National Renewable Energy Laboratory
Innovation for Our Energy Future

Meeting Our Energy Challenges: Transitioning from 20th Century Fuels to 21st Century Options

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June 9, 2010

State Energy Advisory Board

U.S. Department of Energy

NREL is a national laboratory of the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy operated by the Alliance for Sustainable Energy, LLC

Humanity's Top Ten Problems for next 50 years

1. **Energy**
2. **Water**
3. **Food**
4. **Environment**
5. **Poverty**
6. **Terrorism & War**
7. **Disease**
8. **Education**
9. **Democracy**
10. **Population**

2003: 6.3 Billion people

2050: 9-10 Billion people

Source: Nobel laureate, Richard Smalley

Energy is a means to an end, not an end in itself.

Heat and power for where we live and work

Sustainable Electricity System

Fuel and power for mobility and access

Sustainable Transportation System

Our Energy System

Supply & Conversion

Oil 40%

Coal 23%

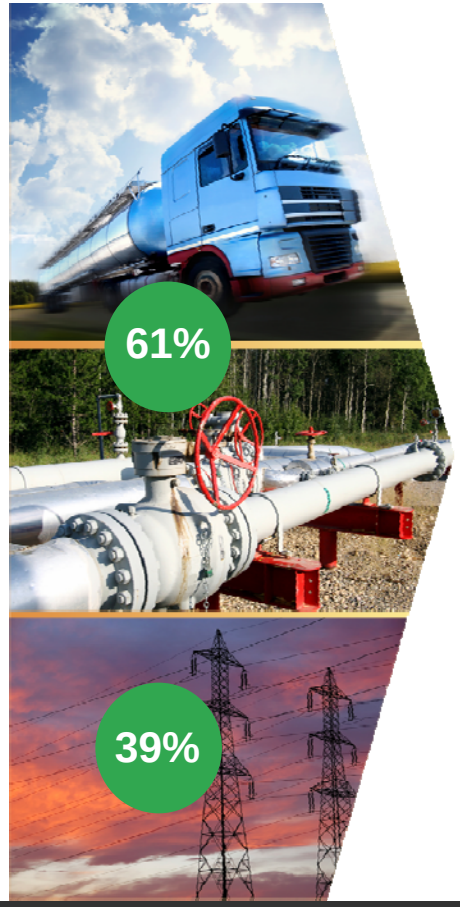
Natural Gas 23%

Nuclear 8%

Hydro
Wind
Solar
Biomass
Geothermal
6%

100 Quads

Transmission & Distribution



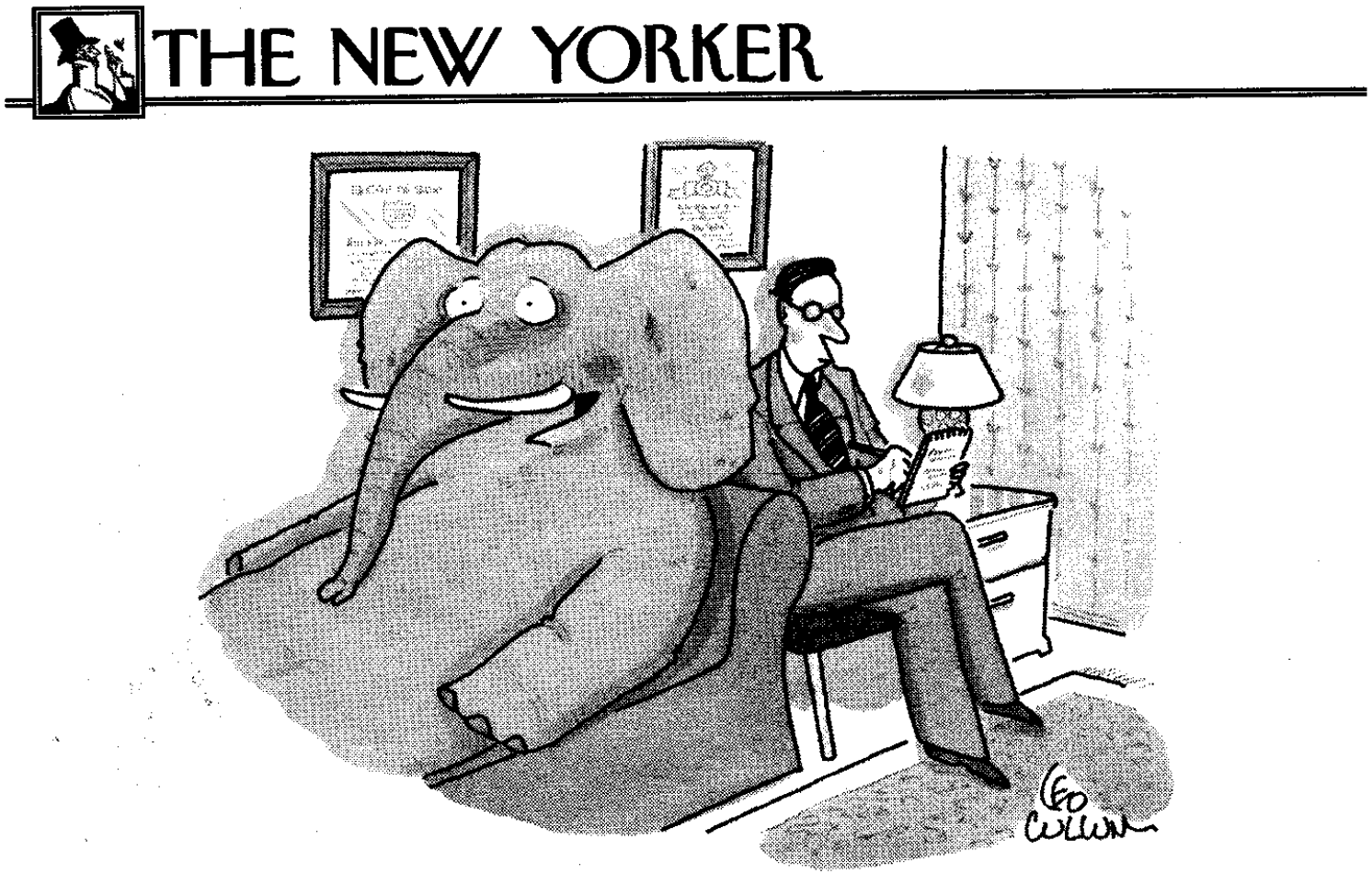
Utilization

27%

40%

33%

Lost energy as inefficiencies – 62%



"I'm right there in the room, and no one even acknowledges me."

