The Future of Energy Efficiency and Renewable Energy Technologies

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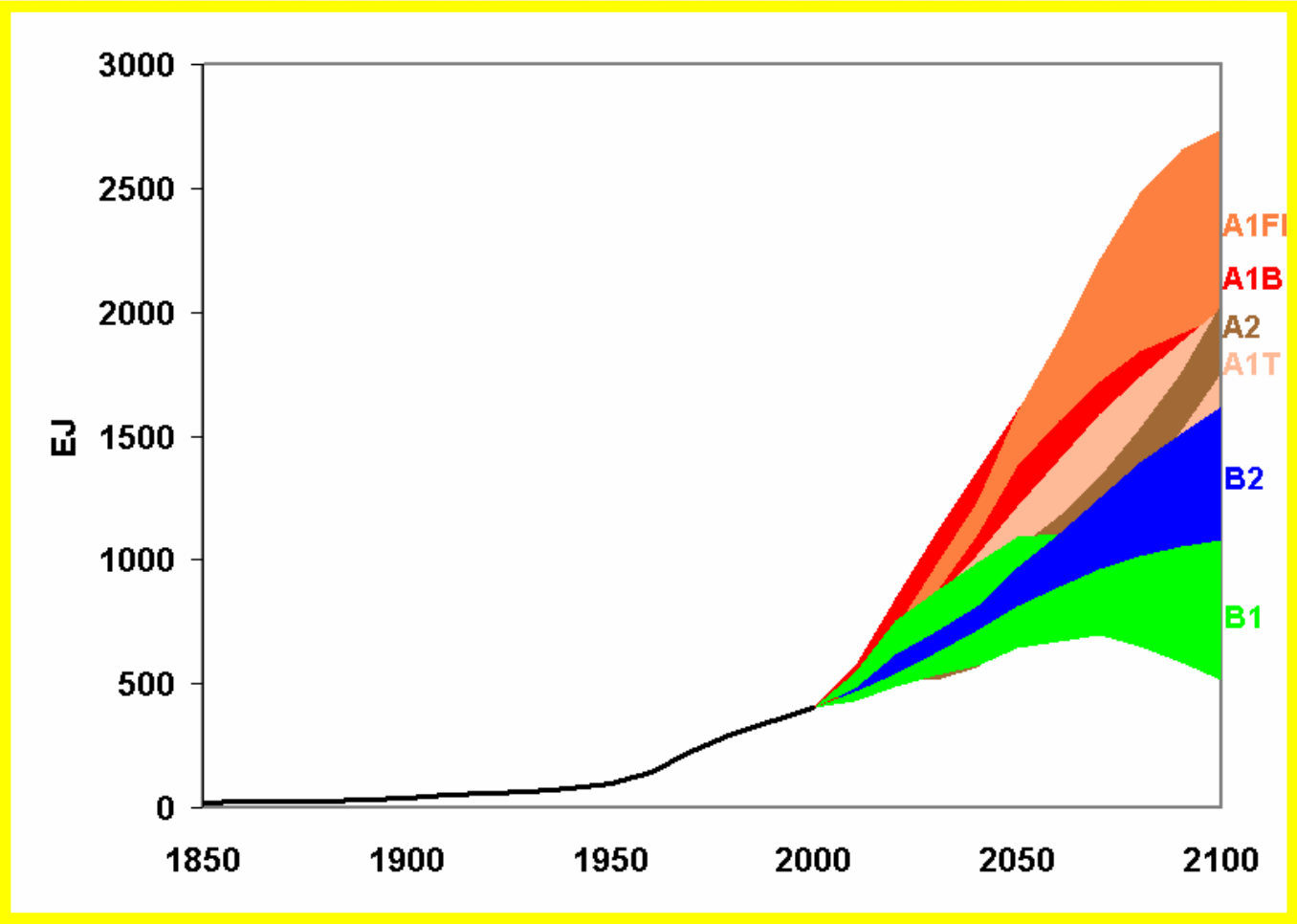
At a 2% Annual Growth Rate, a 7-fold Increase Would Occur by 2100



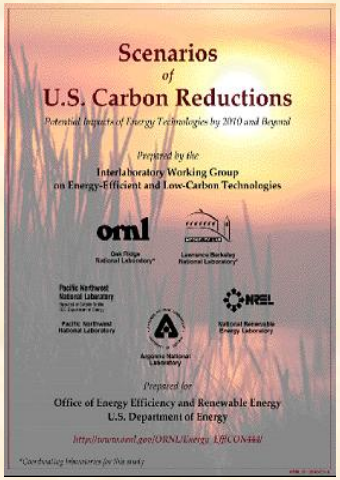
Where today's technologies would take us

Where our current aspirations for technologies would take us

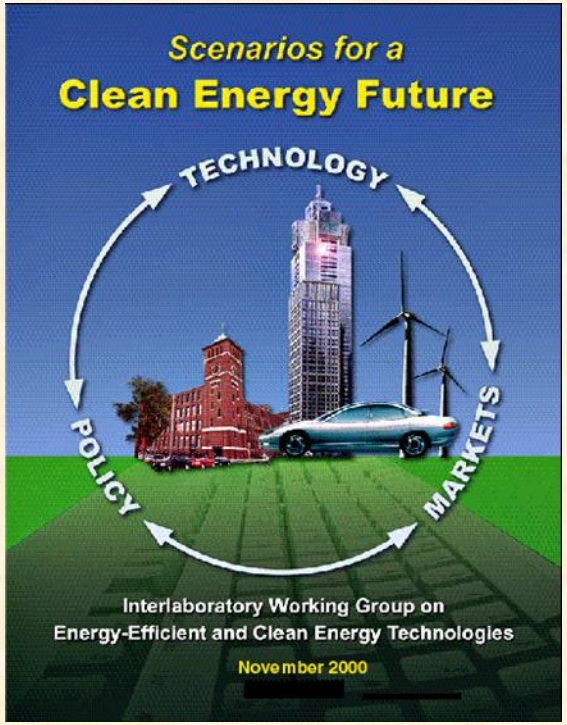
Where we may need to go to stabilize carbon

