Energy Policy for the Next Administration

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Central New York Council for the Social Studies
October 20, 2008

Two main goals for energy policy

1. Reduce emissions of greenhouse gases
   ⇨ *Especially carbon dioxide from fossil fuel combustion*

2. Reduce consumption of oil
   ⇨ *Especially imported oil*

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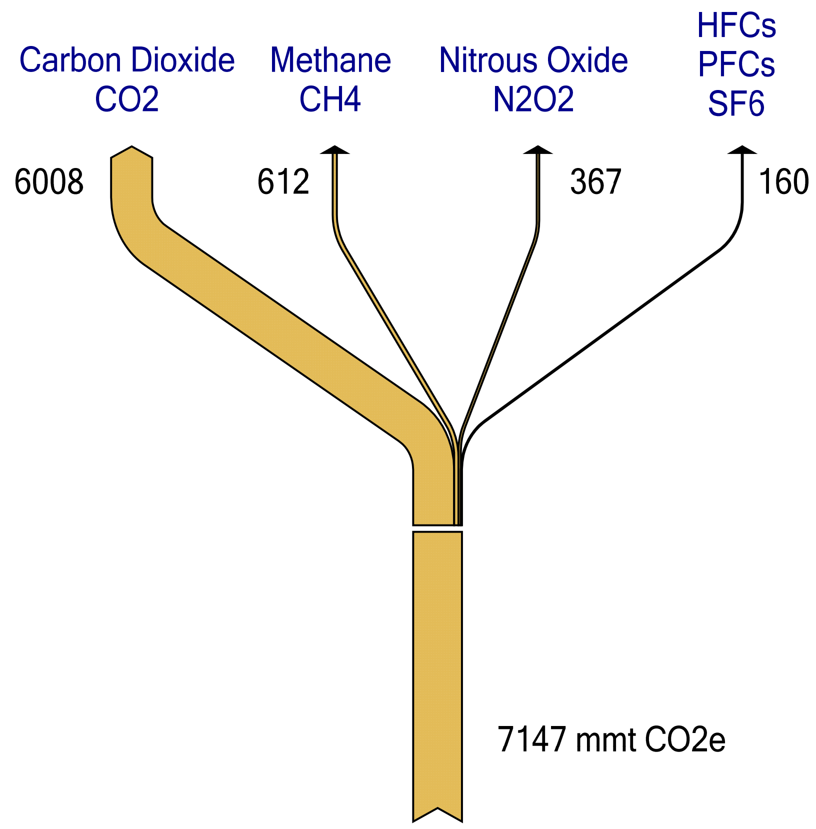
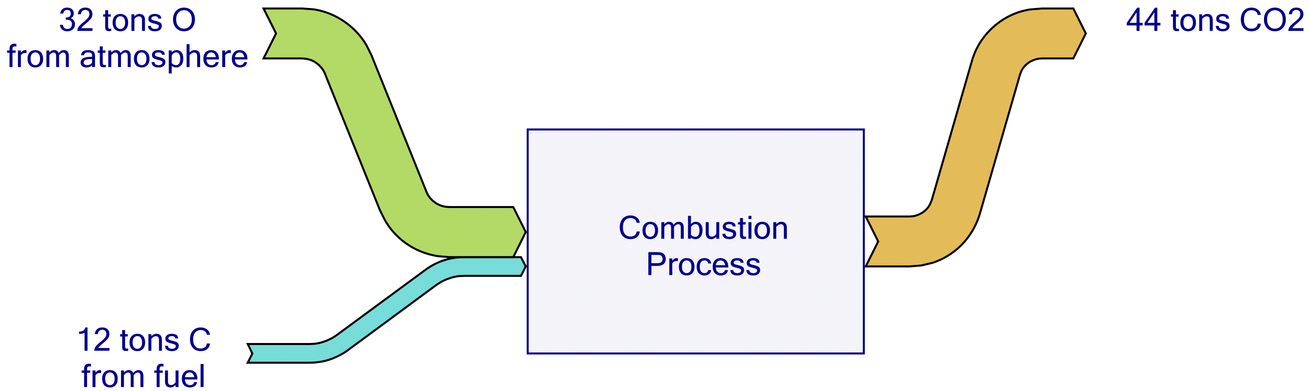
US greenhouse gas emissions in 2005

Gas	Mmt	Mmt CO2e
Carbon Dioxide	6008	6008
Methane	27	612
Nitrous Oxide	1.2	367
Halocarbons	--	160



Where does the CO2 originate?



- Equivalent measures: 12 tons of carbon ⇔ 44 tons of CO_2

How much energy is used?

- Energy units at the national level
  - ⇨ *Measured in "quads"*
  - ⇨ *1 quad is 1 quadrillion BTUs (British Thermal Units)*
  - ⇨ *Quadrillion = 10^15*

- World energy consumption
  - ⇨ *400 quads per year*
  - ⇨ *1 quad every 22 hours*

- US consumption
  - ⇨ *100 quads per year*
  - ⇨ *25% of the world total*

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How large is a quad?

- Fuels having 1 quad of energy content:
  - ⇨ *45 million tons of coal*
  - ⇨ *1 trillion cubic feet of natural gas*
  - ⇨ *170 million barrels of crude oil*

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Putting a quad in perspective …

Coal delivered by “unit trains”: 100 cars, about 1 mile long

University of Wyoming, http://smtc.uwyo.edu/coal/trains/unit.asp

How many trains?

- 1 train = 10,000 tons
  - ⇨ *Fuels a 300 MW power plant for about 3 days*

- 1 quad = 4,500 unit trains

- How many tankers?
  - ⇨ *1 tanker = 1 M barrels*
  - ⇨ *1 quad = 170 tankers*

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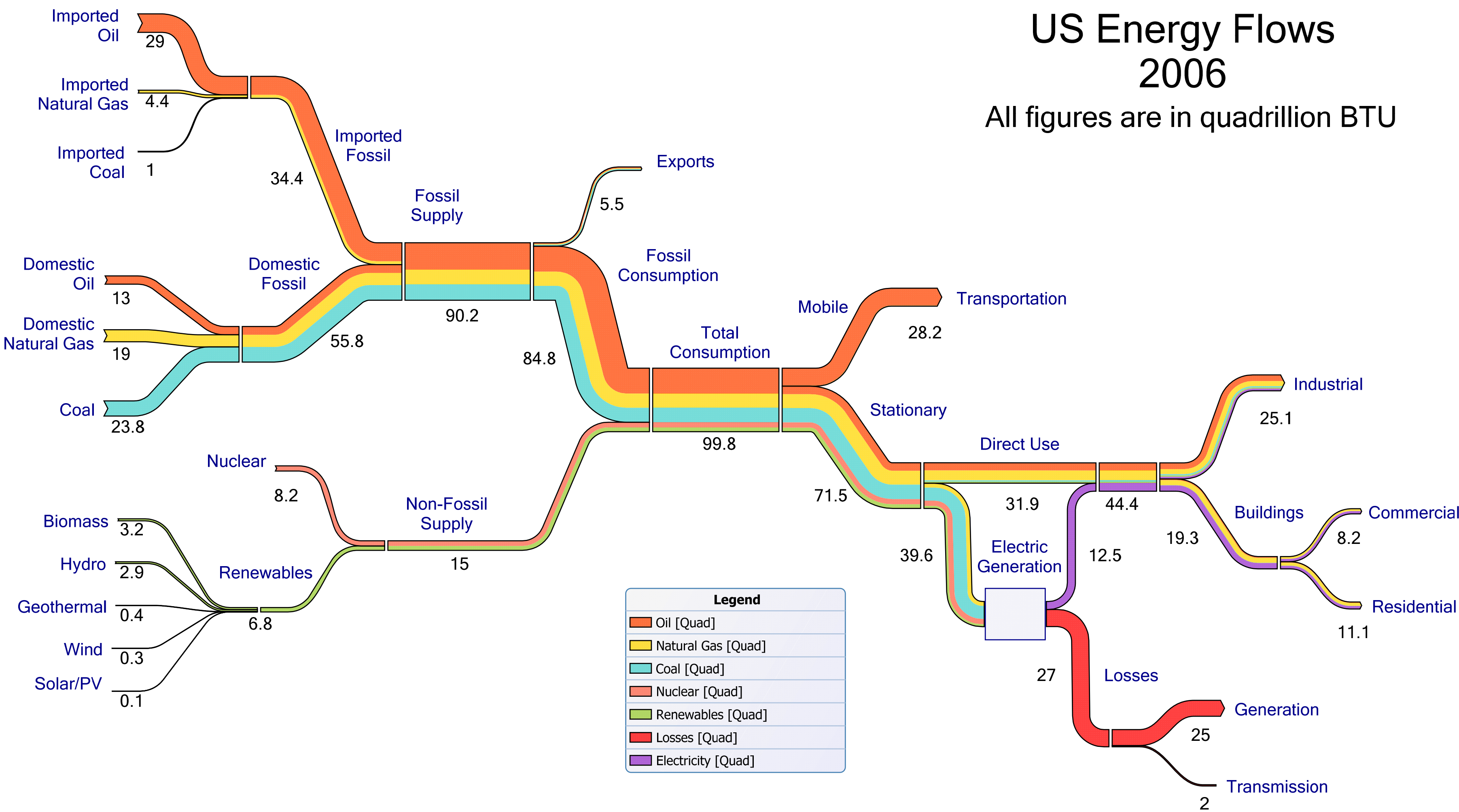
US Energy Flows 2006