Energy Is the Elephant in the Room…

…An operating cost, a cost of doing business

… A vulnerability for businesses that require 99.9999% reliability

… A factor in local environmental conditions and associated human health

… A factor, for better or worse, in local economies

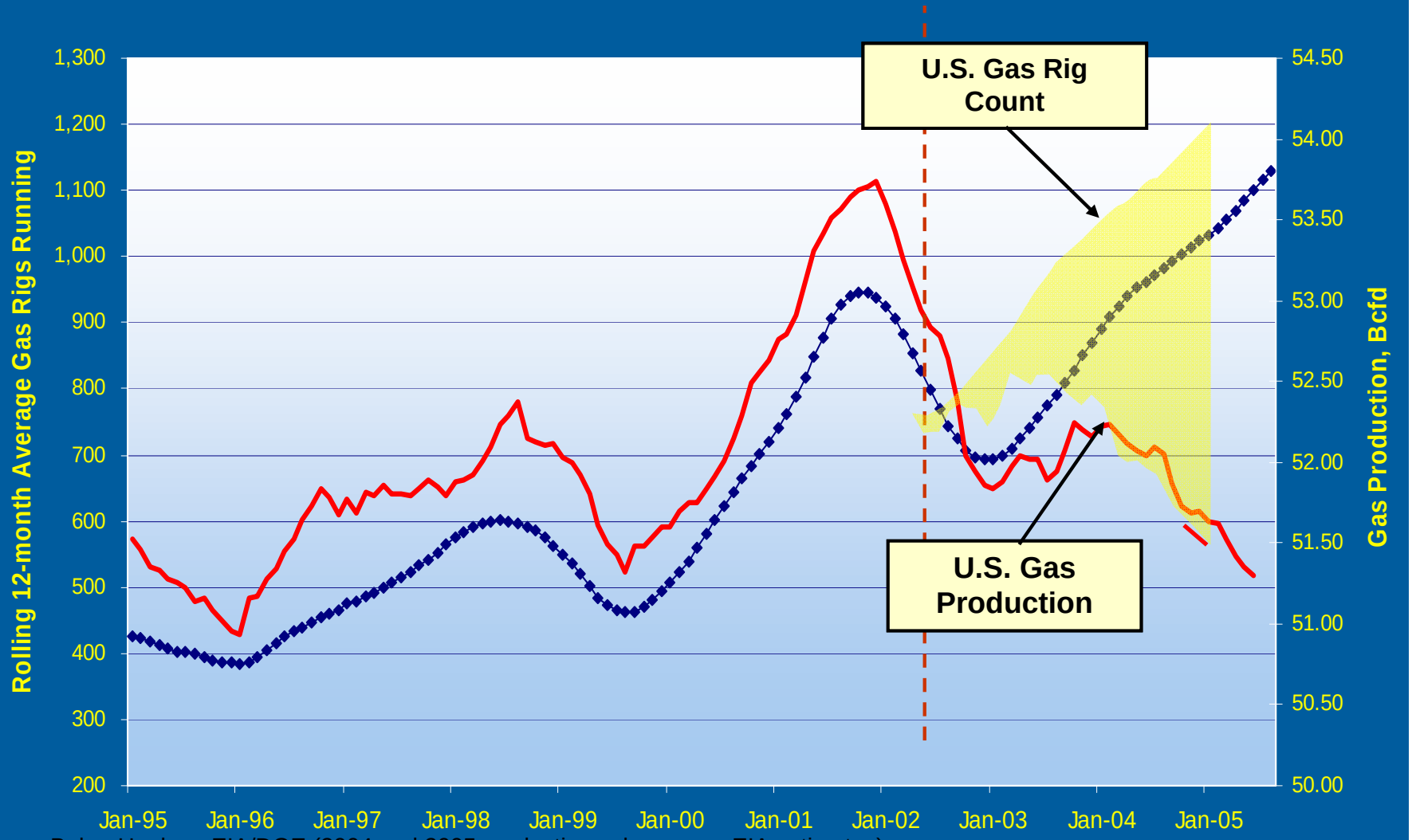
… A homeland security concern

… A national security concern

… A behind-the-ticker-tape factor on Wall Street

A Look at Costs…

More and More U.S. Gas Wells Producing Less and Less



Source: Baker Hughes, EIA/DOE (2004 and 2005 production volumes are EIA estimates)

Challenges for Natural Gas

- Pressure on conventional supplies

- Uncertainties regarding enhanced recovery (hydro-fracturing)
  - --Undocumented success rate
  - --Cost
  - --Water requirements

According to Peabody Coal, there will be a ....

59 %

Increase in the Cost of

Powder River Basin (Wyo) Coal

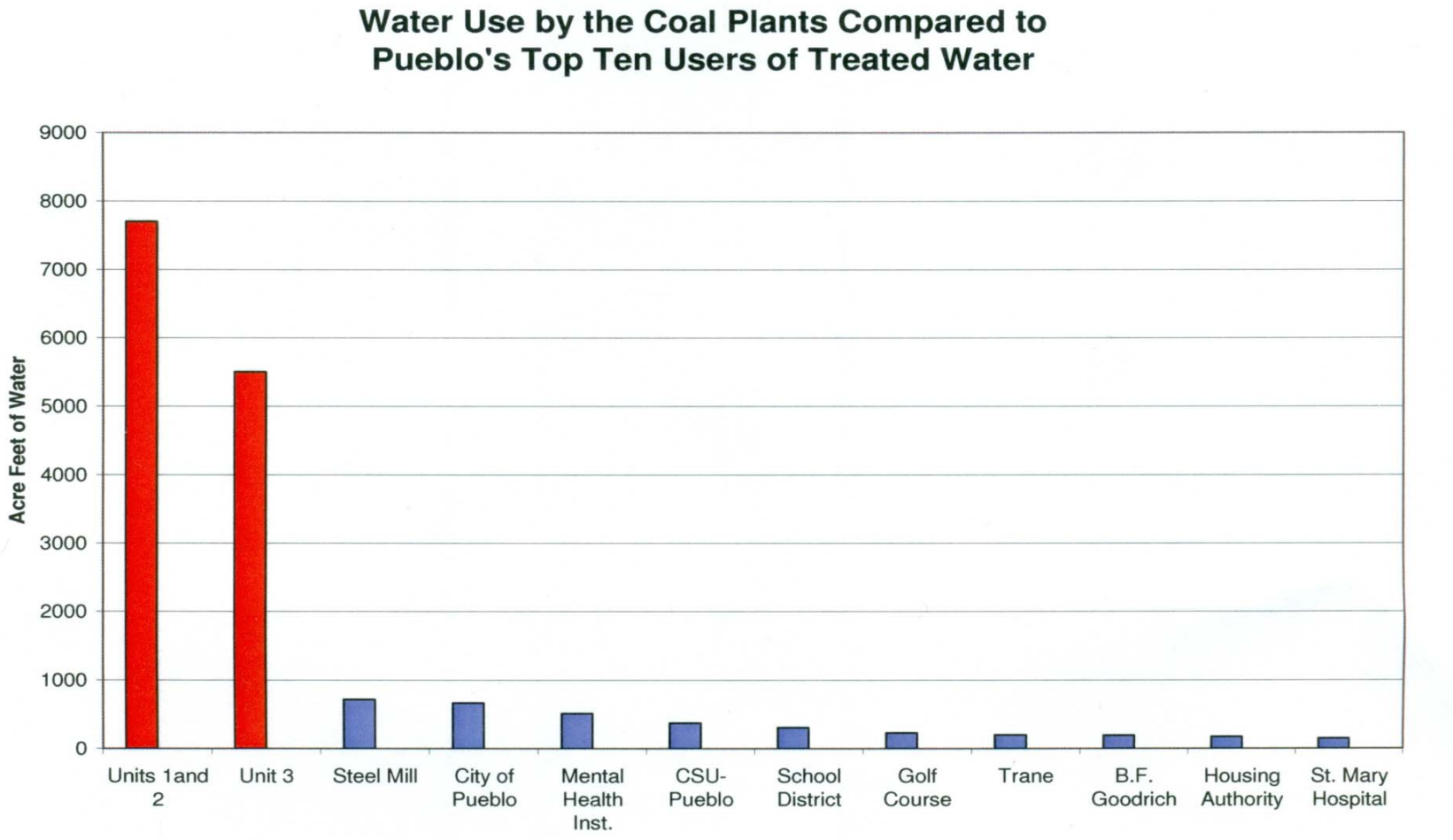
Between 2007 and 2009

Source: Peabody Coal, Presentation to Investors,
September 6, 2007 Lehman Brothers Conference

Challenges for Coal

- **Pressure on *affordably* extractable supply: increased demand without parallel increase in supply**
  - Population and economic growth
  - Larger electricity needs in built environment
    - *Larger footprints, especially in residential sector*
    - *Principal-agent dilemma inhibiting energy efficiency investments*
  - Electrification of transportation and industrial sectors
- **Rising prices: ~10% in recent years**

Figure 4
Water Use by the Pueblo Coal Plants Compared to the Top 10 Water Users in the State
(Information from the Annual Report of the Pueblo Board of Water Works)



Challenges for Coal -- 2

- **Need for large amounts of cooling water, even with hybridized systems**

- **Air- and Water-borne Emissions**

  Hazardous pollutants: mercury, arsenic, benzene, chromium, lead, sulfuric acid mist

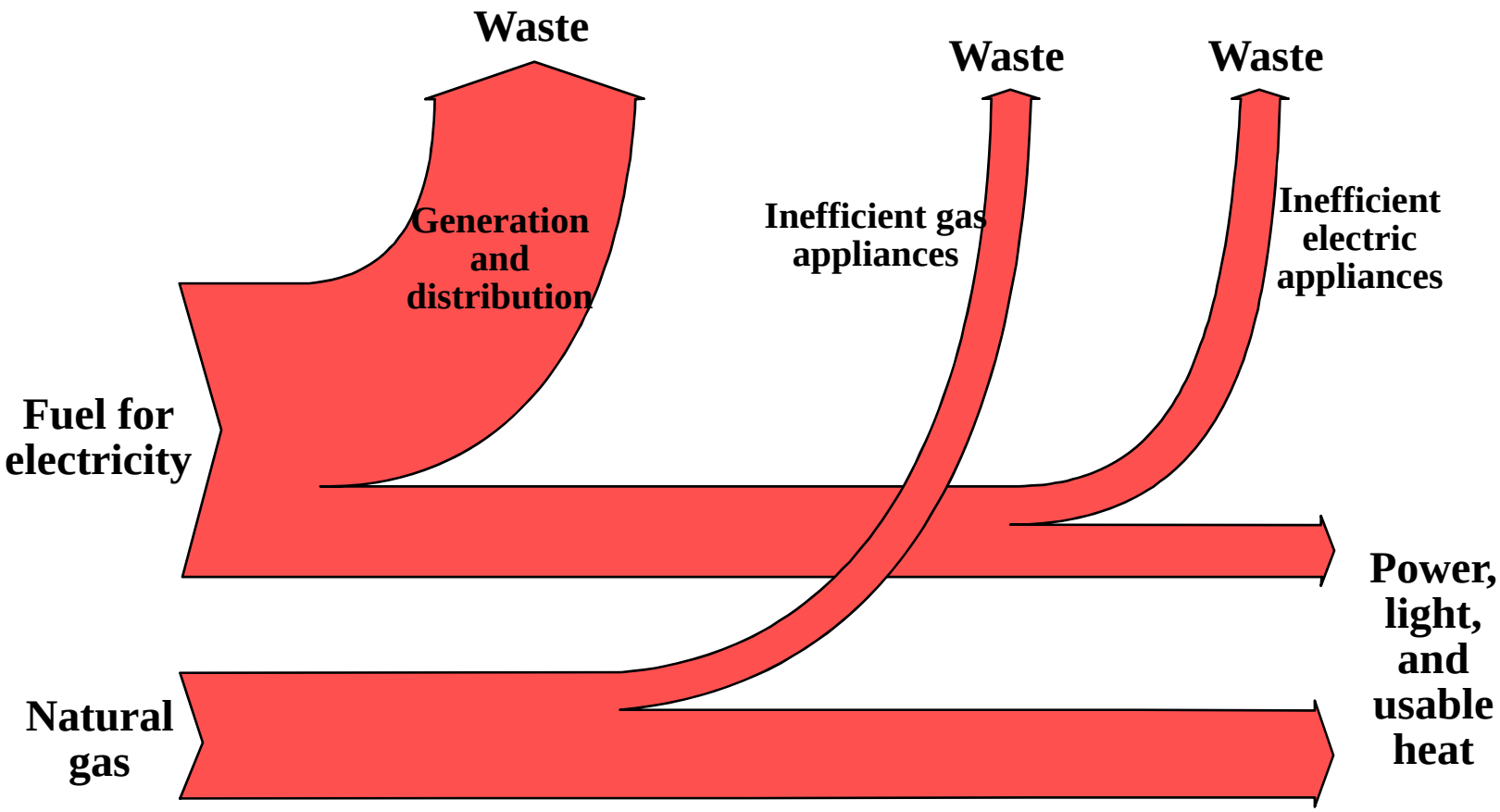
  Other regulated pollutants: NOx, SOx, fine particulates,CO2