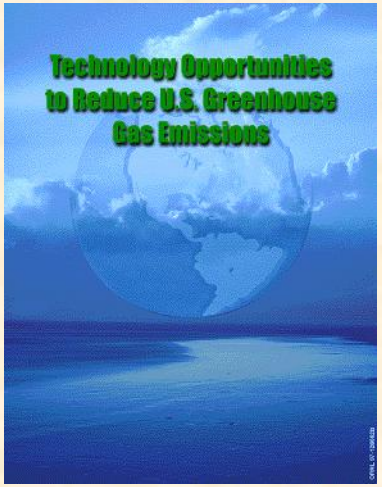
Nakicenovic, Joint IPP-DRDA-DOE Workshop, Garching, Germany, 12/10/2003

Several Multi-Lab Studies Have Detailed the Potential for Improved Energy Efficiency



Scenarios of U.S. Carbon Reduction (1997)
www.ornl.gov/Energy_Eff

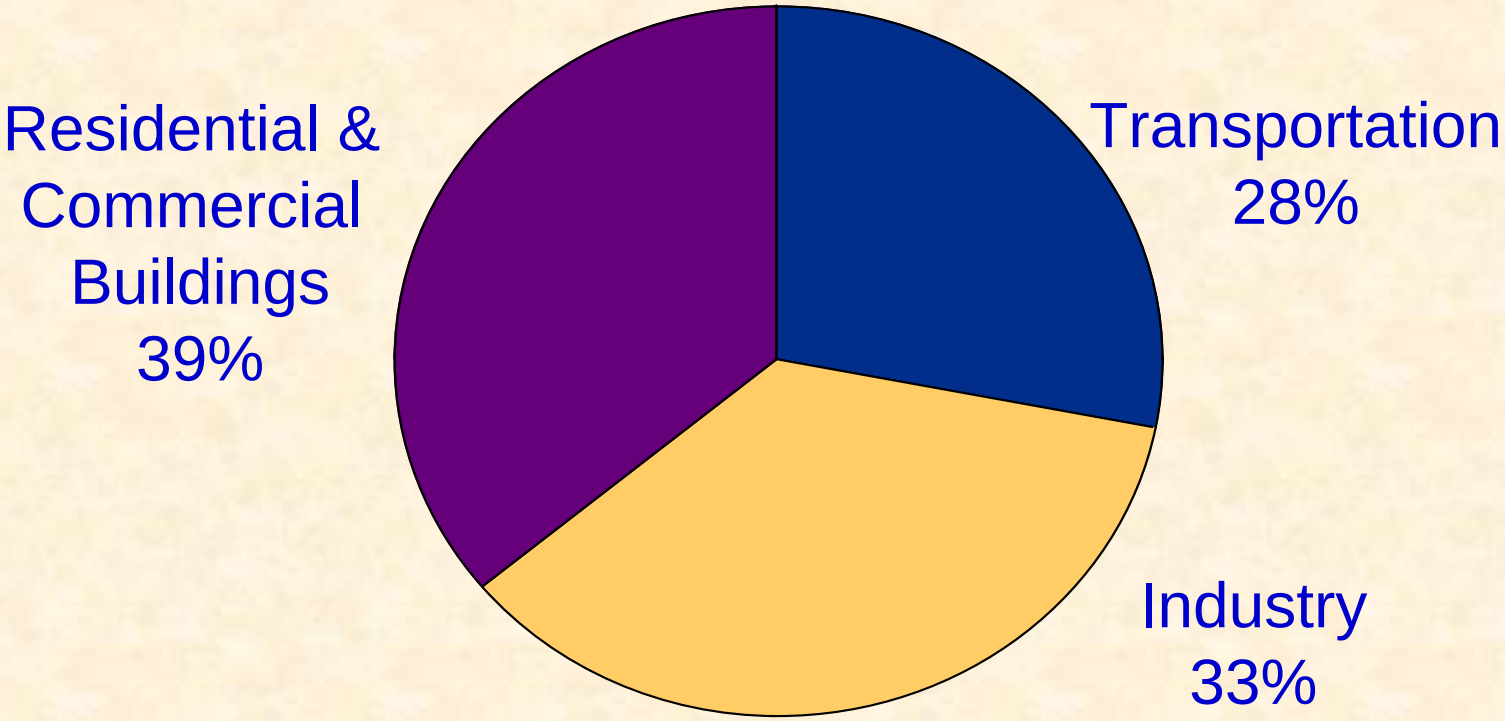




Technology Opportunities to Reduce
U.S. Greenhouse Gas Emissions (1998)
www.ornl.gov/climate_change/climate.htm

