Energy Quality, Net Energy and the Coming Energy Transition

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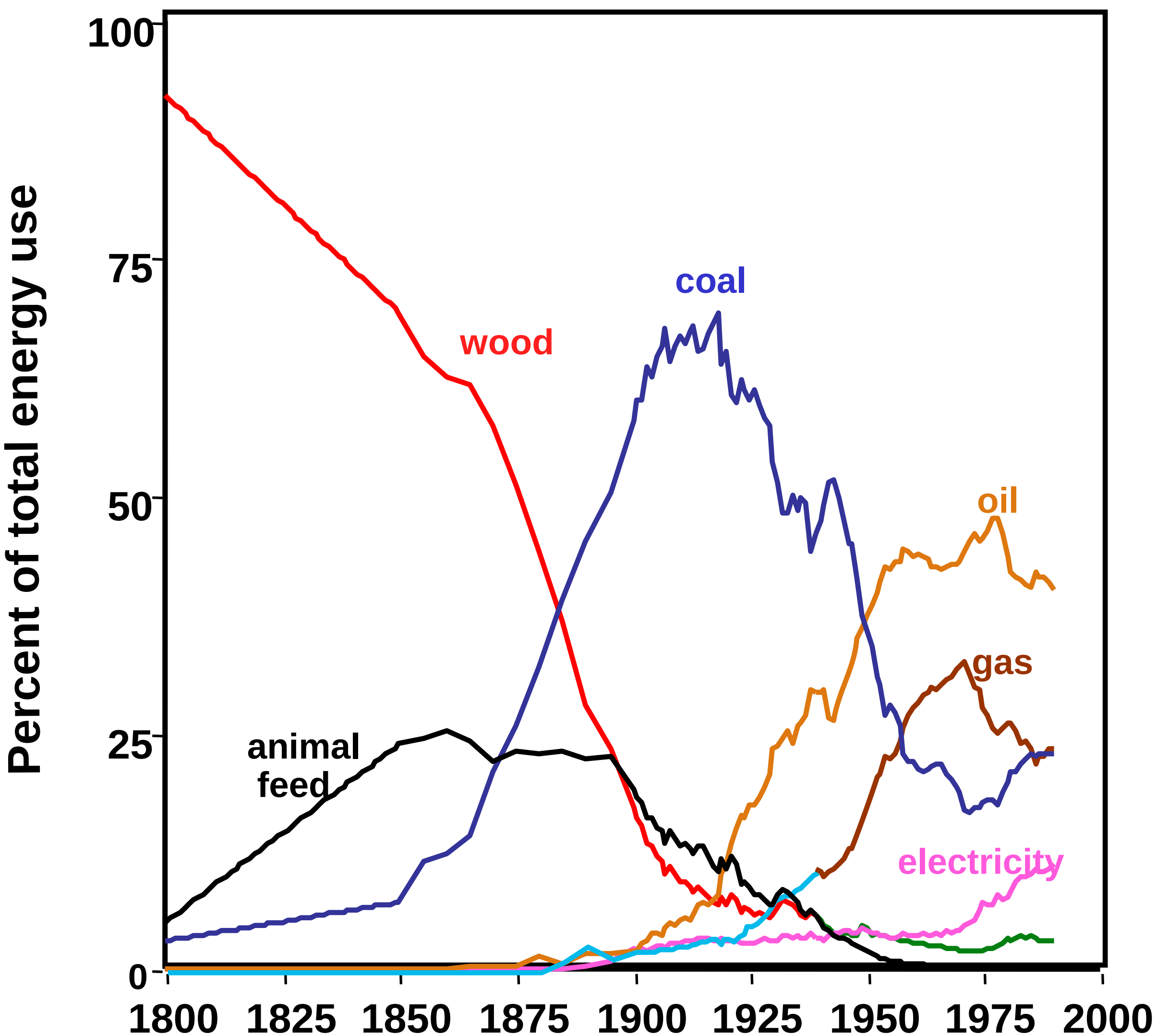
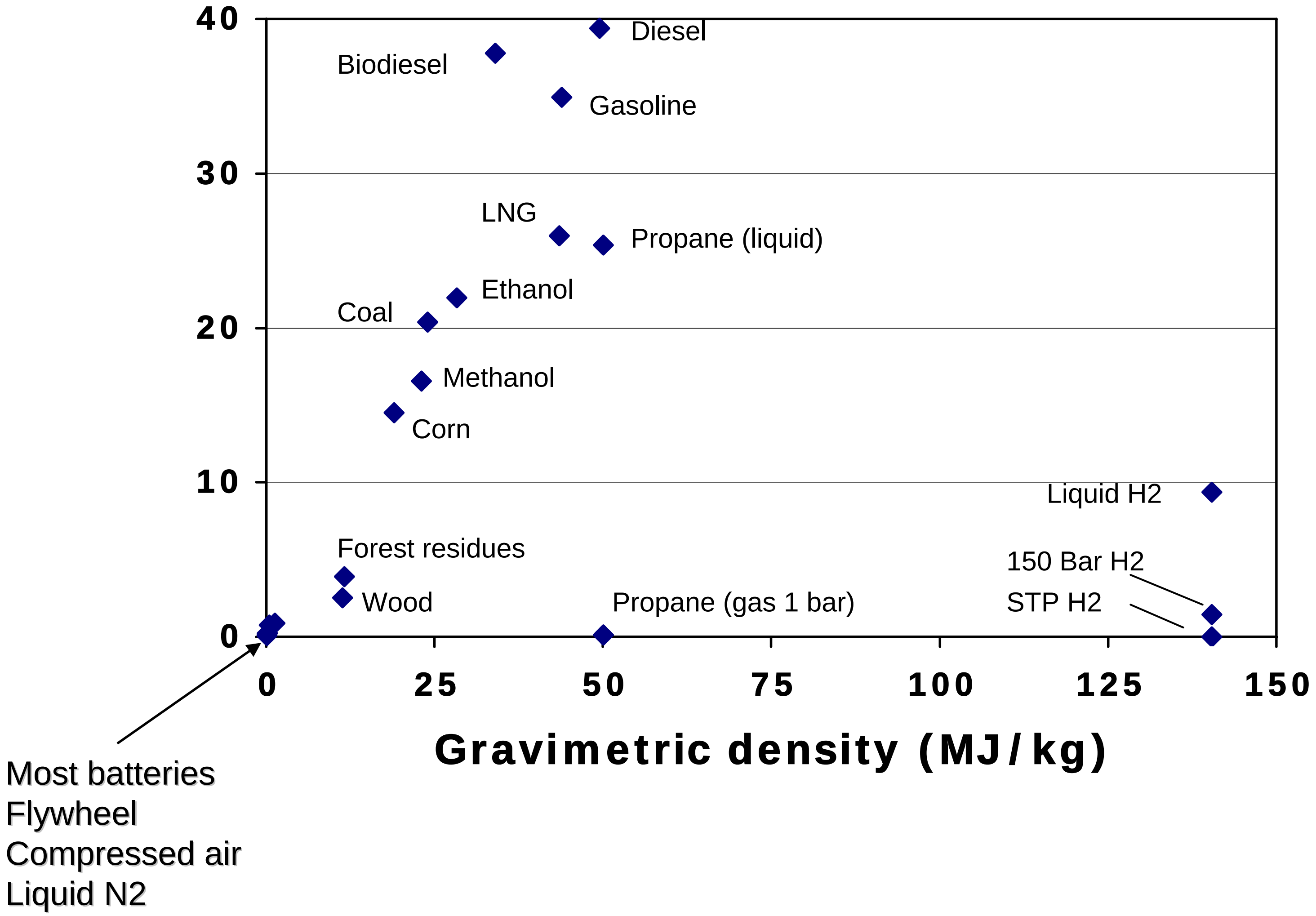
Composition of U.S. Energy Use