Challenges for New Nuclear Power Plants

- **Rising uranium costs/global competition**
- **Rising costs of cement and steel**
- **NIMBY**
- **Long lead times** *(12 years, minimum)*
- **Projected cost: 30 cents/kWh**
- **Waste disposal issue**
- **Cooling water**
- **Wall Street perception of risk**
- **Need for continuing hefty subsidies**
  - **Price-Anderson Act**

What is the Cost of Waste?

Consumption for Average Residential Customer



Source: A Micro-Grid with PV, Fuel Cells, and Energy Efficiency, Tom Hoff, Clean Power Research.com

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Energy Intensity

The American economy is, after Canada's, the most energy-dependent in the advanced industrialized world, requiring the equivalent of a quarter ton of oil to produce $1,000 of gross domestic product. *We require twice as much energy as Germany -- and three times as much as Japan -- to produce the same amount of GDP.*

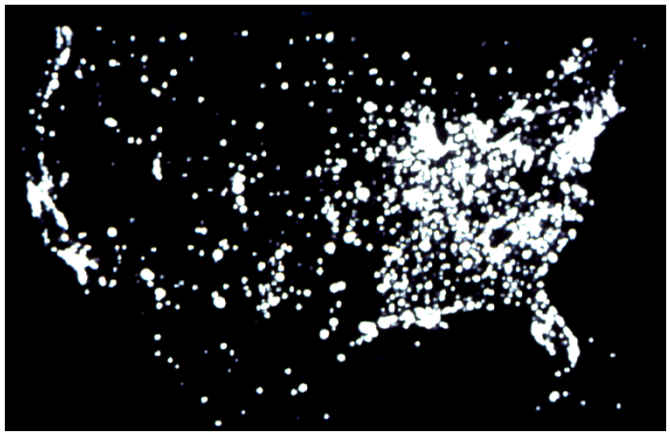
Source: Ricardo Bayon, *The Atlantic Monthly*, Jan/Feb. 2003

Homeland Security:

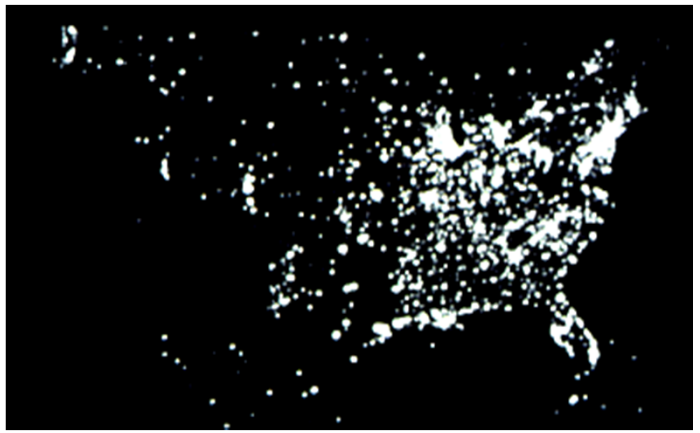
How vulnerable are we?

Homeland Security:
Vulnerability of the Electrical Grid to Natural Disasters

High-voltage power line cut by fallen tree limb near Oregon/California border - August 10, 1996



Before

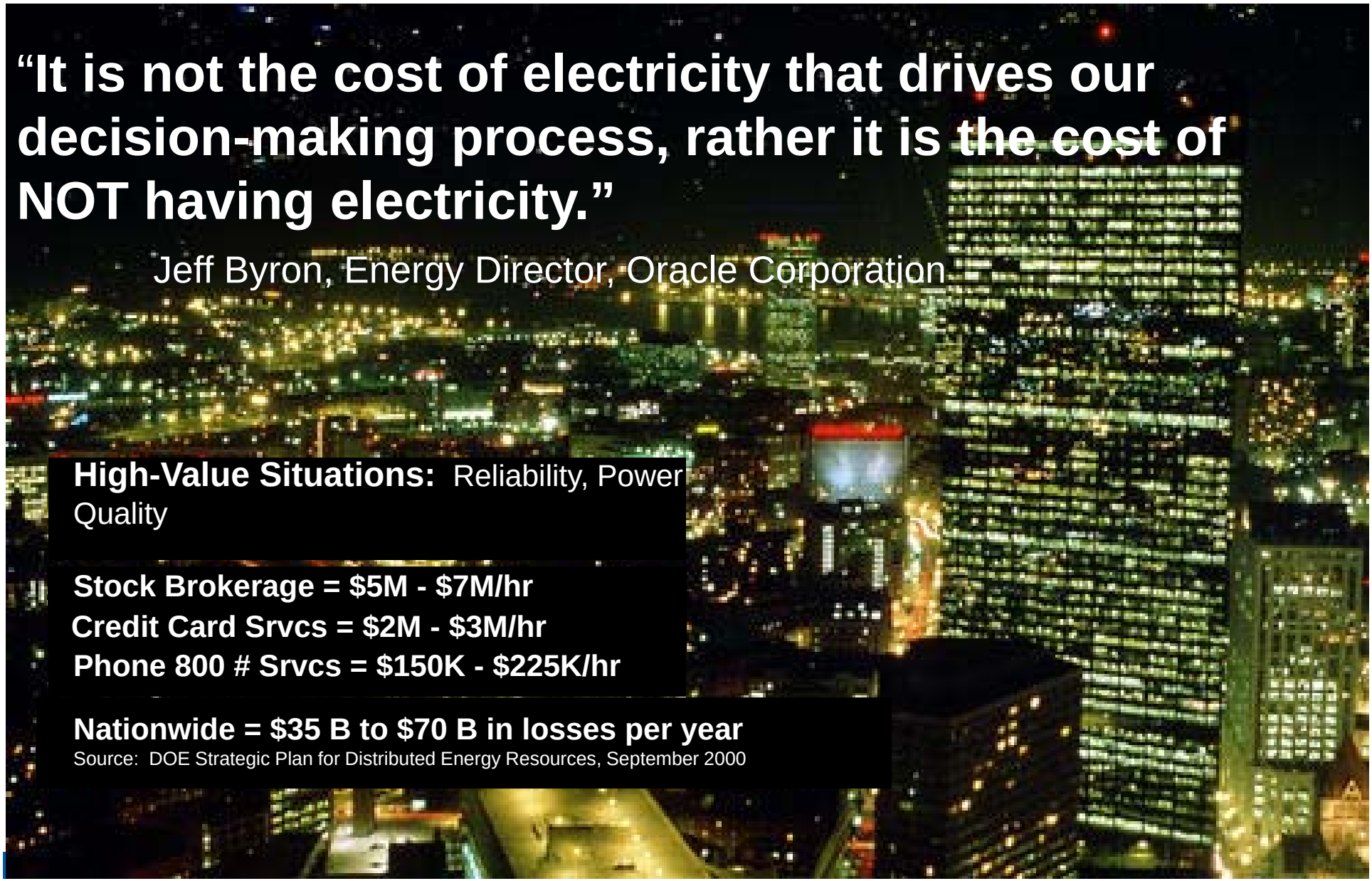


After

- **Affected a 9-state region**
- **Lasted up to 3 weeks in some areas**
- **Almost 16 million people affected in California alone**

Source: W. Becker, U.S. DOE

Vulnerability of Our Economy to Power Outages



"It is not the cost of electricity that drives our decision-making process, rather it is the cost of NOT having electricity."