Scenarios for a Clean Energy Future (2000)
www.ornl.gov/ORNL/Energy_Eff/CEF.htm

Energy Efficiency Improvements Are Needed in Every Sector



U.S. Energy Consumption by Sector: 2002

Source: EIA, *Annual Energy Outlook 2004*, Table A2

ORNL and Partners Building Village of "Zero Energy" Houses

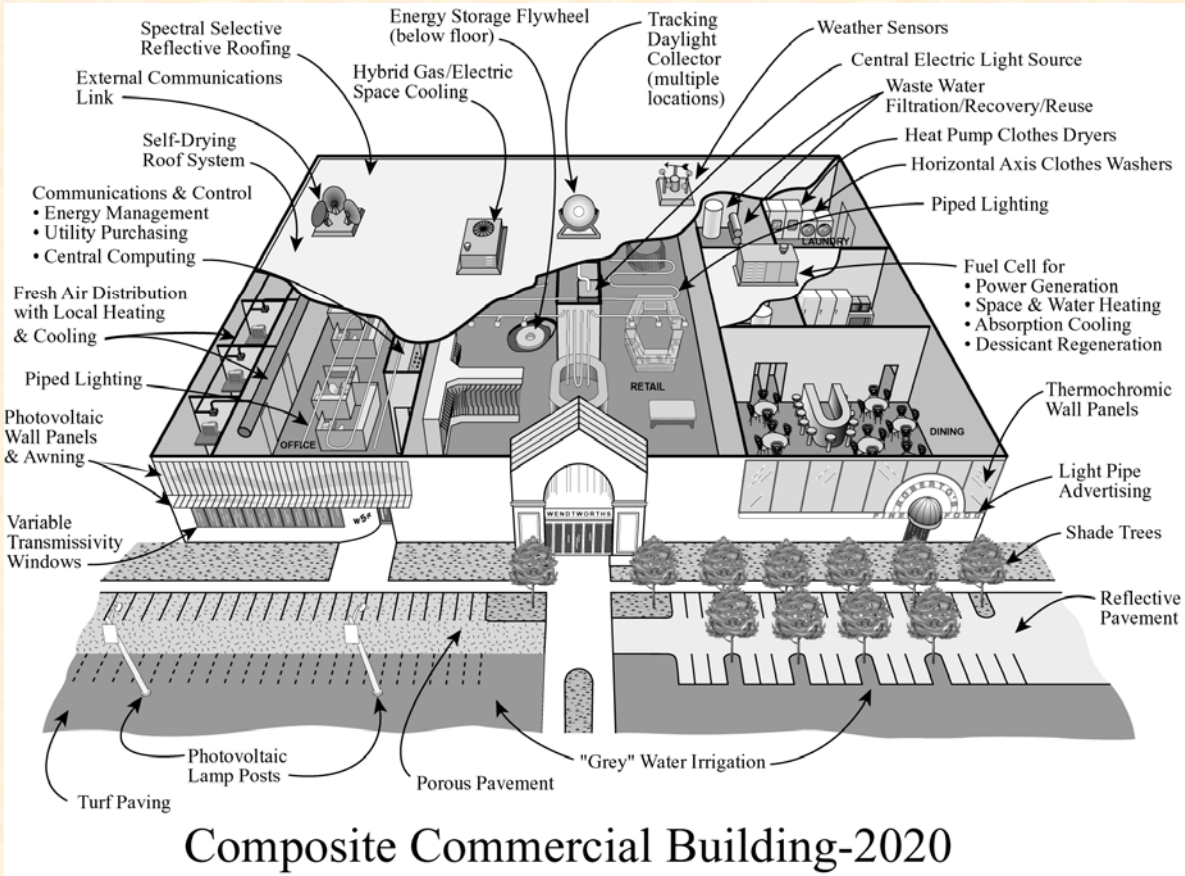
- **The "Zero Energy" goal is for houses to produce as much energy as they use**
- **Advanced energy technologies being researched with Habitat for Humanity**
  - **HPWH**
  - **High velocity ducts**
  - **Photovoltaics**
  - **Structural insulated panels**
- **Up to 90% more efficient than typical Habitat for Humanity (HFH) homes**

Solar panels on the roof will generate electrical power for the home.

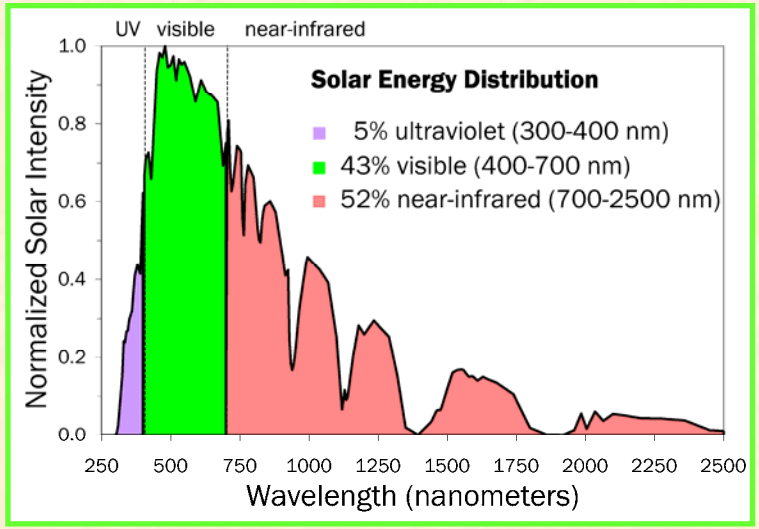
Sponsor: Building Technologies
Partners: Habitat for Humanity, Tennessee Valley Authority, building materials manufacturers

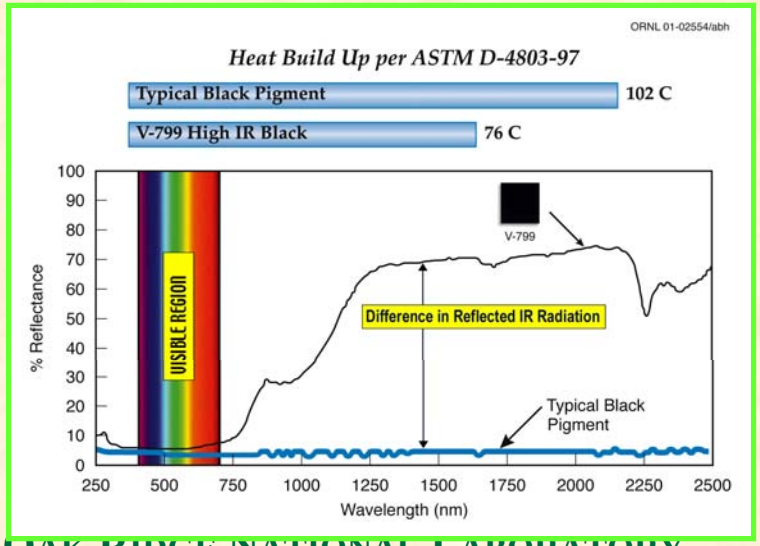
Composite Commercial Building in 2020

- **Solid state lighting integrated into hybrid solar daylighting systems**
- **Smart windows**
- **Photovoltaic roof shingles, walls, and awnings**
- **Solar heating and superinsulation**
- **Combined heat and power–gas turbines and fuel cells**
- **Intelligent building systems**