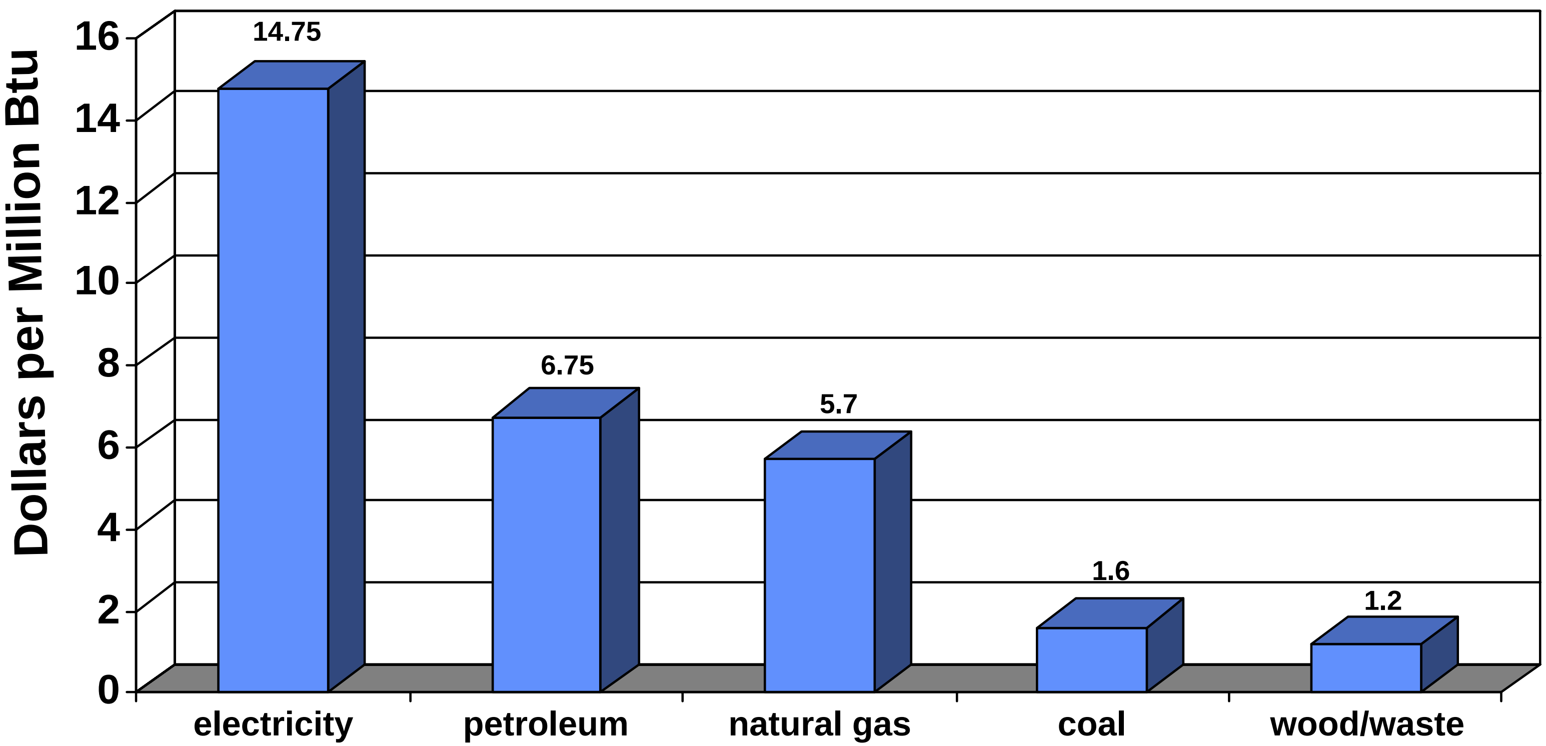
The Concept of Energy Quality

- The economic usefulness of a heat unit of fuel or electricity
- How much GDP can 1 Joule produce?
- What determines energy quality?
  - a combination of physical, chemical, engineering, economic, and environmental variables
  - cost, weight, density, safety, amenability to storage, heat content, pollution, conversion efficiency, ease of transport
- No single metric or perspective can adequately reflect energy quality