Jeff Byron, Energy Director, Oracle Corporation

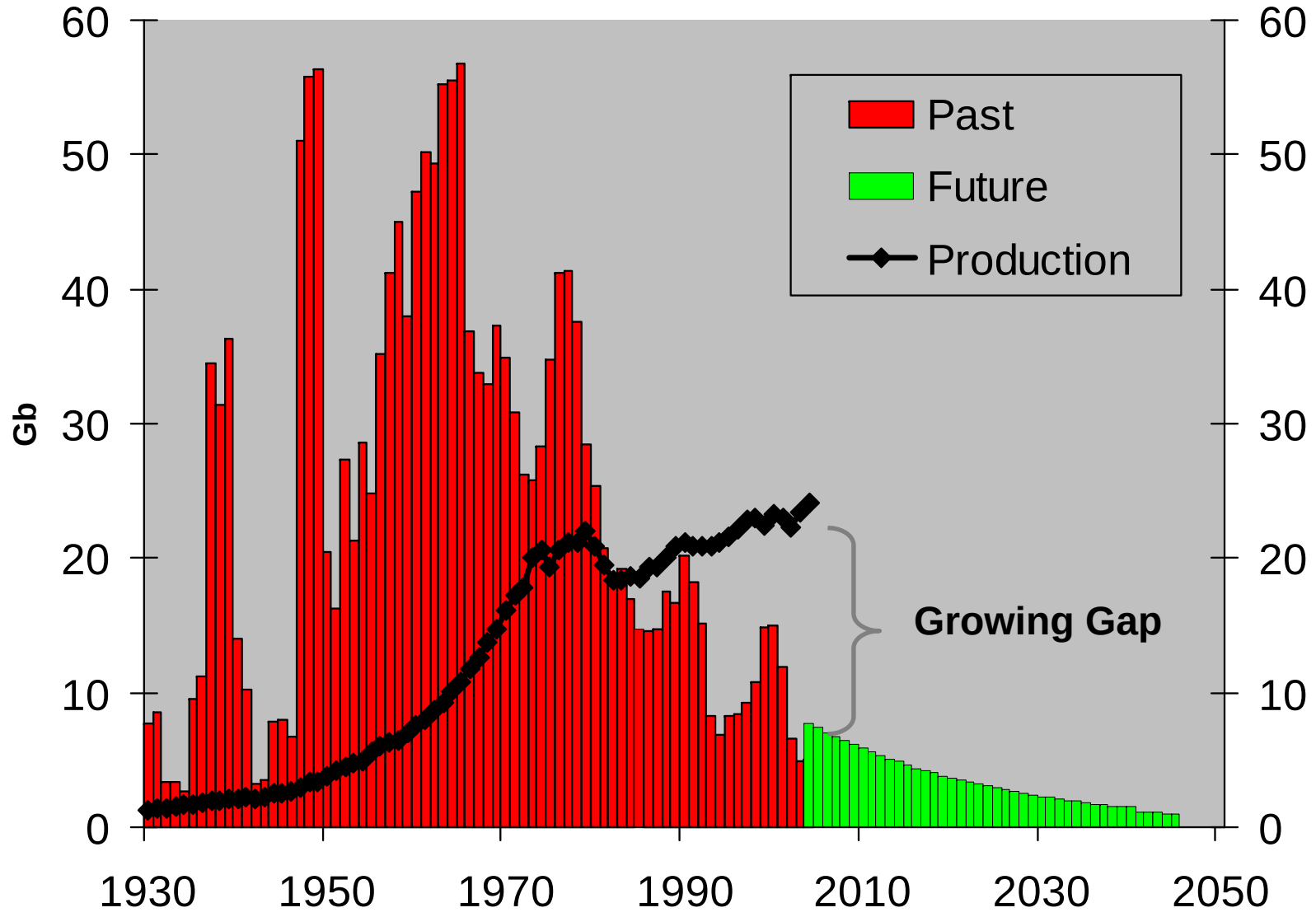
High-Value Situations: Reliability, Power Quality

Stock Brokerage = $5M - $7M/hr
Credit Card Srvcs = $2M - $3M/hr
Phone 800 # Srvcs = $150K - $225K/hr

Nationwide = $35 B to $70 B in losses per year

Source: DOE Strategic Plan for Distributed Energy Resources, September 2000

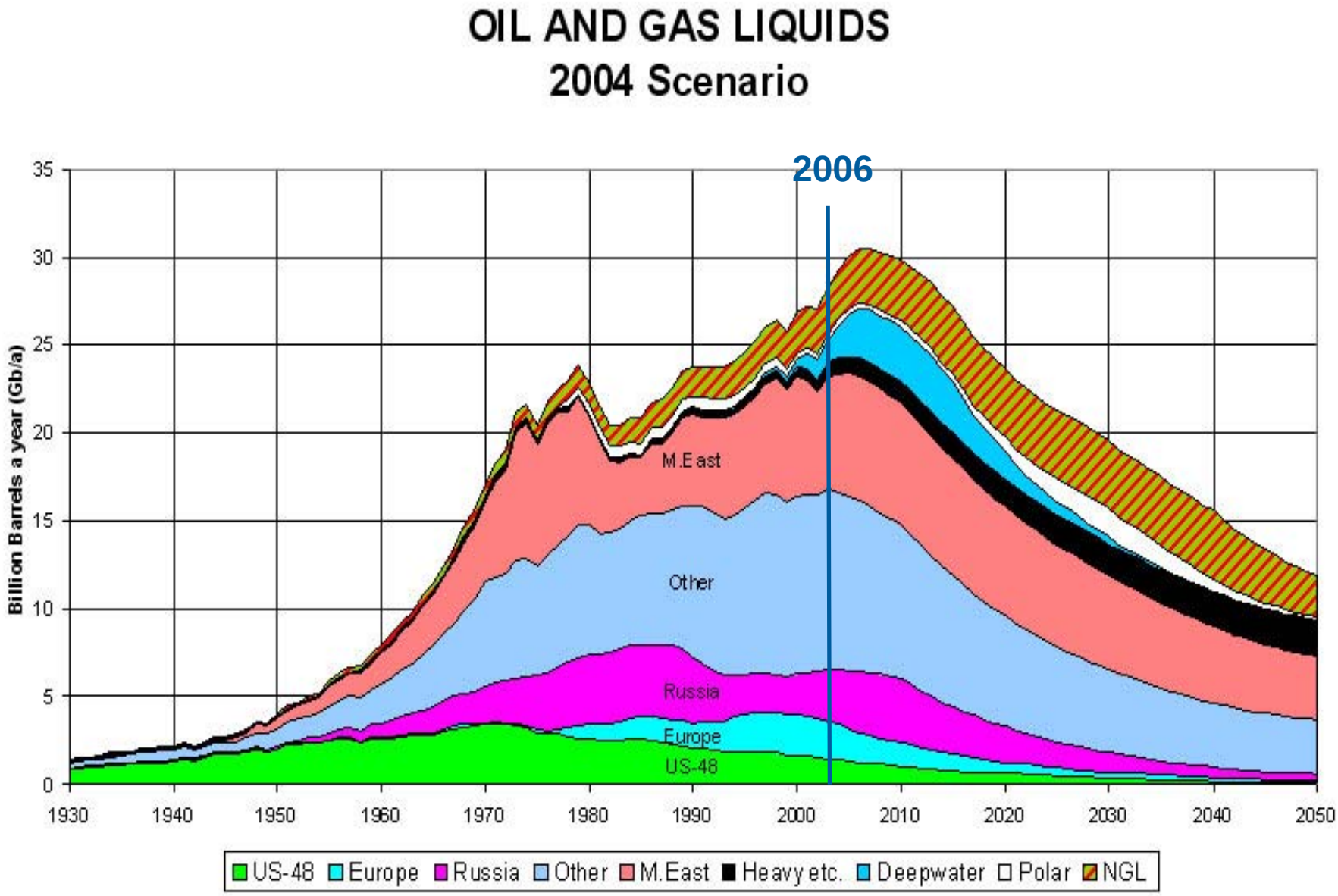
Worldwide Discovery Trend



Source: Campbell, May 2005

Peak Oil Theory

according to Colin Campbell, Assoc. for the Study of Peak Oil



The world consumes about two barrels of oil for every barrel discovered.

The U.S. has consumed about 2/3 of its oil!

It’s like drinking 4 cans and having only 2 left!

Except that we’re drinking the last two much faster than the first two!

What is the value of energy if you don't have any?

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Individual, Regional and Global Environmental Impacts