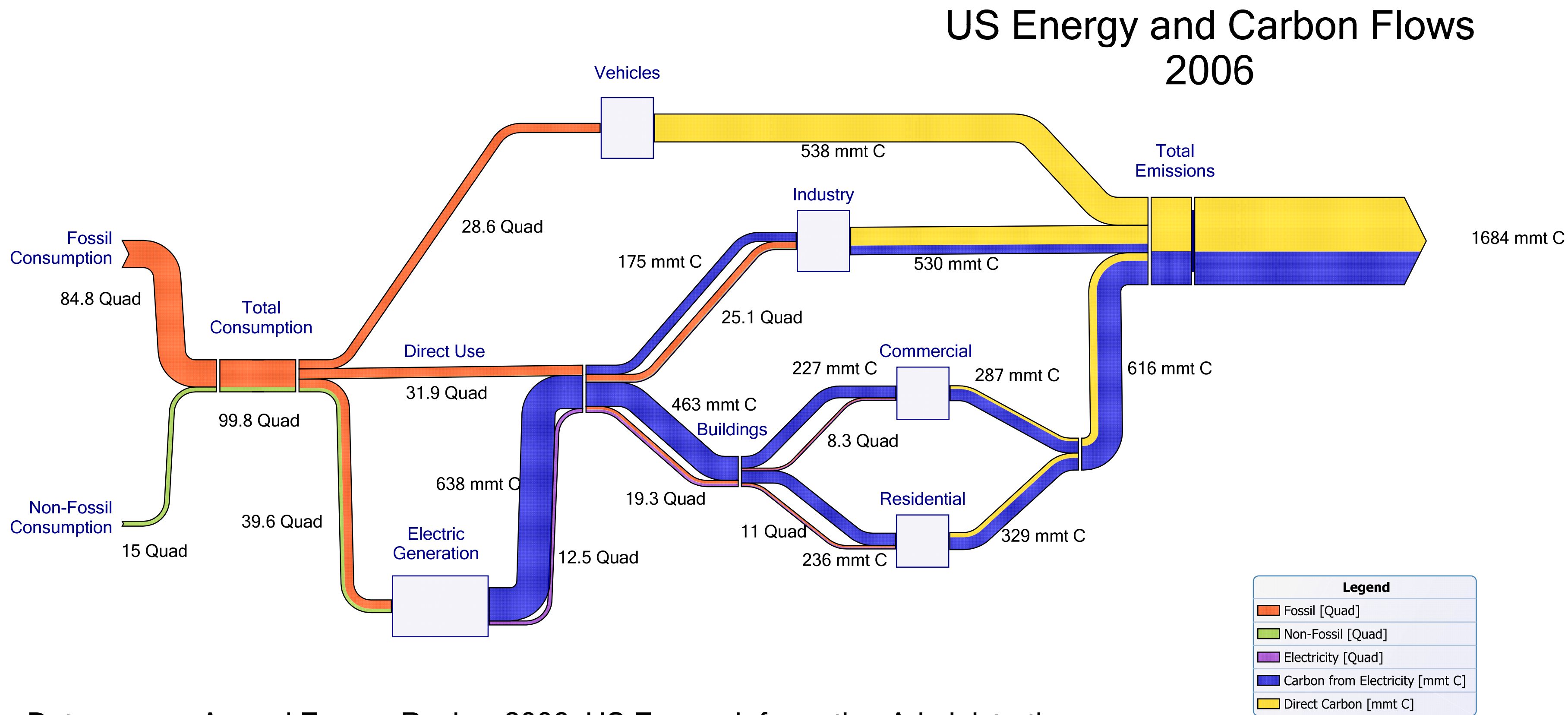
All figures are in quadrillion BTU



Data source: Annual Energy Review 2006, US Energy Information Administration

Translating energy into CO_2

- Natural gas
  - ⇨ *14.5 mmt C per quad*
  - ⇨ *Lowest carbon per quad of fossil fuels*
- Oil
  - ⇨ *About 20 mmt C per quad*
  - ⇨ *38% more carbon than gas*
- Coal
  - ⇨ *26 mmt C per quad*
  - ⇨ *80% more carbon than gas*



