

Carbon in US Energy Production

Peter Wilcoxon
Departments of Economics and Public Administration
The Maxwell School, Syracuse University

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<http://wilcoxon.maxwell.insightworks.com/pages/talks/>

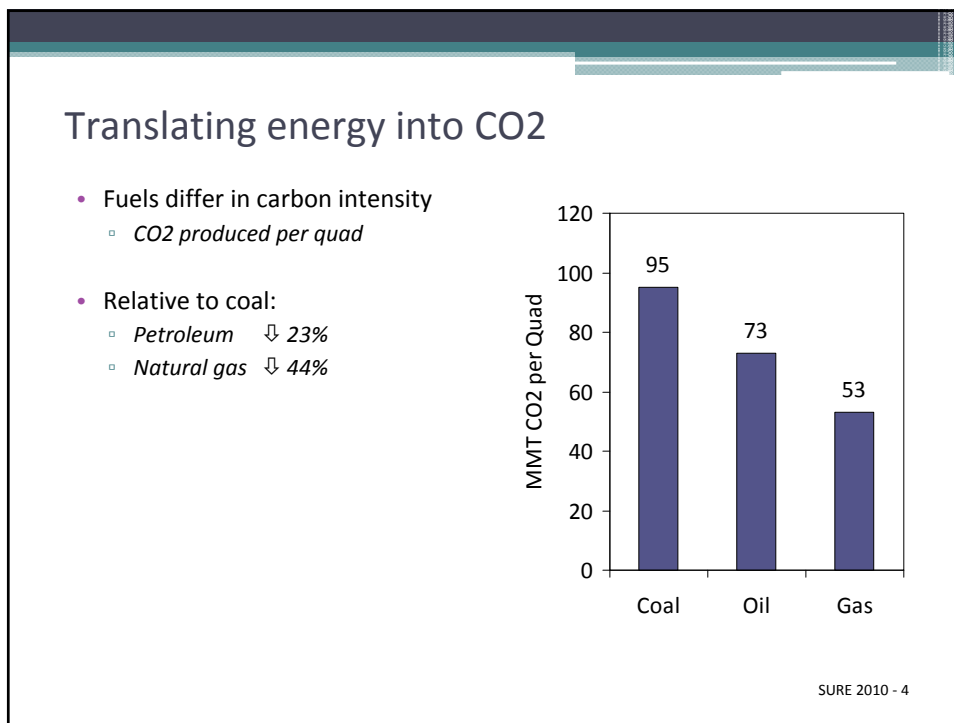
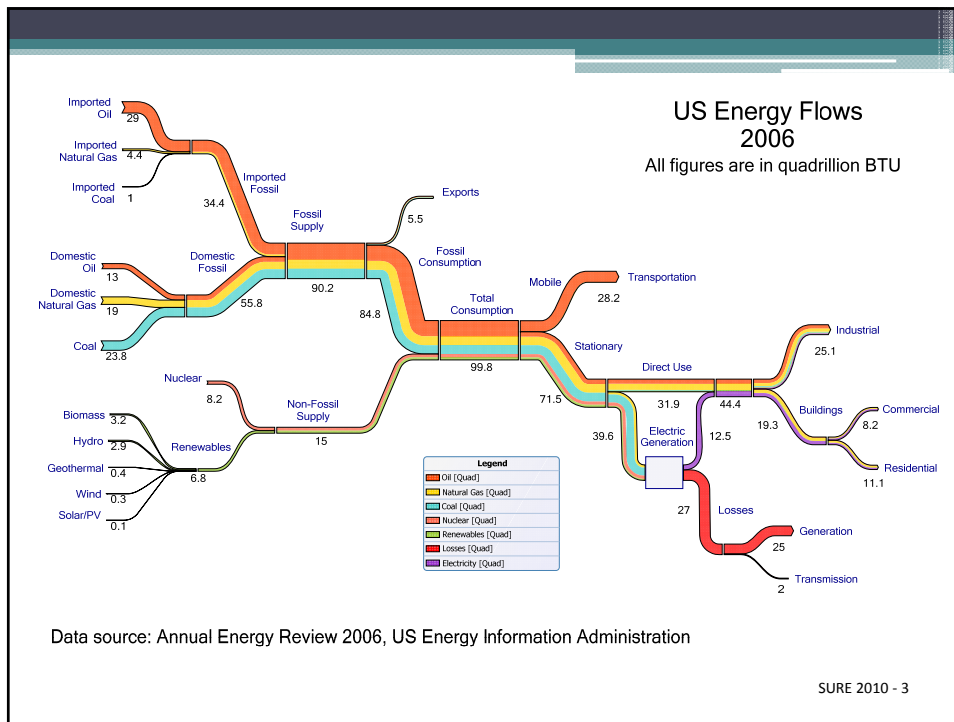
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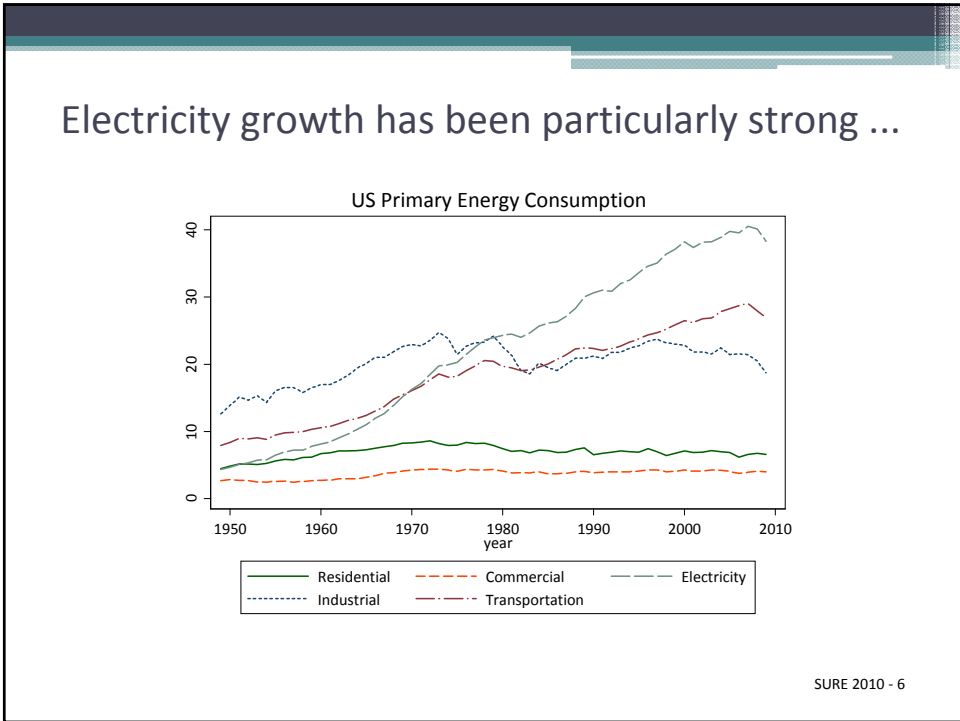
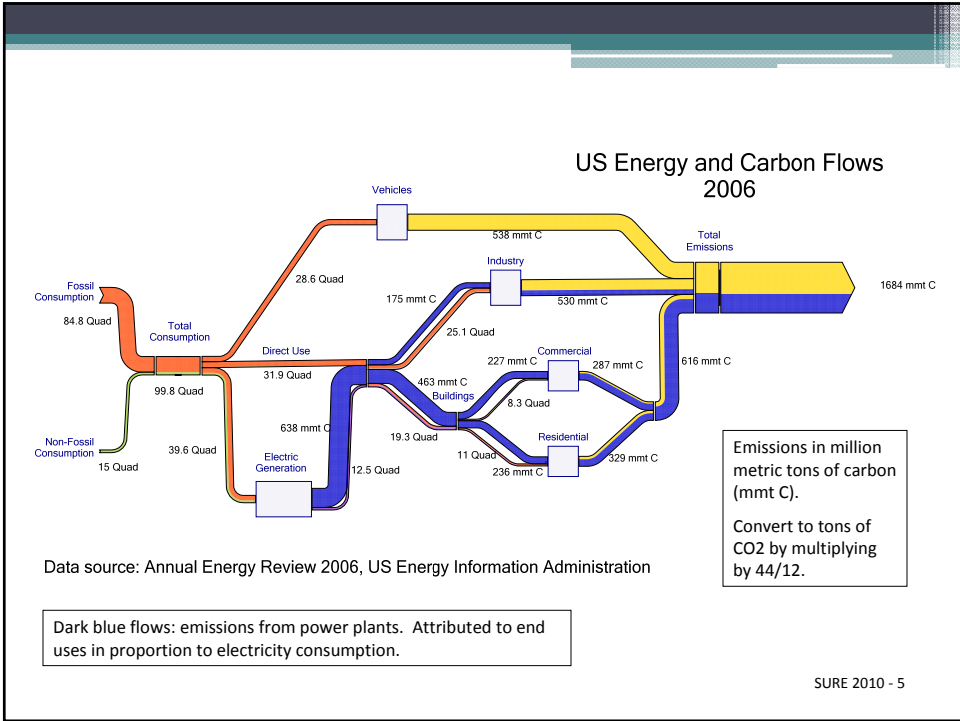
Fuel use and energy units

