Our Energy Policy –
A time for change and the importance of leadership

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Energy connects to three key issues:

1. Our economic well being and quality of life

2. Our national and international security

3. The environment at multiple scales – from local to global

Even if you don't believe our fossil fuel use is driving climate change, there are many indicators suggesting we need to transition from the age of hydrocarbons to a new more sustainable energy destination.

but

Energy is receiving too little attention given:

1. Importance of the services it provides
2. National security implications that surround supplying energy when and where it is needed
3. Need to provide the $ and human capital for implementing such a transition

In search of a new energy destination

“Making predictions is always difficult, particularly if it is about the future.“

“If you don’t know where you are going any road will do“

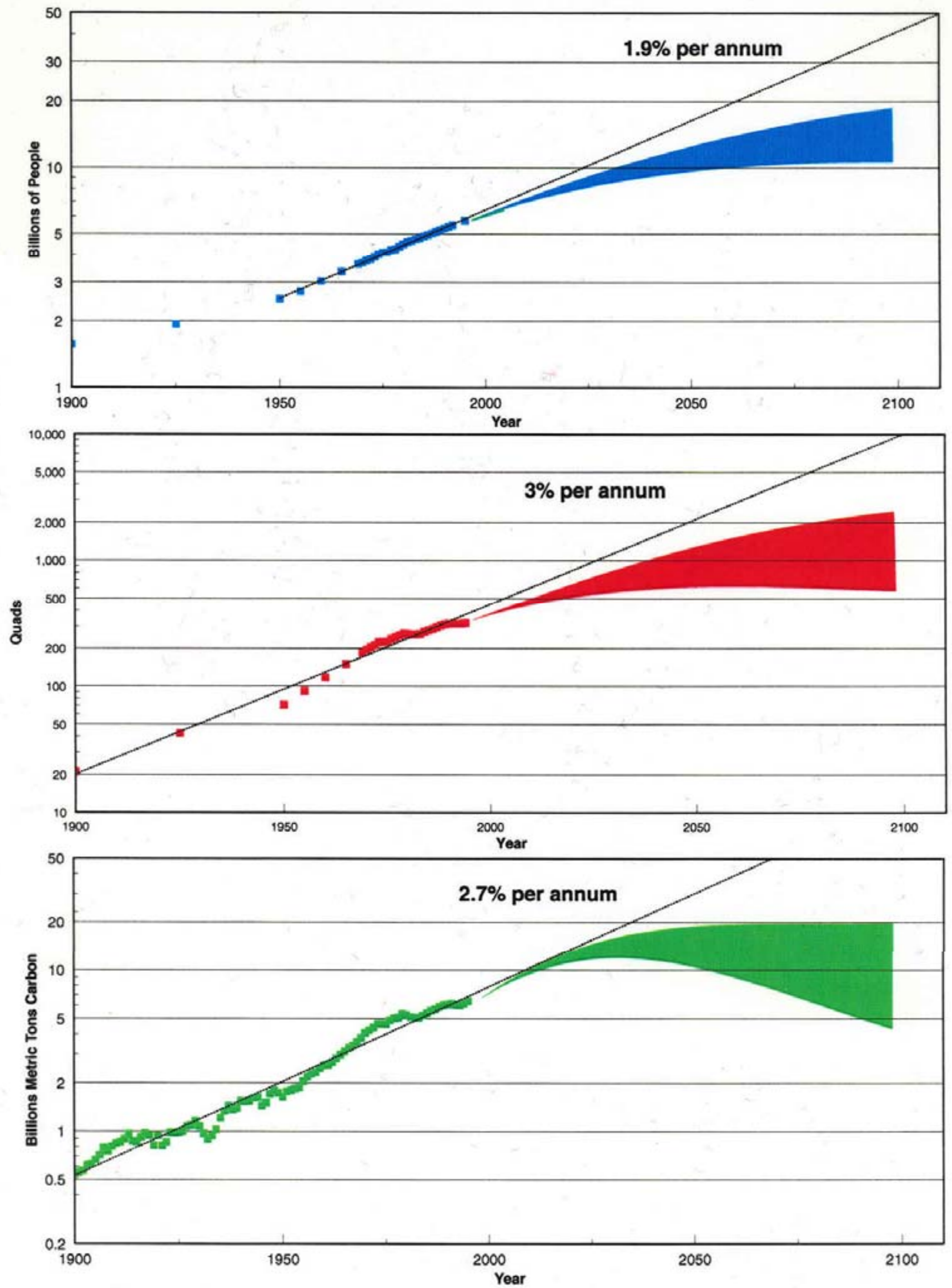
“The only people that accept change are toll collectors“

Sources: Niels Bohr, Yogi Berra, Morris Cohen et al.