Data source: Annual Energy Review 2006, US Energy Information Administration

A very large problem …

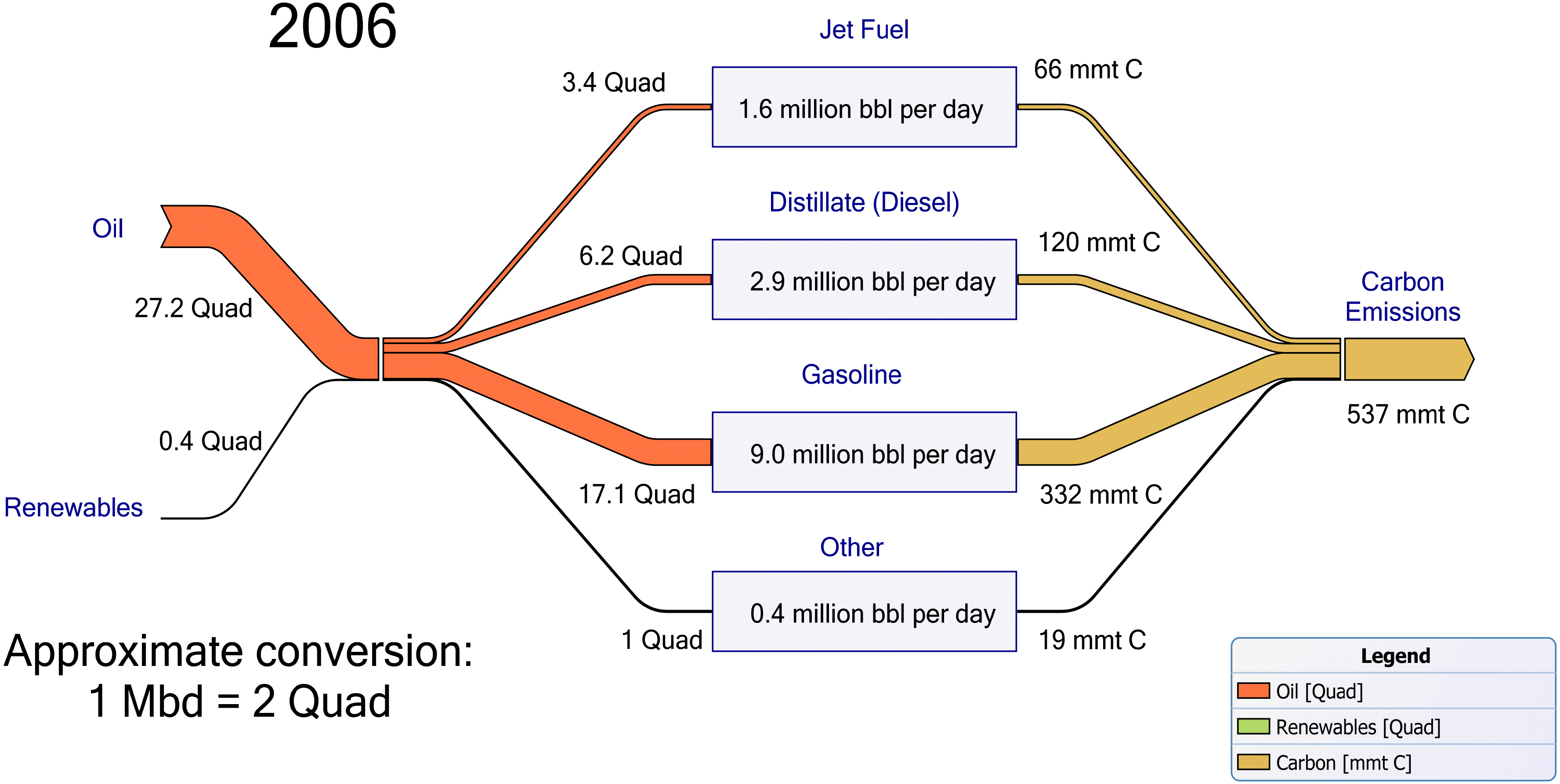
- US fossil energy
  - ⇨ *86 quads*

- US emissions
  - ⇨ *6 billion tons of CO_2 or 1.7 billion tons of C*

- In the long term, need to bring both down to nearly 0

Transportation

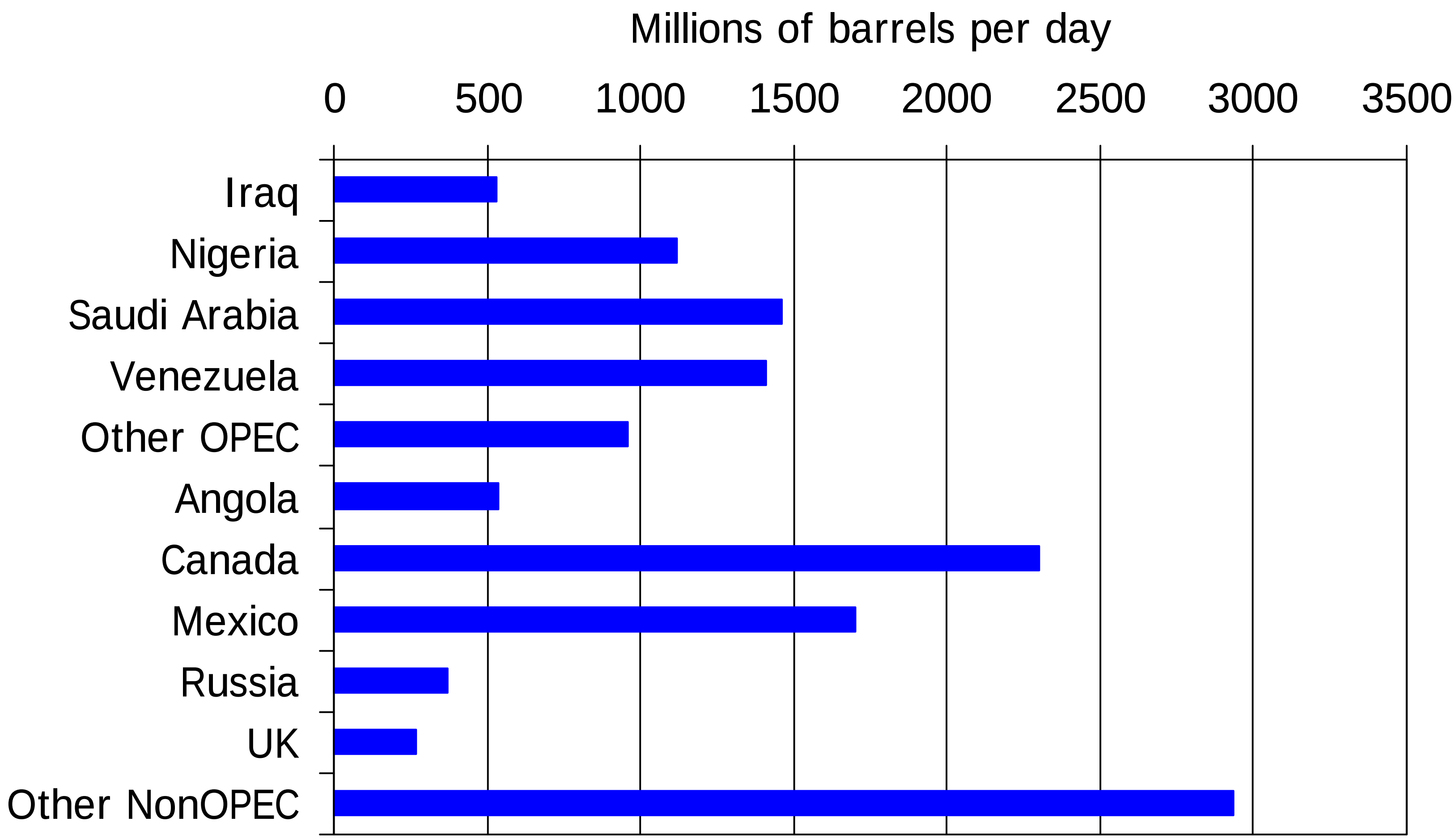
US Transportation Sector
2006



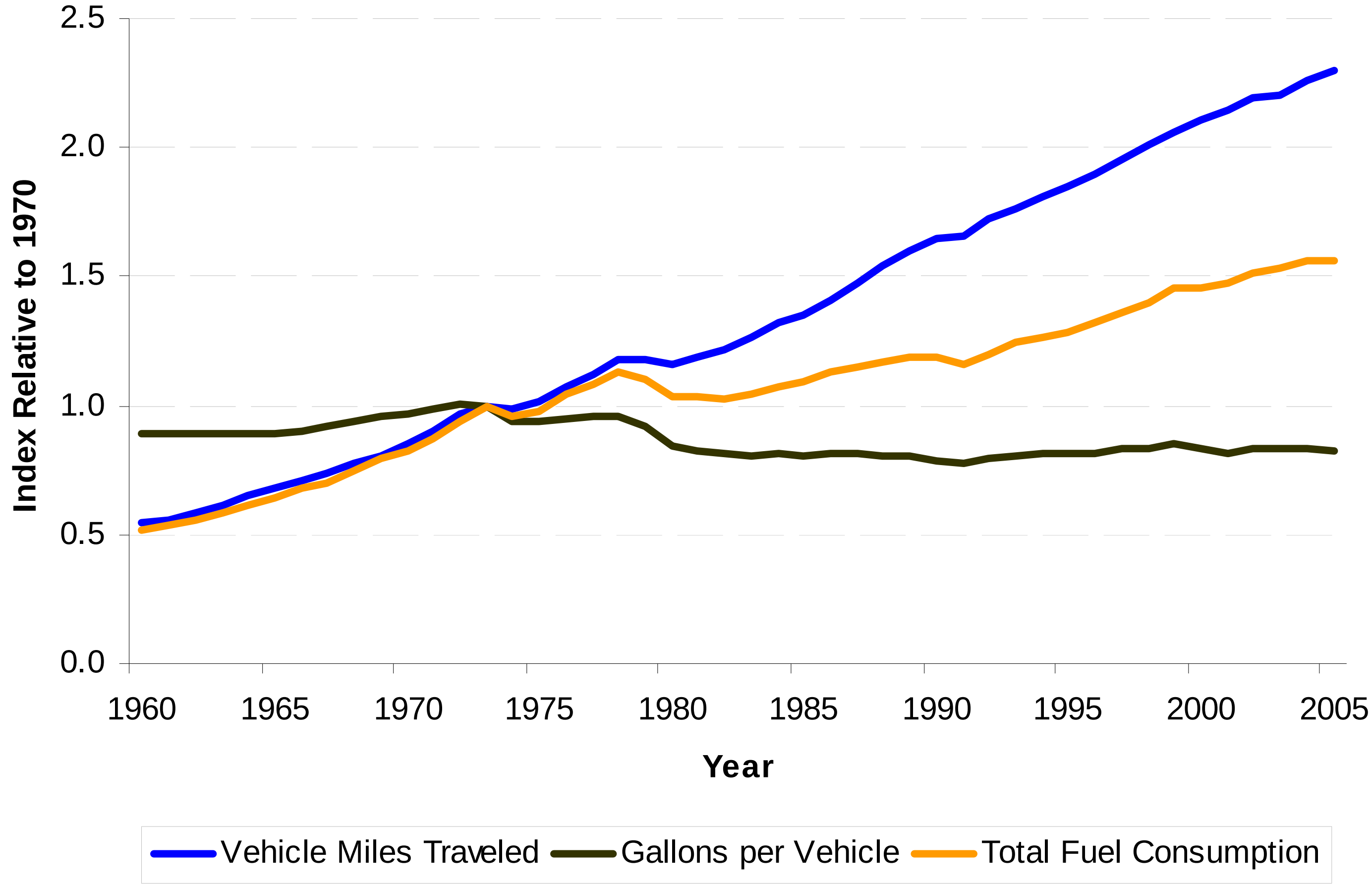
Approximate conversion:
1 Mbd = 2 Quad

Data source: Annual Energy Review 2006, US Energy Information Administration

Sources of imported oil



Slightly better cars but a lot more driving



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Abating vehicle emissions

- Shift fuel mix -- less CO_2 per unit of energy, less imported oil
  - ⇨ *Toward natural gas*
  - ⇨ *Toward biofuels (really feasible?)*