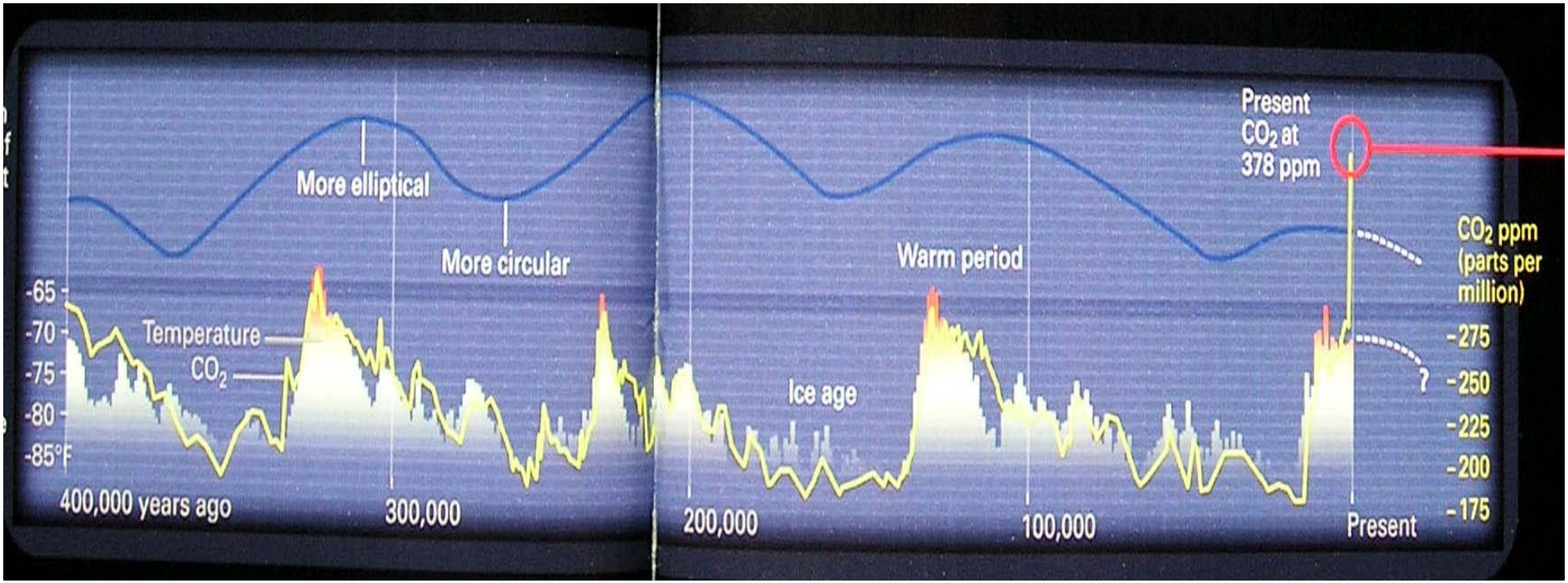
Air Emissions & Public Health

45% of U.S. Population live in non-attainment areas.

121.4 million Americans lived in counties that violated national air quality standards in 2000.

The American Lung Association estimates that Americans spend >$50 billion a year on health care as a result.

Unprecedented Levels of CO_2



CO2 concentrations currently ~ 390

How long can you operate past the red line…

…with your car's engine?

…with your planet?

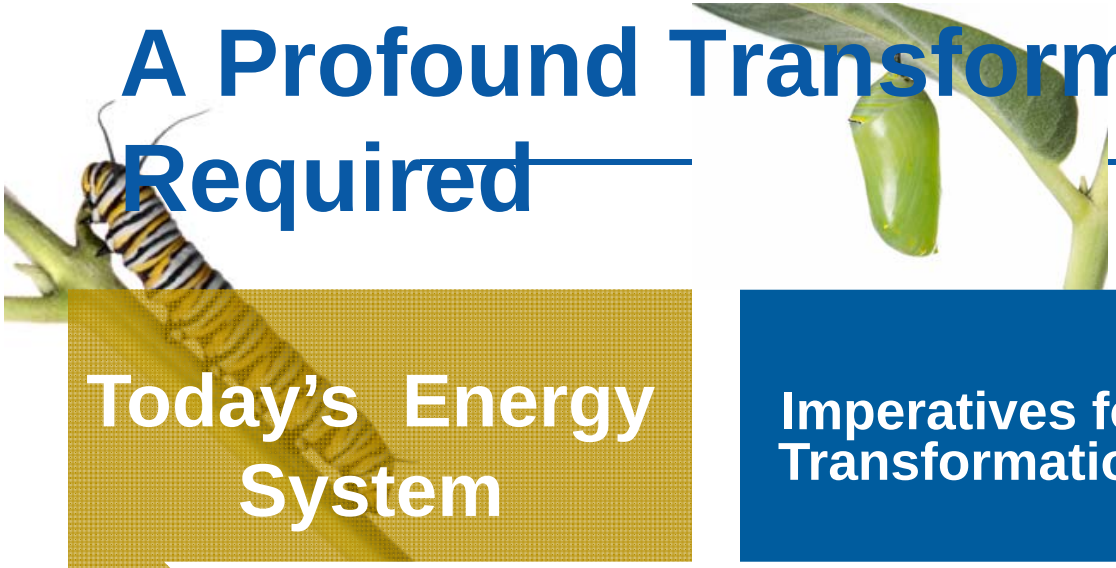
Business As Usual

- **Expensive, and getting more so**
  - **Rising fuel and commodity costs, possible carbon penalties**
- **Environmental issues**
- **Impacts on human health**

Yet our energy appetite is increasing.

- **Commercial sector lag in adopting energy efficiency (principal-agent dilemma)**
- **New homes larger than old ones**
- **Urban sprawl: impact on transportation fuel use and associated emissions**
- **General growth (economic, population)**

A Profound Transformation is Required



Today's Energy System

- Dependent on foreign sources
- Subject to price volatility
- Increasingly unreliable
- 2/3 of source energy is lost
- Produces 25% of the world's carbon emissions

Imperatives for Transformation

DEFINE THE END STATES

REDUCE NEW TECHNOLOGY RISK

ACCELERATE ADOPTION

Sustainable Energy System

- Carbon neutral
- Efficient
- Diverse supply options
- Minimal impact on resources
- Creates sustainable jobs
- Accessible, affordable and secure

"We cannot know with absolute certainty, so we do nothing… The essential human dilemma is that all our experience is in the past and yet ***all our decisions relate to the future***."

Richard D. Lamm, in Elliott, Ethics for a Finite World

Technology-Based Solutions:

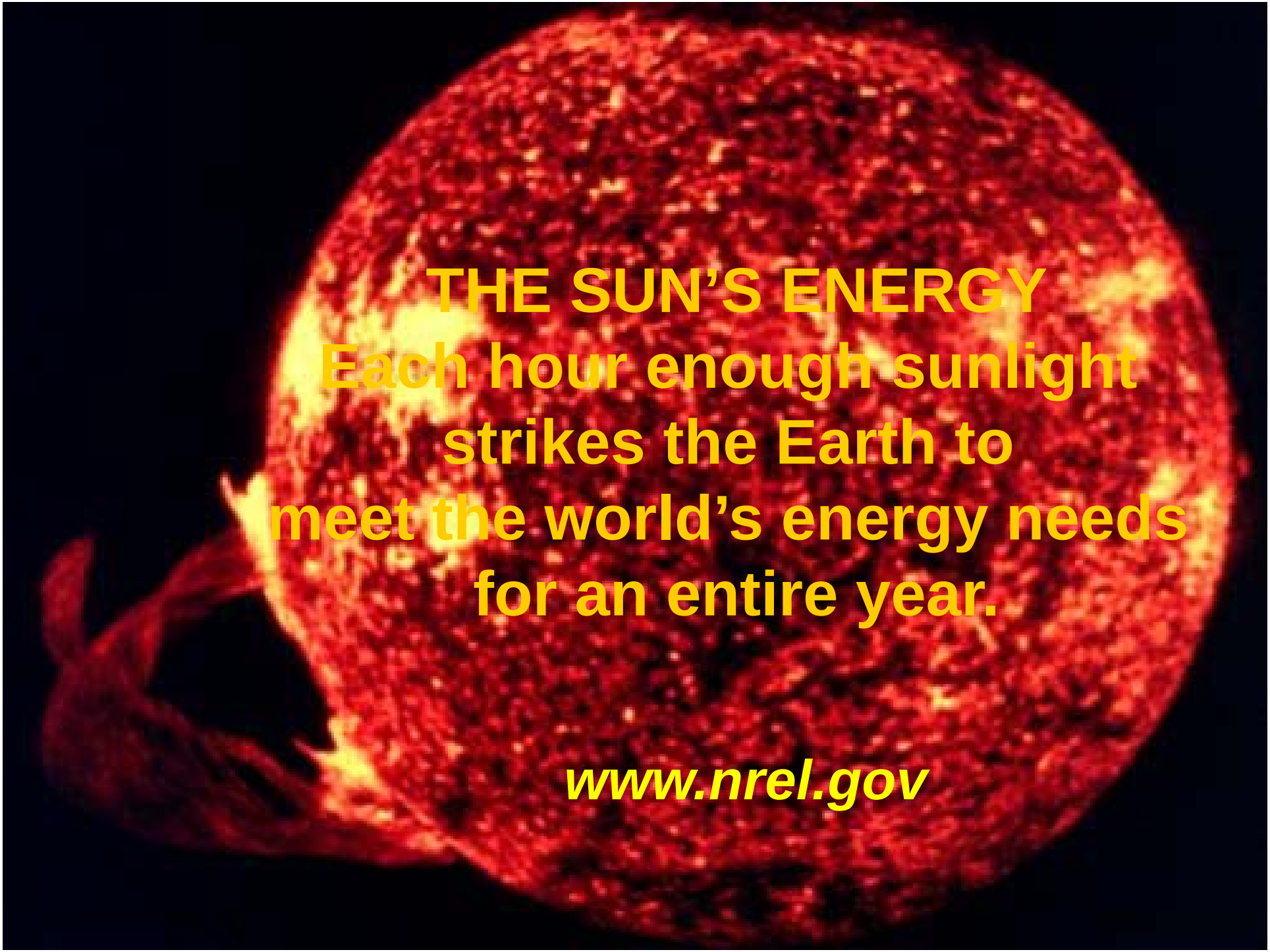
There is no single or simple answer.