Troubling Energy-Related Megatrends

- ❑ Increases in world population continue to increase energy demand
- ❑ Energy efficiency standards continue to be too low
- ❑ Environmental and health concerns are increasing on all scales from local to global
- ❑ Increased consumption of our natural resources – land, air, water, and minerals
- ❑ Increased consumption of all maldistributed fossil fuels – particularly gas and oil
- ❑ Energy security concerns increase due to potential supply interruptions and infrastructure vulnerabilities

Worldwide Population, Energy Use, and Carbon Emission



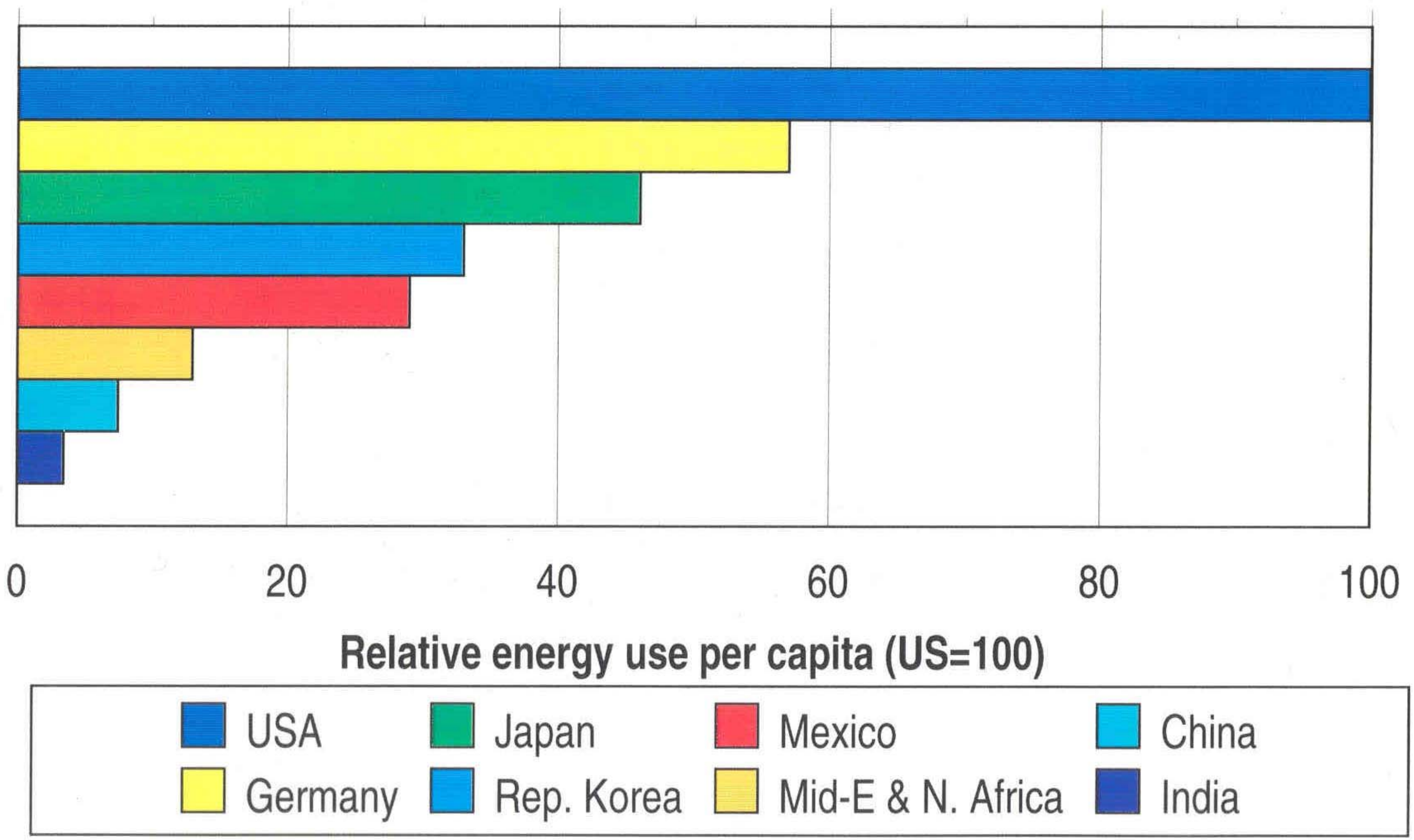
What is the Earth's carrying capacity for humans?

Can we achieve a sustainable, asymptotic World?

What are the limits of humans to adapt?