- National fuel use is measured in quads
 - *1 quad = 1 quadrillion BTU (10^{15})*
- How large is a quad?
 - *Coal "unit trains": 100 cars, about 1 mile long*
 - *1 train fuels a 300 MW power plant for about 3 days*
 - *1 quad = 4,500 unit trains*

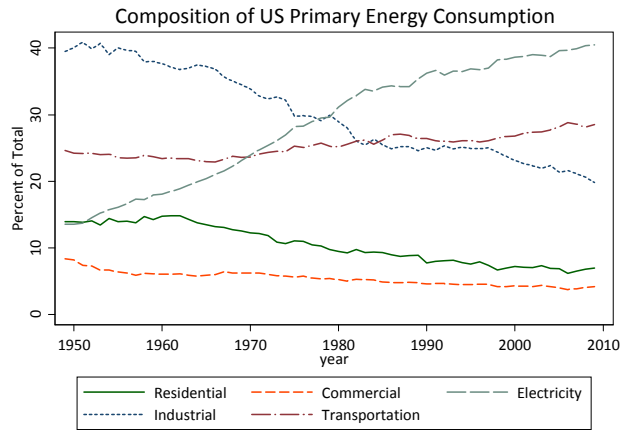


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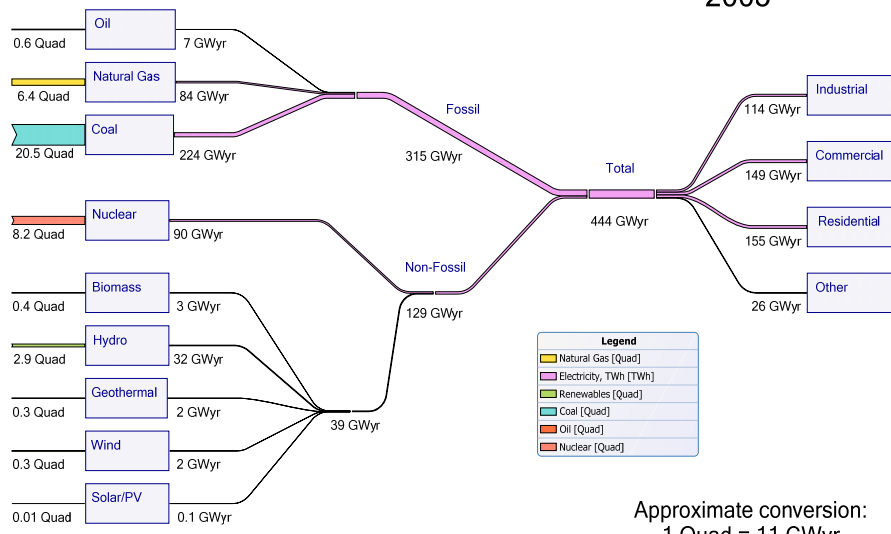


... especially as a share of the total



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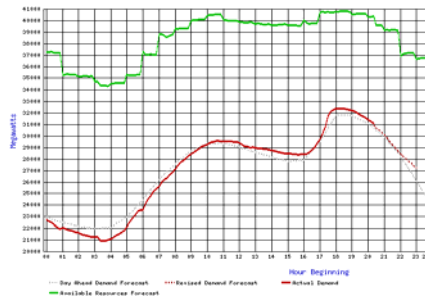
US Electricity Flows 2006



Data source: Annual Energy Review 2006, Energy Information Administration

California load curve

- Independent System Operator (ISO)
 - Operates part of the electrical grid
- Data for January 21, 2008
- 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