Energy efficiency

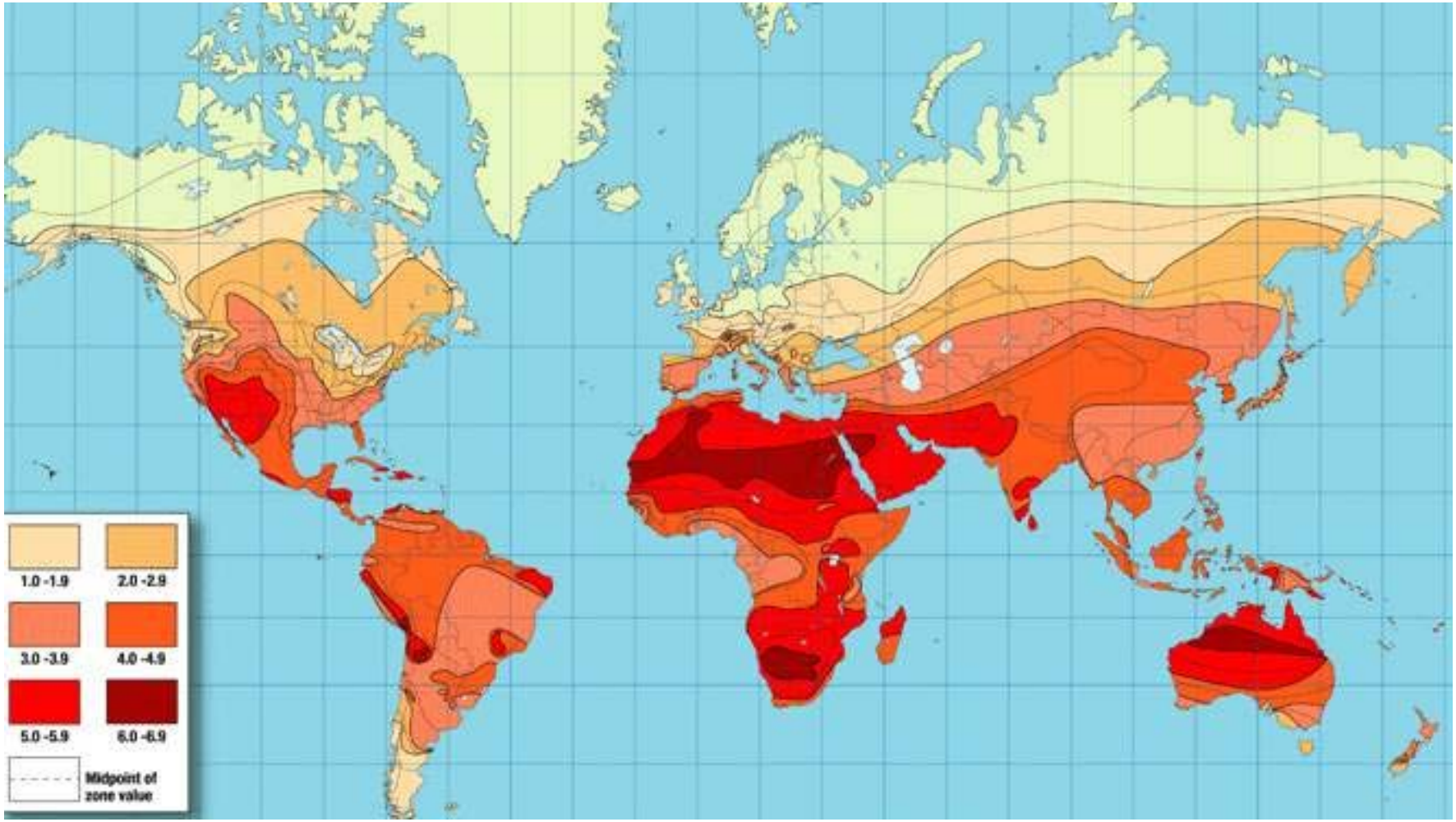
Renewable energy

Nonpolluting transportation fuels

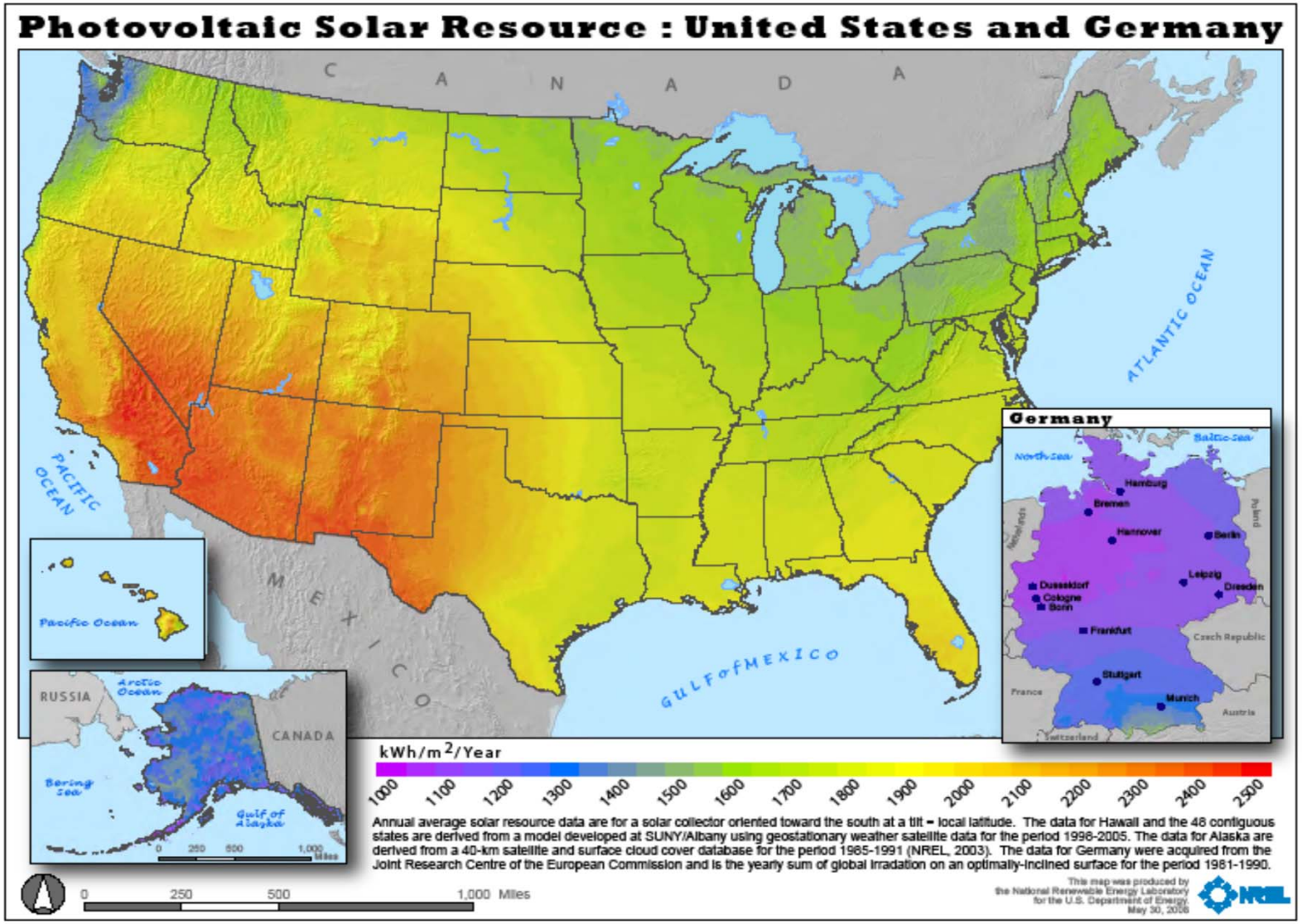
Transition to smart, resilient, distributed energy systems


THE SUN'S ENERGY
Each hour enough sunlight
strikes the Earth to
meet the world's energy needs
for an entire year.
www.nrel.gov

Robust Global Solar Resource

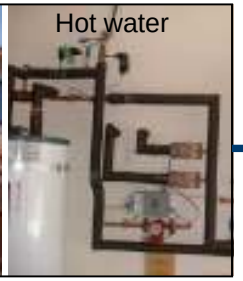


Source: http://howto.altenergystore.com/Reference-Materials/Solar-Insolation-Map-World/a43/


Photovoltaic Solar Resource : United States and Germany
CANADA
ATLANTIC OCEAN
PACIFIC OCEAN
MEXICO
GULF of MEXICO
Pacific Ocean
RUSSIA
Arctic Ocean
CANADA
Bering Sea
Gulf of Alaska
0 250 500 1,000 Miles
Germany
Baltic Sea
North Sea
Hamburg
Bremen
Hannover
Berlin
Leipzig
Dresden
Duesseldorf
Cologne
Bonn
Frankfurt
Stuttgart
Munich
Czech Republic
France
Austria
Switzerland
kWh/m2/Year
1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500
Annual average solar resource data are for a solar collector oriented toward the south at a tilt = local latitude. The data for Hawaii and the 48 contiguous states are derived from a model developed at SUNY/Albany using geostationary weather satellite data for the period 1998-2005. The data for Alaska are derived from a 40-km satellite and surface cloud cover database for the period 1985-1991 (NREL, 2003). The data for Germany were acquired from the Joint Research Centre of the European Commission and is the yearly sum of global irradiation on an optimally-inclined surface for the period 1981-1990.
0 250 500 1,000 Miles
This map was produced by the National Renewable Energy Laboratory for the U.S. Department of Energy. May 30, 2008
NREL

Applications of Solar Heat and Electricity

Solar Thermal



Photovoltaics (PV)

Concentrating Solar Power (CSP)

Distributed Generation, on-site or near point of use

Centralized Generation, large users or utilities

- Transportation
- Residential & Commercial Buildings
- Industrial

Challenges in Realizing Solar Electricity

Photovoltaics

Interconnection

- Predictable and reasonable regulations governing interconnection of PV systems are required to assure timely and cost-effective development of PV projects.