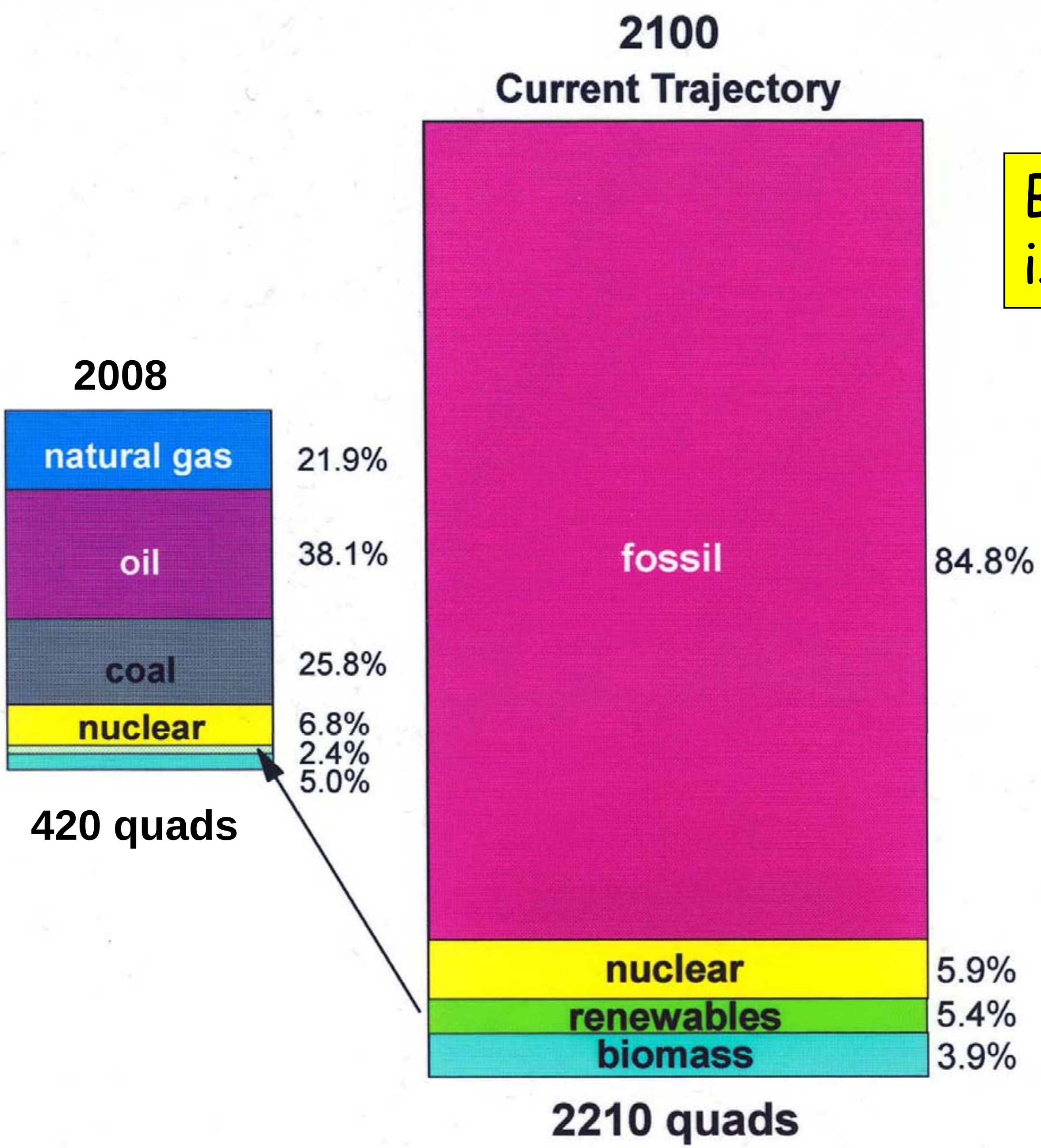
What is the evolving role of technology in achieving a sustainable future?

Relative Commercial Energy Use Per Capita



MIT Energy Laboratory

Evolving Portfolio of Energy Supplies



Business as Usual is not sustainable!

Progressing toward an asymptotic world ?