  - ⇨ *Toward electricity with sequestration*

- Improve fuel efficiency -- less energy per mile
  - ⇨ *Hybrids*
  - ⇨ *Advanced diesel*
  - ⇨ *Public transportation*

- Reduce driving -- fewer miles
  - ⇨ *Live closer to work*
  - ⇨ *Change habits*

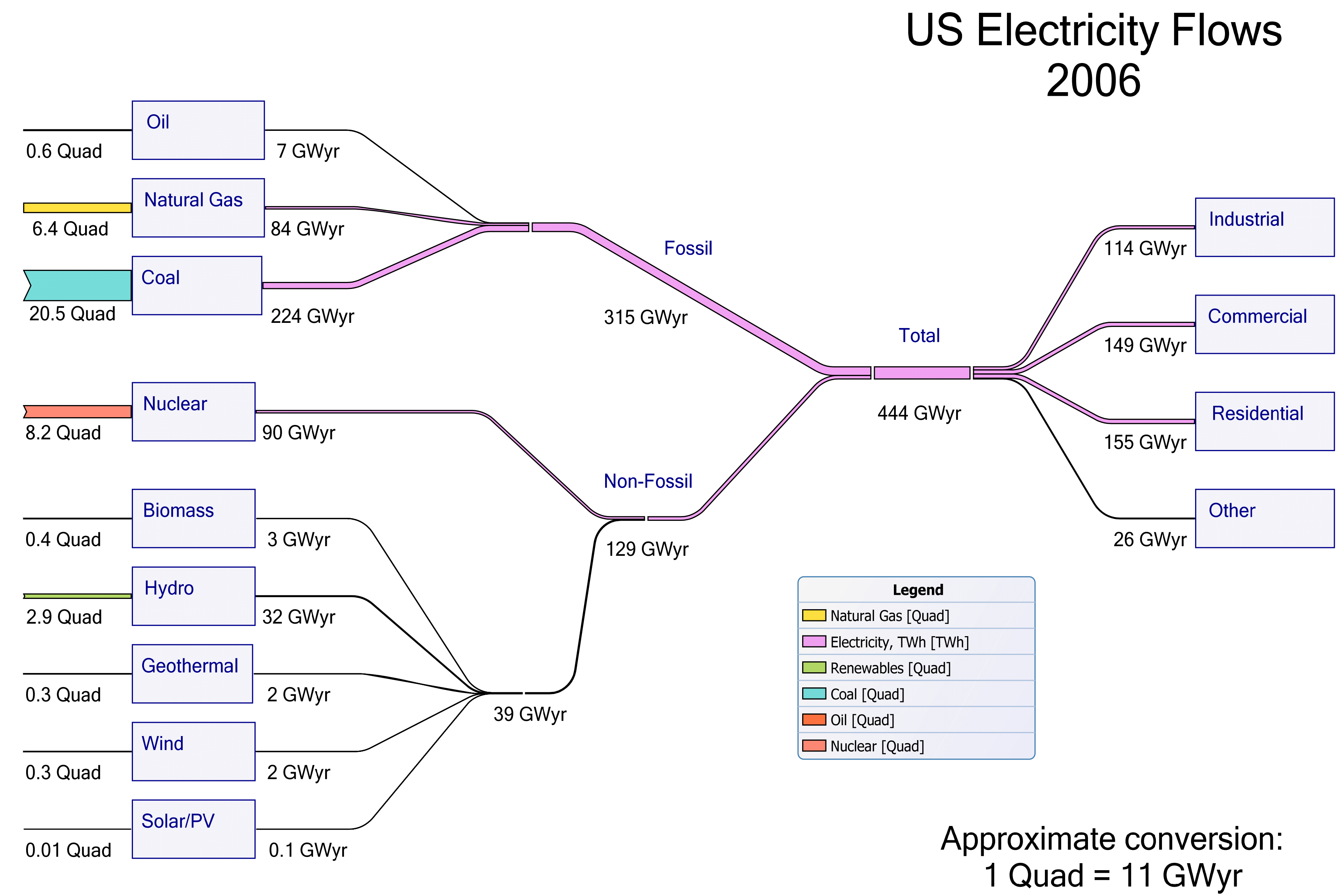
Electricity

Electric sector has multiple roles

- Adapting to climate change
  - ⇨ *Higher summer temperatures*
  - ⇨ *Potentially greater peak demand for electricity*

- Implementing climate policies
  - ⇨ *Generation and delivery of renewable power*
  - ⇨ *Replace on-site fuel use in order to sequester carbon*
  - ⇨ *Support plug-in hybrids*

- Implications
  - ⇨ *Even greater role for the grid*



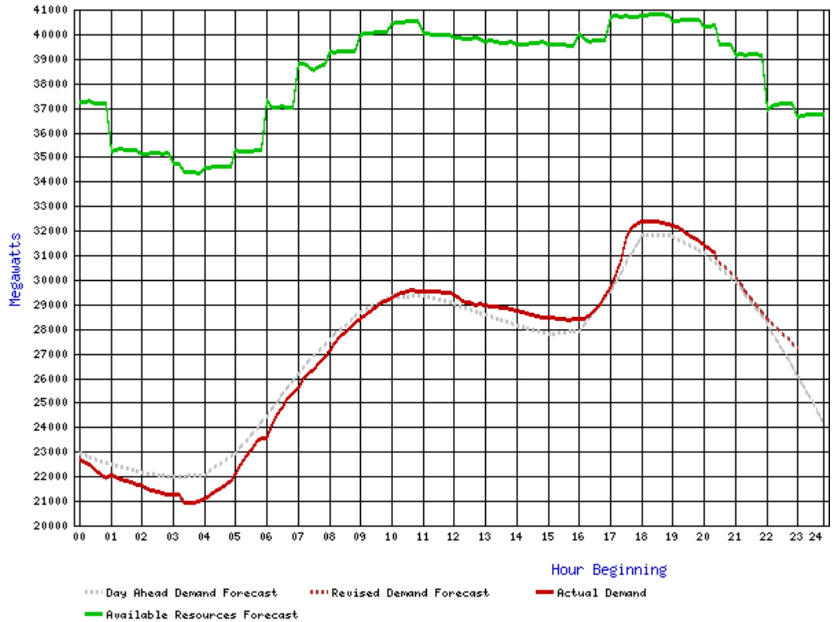
Data source: Annual Energy Review 2006, Energy Information Administration

Key problem for power producers...