IR Reflective Colors





Collaborative R&D Between Industry, ORNL, LBNL, and the California Energy Commission

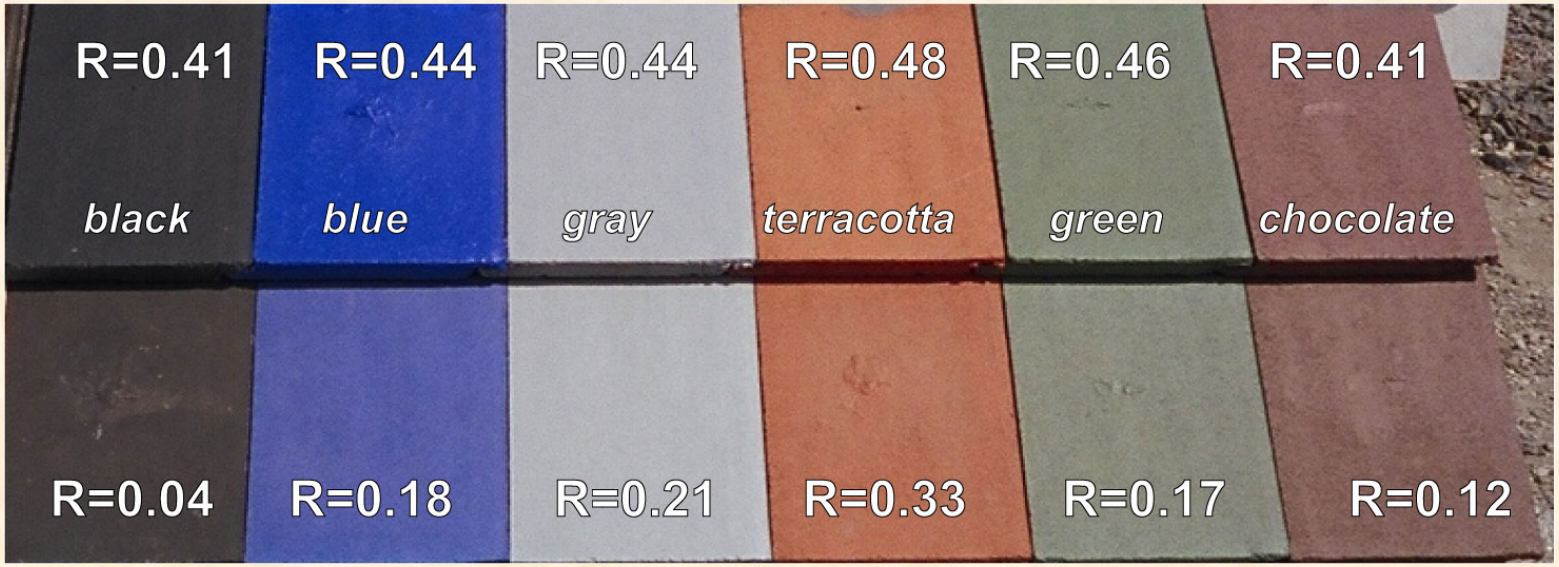
⌘ **Project Scope:**

Develop Roofing Products that Reflect a Large Percentage of Infrared Energy

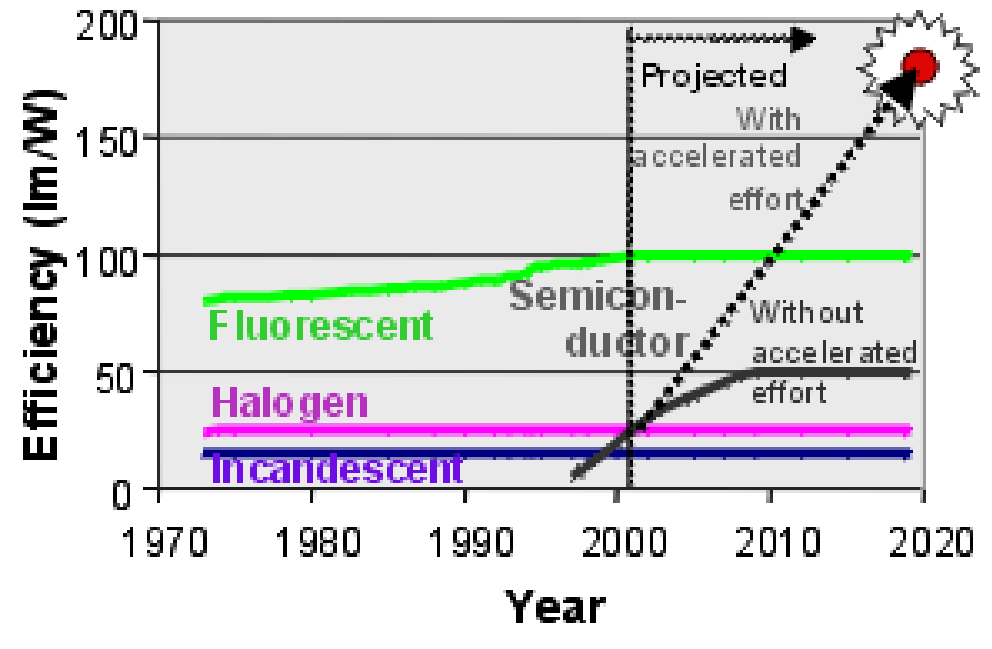
⌘ **Potential Benefits (CA):**

Electricity savings	**14.8 GWh**
Peak power savings	**9.2 MW**

Example: Development of Cool Roof Tile Coatings



Solid State Lighting Holds Great Promise



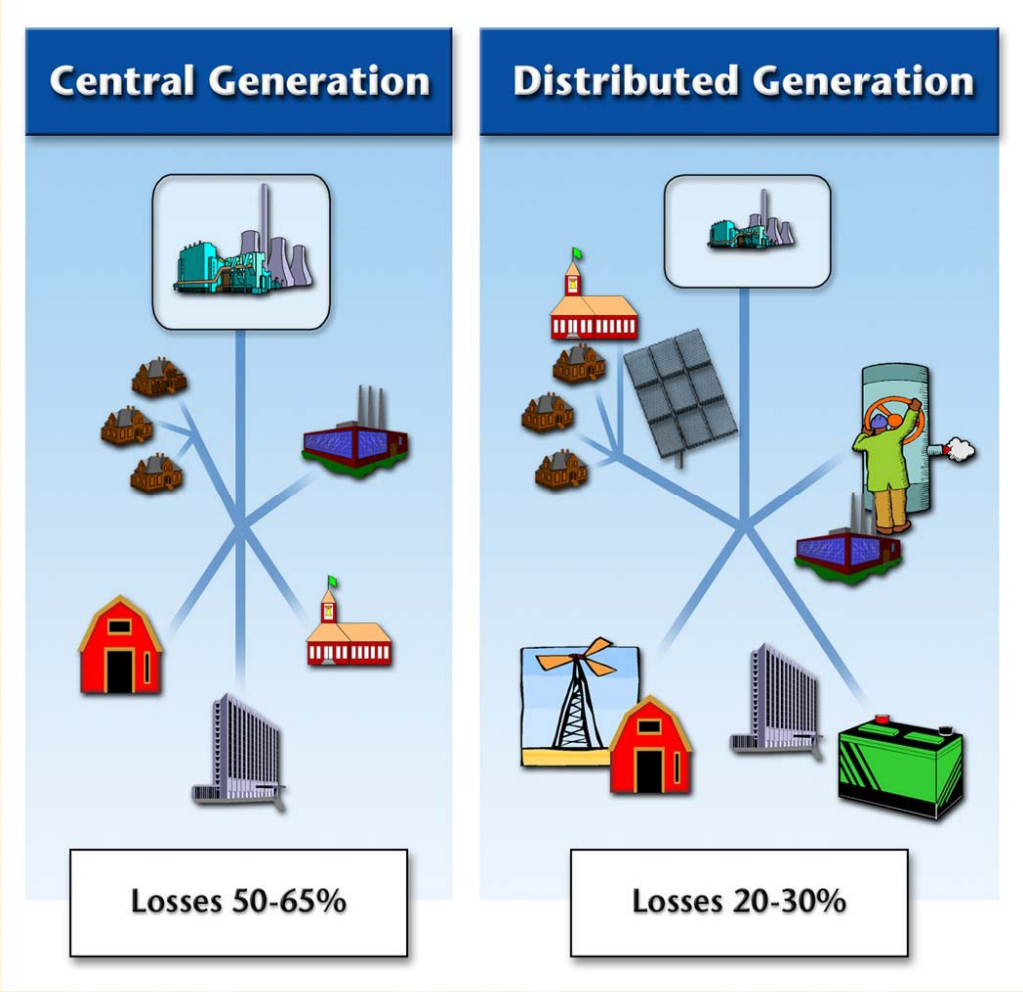
Advanced Materials Can Cut Energy Use in Energy-intensive Industries

- **New crack-resistant alloys for Kraft recovery boiler tubes**