- Population - 6+ billion growing to 10 to 15+ billion
- Total primary energy –
  - 400 quads growing to 2000+ quads annually
  - 73 billion growing to 365+ billion bbl of oil/yr
  - 13 TW growing to 65+ TW
- Per capita energy per year –
  - 10 BOE/yr-person growing to 25 BOE/yr-person
- Number of cars and trucks -
  - 750 million now growing to 5 + billion
- MW electric generating capacity -
  - 3.5 million MWe now growing to 15+ million MWe

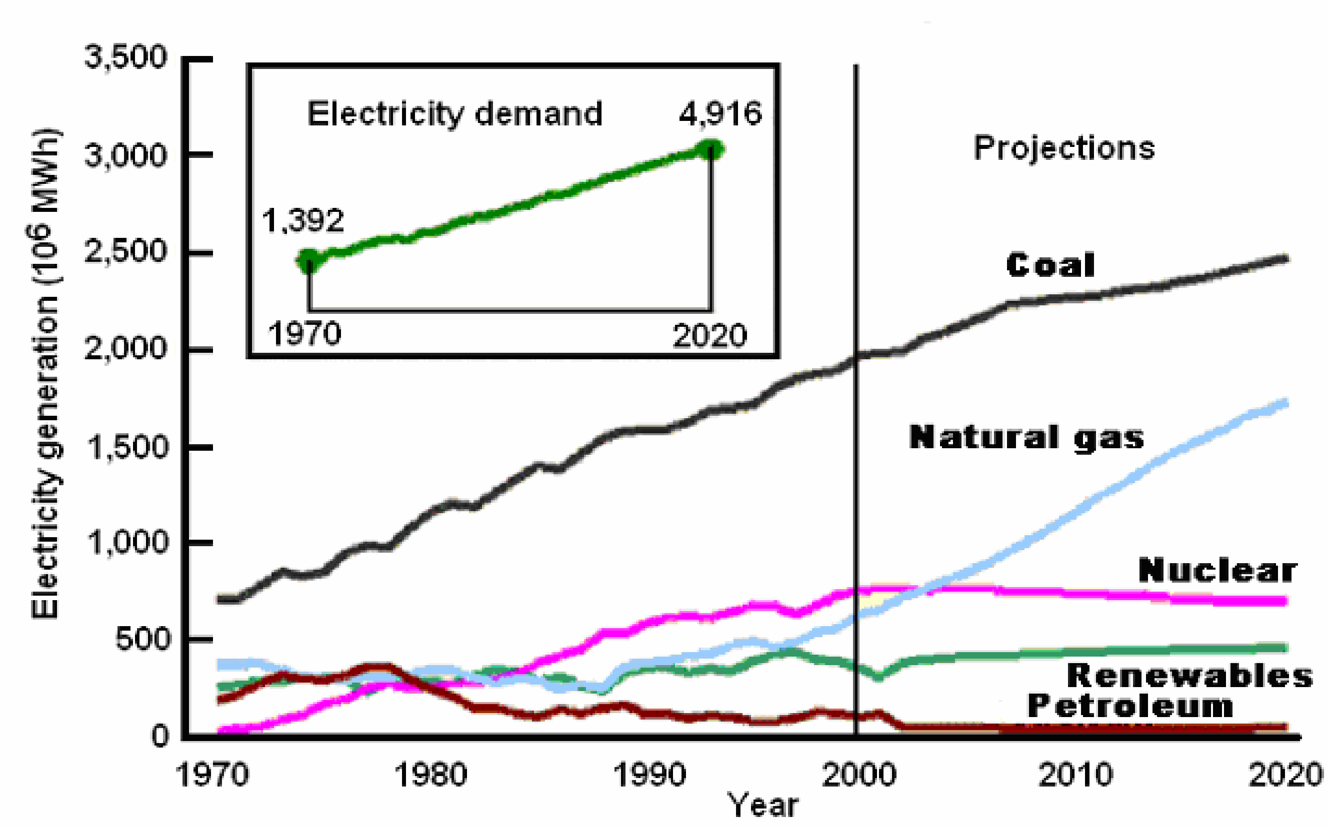
1 quad = 10^{+15} BTU ≅ 10^{+18} J = 1 EJ
1 TW = 10^{+12} W or J/s

What about the United States ?

- Population -300 million growing to 500 million ??
- Total primary energy –
  100 quads growing to ???
- Per capita energy per year –
  70 BOE/yr-person growing to ????
- Number of cars and trucks -
  250 million growing to ???
- MW electric generating capacity -
  1 million MWe = 1 TWe growing to ???