- Need to follow variations in demand
- Power demand varies strongly over the day
  - ⇨ *Higher during the day than at night*
- Also varies strongly over the year
  - ⇨ *Higher in the summer due to air conditioning*

California load curve

- Independent System Operator (ISO)
  - ⇨ *Operates part of the electrical grid*
- Data for January 21st
- Demand (red curve):
  - ⇨ *Min at 3:30 am, 21 GW*
  - ⇨ *Max at 6:30 pm, 32.5 GW*
  - ⇨ *Max is 55% higher*
- Capacity (green curve):
  - ⇨ *34.5–41 GW*

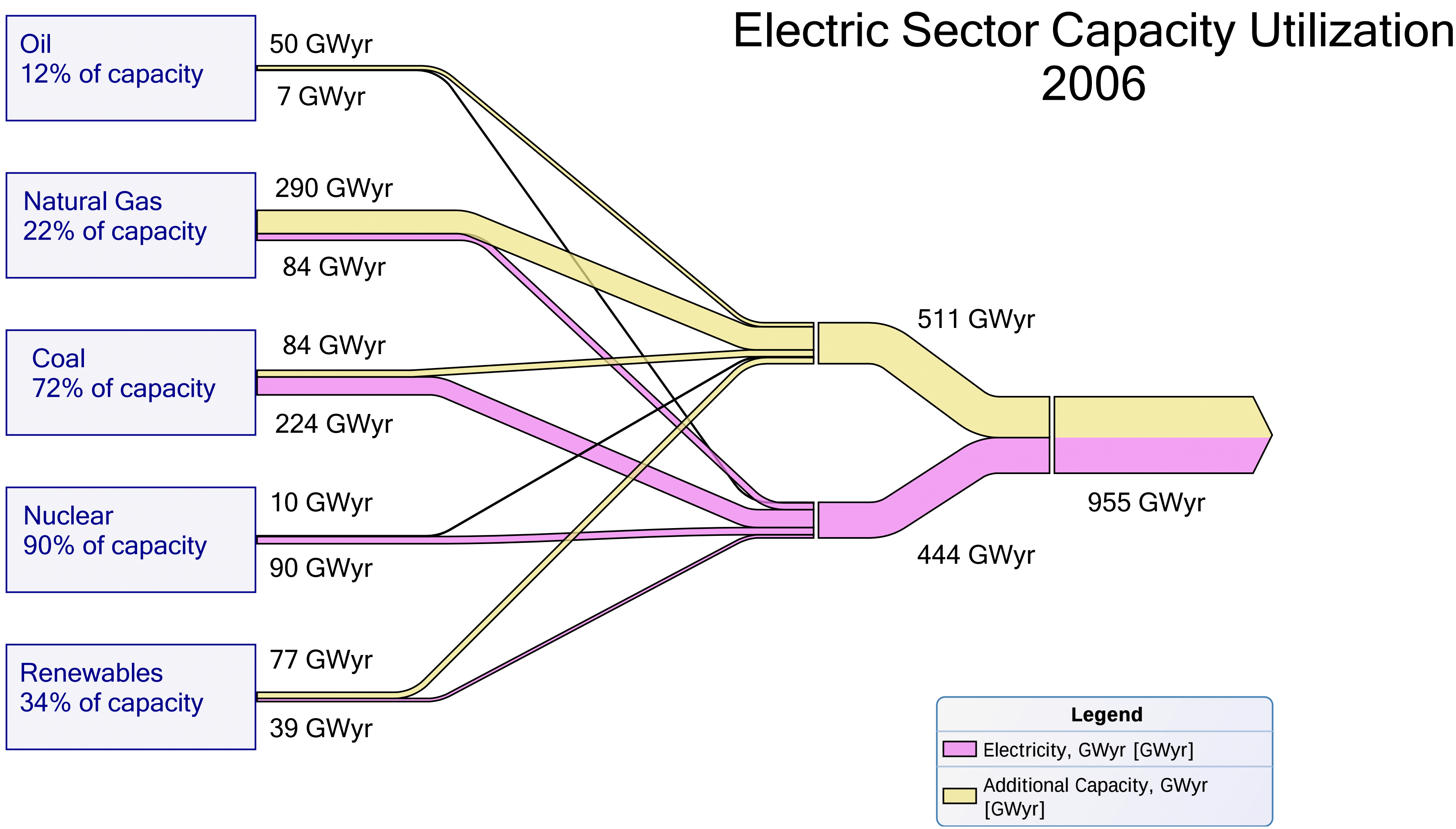


Base load vs. peaking plants

- Generators brought on line as needed
  - ⇨ *Dispatching order*

- Base load
  - ⇨ *Run almost all the time*
  - ⇨ *Expensive to build, slow start, cheap to run*
  - ⇨ *Coal, nuclear*

- Peaking
  - ⇨ *Run during peak periods*
  - ⇨ *Cheap to build, quick start, expensive to run*
  - ⇨ *Gas, oil, others*



Electric Sector Capacity Utilization
2006
Oil
12% of capacity
50 GWyr
7 GWyr
Natural Gas
22% of capacity
290 GWyr
84 GWyr
Coal
72% of capacity
84 GWyr
224 GWyr
Nuclear
90% of capacity
10 GWyr
90 GWyr
Renewables
34% of capacity
77 GWyr
39 GWyr
511 GWyr
444 GWyr
955 GWyr
Legend
Electricity, GWyr [GWyr]
Additional Capacity, GWyr [GWyr]

Details about power plants

- About 17,000 generating units
  - ⇨ *Plants have multiple generating units*
  - ⇨ *About 5,300 plants*

- Main generating technologies
  - ⇨ *Internal combustion*
  - ⇨ *Steam turbine (35% efficiency)*
  - ⇨ *Gas turbine (35% efficiency)*
  - ⇨ *Combined cycle (55-60% efficiency)*

    Gas turbine plus steam turbine

  - ⇨ *Renewable: hydro, wind, photo voltaic*

Summary of generation mix

Fuel	Capacity (GW)	Generation (GWyr)	Fossil Fuel Use (Quads)	Carbon (Mmt C)
Oil	57	7	0.6	13
Gas	374	84	6.4	93
Coal	310	224	20.5	532
Fossil total	741	315	27.5	638
Nuclear	100	90	--	--
Renewables	116	39	--	--
Total	958	444	27.5	638

Leading options for replacing fossil

- Integrated gasification combined cycle coal (IGCC)
  - ⇨ *With carbon capture and sequestration (CCS)*
- Combined cycle gas (CC)
  - ⇨ *With CCS*
- Nuclear
- Renewables
  - ⇨ *Biomass*
  - ⇨ *Hydro*
  - ⇨ *Wind*
  - ⇨ *Solar thermal*
  - ⇨ *Solar photovoltaic*

Cost of building new power plants

Technology	Capital Cost per kW of capacity
Coal	$1,206
IGCC	$1,394
IGCC with CCS	$1,936
Gas Turbine	$400
Combined Cycle	$550
CC with CCS	$1,055

Technology	Capital Cost per kW of capacity
Adv Nuclear	$1,802
Biomass	$1,714
Hydro	$1,364
Wind	$1,127
Solar Thermal	$2,675
Solar/PV	$4,114

Replacing fossil capacity

- Summer fossil capacity now 741 GW

- Replace with IGCC CCS coal plants?
  - ⇨ *$2000 per kWh*
  - ⇨ *Per GW: $2 billion*
  - ⇨ *Current capacity: 741 GW * $2 B = approx $1.5 T*
  - ⇨ *For comparison: US GDP approx $13 T ($2 T investment)*

- Not impossible but definitely expensive
- Also, very uncertain: no large scale CCS plants
- Population growth makes things worse

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Very important implication

- Would be less expensive if demand were lower
- Need to reduce fuel use on the demand side

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Transmission grid

- Can we get power where it's needed?

