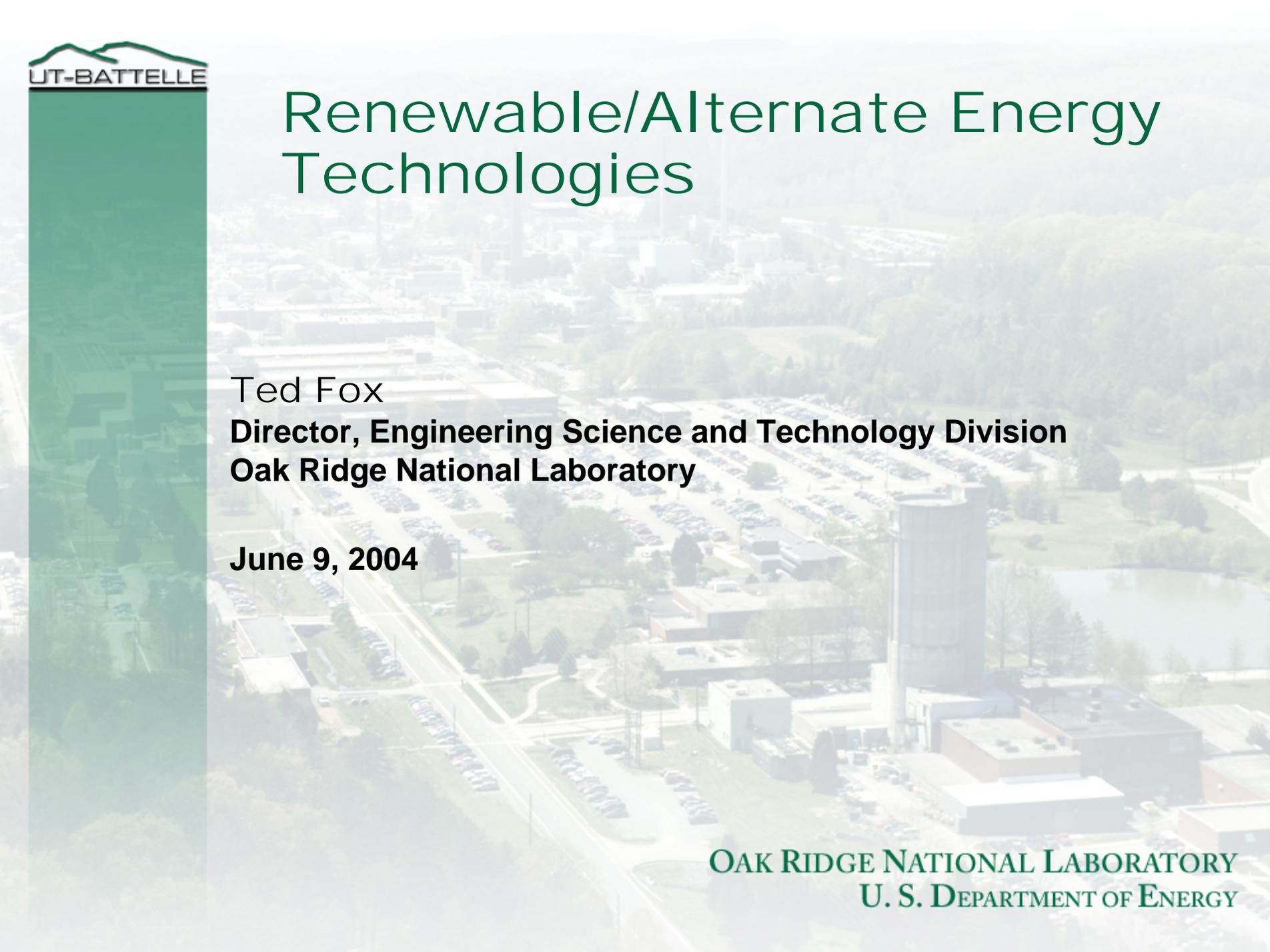


Renewable/Alternate Energy Technologies

Ted Fox

**Director, Engineering Science and Technology Division
Oak Ridge National Laboratory**