1 quad = 10^{+15} BTU ≅ 10^{+18} J = 1 EJ
1 TW = 10^{+12} W or J/s

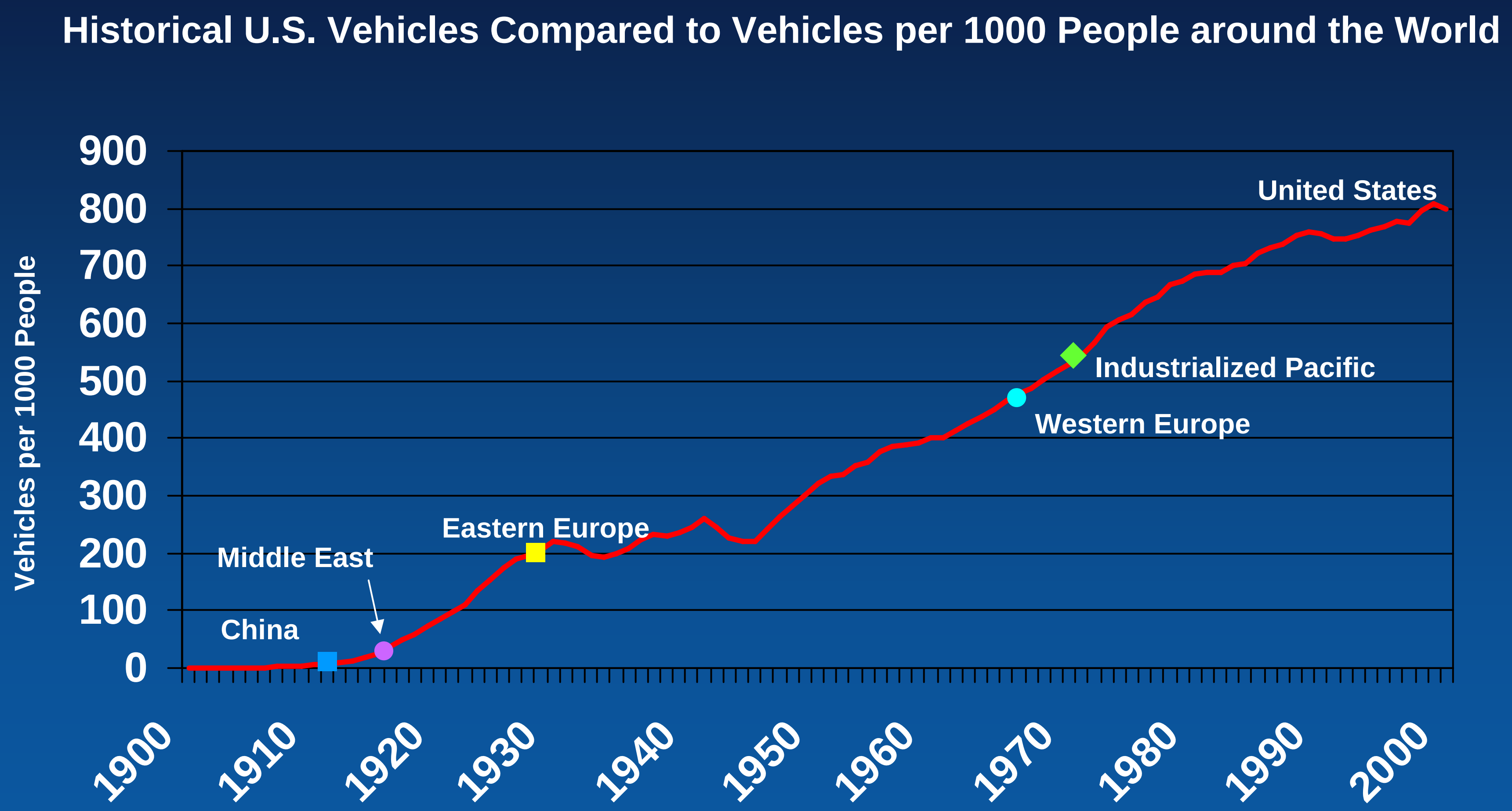
Projected growth in US electricity demand and supply



US electricity generation by energy source 1970-2020 in millions of MWe-hr.
Source: EIA (2005)