Energy Density

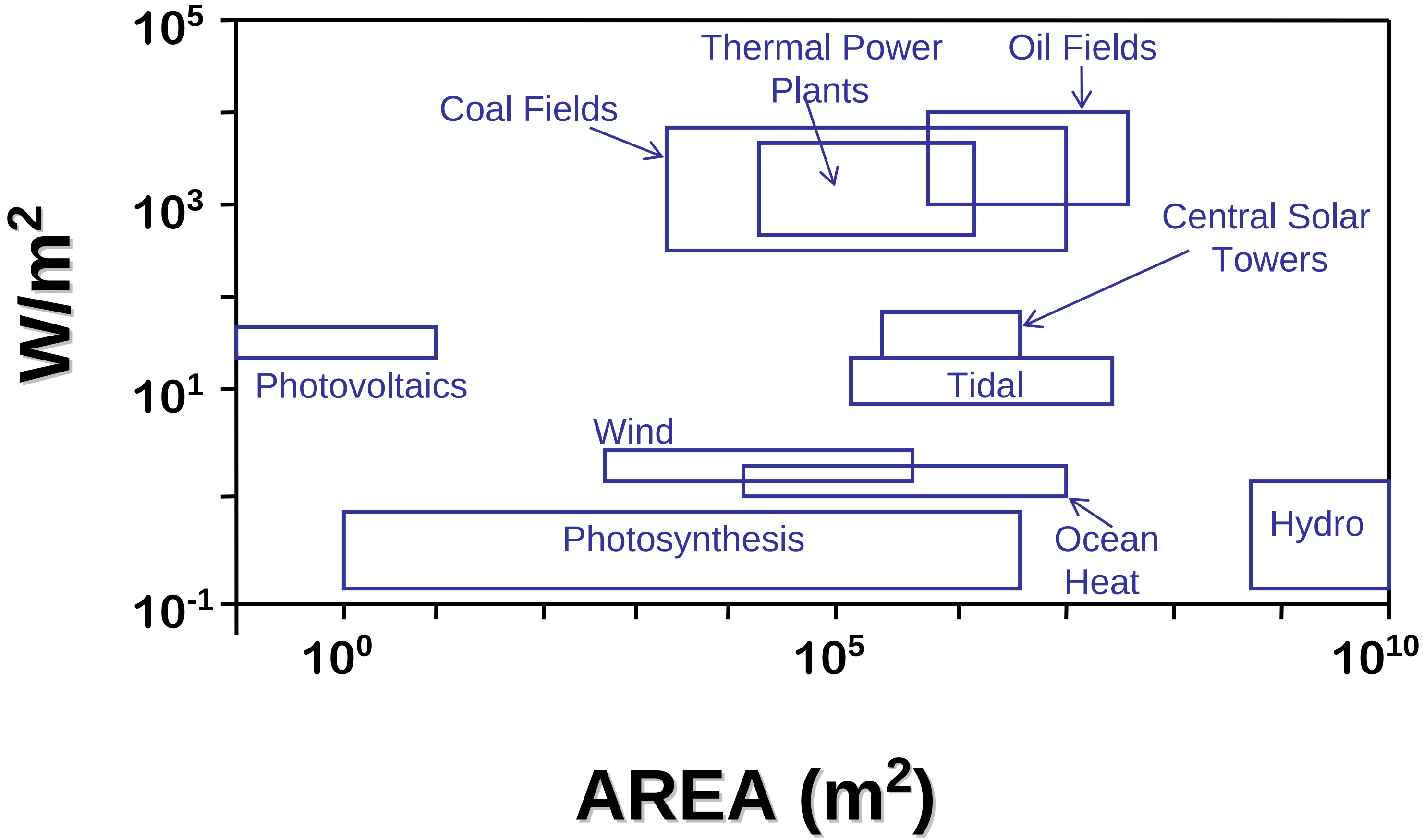


Energy Prices
(U.S. Industrial End Use Prices)

