

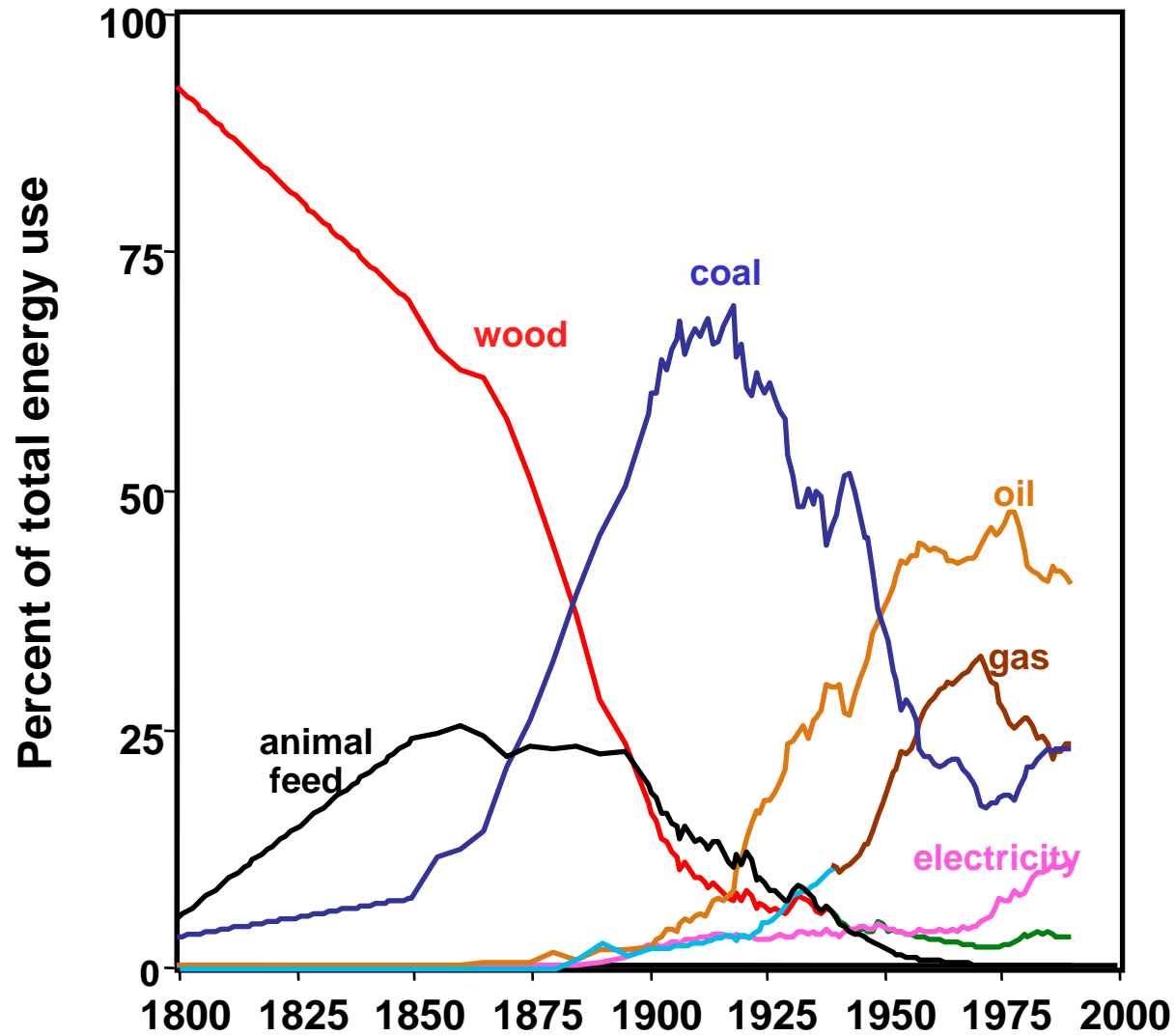
Energy Quality, Net Energy and the Coming Energy Transition