Net Metering

- Net metering allows generators interconnected to a utility grid to be compensated for the electricity their PV system produces when it is not used on-site at the time of generation. These provisions are inconsistent across States, and often do not reflect fair market value.

Grid Integration Codes and Standards

- As PV market penetration increases, new codes/standards are needed to maintain grid reliability and economics:
  - Advanced Metering Infrastructure
  - Real-Time Pricing Signals
  - Communications Protocols for DG-Grid Interaction

Concentrating Solar Power

Land Access

- Efficient and predictable permitting processes for use of Federal lands in CSP project development are needed – the current regime is causing protracted timelines and increasing development costs.

Transmission Access

- Development of CSP projects requires construction of new transmission "spurs" and corridors – the current regime does not allow for efficient cost allocation or rapid permitting for new lines.

State CO_2 & RPS Regulations

- Uncertainty about compliance costs for RPS requirements and CO_2 prices introduces complications into power purchase agreement negotiations for CSP project development.

Lack of Long-term Policies and Market Predictability

- PV manufacturers site capacity close to markets, and are reluctant to make major capacity investments in the U.S. while long-term incentive environment is uncertain, inhibiting scale-up and cost reduction.
- Downstream PV companies are even more reluctant to invest in distribution /installation capacity while long-term incentive structures are uncertain.
- Financing for CSP project development can be secured only on the basis of a negotiated off-take contract (PPA) with a utility – uncertainty in long-term incentive environment complicates transactions.

Energy Efficiency

"Every watt not used is a watt that doesn't have to be produced, processed, or stored."

Richard Perez, Homepower Magazine

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Energy is "produced" on the demand side.

Properly designed and oriented buildings use *60%* *less* energy than conventional structures.

Only 10% of energy input to conventional light bulbs produces light; *90%* *is thrown off* as heat – which often must be cooled, requiring more electricity.

U.S. utility system wastes enough energy each year to meet the power needs of Japan.

Energy Efficiency:
The Cheapest Option

- Costs < 2 cents/kWh
  - *Compared to ~ 9.5 cents+/kWh*
- Permits equipment downsizing
  - *Save $$$ on purchase price*
  - *Save $$$ on energy operating costs*

The "Power" of Buildings

They consume 72% of the nation's electricity and 55% of our natural gas!

***New Buildings*:**

50-year legacy

What Makes a Building Energy Efficient?

- **Proper orientation and design of structure**
- **Proper design and installation of HVAC**
- **Proper installation of insulation**
- **Reduced air leakage**
- **Water conservation**
- **Efficient windows**
- **Efficient lighting**
- **Efficient appliances, equipment**

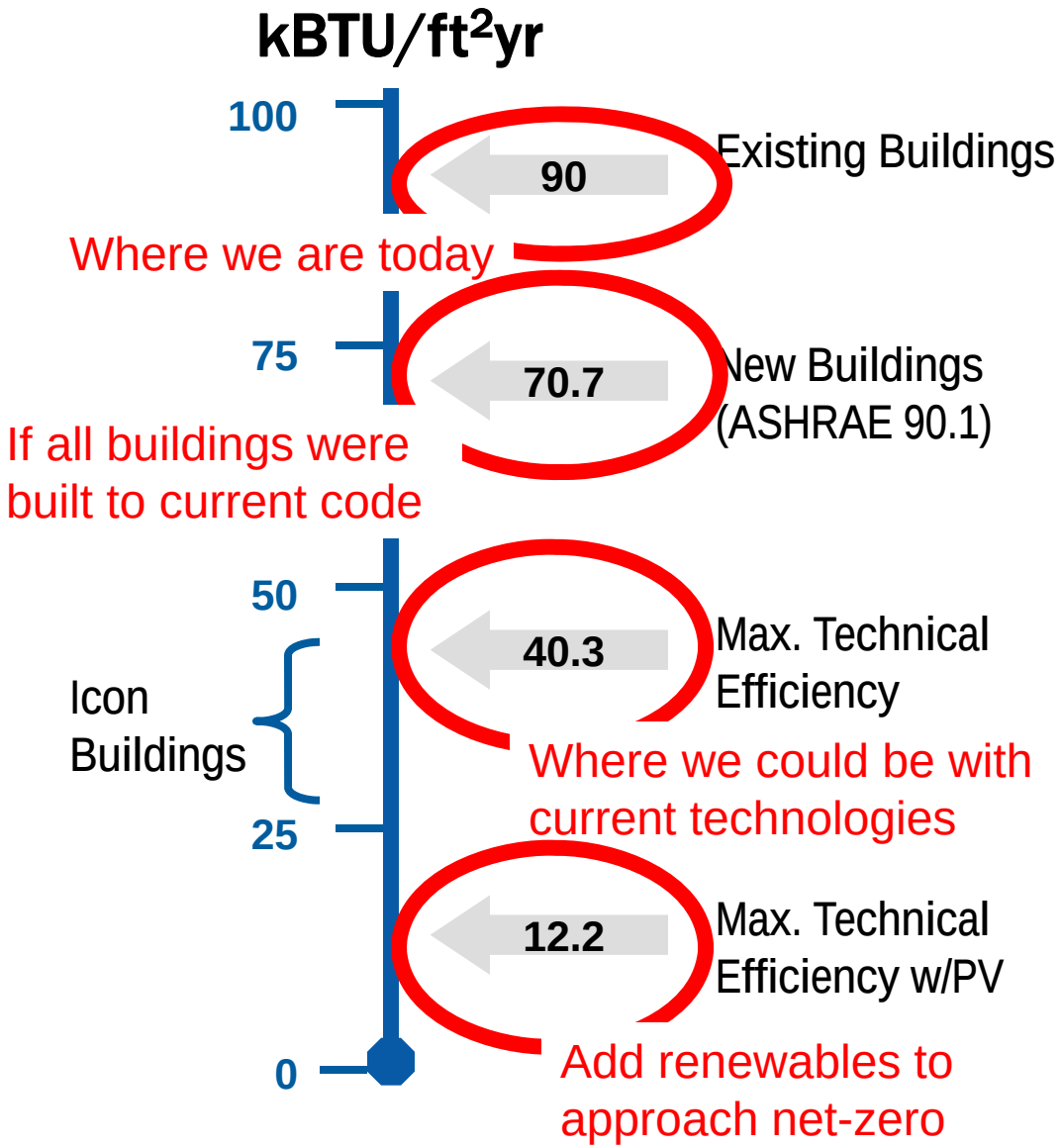
Comments from an NREL researcher…

"Today's building designs mortgage the energy future of this country."

– *New buildings: a 50-year legacy.*

"Code compliant 'energy efficient' buildings are the worst buildings you can 'legally' build."