- Especially important for wind and solar
  - ⇨ *Best locations are far from cities*
  - ⇨ *Need geographic dispersion*

More grid capacity needed for wind

Variation in wholesale electricity prices due to grid congestion

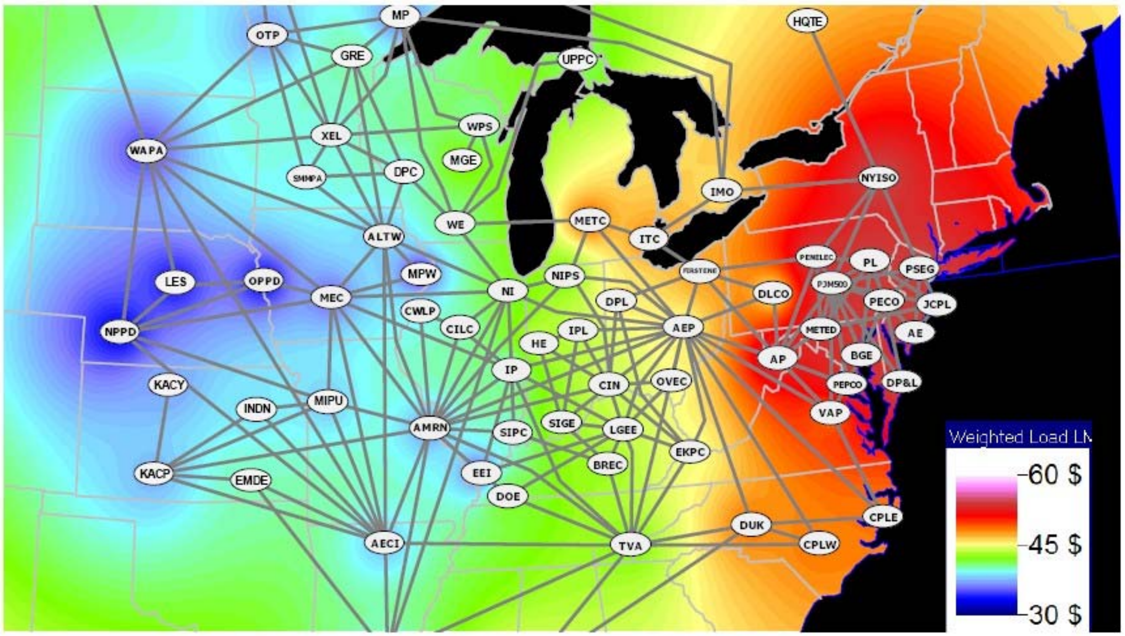


Figure 2.2-3 Contour Map of Annual Load Weighted LMP

From “2006 Midwest ISO-PJW Coordinated System Plan (CSP),” revised December 20, 2006.

Reducing demand?

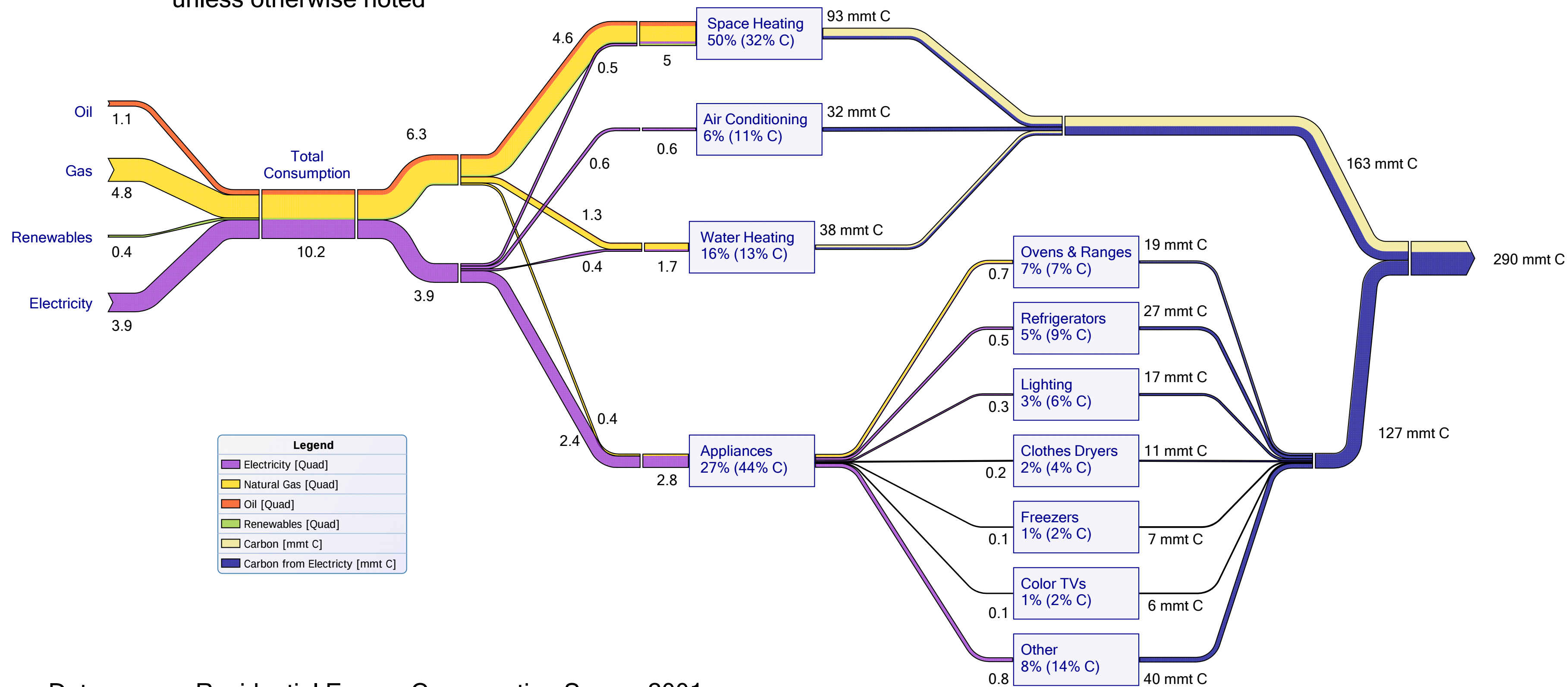
- Very quick overview of energy use

- Residential and commercial
  - ⇨ *Heating*
  - ⇨ *Air conditioning*
  - ⇨ *Water heating*
  - ⇨ *Appliances*

- Industry
  - ⇨ *More difficult due to accounting for feedstocks*
  - ⇨ *Mostly in the production process*
  - ⇨ *Most of that is heating*

US Residential Energy Consumption 2001

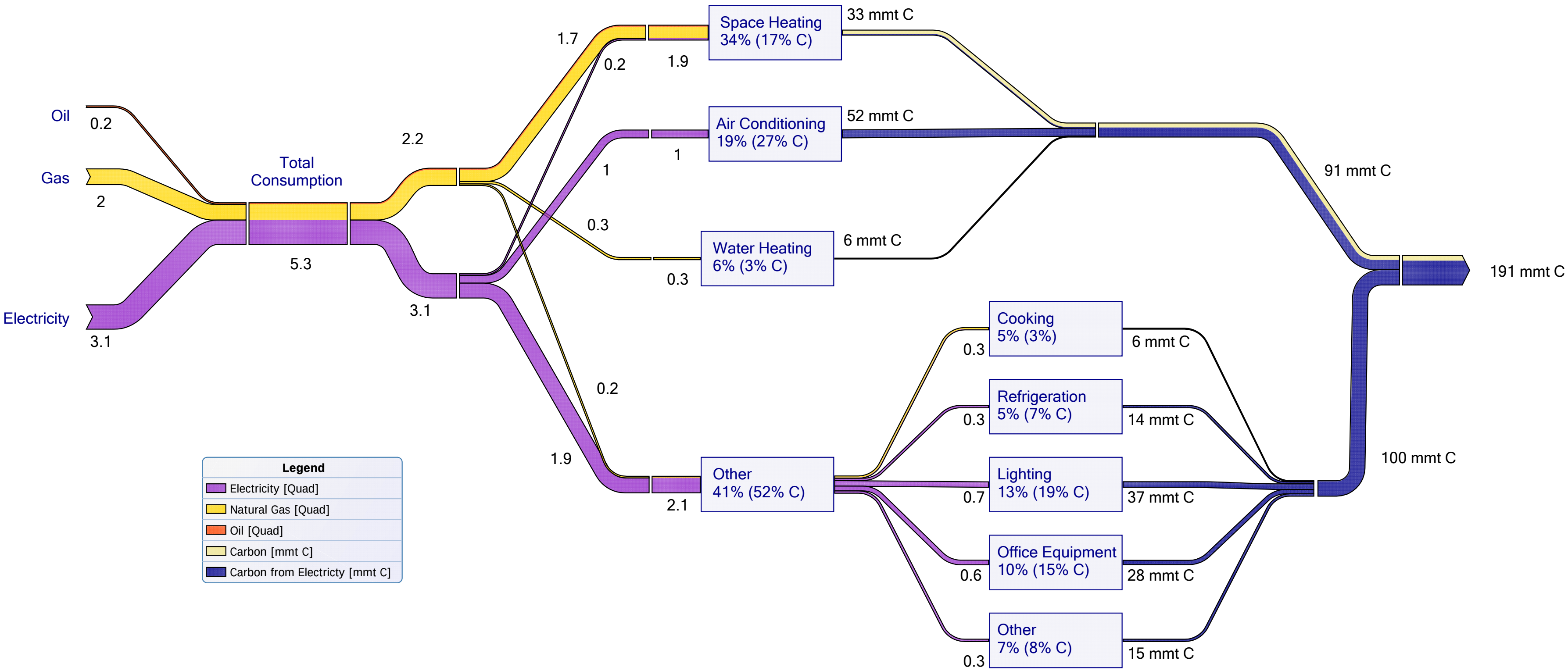
Values in quadrillion BTU
unless otherwise noted