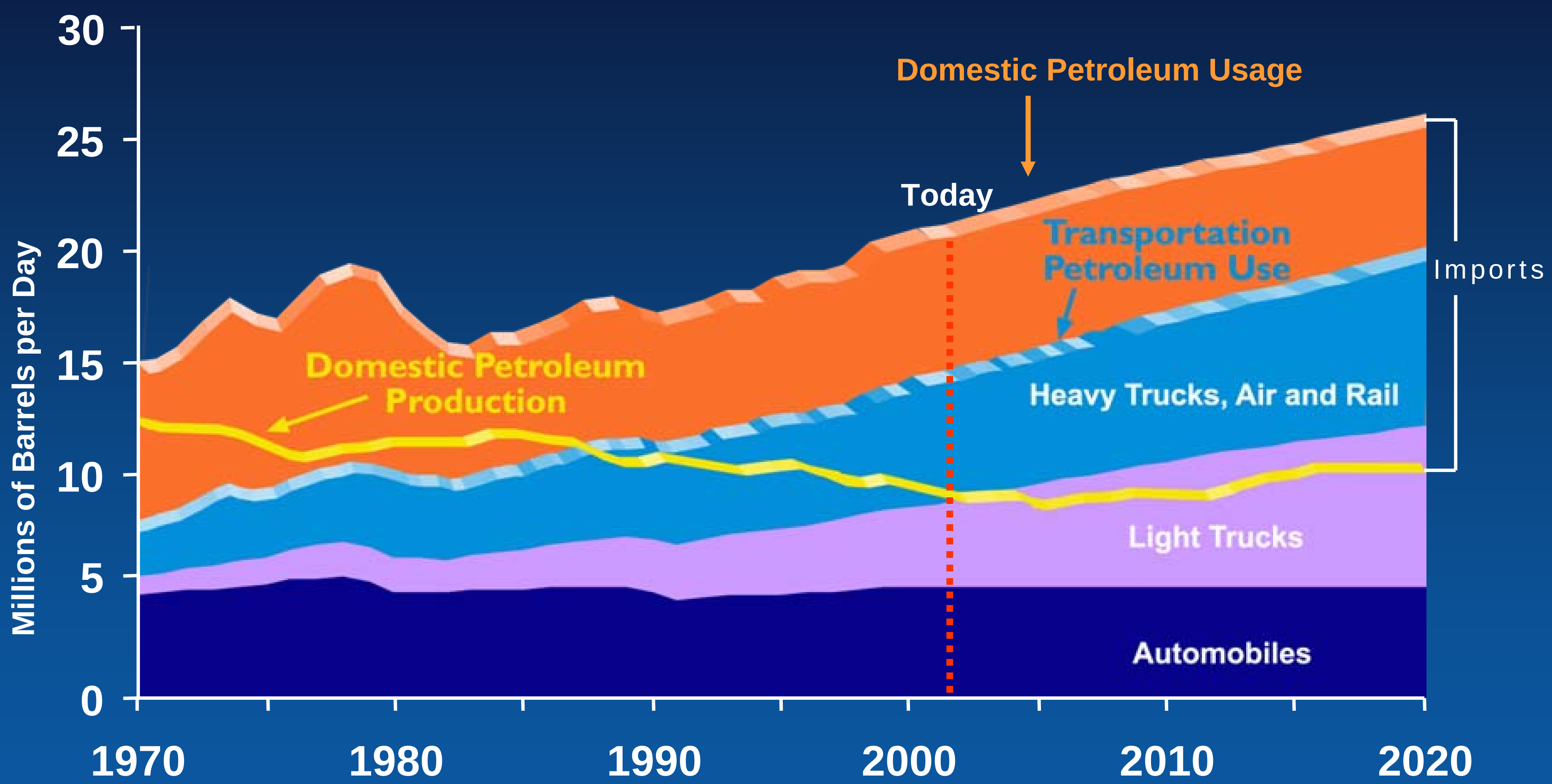
Current US generating capacity is now about 1,000,000 MWe or 1 TWe

Vehicles per Thousand People: U.S. Compared to Other Countries



Sources:
U.S. data
Vehicles: U.S. Department of Transportation, Federal Highway Administration, *Highway Statistics 2000*, Table VM-1, and earlier annual editions.
Population: U.S. Department of Commerce, Bureau of the Census Time Series of National Population Estimates: April 1, 2000 to July 1, 2001
Other countries/regions
Energy Information Administration, *International Energy Outlook 2002*, DOE/EIA-0484(2002), p. 256.

U.S. Use of Petroleum



Actual: Annual Energy Review 2000 Tbls 1.2, 5.1 and 5.12
Forecast: Annual Energy Outlook 2002 Tbls 7 and 11
Split between Autos and Lt Truck: Transportation Energy Data Book Edition 21 Tbl 2.6
Updated October 2002

U.S. Dependence on Conventional Foreign Oil

Have Oil		Use Oil	
Saudi Arabia	24%	U.S.	25%
Iran	12%	China	8%
Iraq	10%	Japan	6%
Kuwait	9%	Russia	3%
UAE	9%	Germany	3%
Venezuela	7%	India	3%
Russia	5%	Canada	3%
Libya	3%	S. Korea	3%
Nigeria	3%	Brazil	3%
U.S.	2%	Mexico	3%
China	2%	France	2%
Qatar	1%	U.K.	2%

The U.S. uses more than the next 5 highest consuming nations combined.

Updated June 2007. Source: Annual Energy Review 2007 (EIA), Tables 11.4 and 11.10.

