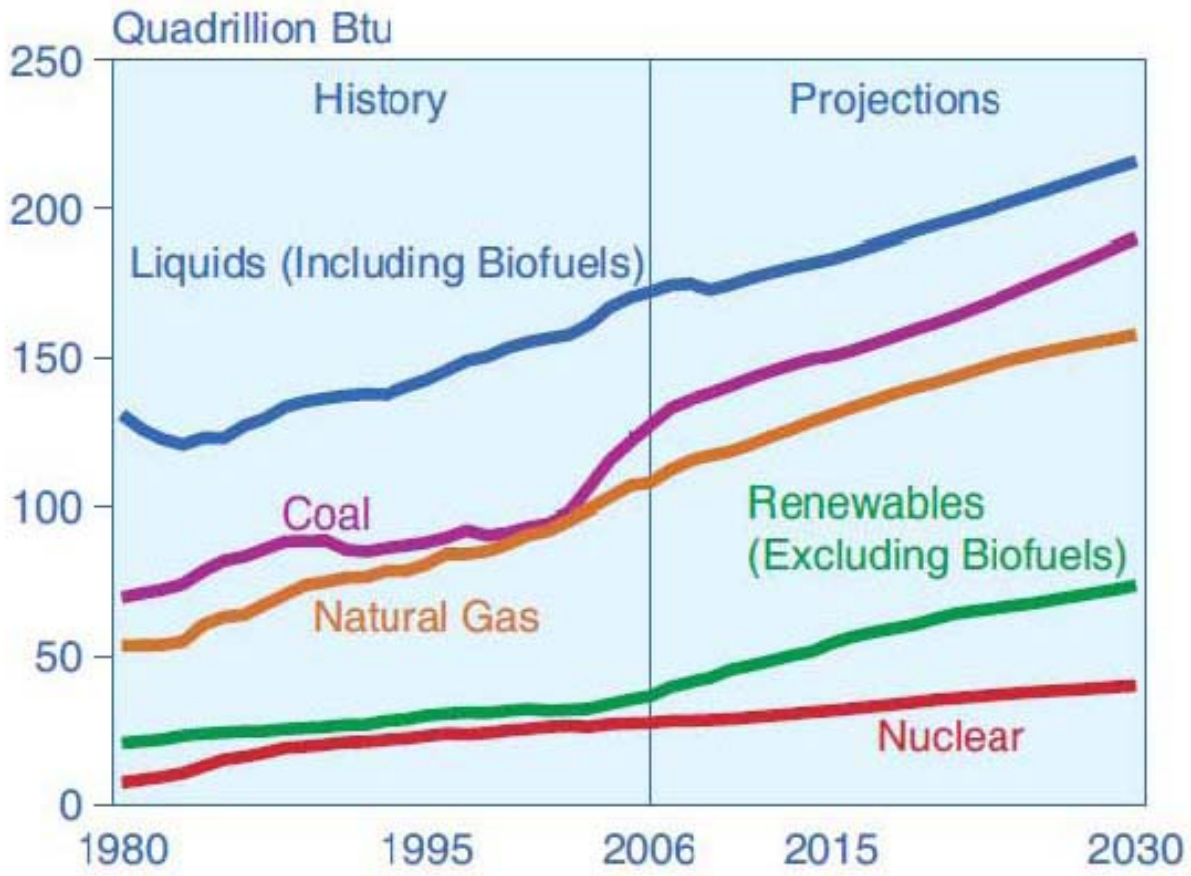
Presented by:
Martin Keller
Associate Laboratory Director
Energy and Environmental Sciences
Oak Ridge National Laboratory

September 15, 2011

U.S. DEPARTMENT OF ENERGY

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

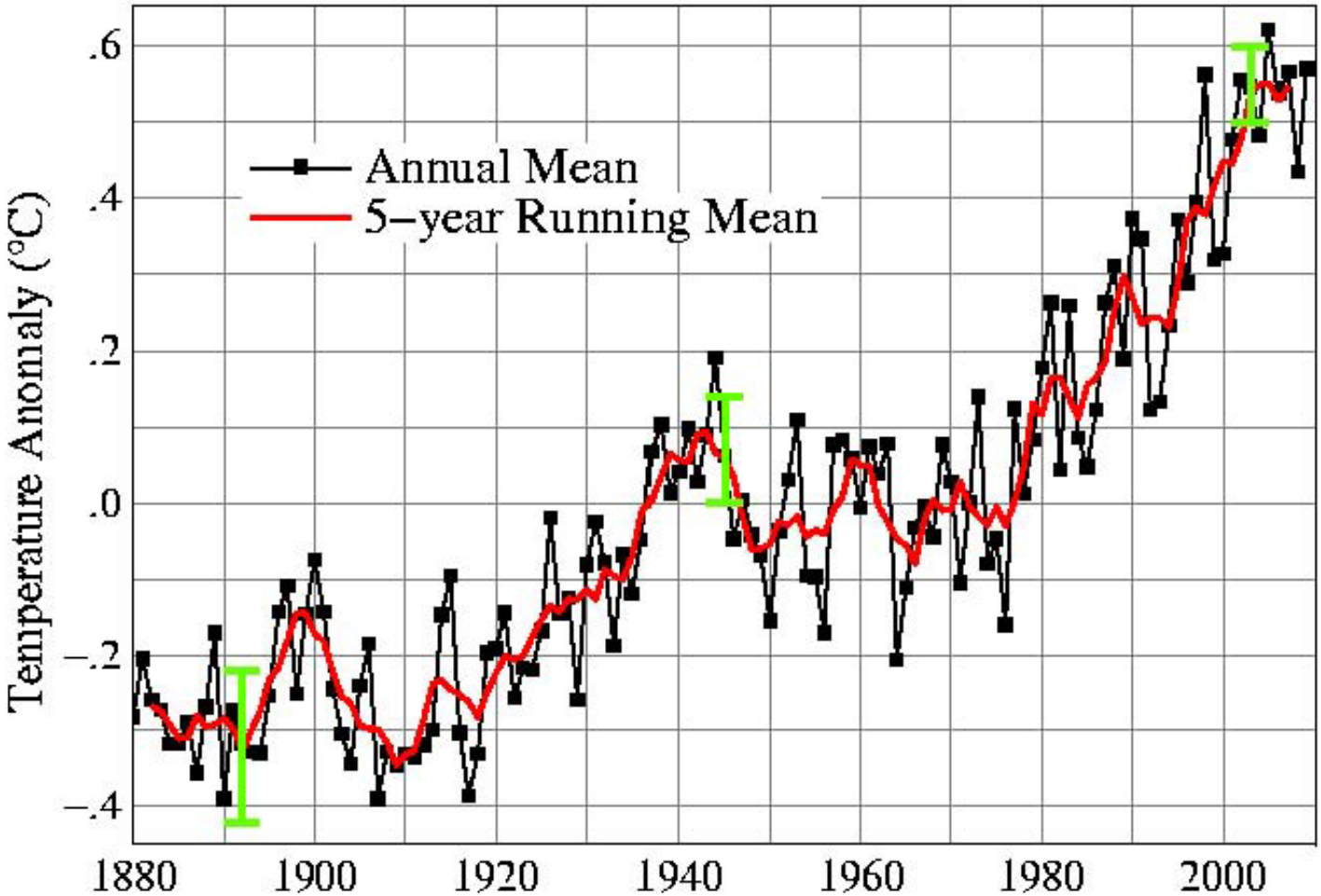
Energy Use: 1980-Present and Projections to 2030