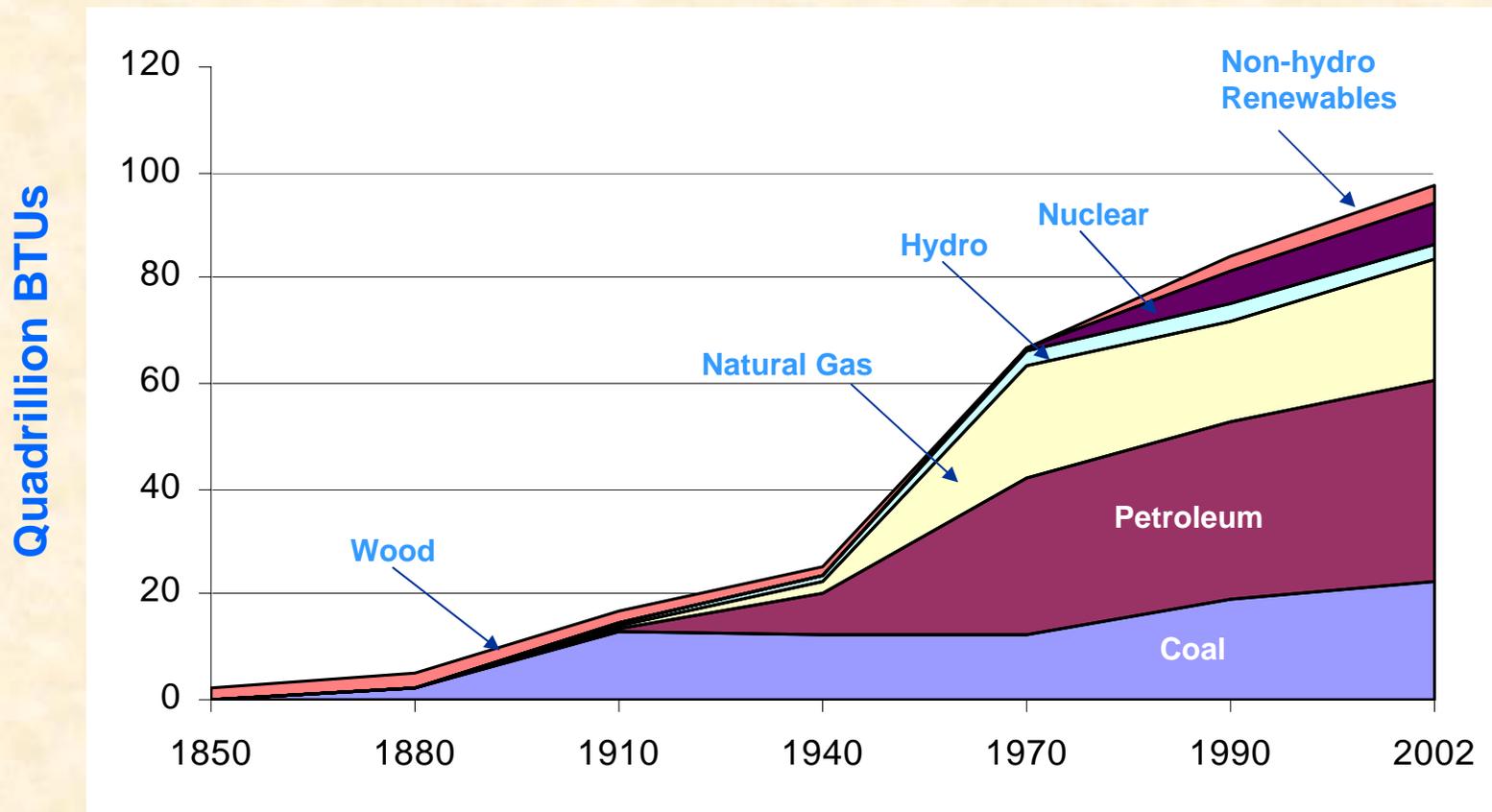
June 9, 2004

An aerial photograph of the Oak Ridge National Laboratory campus, showing various buildings, parking lots, and a large body of water in the background.