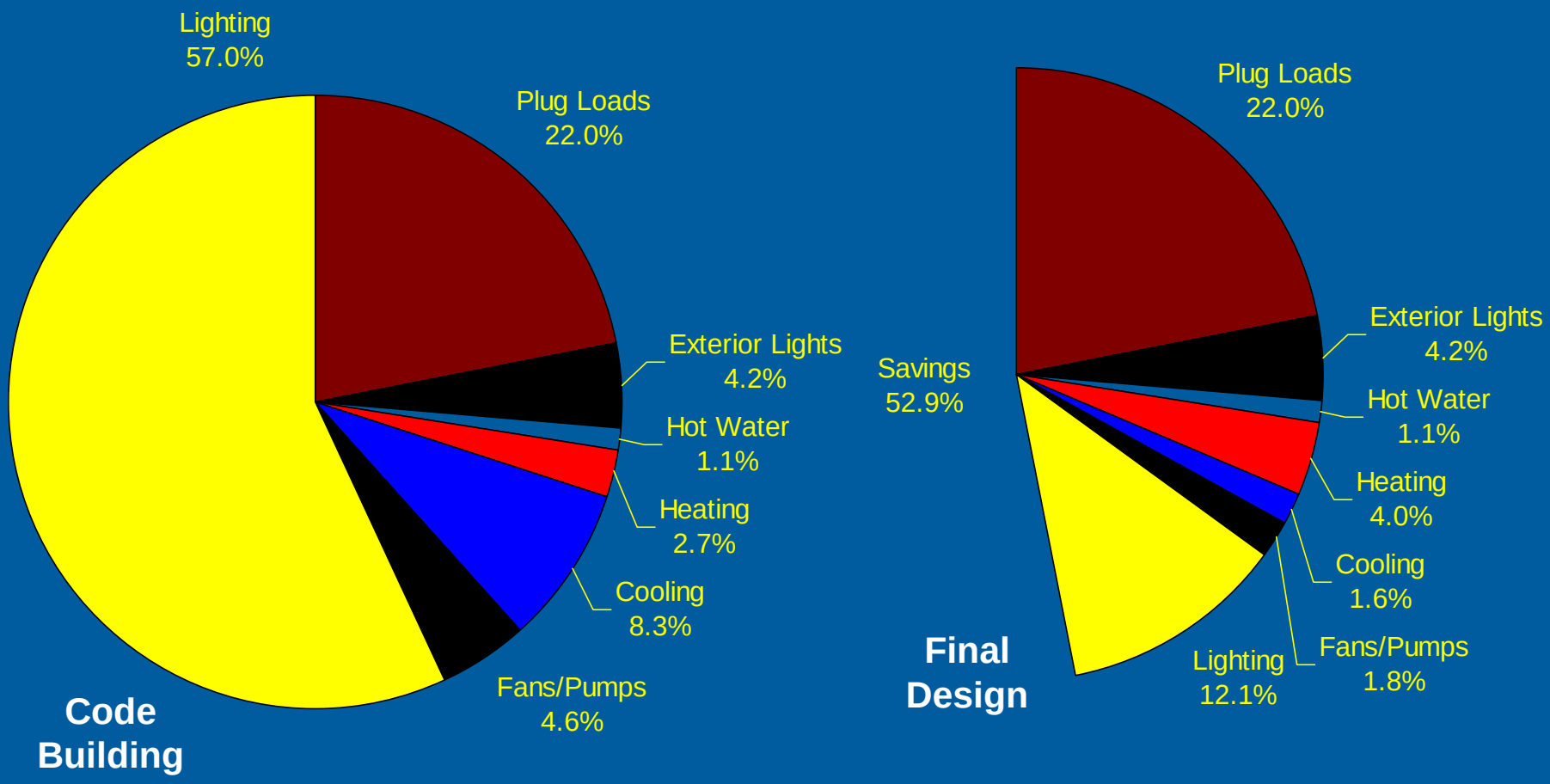
Commercial Building Opportunities



Technology Directions

- Standards
- Net-Zero Energy Buildings
- Solid-State Lighting
- Smart-Control Systems
- Combined Heating and Cooling
  - ➢ Thermally-activated systems
  - ➢ Waste heat use

Loads Example



72% savings excluding plug loads and exterior lights

Net- or Near-Zero Energy Buildings

…generate as much, or almost as much, energy as they consume on an annual basis. ZEBs can be totally self-sustaining (grid-independent) or, if grid-connected, net electricity exporters.

Net Zero Energy Habitat for Humanity Home

- ***Superinsulated walls, floors and ceilings***
- ***Efficient appliances***
- ***Solar water heating system***
- ***Compact fluorescent lighting***
- ***Windows coated with thin layers of metallic oxide to help keep heat in during the winter and out during the summer.***
- ***4-kilowatt photovoltaic system***

Reducing Demand Through Energy Efficiency, Generating Electricity with the Sun…

Shea Homes, San Diego CA

Plug-In Hybrid Electric Vehicles (PHEV)

Status:

- PHEV-only conversion vehicles available
- OEMS building prototypes
- NREL PHEV Test Bed

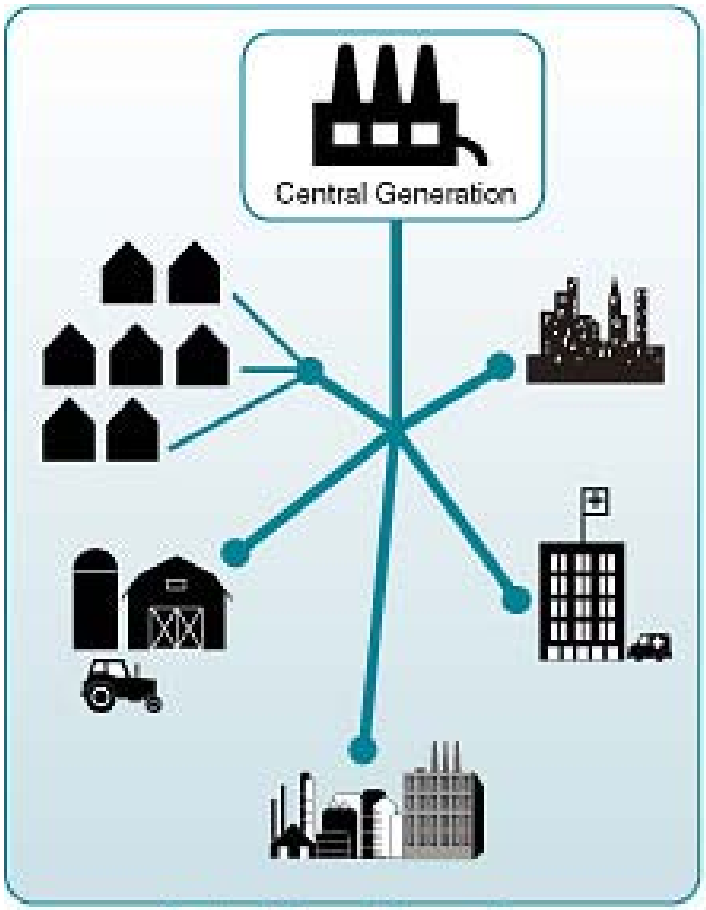
NREL Research Thrusts

- Energy storage
- Advanced power electronics
- Vehicle ancillary loads reduction
- Vehicle thermal management
- Utility interconnection
- Vehicle-to-grid

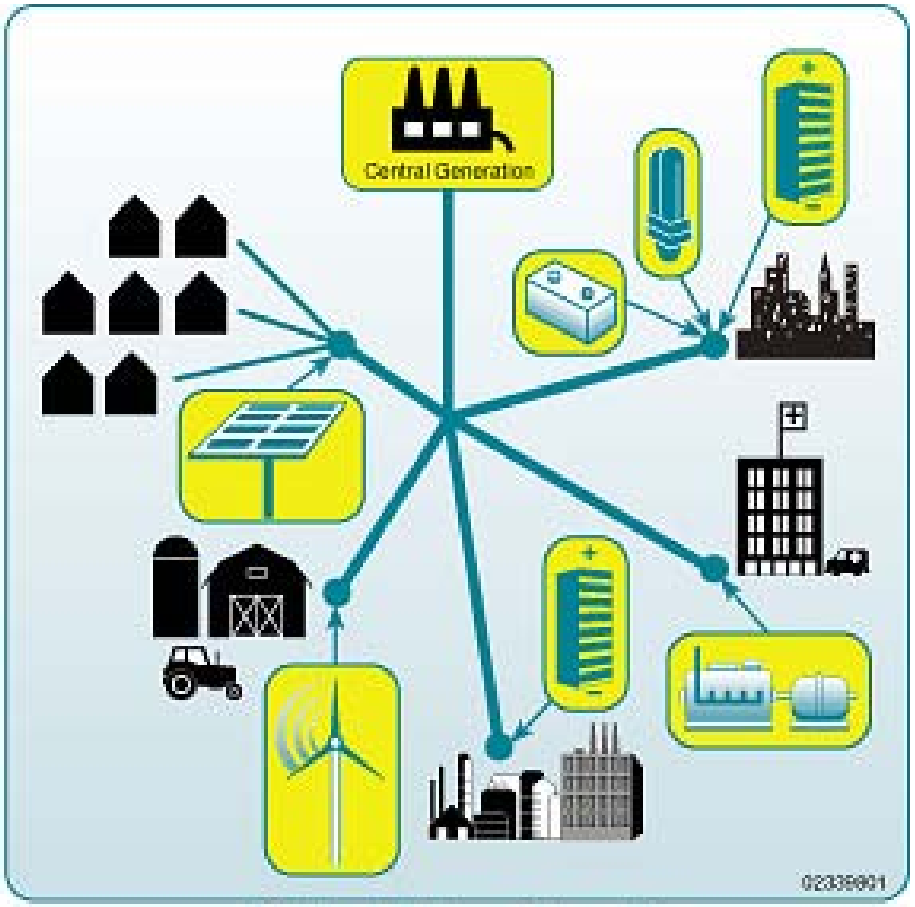
Key Challenges

- Energy storage – life and cost
- Utility impacts
- Vehicle cost
- Recharging locations
- Tailpipe emissions/cold starts
- Cabin heating/cooling
- ~33% put cars in garage

Distributed Energy



Central Power Generation



Distributed Power Generation

21st Century Utility

Premise #1: **Buildings last for ~50 years and constitute a lasting legacy.**

How will utilities supply electricity to them? Will it be the 20th century way, bringing electrons in by wire? Or will the buildings help supply their own needs?

Premise #2**: Customers do not purchase electrons or therms; they buy heat, cooling, lighting, etc. – *i.e.*, energy/power services.**

How will utilities meet the need for services?

"Conservation Power Plant"

Programs, policies replaced bricks, boilers.

- **Loan programs for residential efficiency improvements, building code upgrades, rebates for high-efficiency equipment, etc.**

***Bottom Line*: 550 megawatts of documented, sustained energy savings**

***2nd Bottom Line*: Removed 450-MW coal-fired plant from planning books.**

… During a decade in which Austin's economy grew by 46 percent and its population doubled!

Infrastructure and Industrial Capacity: Opportunities for Growth

- ***TRANSMISSION!***
- **Energy storage for intermittent resources**
- **Trained work force**
- **Mass manufacturing capacity**

Making Transformational Change

Requires an integrated approach

Unleashing market-driven innovation

FILL technology pipeline

INFORM decision makers about choices

ENSURE appropriate market price signals

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