Source: EIA *International Energy Outlook 2009*

Secretary of Energy Steven Chu, March 29, 2010

Climate Change is Real: The Temperature Record from 1880-2007



Source NASA: http://data.giss.nasa.gov/gistemp/graphs/

Secretary of Energy Steven Chu, March 29, 2010

Where was the Carbon going in 2006? (Canadell *et al*., PNAS 2007)

800 GtC or 380 ppm

+4.1 GtC/yr or + 1.9 ppm/year

Fossil Fuel & Cement	+7.6 Gt C/year
Land Use Change	+1.5 Gt C/year
Ocean Uptake	-2.2 Gt C/year
Terrestrial Uptake	-2.8 Gt C/year

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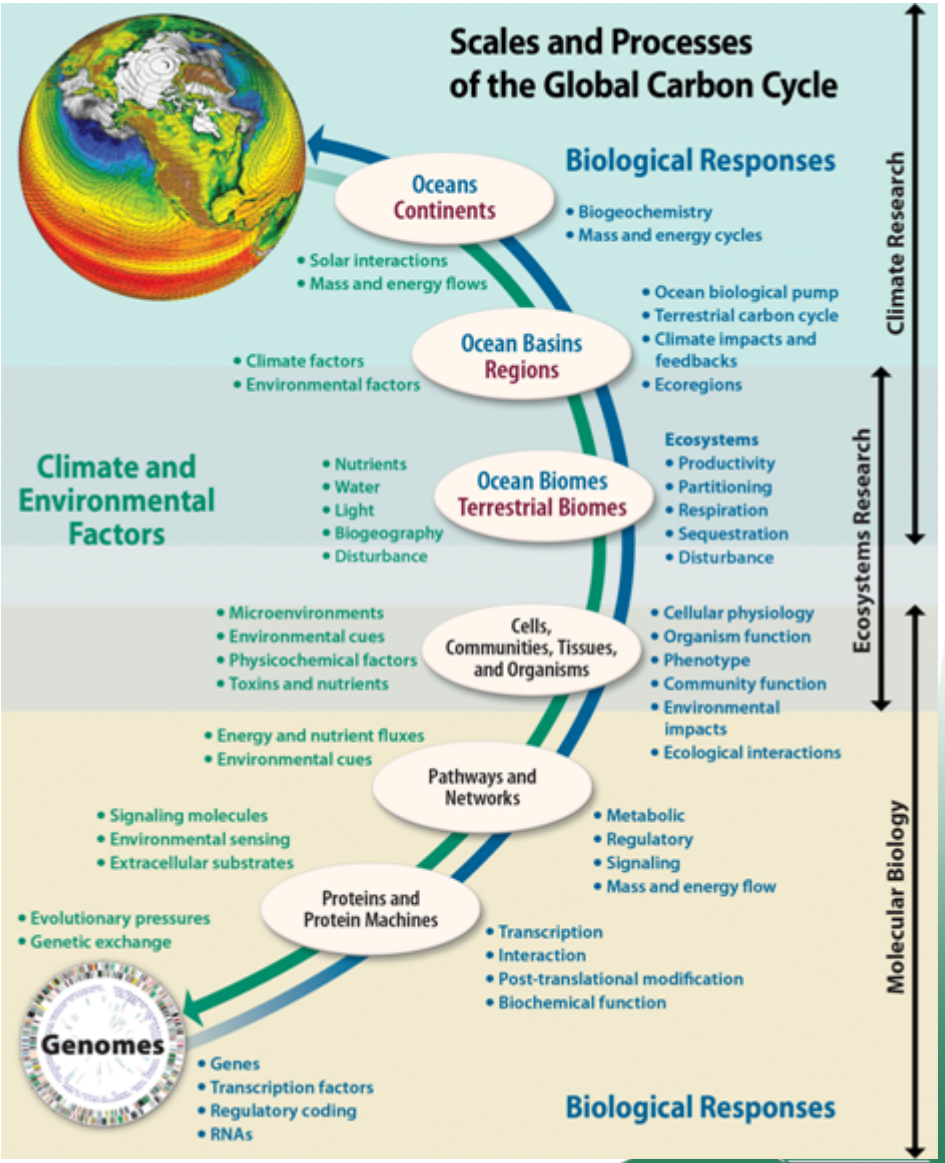
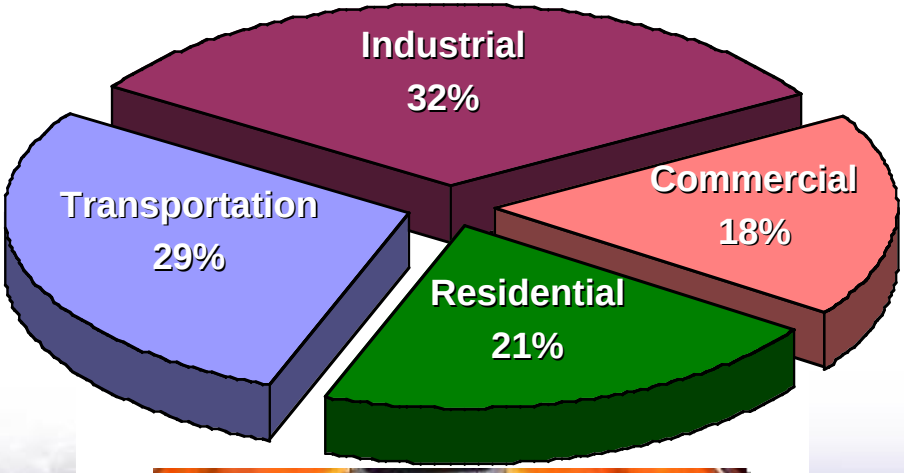
New Scaling and Complexity in Climate Change Science