Key motivations for finding sustainable long term options for supplying US electricity and transport fuels

1. **The US electricity supply system is threatened** with demand for electricity outstripping supplies in the next 15 to 25 years
   - In the next 15 to 20 years 40 GWe of "old" coal-fired capacity will need to be retired or updated because of a failure to meet emissions standards
   - In the next 25 years, over 40 GWe of existing nuclear capacity will be beyond even generous re-licensing procedures
2. **Projected availability limitations and increasing prices for natural gas** are not favorable for large increases in electric generation capacity for the foreseeable future
3. **Public resistance to expanding nuclear power** is not likely to change in the foreseeable future due to concerns about waste and proliferation. Other environmental concerns will limit hydropower growth as well
4. **High costs of new clean coal plants** as they have to meet tightening emission standards and may have to deal with carbon sequestration.
5. **Imported oil demand will likely increase in the US** and most of it will come from countries that don't like us.

U.S. energy goals are not currently focused on carbon management!

- Increase homeland security – requires increased energy infrastructure security
- Reduce dependence on imported oil
- Increase energy system performance
  - more efficient per unit of output
  - more robust -- flexible, reliable and durable
  - more distributed
  - lower environmental impacts -- cleaner
  - lower cost.

Achieving sustainability – requires connecting values to prices and costs

1. How much is avoiding a ton of carbon worth?
2. How much is energy independence worth?
3. What is the value of a natural resource such as an acre of land, a river, etc.
4. How much is energy security worth?
5. Are clean energy and high efficiency valued properly?

If “it’s all about money”, fossil energy is still a “bargain” given the services it provides

If "it's all about money", fossil energy is still a "bargain" given the services it provides

Oil -- $ 90/bbl = $16 / million Btu

Natural gas -- $10 / 1000 scf = $ 10 /million Btu

Coal -- $ 30/ton = $ 1.6 / million Btu

But, the impacts of rapidly rising or unstable energy prices and supplies can be very significant and damaging

Exploring options for a Sustainable Energy System

Desirable attributes of a sustainable energy technology

- **Non-depletable**
- **Low impacts on natural resources --** land, water, etc., across process life cycle
- **Accessible and well distributed** – available close to demand
- **Emissions free** – no NO_x, SO_x, CO_2, particulates, etc.
- **Scalable and efficient** – from 1 kW to 1000 MW (t or e)
- **Dispatchable** - for base load, peaking, and distributed needs
- **Robust** - simple, reliable, durable and safe to operate
- **Flexible** - applications for electricity, heat, and co-gen
- **Economically competitive**

Green is becoming a favorite color

- green power
- green chemistry
- green buildings
- green schools
- green electrons

New performance paradigms are emerging

- zero emissions power plant
- zero emissions chemical plant
- zero (net) energy building
- zero emissions vehicle (ZEV)

Practical implementation of new performance standards requires full life cycle accounting (LCA)

But we must play by the rules

- The 1st and 2nd Laws of thermodynamics are relevant
- Heat and electric power are not the same
- Conversion efficiency does not have a single definition
- All parts of the system must work – fuel supply, fuel and energy converters, control and monitoring sub systems, and the interconnection if required

Fossil and Nuclear Options

- **Fossil** – both conventional and unconventional oil and gas resources are depletable and maldistributed worldwide; and although coal is more abundant, the adoption of carbon capture and sequestration will be costly and not a permanent solution

- **Fission** **–** no carbon emissions but wastes, proliferation and safety remain as dominant public acceptance issues

- **Fusion** **–** technology not ready with uncertain costs and performance

Where do we go from here ?

Renewable energy technologies have high sustainability index scores

- ❑ **Solar**
- ❑ **Wind**
- ❑ **Biomass**
- ❑ **Hydro**
- ❑ **Geothermal**

But the quality and availability of renewables vary widely and their costs relative to fossil fuels remain high

Suggestions for making a transition to Sustainable Energy

1. Support a balanced portfolio of basic and applied research for both renewable and non-renewable supply and end-use options
2. "Raise the bar much higher" -- mandate high performance, high efficiency standards for buildings, appliances, vehicles, and industrial processes
3. Support a multi-dimensional portfolio approach and stay the course for the long term (10 to 50 yr)
4. Support quantitative resource assessment on a national level
5. Provide integrated full life cycle assessment of all options