  - **5-10% improvement in energy efficiency of boiler operations**

- **Nickel aluminide alloys improve energy efficiency in steel, heat treating industries**
  - **Energy efficiency improvements range from 10–25%**

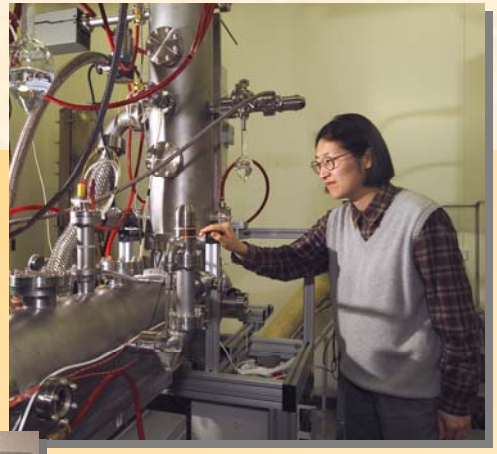
Combined Heat and Power Can More Than Double the Efficiency of Power Production

- **Modular electricity generation located on site**
- **Thermal energy used for cooling, heating, dehumidification**
- **Energy efficiency increased from 35% to 80%**

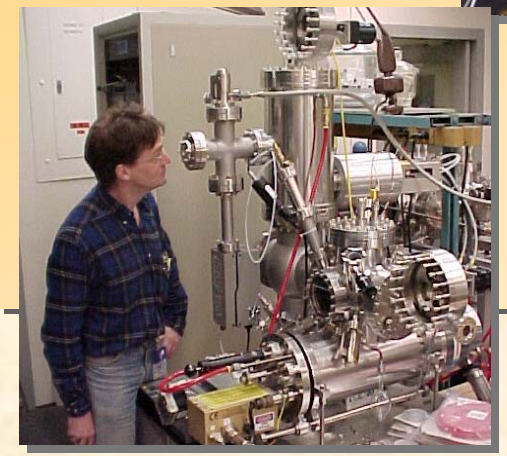


High-temperature Super-conducting Materials Offer "Transmission without Friction"