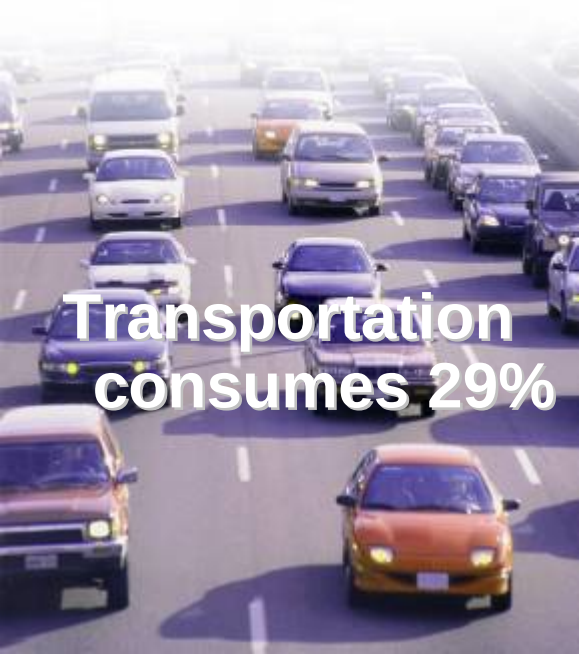
- Multiple, interacting factors from molecular to global scales
  - Nitrogen cycle
  - Feedbacks in critical ecosystems (e.g., boreal, permafrost, tropical forests)
  - Shifts in biological systems at molecular scale with impacts at large scales

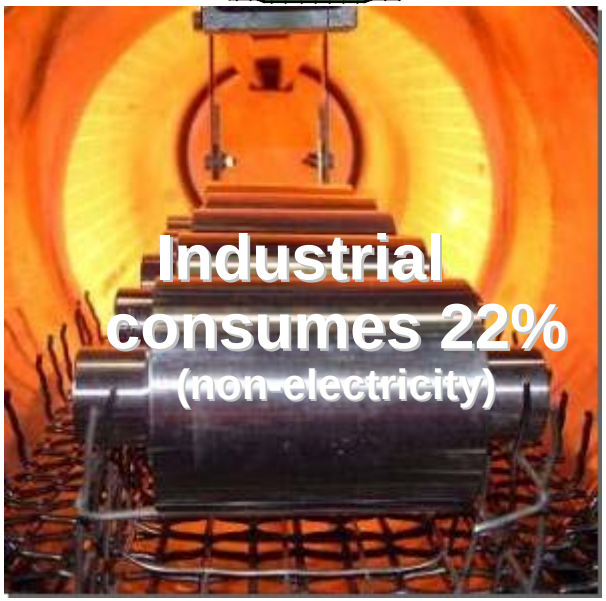


U.S. DOE. 2008. Carbon Cycling and Biosequestration: Report from the March 2008 Workshop, DOE/SC-108, U.S. Department of Energy Office of Science (http://genomicsgtl.energy.gov/carboncycle/).

A Majority of Energy is Consumed in Transportation and Electricity Sectors







ORNL's Vision for a Sustainable Community

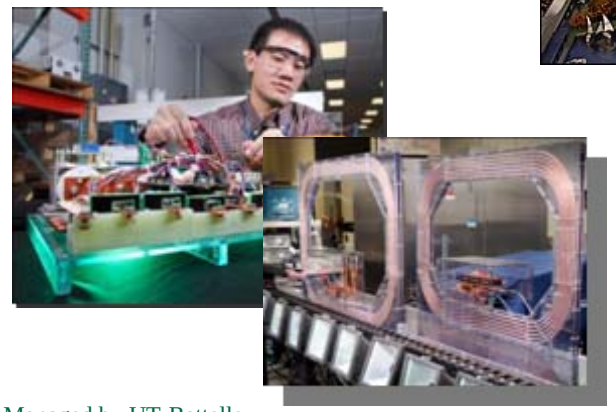
ORNL's Vision for a Sustainable Community

Climate Impact

An integrated approach is needed!

Energy

Transportation



Building Technologies

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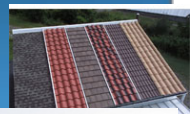
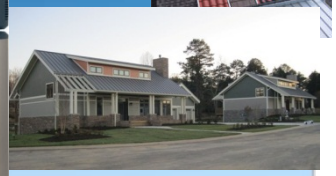
ORNL's Vision for a Sustainable Community

Green Intelligent Buildings

- Commercial and residential integration
- Envelopes
- Appliances
- Cool roofs



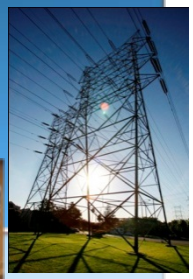


Industrial

- High efficient processes

Smart Grid

- Situational awareness
- Advanced communications and controls
- Energy storage



Renewables

- Bioenergy
- Solar
- Geothermal systems
- Wind

Sustainability

- Waste reduction
- Water management

Intelligent Transportation Systems

- Integrated land use planning
- Public transit friendly
- Alternate mobility choices (incl. freight)
- Clean fuels
- Intelligent vehicles and infrastructure

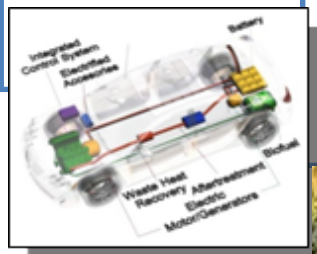
Sustainable Transportation R&D in Diversity of Technologies

Accelerating electrification

- Wireless power transfer
- Advanced battery materials, processing, and modeling
- Battery secondary use studies

Efficient vehicles

- Lightweighting
- Advanced electric/ combustion hybrid power trains
- Trucks as well as autos



Alternative fuels

- Drop-in biofuels for legacy cars
- Renewable fuels for advanced engines

Intelligent systems and operations

- Managing congestion
- Efficient operations in commercial vehicles
- Data for decision-making
- Communications

New technologies and processes for:

- Safe, secure, and affordable vehicles for passengers and freight
- Domestic production of transportation fuel
- Reducing environmental impacts of transportation
- Predictable, reliable transport schedules

Today's Intelligent Transportation Systems:
Grounded in mainstream safety applications…

Instrumented infrastructure:
- Cameras
- Inductive loop sensors
- Radar
- Weather sensors
- Toll tag readers
- Dynamic message signs

Smart Infrared Inspection System detects brake, wheel, and tire problems by comparing infrared thermal images of wheels as the vehicle enters a weigh station.