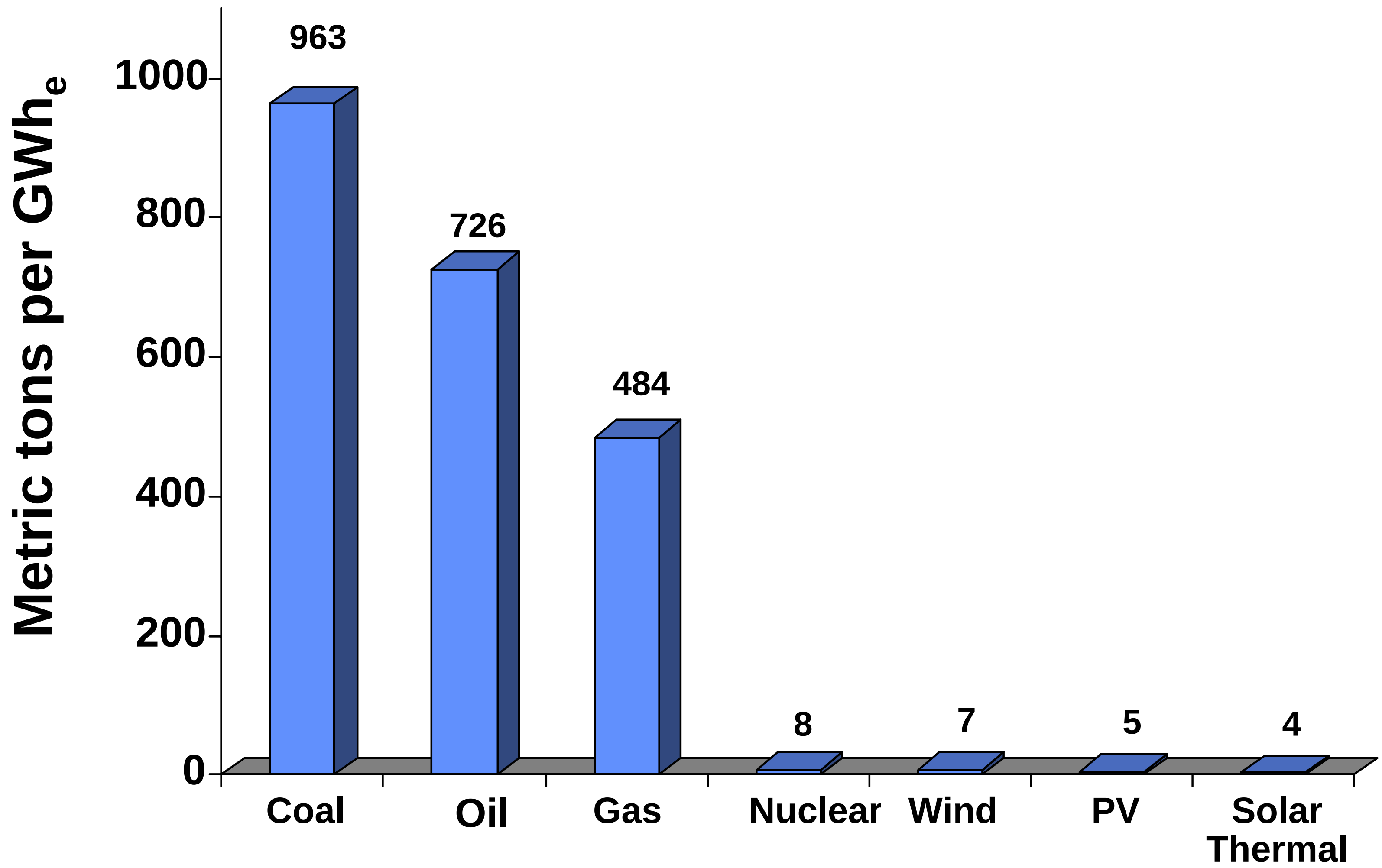


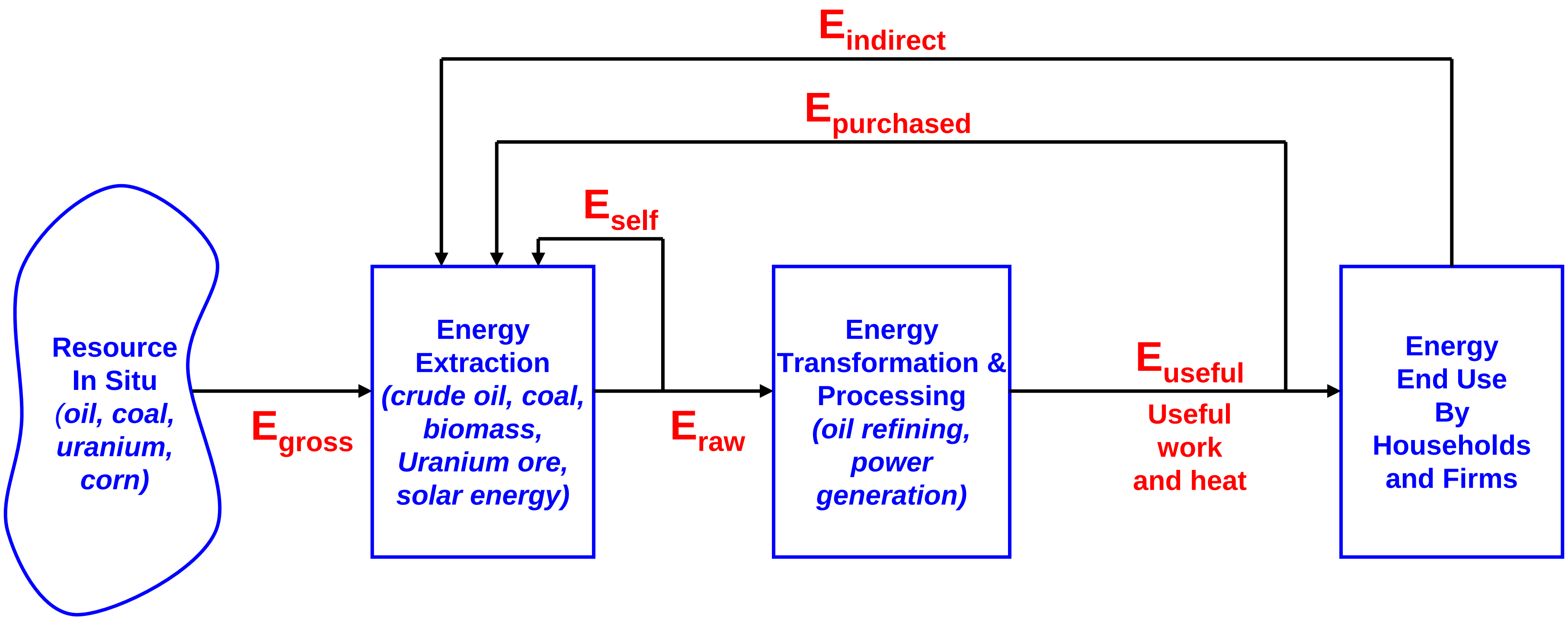
Power Densities

Source: Smil (1991)