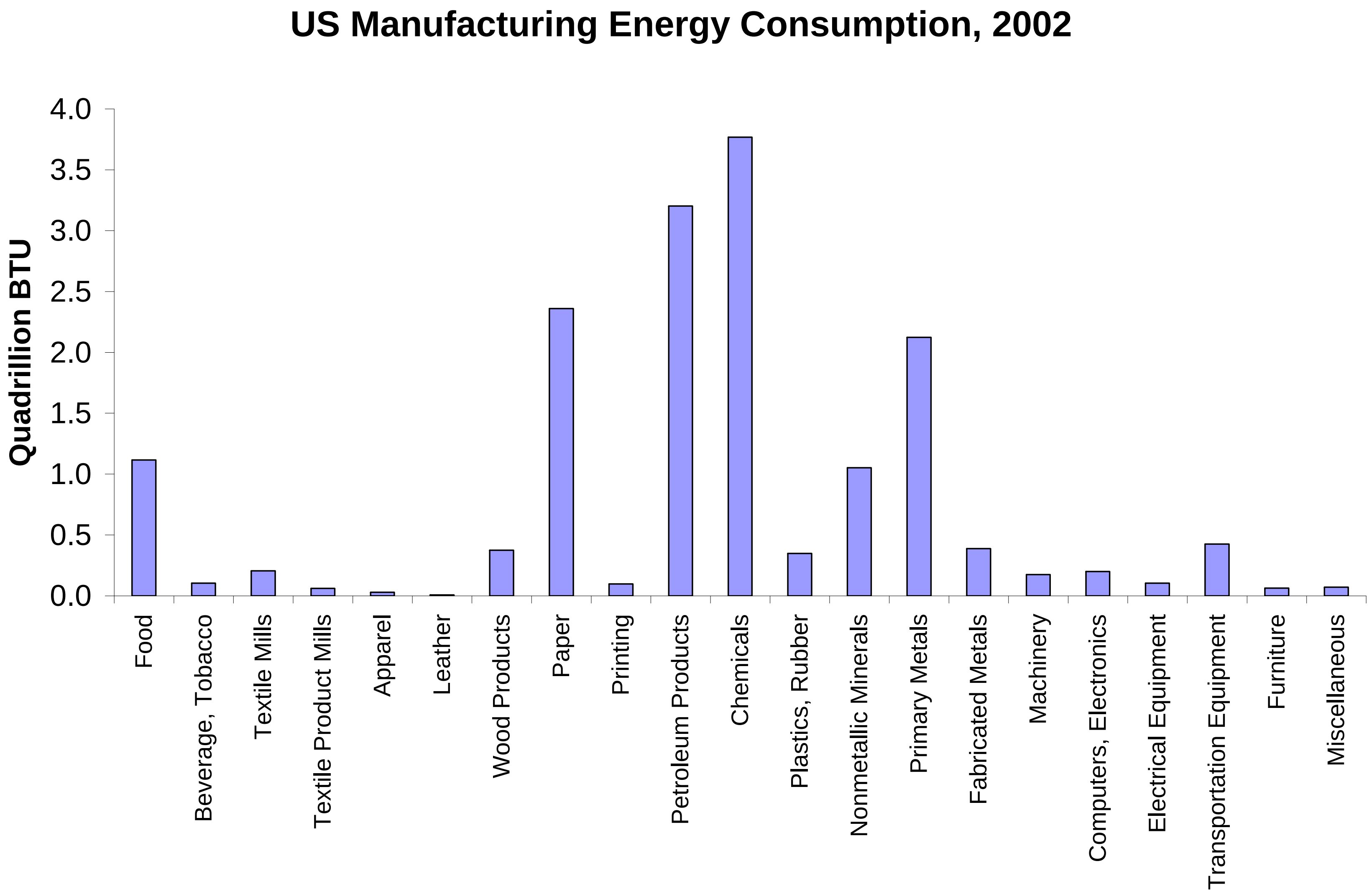
Data source: Residential Energy Consumption Survey 2001

US Commercial Building Energy Consumption 1999

Values in quadrillion BTU
unless otherwise noted



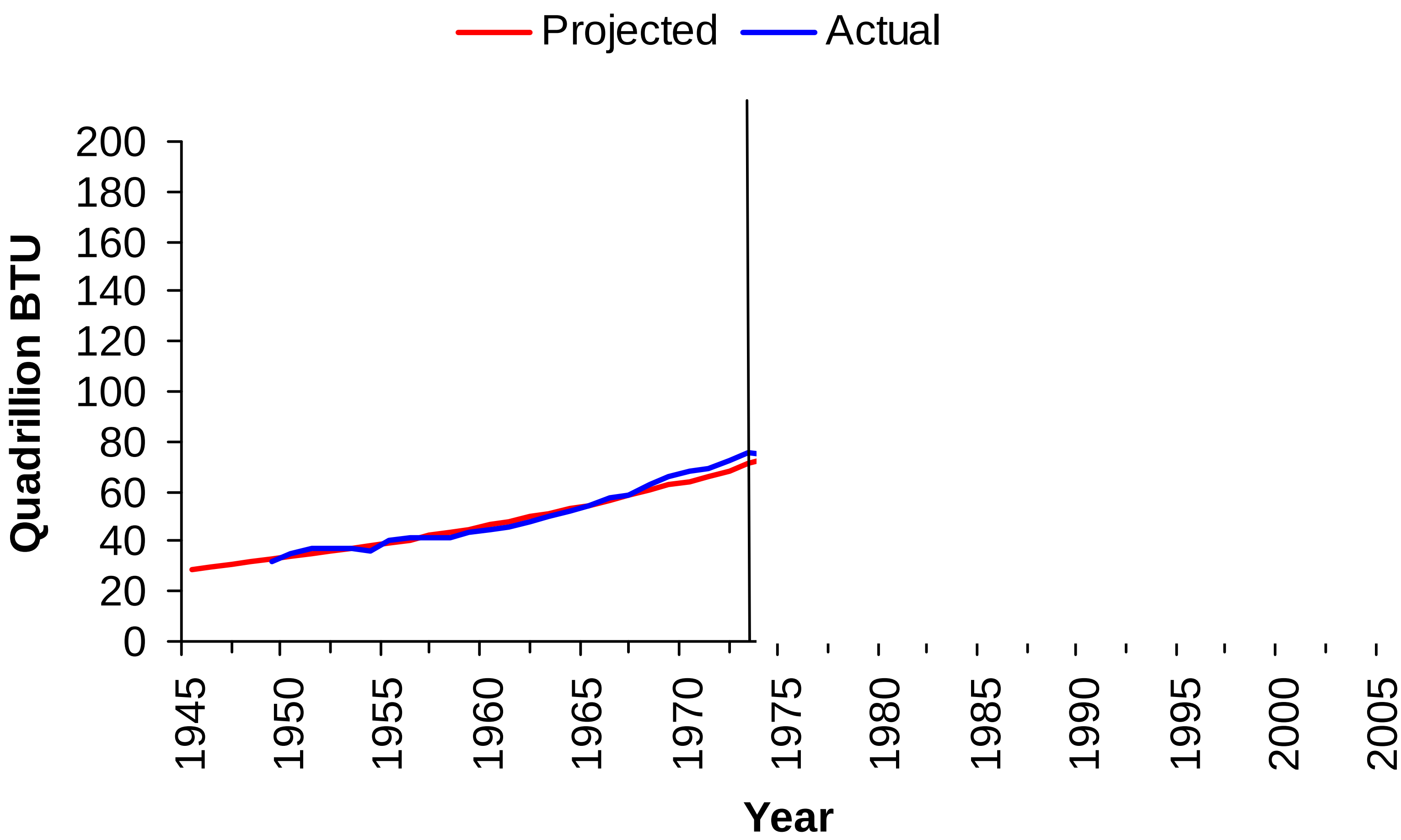
Data source: Residential Energy Consumption Survey 2001