Applications:
- Traffic metering and management
- Multi-mode transit management
- Electronic toll collection
- Congestion mitigation for air quality, etc.

Venues:
- Freeways
- Arterials
- Urban transit
- Public safety (e.g., signal pre-emption for fire/rescue), etc.

ITS deployment in 2010:
- Dynamic message signs: 3X increase in 10 years
- Freeway agencies using radar doubled since 2000
- Real time data capture and management covers 56% of city freeway miles
- CCTV adopted by 86% of freeway agencies
- Transit advanced vehicle location and computer-added dispatch: 87%

Emerging Intelligent Transportation Systems:
Advancing energy efficiency, mobility, compliance in the future…

Instrumented vehicles:
•Supporting *vehicle-to-infrastructure and vehicle-to-vehicle* data exchange

Applications:
•Integrated multi-agency corridor management
•Coordinated traffic adaptive signal control
•Safety and management messaging to individual vehicles

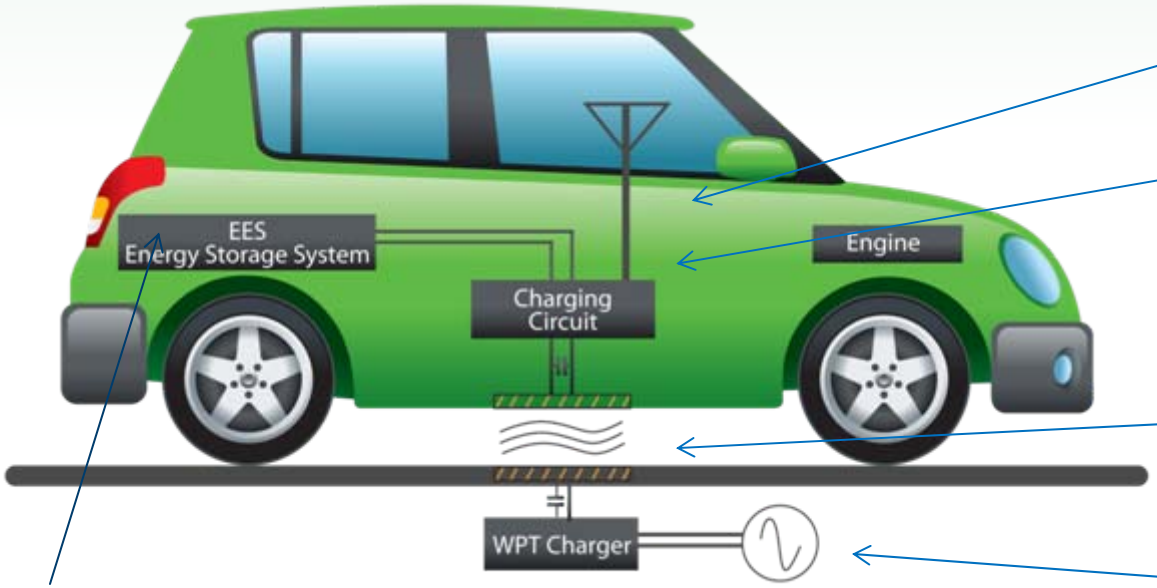
Volume and scale of ITS data collection, processing, filtering into actionable information, archiving… coupled with need for low latency (safety applications) indicates ***high performance computing power…***

LandScan is an activity-based population distribution and dynamics model that enables transportation and evacuation planning, consequence assessment, etc.

ITS enables electrification of transportation. Examples: WPT dynamic power allocation to embedded coils based on vehicle, billing for energy consumed, etc.

Wireless Charging Infrastructure for Enhancing Electrification… Range Extension, Convenience

ORNL's innovative and highly efficient coupling coil and system are being integrated with research vehicle for stationary, on-road stationary, and on-road dynamic charging. Will be meeting safety and communications codes and standard.



Vehicle-to-WPT communications for regulation control, positioning, and billing

On-board charger at 6.6 kW for standard 240Vac plug and cable charging, plus WPT dc input port

Active zone field meets international standards (ICNIRP) for public zone magnetic field

Smart grid compliant utility feed and modern power electronics

On-board energy storage system suitable for on-road dynamic high rate burst mode charging – equivalent to dc fast charge

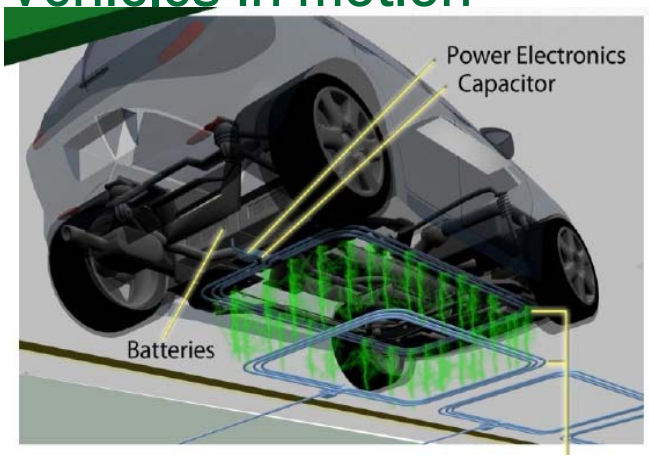
Key Challenges: *Coupling coil & cable efficiency >97%; minimal on-vehicle complexity; low latency V2I communications; and overall >90% efficiency*

WPT Applications in a Sustainable Community… Parking, Opportunity Charging, Fully Dynamic

Stationary vehicles

- Initial demonstration…single coupling coils in stationary locations for public parking; for example, SAE level 2 power of 6.6kW each
- Multiple WPT charging pads next to be deployed for opportunity charging of taxi vehicles on fixed routes

Vehicles in motion



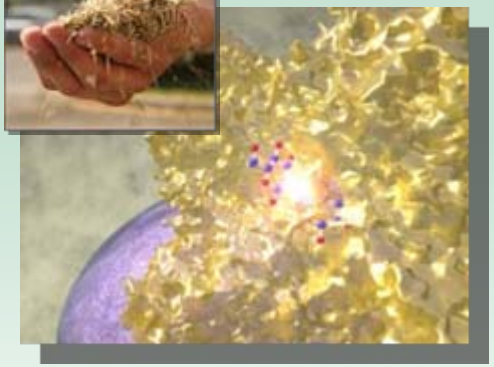
- On-road dynamic charging is the future vision of WPT and requires high power burst mode transfer
- Conventional coil designs require pitch spacing to minimize power flow interruption to moving vehicle