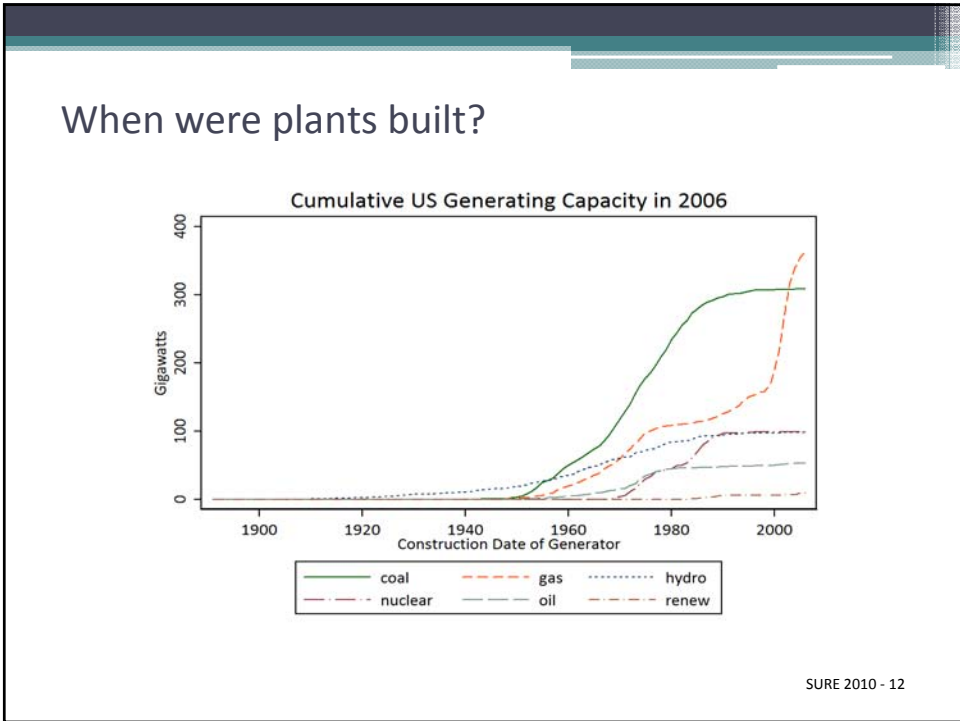
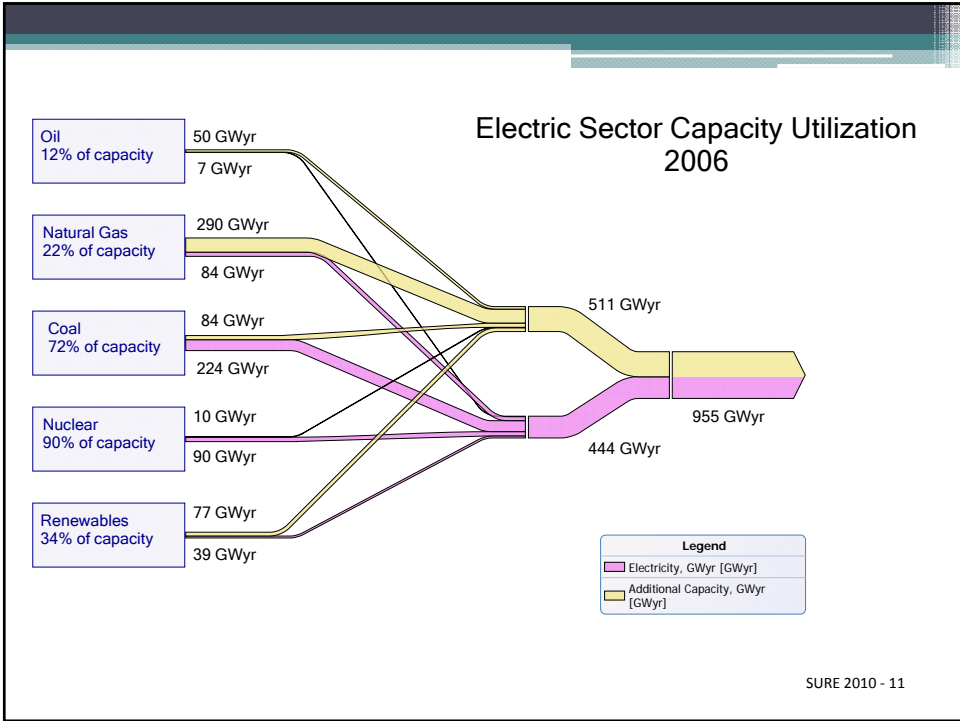


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Types of plants

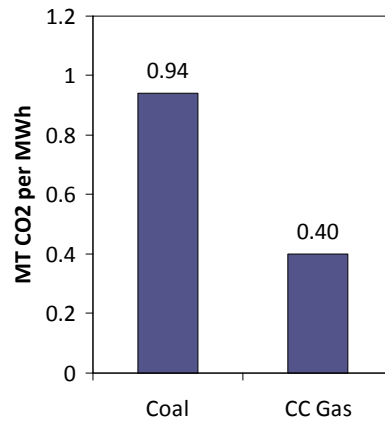
- Base load
 - Run almost all the time
 - Expensive to build, slow start, cheap to run
 - Coal, nuclear
- Peaking
 - Run during peak periods
 - Cheap to build, quick start, expensive to run
 - Gas, oil, hydro
- Intermittent
 - Weather dependent: wind, solar