**OAK RIDGE NATIONAL LABORATORY
U. S. DEPARTMENT OF ENERGY**

Renewable Energy in the U.S. Is Expanding Slowly

(U.S. Energy Consumption by Source: 1850-2002)



Source: EIA Annual Energy Review 2002, Table 1.3

Renewable Energy Technology

Renewable Resources

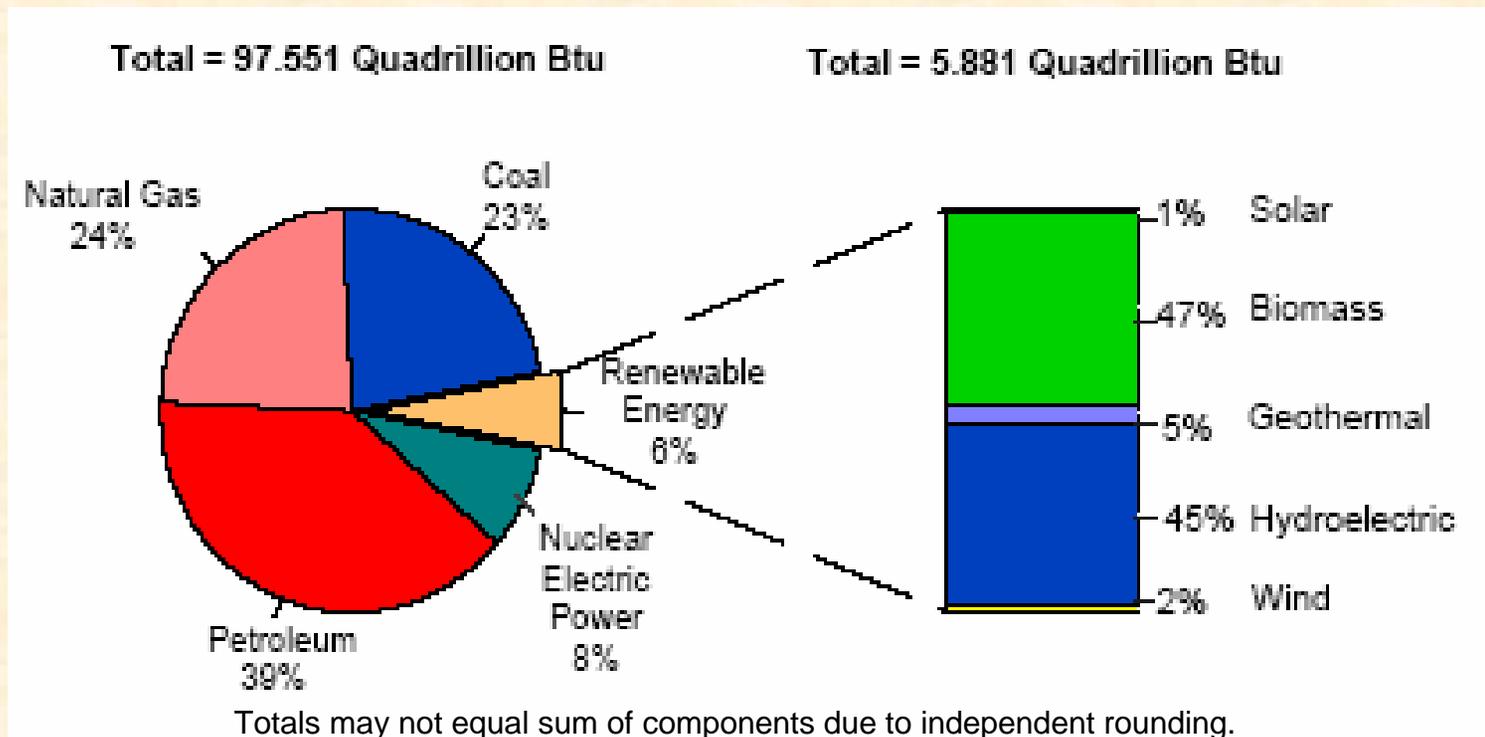
- Hydropower
- Wind
- Solar
- Biomass
- Geothermal