Biomass to Fuels and High Value Chemicals

DOE: Office of Science **DOE: EERE VTP and Biomass**

Industry

Bio-derived alcohols, precursors, chemicals

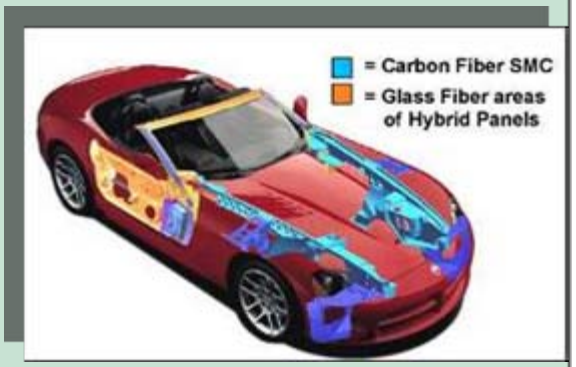


BESC
BioEnergy Science Center

Lignin as low cost feedstock lightweight carbon fiber material

Succinic Acid…Renewable and environmentally friendly bioproduct

Intermediate Ethanol blends vehicle evaluation program



Dual value stream: Ethanol fuel and lignocellulose byproduct is sustainable

Bio-derived chemical (de-icer, solvent applications), commercial plant online 2009

Bio amber

Biomass research yields domestic fuel, high-value chemicals

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Major Differences between the 2005 BTS Study and the 2011 Update

2005 BTS	2011 Update
National estimates – no spatial information	County-level with aggregation to state, regional and national levels
No cost analyses – just quantities	Supply curves by feedstock by county – farmgate/forest landing
Crop residue removal sustainability addressed from national perspective; erosion only	Crop residue removal sustainability modeled at soil – scale; erosion & soil C
No explicit land use change modeling	Land use change modeled for energy crops
Long-term, inexact time horizon (2005; ~2025 & 2040)	2012 – 2030 timeline (annual)
2005 USDA agricultural baseline and 2000 forestry RPA/TPO	2010 USDA agricultural baseline 2010 FIA inventory and 2007 forestry RPA/TPO
Erosion constraints to forest residue collection	Greater erosion plus wetness constraints to forest residue collection

Key commonality – an assessment of biomass potential under a given set of assumptions and available data

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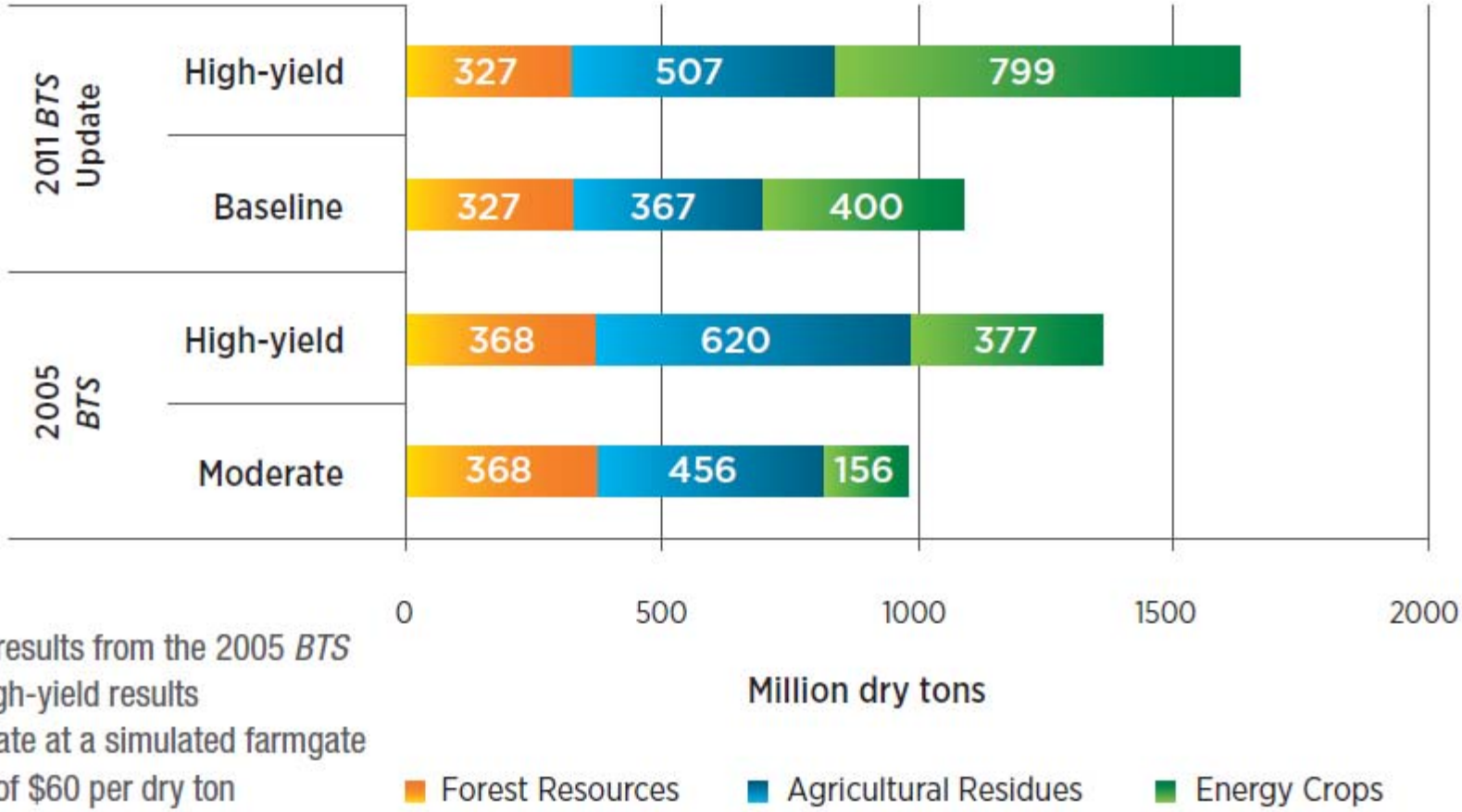
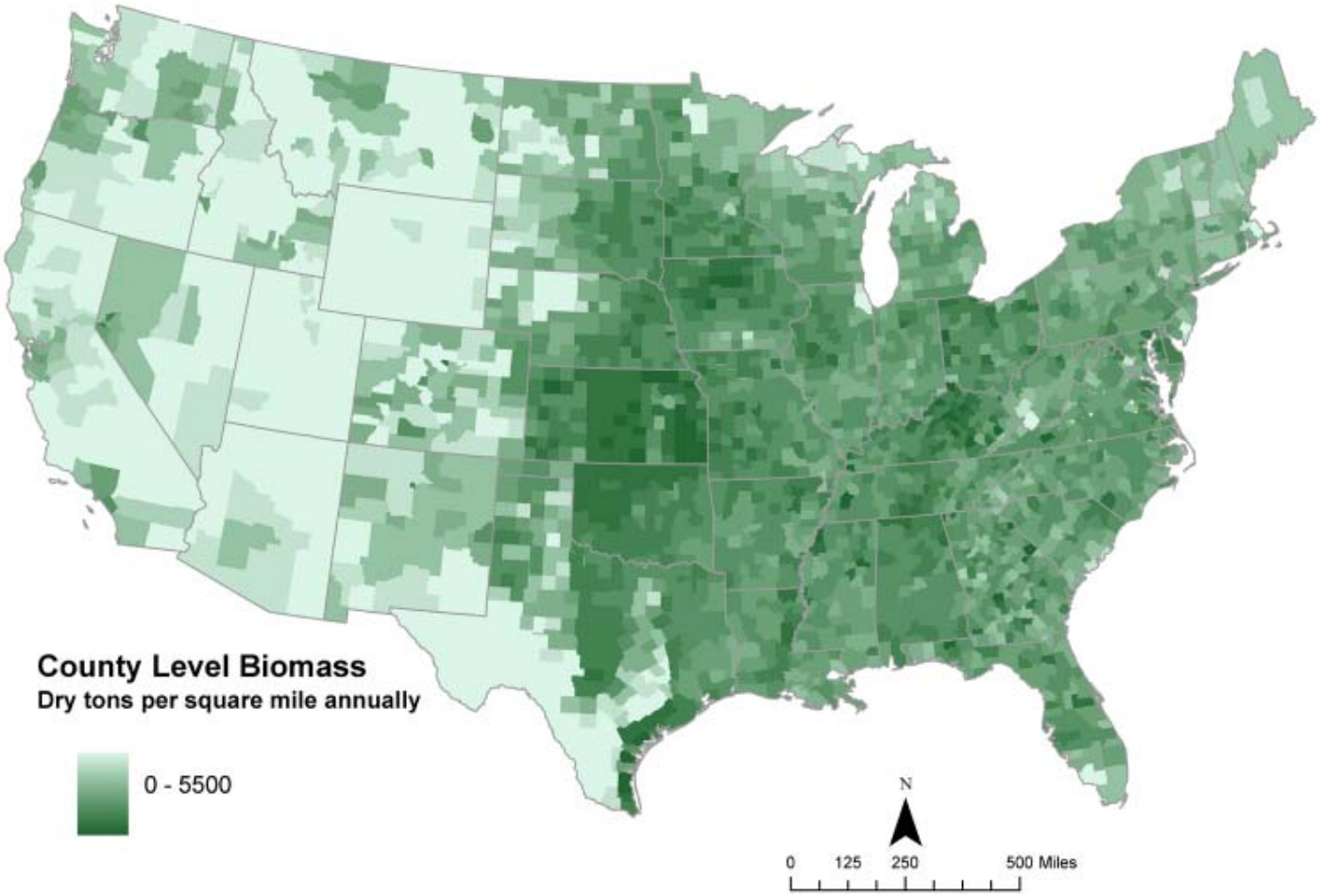
U.S. Billion-Ton Update: Comparison with the 2005 Billion-Ton Study