Suggestions for making a transition to Sustainable Energy

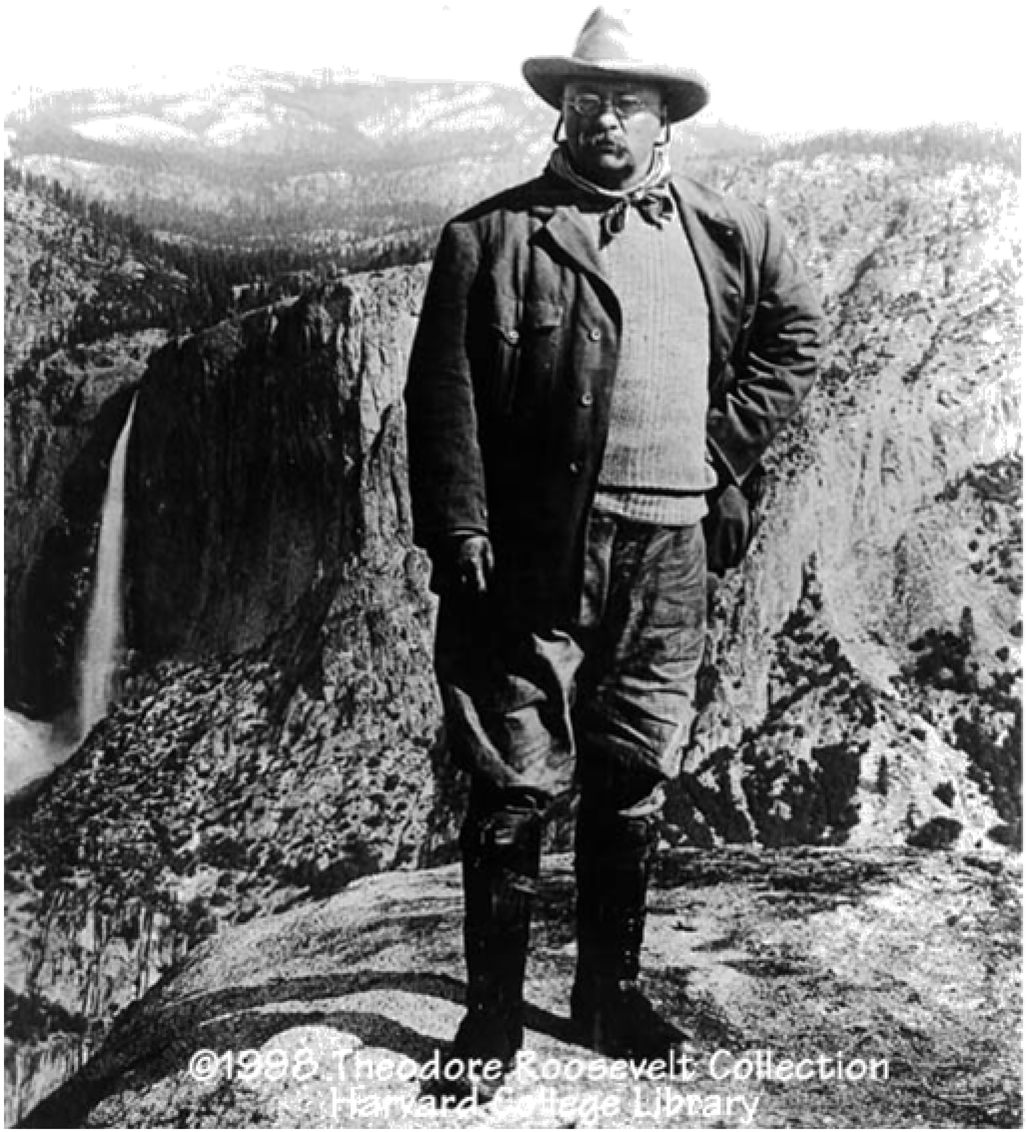
6. Address critical energy infrastructure and balance of systems issues, including storage, interconnection and transmission and distribution
7. Seek collateral, win-win opportunities
8. Support important national R&D assets --
9. Develop human capital, eg. initiate a National Energy Security Fellowship program to engage the next generation of scientists, engineers, and policy makers
10. Support sound public policies that drive new energy markets by removing barriers and promoting deployment

7. Seek collateral,win-win opportunities

Increasing the efficiency of providing a specific energy service yields a sustainable pathway for both reducing demand and lowering energy supply and resource needs, for example

1. Combined heat and power to increase resource utilization efficiency
2. Geothermal heat pumps to increase HVAC efficiency 3 to 4 fold
3. Integrated high efficiency building designs
4. Hybrid energy use with distributed generation
5. Hybrid electric vehicles using renewable fuels
6. Manufacturing processes that use less materials and energy

A young Teddy Roosevelt exploring Yellowstone in late 1800s



President Theodore Roosevelt at the dedication of Yellowstone National Park – circa 1903

“Walk softly and carry a big stick” to motivate and achieve change