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Potential gains from fuel switching

- Carbon intensity of fuels
 - *Gas: 44% less CO₂ per quad*
- Efficiency in generation
 - *Pulverized coal ≈ 34%*
 - *Combined cycle gas ≈ 46%*
- CO₂ per MWh relative to coal:
 - *Natural gas ↓ 57%*



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Leading options for replacing fossil

- Integrated gasification combined cycle coal (IGCC)
 - *With carbon capture and sequestration (CCS)*
- Combined cycle gas
 - *With CCS*
- Nuclear
- Renewables

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Replacing fossil completely?

- Need about 550 GW to eliminate fossil
 - 330 GW base load
 - 220 GW peaking
- Fossil with CCS
 - 410 GW of IGCC CCS coal (80% utilization) = \$1.4 T
 - Add CCS to 220 GW of combined cycle gas = \$220 B
 - Total = \$1.6T
- Intermittent renewables
 - 1300 GW of wind (25% utilization) = \$2.5 T
 - Add CCS to 220 GW of combined cycle gas = \$220 B
 - Total = \$2.7 T

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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

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More grid capacity needed for wind

Variation in wholesale electricity prices due to grid congestion

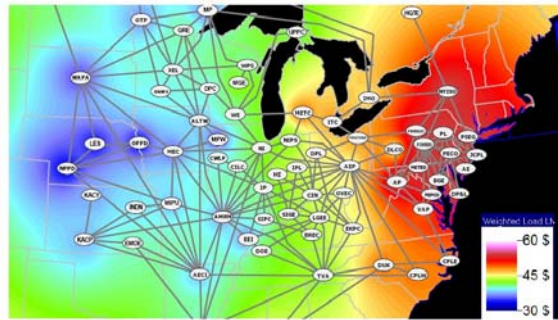


Figure 2.2-3 Contour Map of Annual Load Weighted LMP

From "2006 Midwest ISO-PJW Coordinated System Plan (CSP)," December 2006.

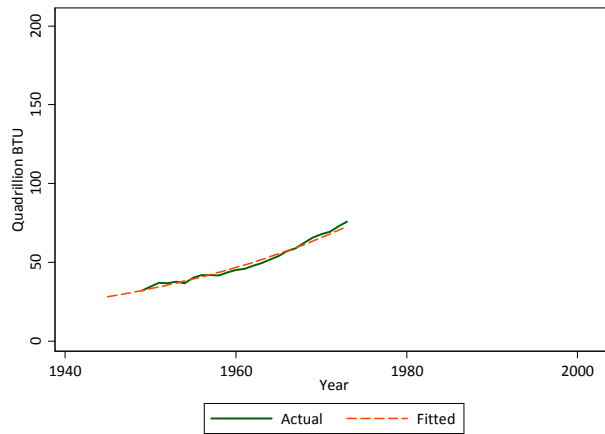
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Historical perspective?

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

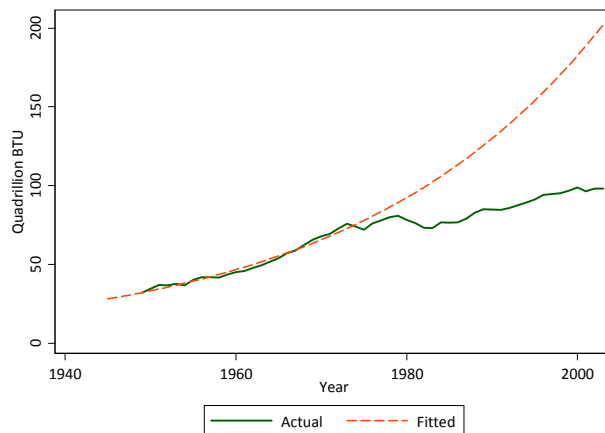
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Exponential growth after the war (3.4%)



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Sharp change after the energy shocks!



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Energy prices matter!

- Stabilized US energy consumption
 - *Flat for about 20 years*
- GDP growth was a little slower
 - *About 0.2% per year: from 3.2% to 3.0%*

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A very large problem ...

- Currently:
 - *86 quads of fossil fuels*
 - *6 gigatons of CO2 emissions*
- To limit temperature increase to 2° C:
 - *Need to bring CO2 down by more than 80%*
- Rough targets by 2050:
 - *16 fossil quads* ↓ *70 quads*
 - *1 gigaton CO2* ↓ *5 gigatons*
- Will be very difficult without a rise in fossil prices

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