High & moderate results from the 2005 *BTS* and baseline & high-yield results from the *BTS* update at a simulated farmgate or roadside price of $60 per dry ton

Potential County-level Resources at $60 per Dry Ton or Less in 2030, under Baseline Assumptions



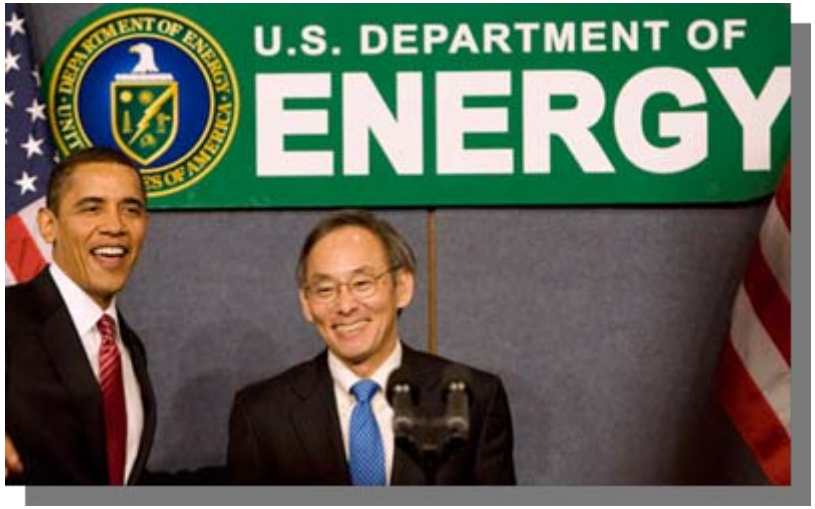
The Obama Energy Plan Calls for an Increase in Energy from Renewable Sources to 10% by 2012 and 25% by 2025

"The nation that leads the clean energy economy will be the country that leads the global clean economy and America must be that nation. I will not accept second place."

- President Obama,
State of the Union address
January 27, 2010

"We'll fund a better, smarter electricity grid and train workers to build it – a grid that will help us ship wind and solar power from one end of this country to another."