- **"Rolling-assisted, biaxially textured substrates" (RABiTS) invention**
- **Substrates require near single-crystal-like performance in kilometer lengths**
- **Possible applications**
  - **Transmission cables**
  - **Transformers**
  - **Motors**
  - **Generators**



Reel-to-Reel annealing and buffer layer deposition for scale-up research and development



RF sputtering is used to deposit oxide multilayers on 10-m long biaxially textured nickel tapes

Low-cost Carbon Fiber Can Drive Down Vehicle Weight

ORNL research has reduced the cost of manufacturing carbon fiber from $4 to < $3/kg. The goal to be competitive with metal is $1.4/kg

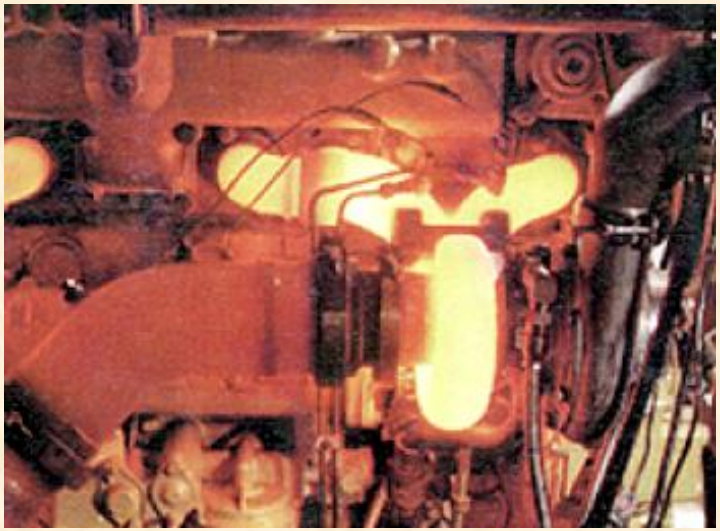
Microwave-assisted carbon fiber production unit at ORNL

Developed lignin-based precursors

Partners: North Carolina State University, Westvaco

Improved Cast Stainless Steel Can Improve Engine and Turbine Efficiencies

- **Engineered microstructure enables CF8C-Plus to be used up to 850°C**
- **Operating at higher temperatures allows engines to run at greater efficiency with fewer emissions**
- **Has denser dispersions of "near nanoscale" niobium carbides inside the grains**
- **Results in high strength and higher ductility**
- **Same cost per pound as cast stainless steel**

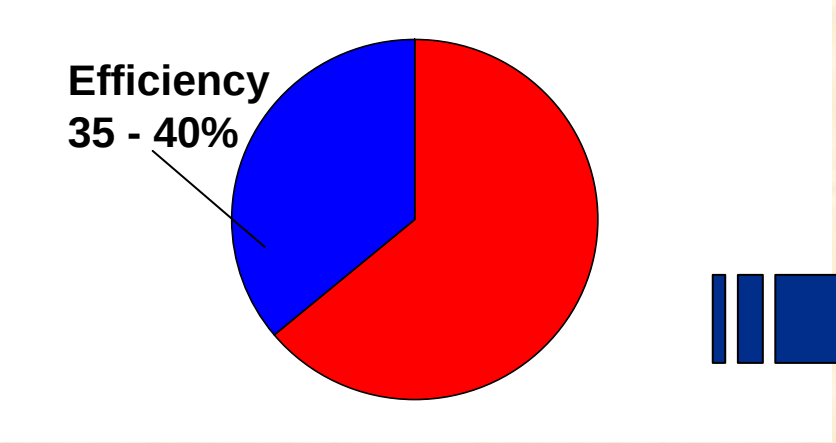


Hot cast iron exhaust manifold and turbo charger on a diesel engine being tested at Caterpillar

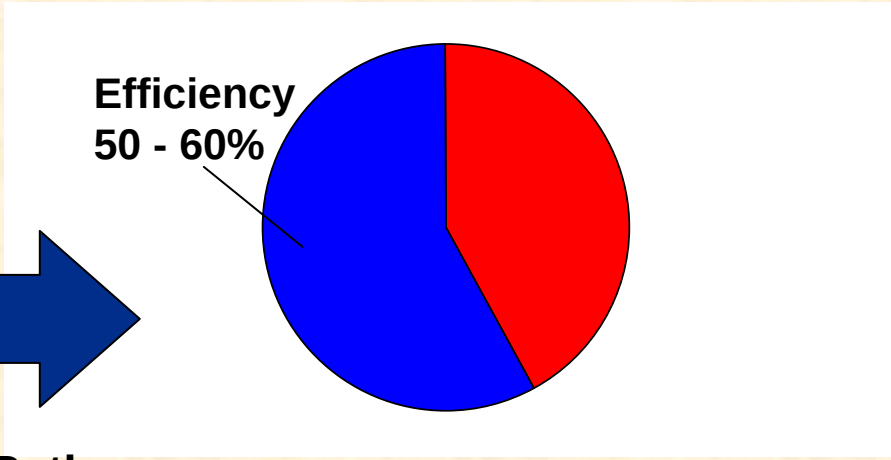
Partners: Caterpillar, Bradley University, Solar Turbines

Improving Engine Efficiency to Enable the Transition to a Hydrogen Economy

Today's Engines



Advanced Combustion Engines



R&D

Losses:

- Emission Controls 3 – 8%
- Exhaust 12%
- Thermodynamic Combustion 16 – 19%
- Heat Transfer 14%
- Mechanical Pumping 6%
- Friction 5%