Carbon Intensity of Power Generation

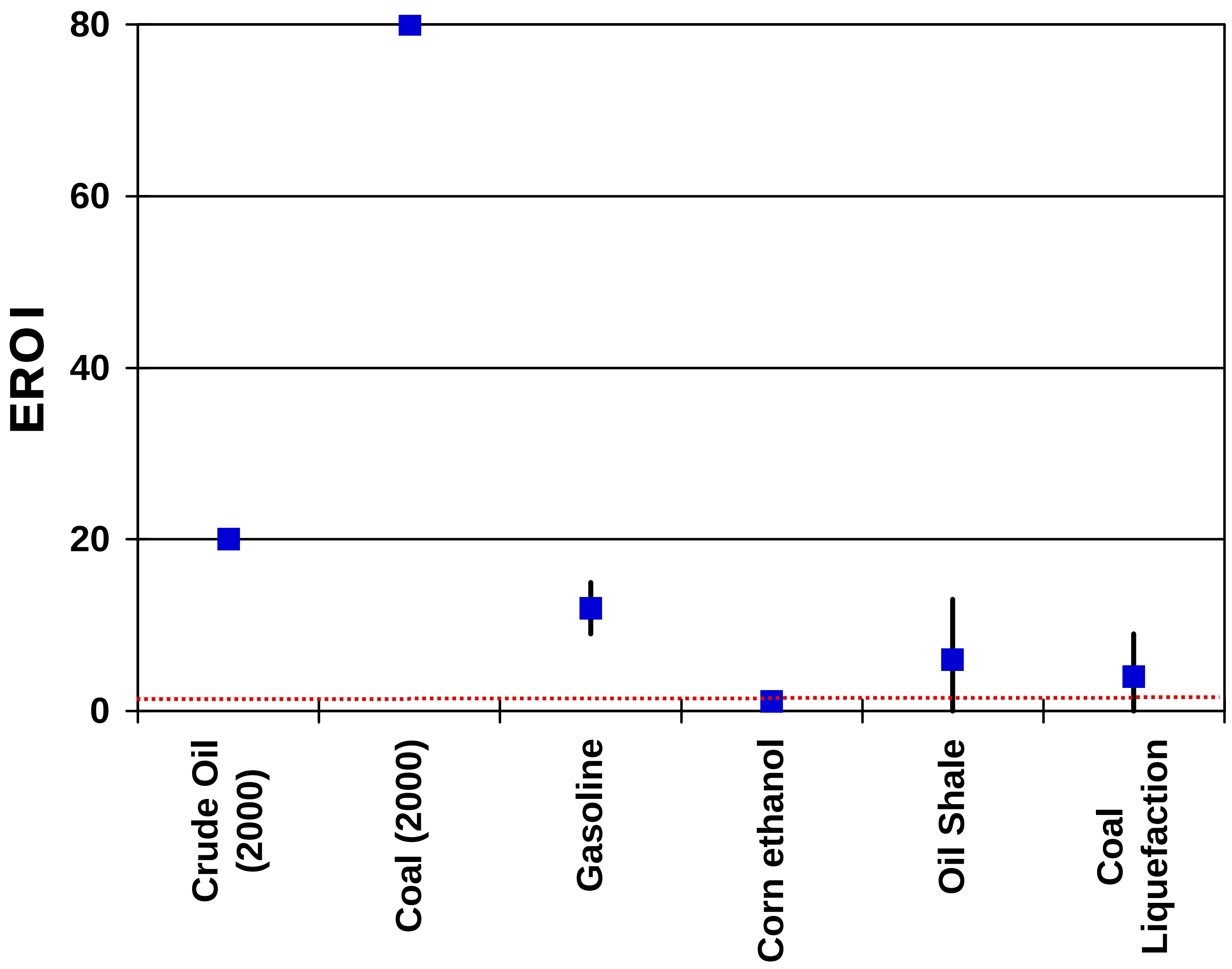




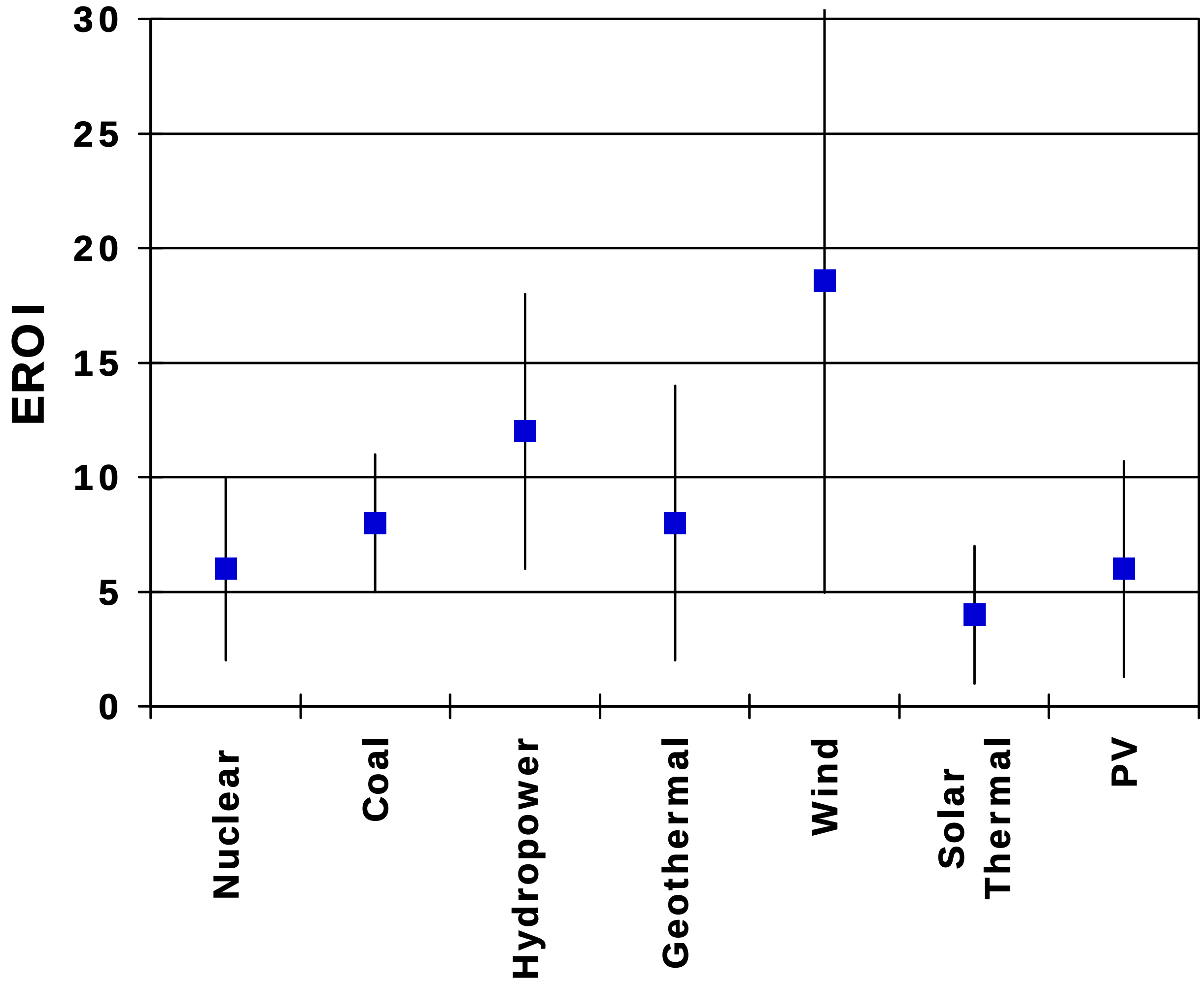
$$\text{Energy Return on Investment} = \frac{E_{useful}}{E_{self} + E_{purchased} + E_{indirect}}$$

$$\text{Energy Surplus} = E_{useful} - \frac{E_{useful}}{E_{self} + E_{purchased} + E_{indirect}}$$