- President Obama,
Speech given at DOE
February 5, 2009



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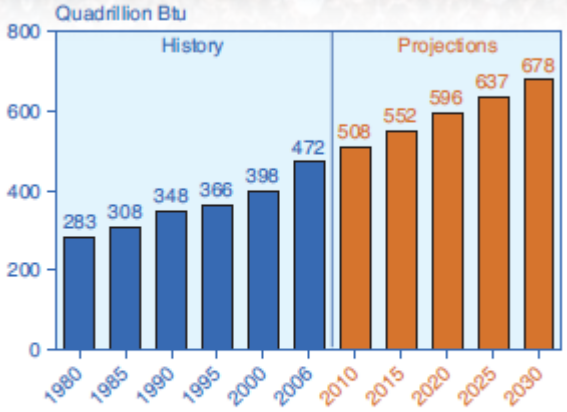
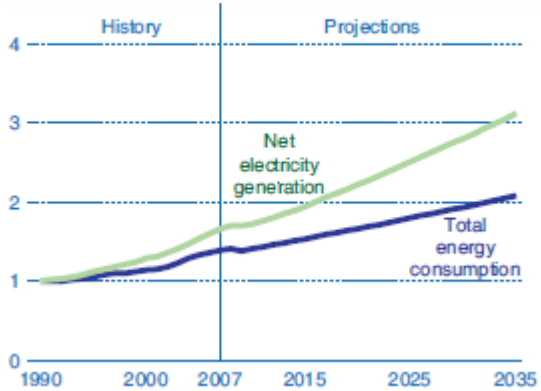
Grid 21 Objectives Address Trends in Energy Demand and Power Generation

Figure 10. World Marketed Energy Consumption, 1980-2030



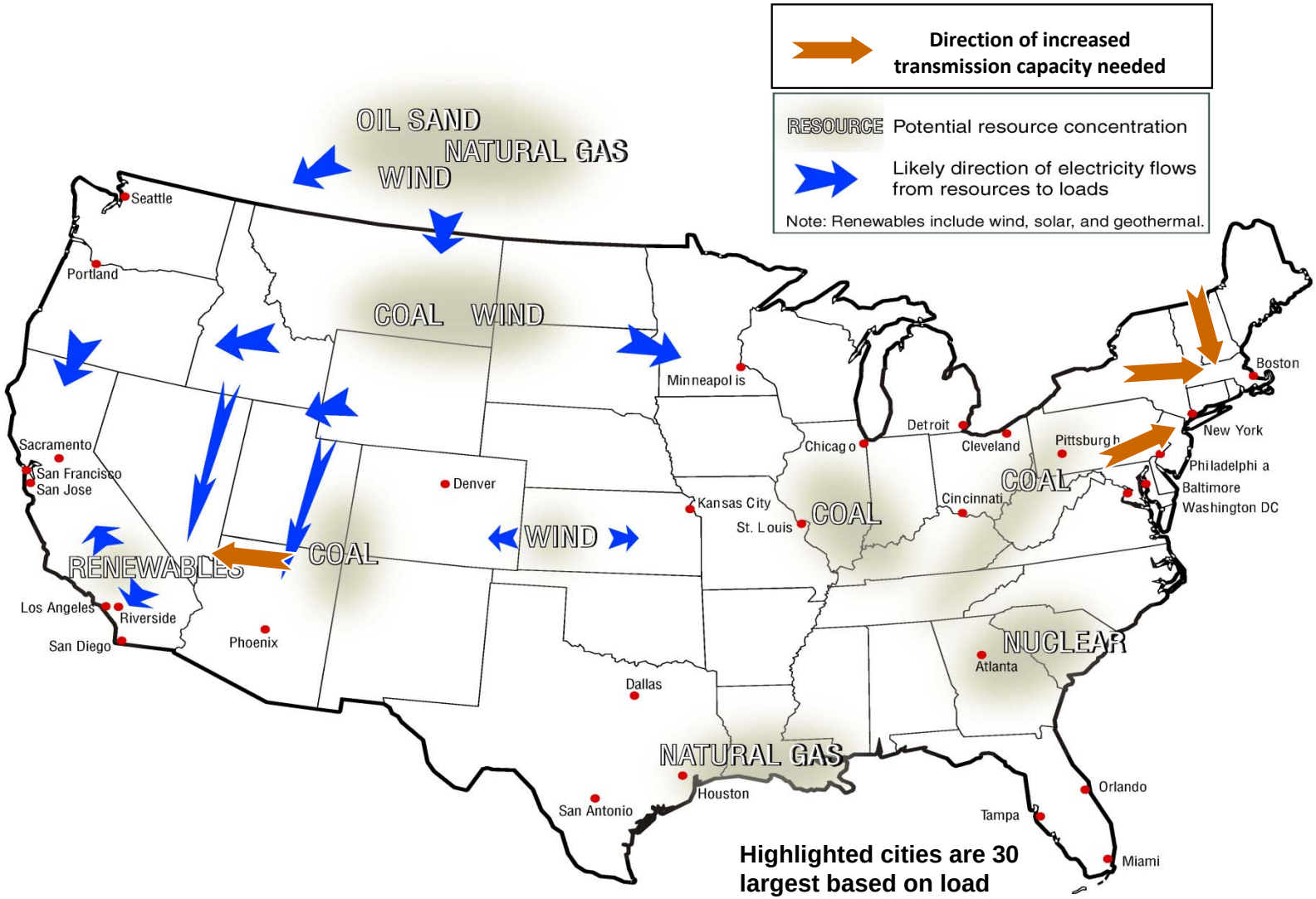
Sources: **History:** Energy Information Administration (EIA), *International Energy Annual 2006* (June-December 2008), web site www.eia.doe.gov/iea. **Projections:** EIA, World Energy Projections Plus (2009).

Figure 67. Growth in world electric power generation and total energy consumption, 1990-2035 (index, 1990 = 1)