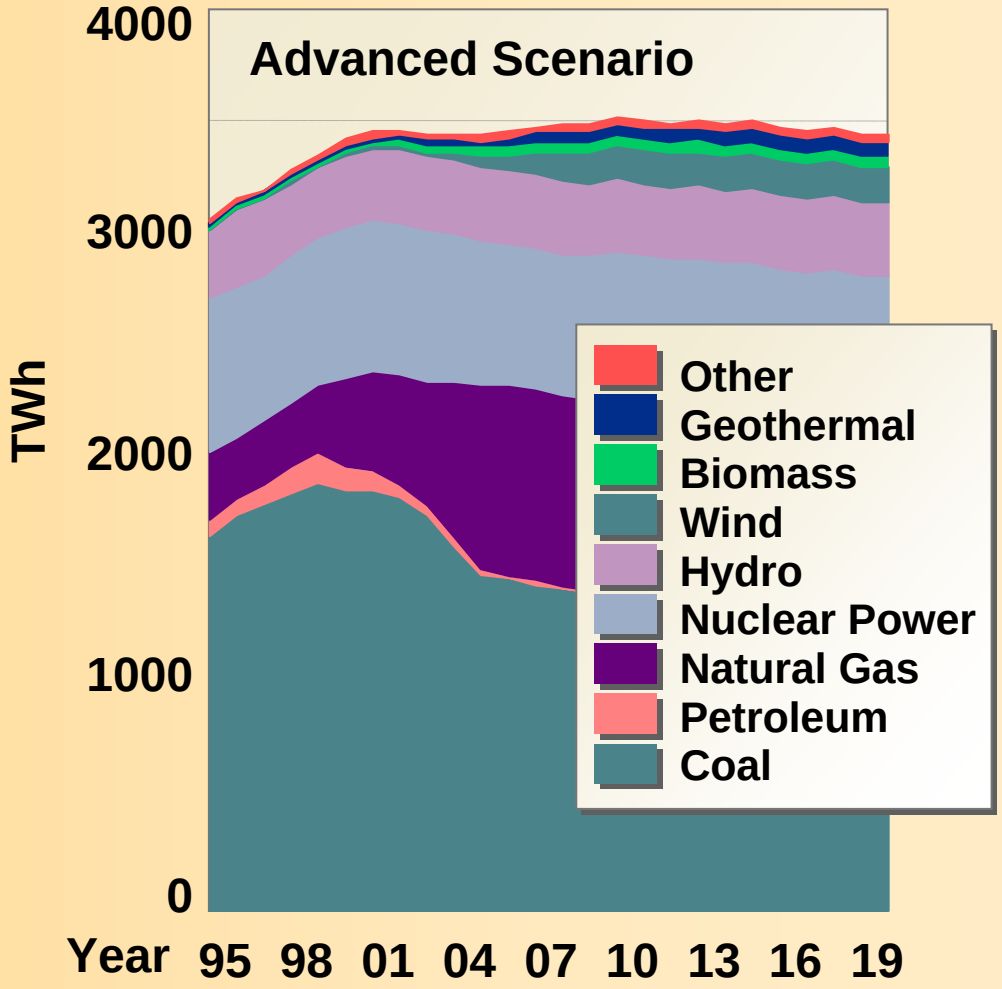
Potential Paths

- Advanced Combustion Regimes
- Advanced Control Strategies
- Waste Heat Recovery
- Reduced Friction Coatings
- Reduced Injection Pressure
- Thermo-electrics
- Engine Electrification
- Enabling Fuels

Losses:

- Emission Controls 1 – 2%
- Exhaust 8%
- Thermodynamic Combustion 14%
- Heat Transfer 10%
- Mechanical Pumping 4%
- Friction 4%