EROI for Fuel Systems

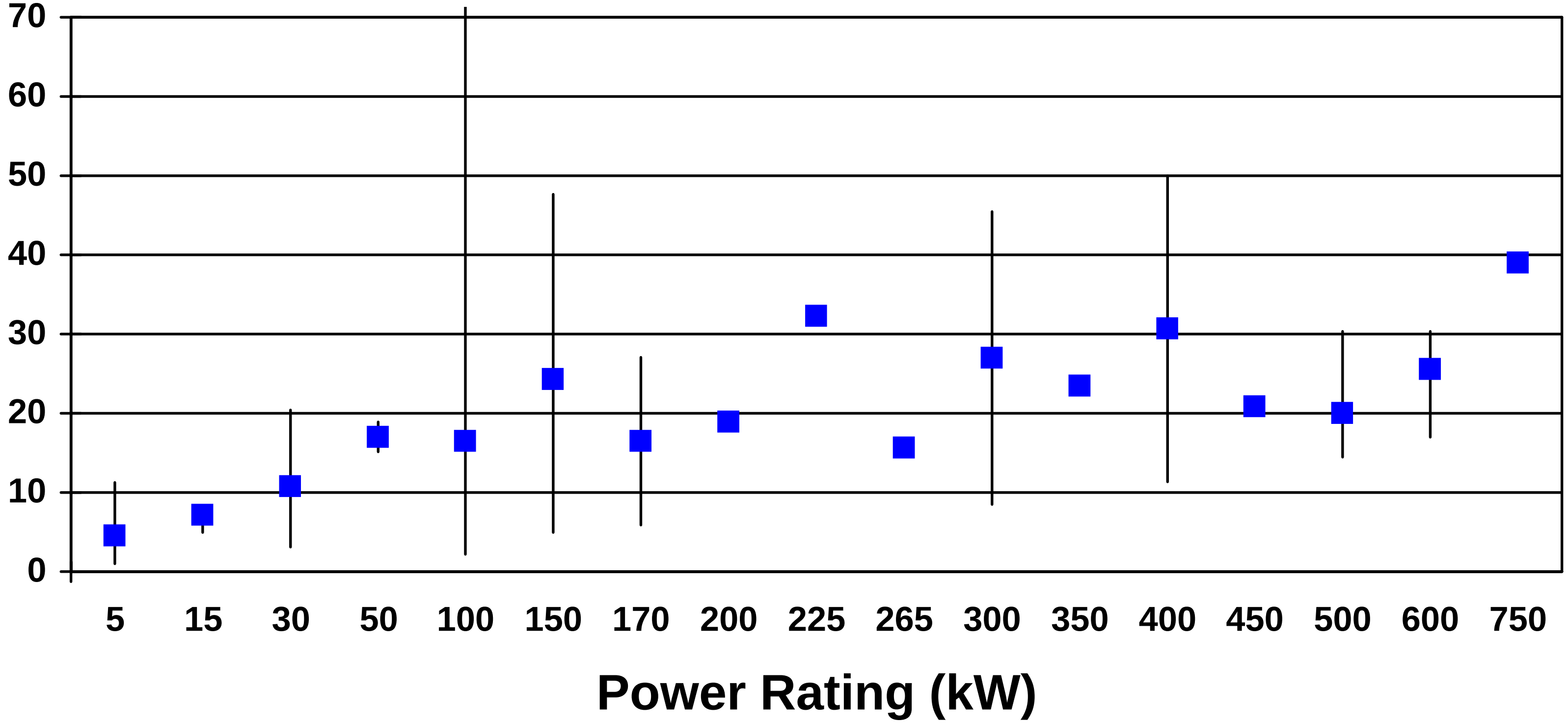


EROI for Electric Power Systems



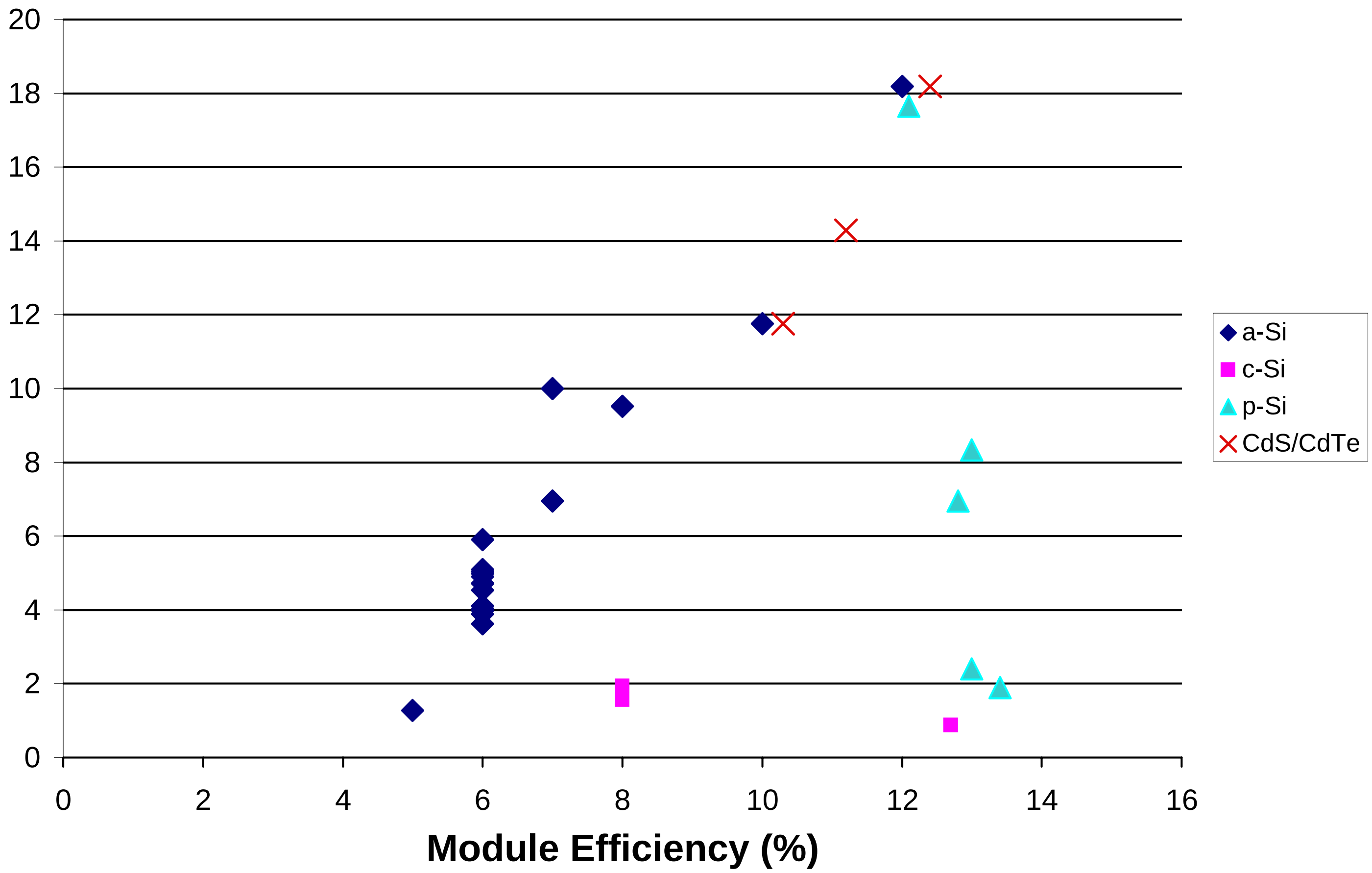
Source: Kubiszewski, Ida, Peter Endres and Cutler J. Cleveland. *A meta-analysis of the energy return on investment for conventional and alternative energy systems.* (unpublished manuscript, Center for Energy and Environmental Studies, Boston University).