Energy Forms

- Light
- Heat
- Electricity
- Hydrogen
- Fuel

Renewable Resources in the U.S. Are Dominated by Biomass and Hydropower (U.S. Energy Consumption by Source: 2002)



Source: Energy Information Administration/Renewable Energy Annual 2002

<http://www.eia.doe.gov/cneaf/solar.renewables/page/rea2002/rea2002.pdf>

Biomass Facts

- **Annual U.S. energy consumption is 2.7 quads**
- **Biomass today produces electricity, heat, transportation fuels, and bioproducts**
- **80% of biopower is generated and used by the pulp and paper industry**
- **Cost of grid-connected biopower is about 8 - 12¢/kWh**
- **Ethanol production – primarily from corn supplies about 1.5% of transportation fuels in the U.S.**

Source: DOE website: www.eere.energy.gov/biomass

The New Industrial Biorefinery



Biomass Feedstock

- Trees
- Grasses
- Agricultural Crops
- Agricultural Residues
- Animal Wastes
- Municipal Solid Waste

Conversion Processes

- Enzymatic Fermentation
- Gas/liquid Fermentation
- Acid Hydrolysis/Fermentation
- Gasification
- Combustion
- Co-firing

USES

Fuels:

- Ethanol
- Renewable Diesel

Power:

- Electricity
- Heat

Chemicals

- Plastics
- Solvents
- Chemical Intermediates
- Phenolics
- Adhesives
- Furfural
- Fatty acids
- Acetic Acid
- Carbon black
- Paints
- Dyes, Pigments, and Ink
- Detergents
- Etc.

Food and Feed

Bioenergy Research Needs

- **Feedstock Supply**
 - Resource assessment
 - Sustainability & life cycle issues
 - Collection/handling/transport
- **Crop Research**
 - Genomics & plant physiology
 - Carbon sequestration
- **Bioconversion**
 - Hydrolysis
 - Immobilized biocatalyst reactors
 - Lignin conversion via ligninases
 - Hydrogen production
- **Thermal Conversion - Gasification**
 - Materials for gasifiers
- **Bioproducts**
 - Carbon fibers from biomass



Geothermal Facts - 2002

- **Annual U.S. energy consumption is 0.3 quads**
- **Cost of geothermal electricity ranges from 5 to 8¢/kWh**
- **Direct geothermal (thermal wells and springs) provide heat for residential, industrial and commercial use.**
 - More than 9000 wells and springs identified in 10 western states
- **Geothermal heat pumps are the most energy and cost-efficient heating and cooling systems available today**
 - More than 500,000 geothermal heat pumps in use today.

Source: DOE website www.eere.energy.gov/geothermal

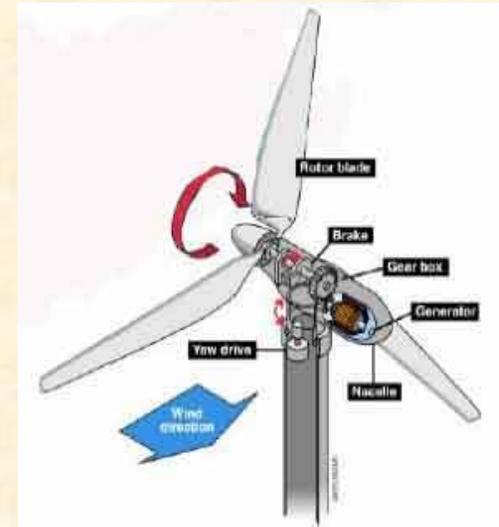
Wind Energy Facts

- **Annual U.S. energy consumption is ~ 0.1 quads**
- **19 states are generating wind power**
- **Cost/kWh ~ 4 to 6¢/kWh (down from 80¢/kWh in 1979)**
- **Wind capacity expanded by 10% in the U.S. during 2002 to 4,685 MW**
- **Research now focusing on low wind areas**
- **2010 target: 3¢/kWh (in Class 4 and above regimes)**