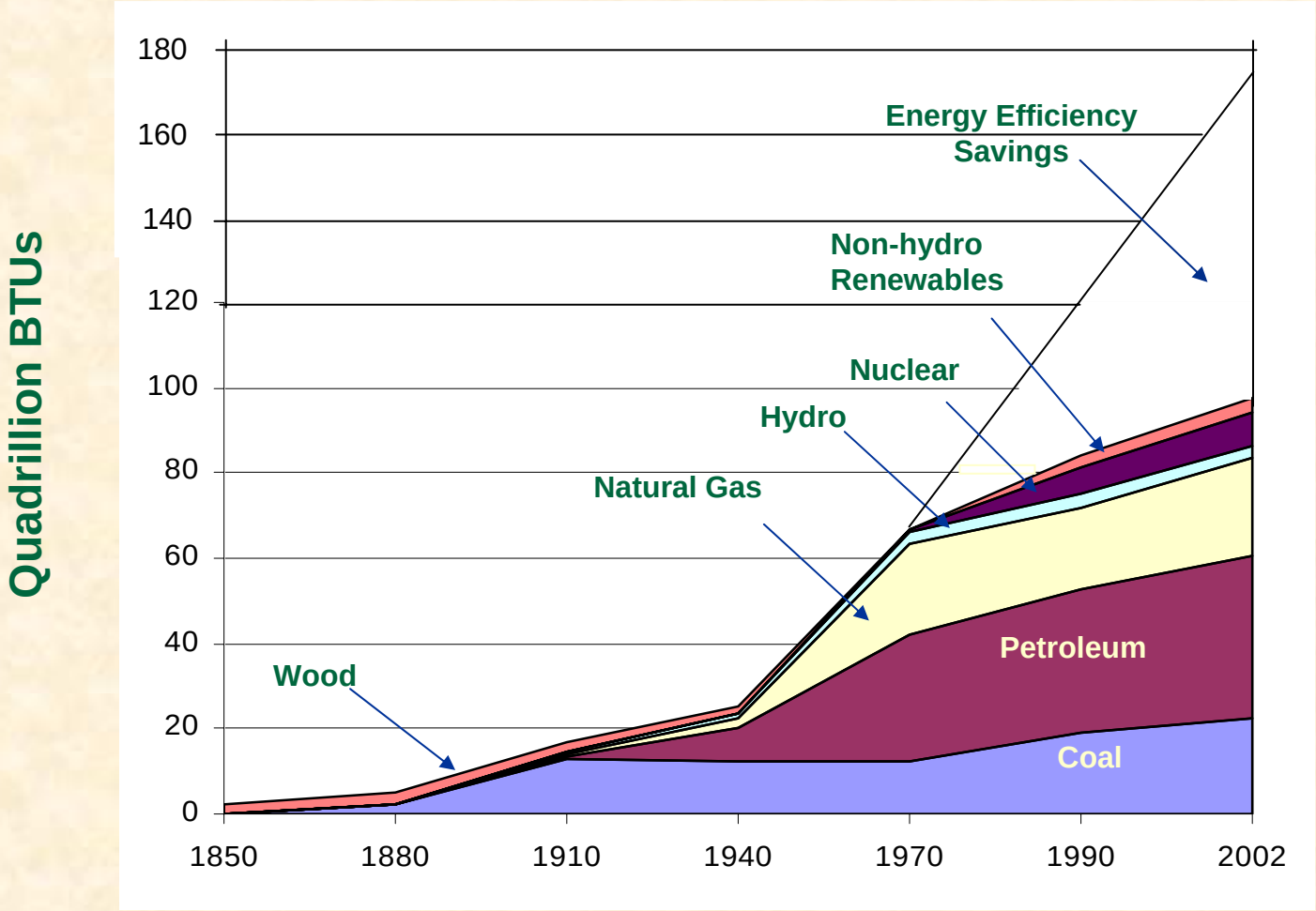
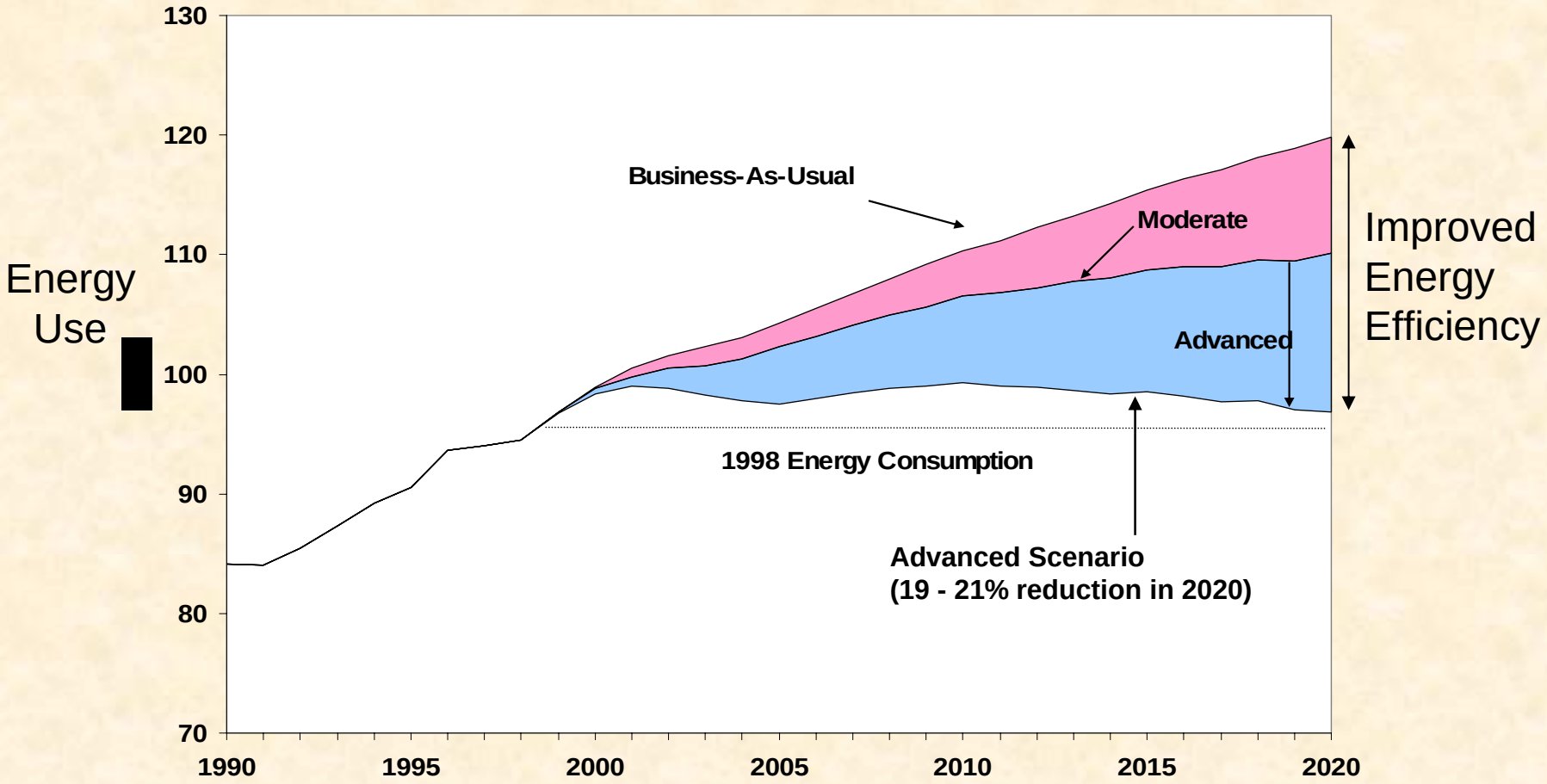
Renewable Power Resources Could Play an Increasing Role



Advances in Materials and Construction Will Ultimately Bring Photovoltaic Technology into Common Commercial Use

Advances in Wind Turbine Technology Will Thrust This Technology into the Mainstream

U.S. Energy Consumption Stabilized with Energy Efficiency Measures



The CEF Study Documents a Large "Economic Potential" for Energy Efficiency