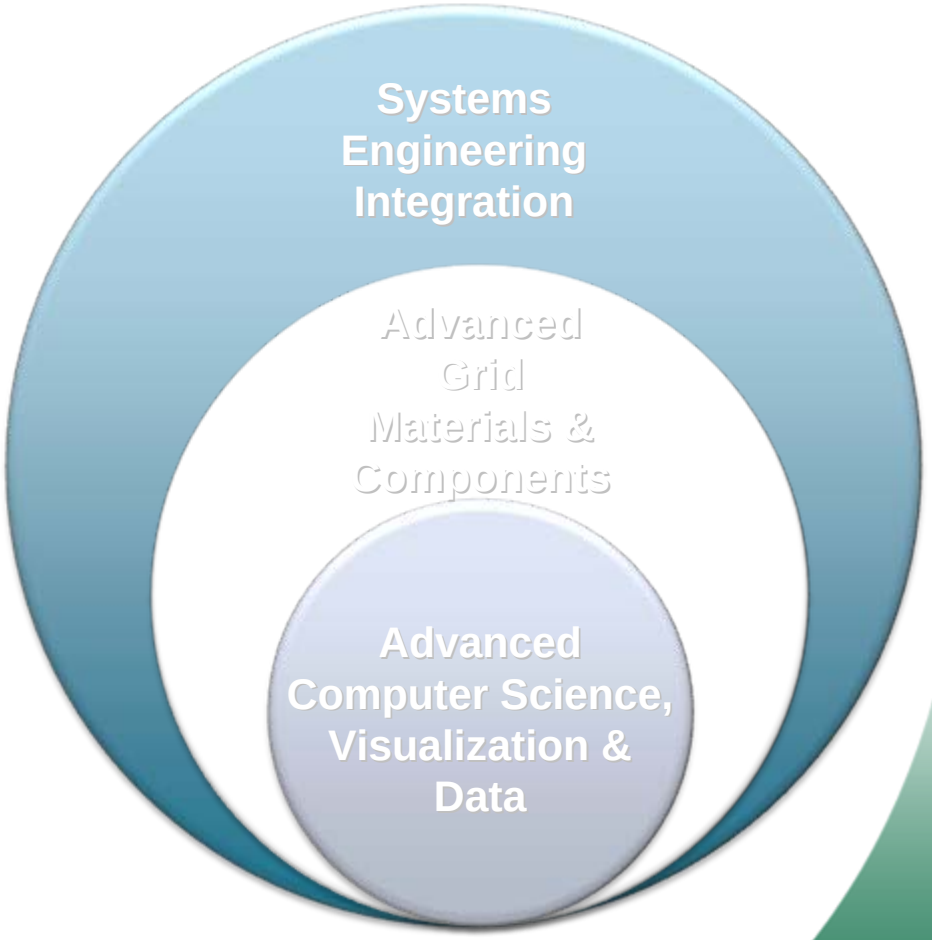
EIA International Energy Outlook 2010

Renewable and Other Strategically Diverse Generating Resources not Near Loads



The Grid 21 Program is Organized Across Three Fundamental Technical Domains

- **Systems Engineering and Integration bridges the gap between research and commercialization**
- **Advanced Grid Materials and Components are the fundamental building blocks the next generation grid**
- **Advanced Computer Science, Visualization and Data provides analytical and computational tools to drive innovation in the other two domains**



The Electric Grid Enables the Clean Energy Future and Systems Electrification

Clean Energy

Grid Operations

End-Use Electrification

OAK RIDGE National Laboratory

The Role of Grid Modeling and Simulation

Future Grid

Electric Vehicles

Renewable Sources

Energy Storage

Load Control

FACTS Flow Valve

Limited slow local control

⇒

Fast Wide-Area Full Control

Intelligence Needed

- Measurement
- Modeling
- Simulation

Key Factors in Leveraging High-Performance Computing Resources Toward Electric Grid Applications

- ***Data.*** Can we collect and organize the data and manipulate it, store it, protect it, distribute it, understand it and manage it in each area of excellence?
- ***Models.*** Can we collect them into useful ensembles, evaluate them, operate them within a user facility,
- ***Analytical function.*** Can the computational capability lead credible policy analysis, policy scenarios, and positions on the nation's power future?
- ***Industry outreach.*** Can the computational science credibly support the utility industry with tools, leveraging corporate R&D funds, and emergency response?

Today's supercomputers are tomorrow's laptops

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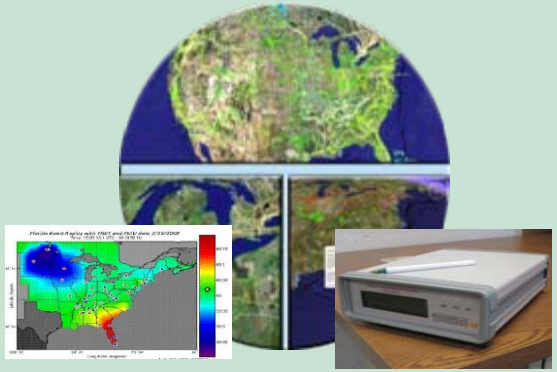
Grid Security: Ensuring the Nation's Critical Infrastructure

The nation's critical infrastructure is under greater vulnerability to cyber and physical attacks. Industry is not equipped to address these challenges. ORNL will utilize its unique expertise in visualization, computing and cyber physical systems to ensure a reliable electricity infrastructure

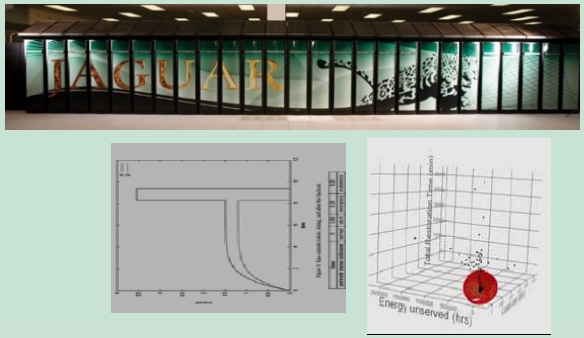
Visualization



Monitoring devices such as ORNL's GridEye system will allow for wide area visualization of the critical infrastructure.

Goal 2013: Deploy 1,000 monitors across the nation.
Goal 2015: Develop high res real-time visualization of frequency response

Computing & Simulation



Utilizing World Class Computing capability, a real-time simulation tool will be developed that will replicate grid operations allowing operators to fully understand response implications.

Goal 2020: Demonstrate real-time simulation tool in TVA operations center

Resilient Controls

Develop a resilient system that allows utility control systems to survive a cyber-physical attack on the critical infrastructure.

Goal 2015: Implement robust and resilient architectures
Goal 2020: Demonstrate ability to detect and repel threat vector

Research and development is needed to improve performance of these concepts and reduce costs

Building Technology Research: from Building Science to Energy Load Simulation and Modeling

SCIENCE — DOE-EERE: BTP — Industry

Mold growth

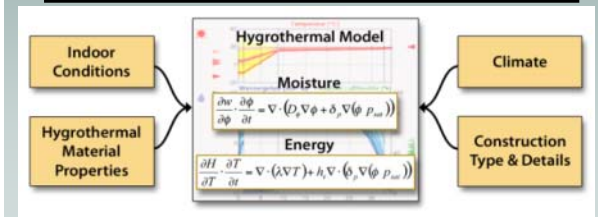
Moisture problems in wall systems

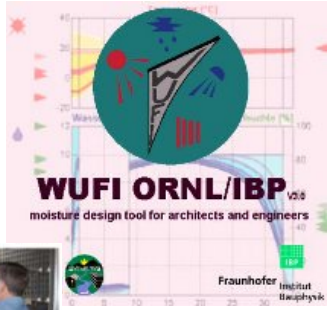
Hygrothermal Properties Labs for Building Materials

Material & System Characterization

Field Research

Advanced Hygrothermal Modeling





Sustainable, Healthy, Comfortable, Durable, Maximum Energy Efficient Buildings

Source: http://www.ornl.gov/sci/ees/etsd/btric/roofs.shtm

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