US Manufacturing Energy Consumption, 2002
Quadrillion BTU
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Food
Beverage, Tobacco
Textile Mills
Textile Product Mills
Apparel
Leather
Wood Products
Paper
Printing
Petroleum Products
Chemicals
Plastics, Rubber
Nonmetallic Minerals
Primary Metals
Fabricated Metals
Machinery
Computers, Electronics
Electrical Equipment
Transportation Equipment
Furniture
Miscellaneous

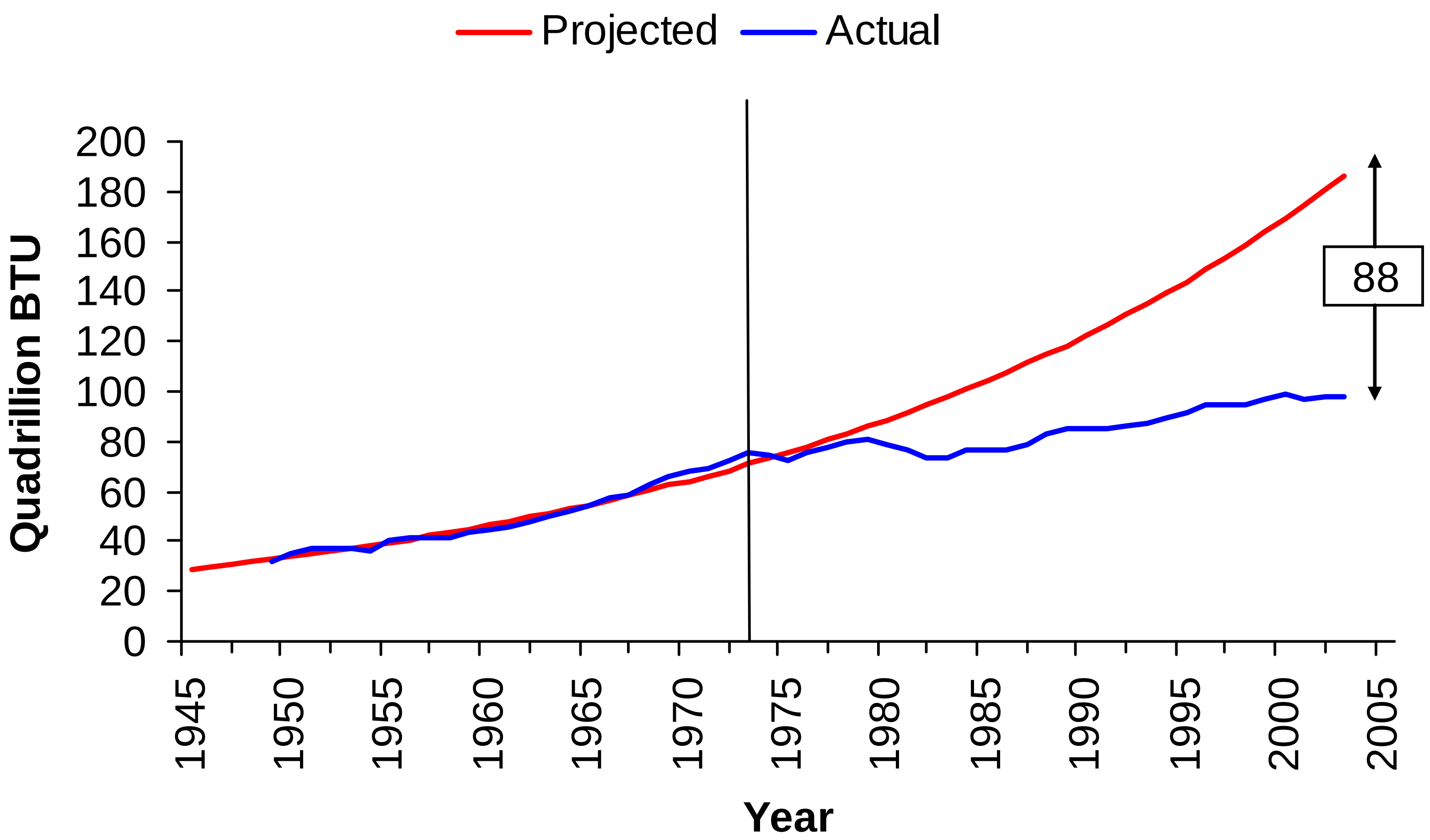
Historical perspective?

- Does fuel use rise inexorably no matter what?
- What do we know from history about fuel use?

US Energy Consumption, 1949-2003



US Energy Consumption, 1949-2003



Energy prices matter!

- Price spikes stabilized US energy consumption for about 20 years
- GDP growth was a little slower: about 0.2% per year

Fundamental economic policy

- Impose a tax on fossil fuels in proportion to carbon content
- Would reduce emissions substantially
  - ⇨ *Powerful incentive to reduce fuel use*
  - ⇨ *Incentive to adopt alternative technologies*
  - ⇨ *Incentive for R&D on alternative technologies*
  - ⇨ *Consistent with historical evidence on energy prices*
- Would reduce imports of oil

What political problems arise?

- Large energy taxes may not be politically viable
  - ⇨ *Not possible to discuss seriously?*
  - ⇨ *Pressure to repeal every year*

- Main policy question becomes
  - ⇨ *Can we get similar incentives with a different policy?*

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Alternatives to a tax

- Tradable emissions permits
  - ⇨ *Issue a limited number of permits to burn fossil fuels*
  - ⇨ *Allow owners to buy and sell*
  - ⇨ *Would raise fuel prices*
  - ⇨ *Costs may be very high*

- Hybrid policy
  - ⇨ *Some tradable permits*
  - ⇨ *Tax provision for exceeding permits*
  - ⇨ *Raises fuel prices with fewer political problems*

Efficiency regulations

- Appliance standards
  - ⇨ *Energy ratings, Energy Star program*
- Building codes
  - ⇨ *Insulation*
  - ⇨ *Windows*
- CAFE standards
  - ⇨ *Vehicle fuel efficiency requirements*

Technology policies

- Subsidies for hybrid cars
- Subsidies for alternative fuels
  - ⇨ *Corn-based ethanol not a good solution*
  - ⇨ *Cellulosic ethanol great but expensive to produce*
- Subsidies for R&D
  - ⇨ *A Manhattan Project for energy ?*
- Carbon capture and sequestration
  - ⇨ *Would allow coal use without climate damage*
  - ⇨ *Basic technologies are known*
  - ⇨ *Need large scale demonstration projects*

No matter what, need fossil fuel prices to rise

- Fossil fuels are currently very cheap

- Technology policies alone won’t be enough
  - ⇨ *Unlikely to produce a “silver bullet” technology that would be cheaper than fossil fuels and also carbon-free*

Energy policy portfolio

- Raise fossil fuel prices via a carbon tax or permit system
  - ⇨ *Will reduce CO2 emissions AND reduce demand for imported oil*
- Promote non-fossil electricity generation
  - ⇨ *Advanced nuclear, wind*
- Renovate and expand the electricity grid
- Encourage alternative vehicle technologies
  - ⇨ *Natural gas*
  - ⇨ *Plug-in hybrids*
  - ⇨ *Electric vehicles*
- Research and development
  - ⇨ *Cellulosic ethanol*
  - ⇨ *Carbon capture and sequestration*