EROI for Wind Power



Source: Cleveland, Cutler, Ida Kubiszewski and Peter K. Endres. 2006. "*Energy return on investment (EROI) for wind energy*." Encyclopedia of Earth. Eds. Cutler J. Cleveland. (Washington, D.C.: Environmental Information Coalition, National Council for Science and the Environment). [First published October 13, 2006; Last revised October 16, 2006; Retrieved October 27, 2006]. <**http://www.eoearth.org/article/Energy_return_on_investment_(EROI)_for_wind_energy**>

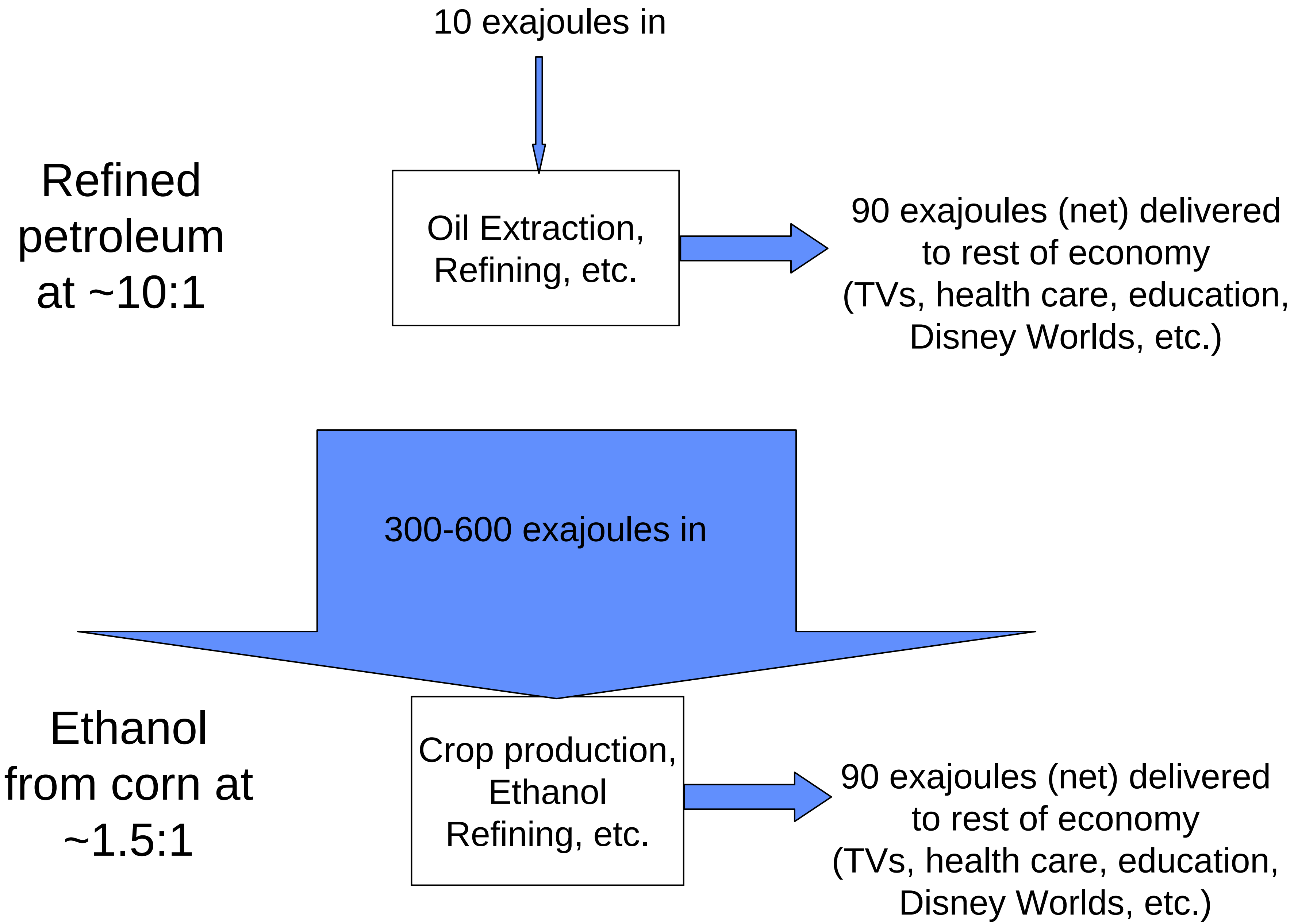
EROI for Photovoltaic Power



Source: Kubiszewski, Ida, and Cutler J. Cleveland. *A meta-analysis of the energy return on investment for conventional and alternative energy systems.* (unpublished manuscript, Center for Energy and Environmental Studies, Boston University).