Sources: Renewable Energy Issues & Trends 2000, Energy Information Administration, Feb 2001; and Wind Energy Fact Sheet, <http://www.awea.org/pubs/factsheets.html>.

Wind Research Needs

- **Low-Speed Wind Technologies**
 - X 20 resource
- **Advanced small turbines for distributed power applications**
- **Computational Fluid Dynamics**
 - Modeling turbulent flow for wind turbine design
- **Modeling Meso-Scale Atmospheric Phenomena**
 - For wind forecasting for utilities
- **Composite Materials**
 - Greater strength
 - Improved fatigue properties
- **Integration of Wind into Power Systems**
 - Challenges of intermittency



Solar Energy Facts

- **Annual U.S. energy consumption is 0.01 quads**
- **Solar Photovoltaics**
 - Silicon modules dominate
 - Commercial modules are 13-17% efficient (best 25%)
 - A new generation of thin-film semiconductors are emerging
 - Grid-connected PV systems currently cost about 20 - 32¢/kWh
- **Solar Buildings**
 - Active solar heating systems use pumps and controls to circulate a heat-transfer fluid
 - Passive solar heating systems rely on natural circulation
 - Transpired solar collectors heat ventilation air
 - Hybrid solar lighting combines daylight with conventional illumination

Source: Renewable Energy Annual 2002, EIA November 2003, http://www.eia.doe.gov/cneaf/solar.renewables/page/rea_data/rea.pdf

Photovoltaics Research Needs

- **Improve fundamental understanding of materials, processes, and devices to provide a technology base for advanced PV options**
- **Optimize PV cell materials, cell designs, and modules; scale up laboratory cell results to product size (10^4 increase in area)**
- **Validate new module technologies outdoors and in accelerated testing to achieve 30-year outdoor lifetimes**
- **Improve and invent new low-cost processes and technologies; reduce module and balance-of-systems manufacturing costs**



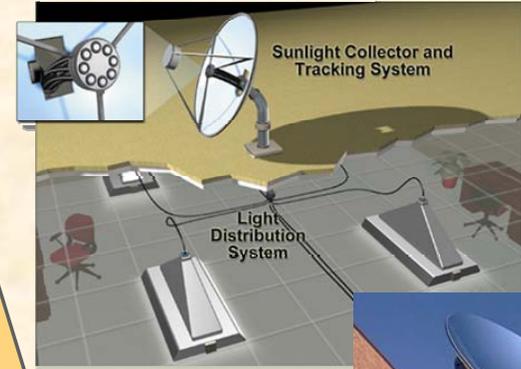
Hybrid Solar Lighting

Hybrid Lighting Uses

- Full solar energy spectrum
- Natural and electric light sources
- Networks of optical fibers
- Hybrid luminaires and control systems

•Projected Benefits

- Payback ~ 2–5 years after R&D
- Student/worker productivity shown to be much higher under natural lighting
- Significant public interest



Hybrid
Lighting
Design
Concept



Prototype Hybrid Luminaire

What's The Future For Renewable Energy?



Can renewable energy technologies compete on cost alone?

It depends on the success of R&D...

Do they have to compete on cost alone?

It depends on consumer preferences...



Resources

- Oak Ridge National Laboratory www.ornl.gov/EERE
- National Renewable Energy Laboratory www.nrel.gov
- U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy www.eere.energy.gov
- U.S. Energy Information Administration
<http://www.eia.doe.gov/>
- U.S. Climate Change Technology Program
www.climatechange.gov
- International Energy Agency www.iea.org