Ethanol Follies

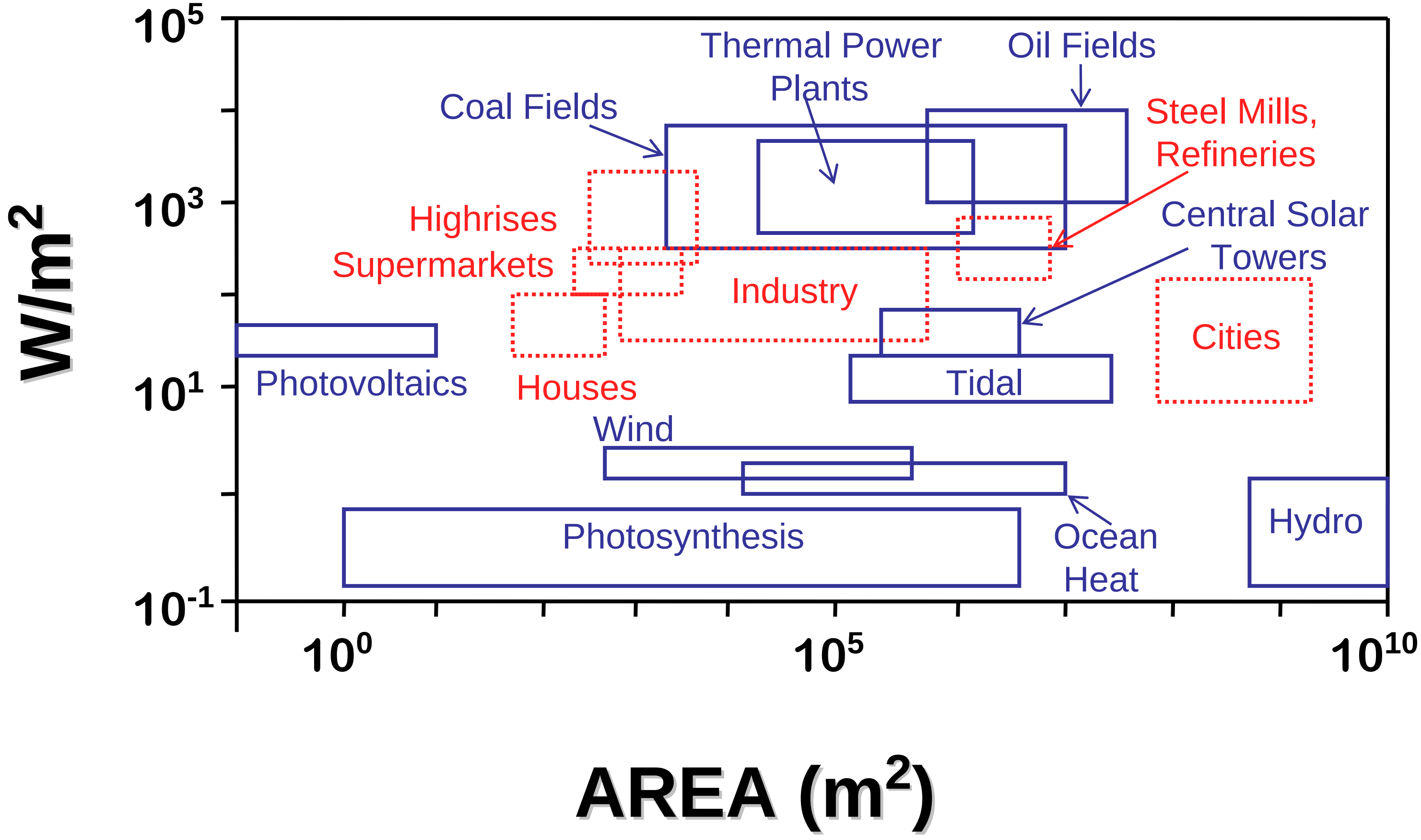
- **Energy break-even is a red herring**
- **Relevant question: What is the EROI relative to the fuel it is replacing?**



10 exajoules in
Refined petroleum at ~10:1
Oil Extraction, Refining, etc.
90 exajoules (net) delivered to rest of economy (TVs, health care, education, Disney Worlds, etc.)
300-600 exajoules in
Ethanol from corn at ~1.5:1
Crop production, Ethanol Refining, etc.
90 exajoules (net) delivered to rest of economy (TVs, health care, education, Disney Worlds, etc.)

Power Densities for Energy Sources and End Uses

Source: Smil (1991)



Conclusions

- Even in their relatively depleted states, conventional fossil fuels remain superior in most aspects of “quality”
- Oil is special (duh); peak in 10-30 years poses unique challenges
- Demand-side: the third rail of U.S. energy policy
- Market will not send socially optimal signals regarding transition

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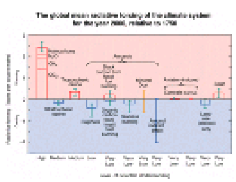
FEATURED ARTICLE: Impact of ozone on climate change



Ozone is a radiative active compound; it absorbs long-wave infrared (LWIR) radiation emitted from the Earth's surface and so contributes to the greenhouse effect. But ozone near the tropopause has a much larger influence on the radiative balance compared to ozone at surface level. Ozone absorbs infrared radiation and re-emits this radiation at an energy level equivalent to about 18° Celsius. This means that the impact of ozone at surface temperature is not very important. It is a much more effective greenhouse gas at the tropopause where temperatures of –60 to –80°C are encountered. In the Intergovernmental Panel on Climate Change (IPCC) 2000 report, the forcing (change) in the radiative balance is estimated to be about 0.3 watt/m 2 (range: 0.1 to 0.6) due to the increase of tropospheric ozone near the tropopause and a forcing of –0.1 (range: -0.05 to -0.2) watt/m 2 due to the decrease of stratospheric ozone. The total forcing from all greenhouse gases together is about 2.5 watt/m 2 (see Figure 1). There has been much discussion concerning the origin of the elevated ozone concentrations near the tropopause (see Figure 2). The process of ozone formation in the higher troposphere is, contrary to that in the stratosphere, the same as in the lower troposphere (see Figure 3). Hydrocarbons and nitrogen oxides (Nox) are involved in reactions producing ozone and other oxidants. The formation of ozone by NOx molecules is stopped by the conversion of nitrogen oxides to nitric acid. A popular hypothesis was that aircraft emissions were responsible for increased nitrogen oxide concentrations near the tropopause, leading in turn to increased ozone concentrations. Most of the emissions from airplanes are discharged at this altitude and vertical...

FEATURED AUTHOR: Joanie Kleypas

Joanie Kleypas is a marine ecologist/geologist at the National Center for Atmospheric Research with a background ranging from fish ecology to coral reef modeling. Her work concentrates on the interactions between coral reef ecosystems and climate, particularly on the large-scale environmental controls on coral reef ecosystems. Her most recent publications address how climate change will affect coral reefs and other marine ecosystems. Further Reading Coral Reefs and Global Climate Change Impacts of Ocean Acidification on Coral Reefs and Other Marine Calcifiers
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Articles written by Joanie Kleypas

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