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*Peak Oil and the Environment
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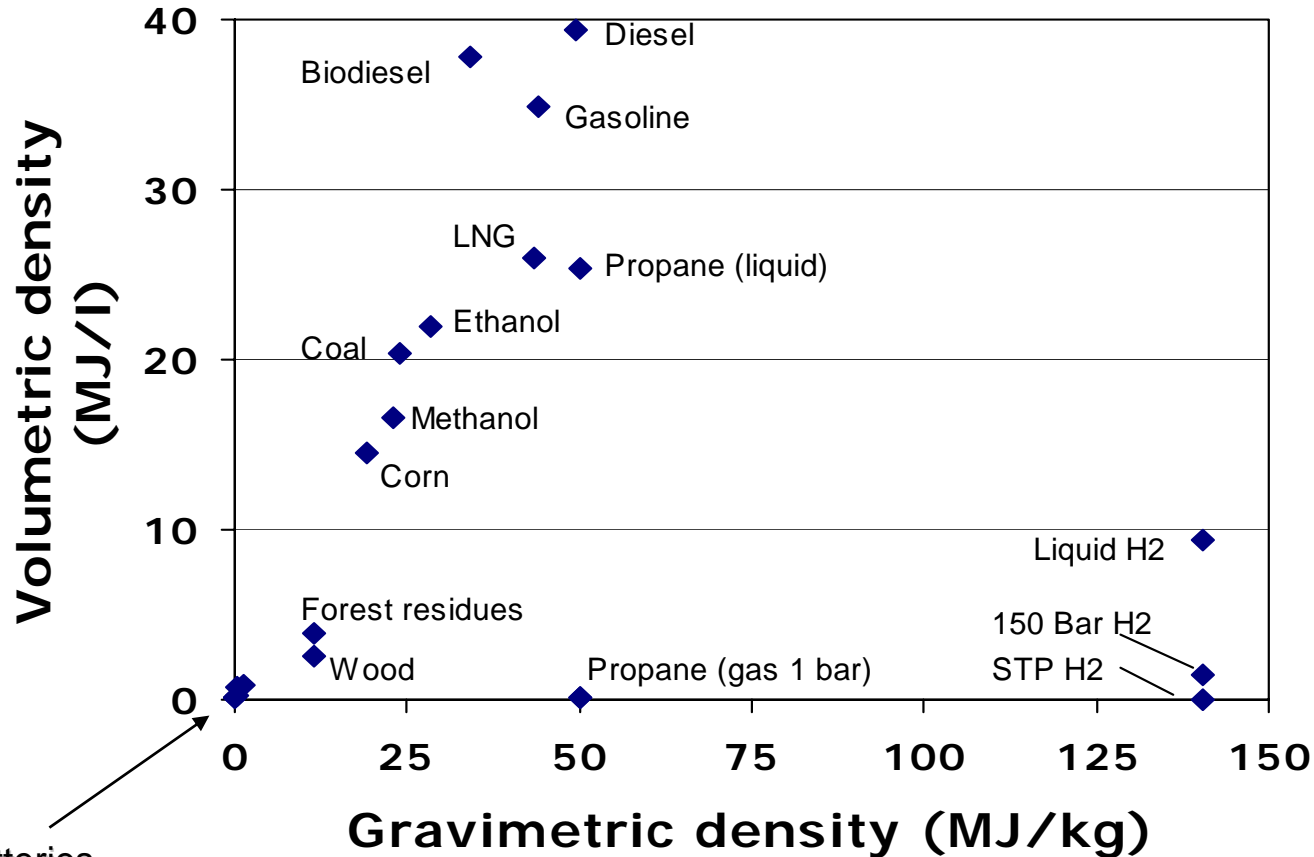
Composition of U.S. Energy Use



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**

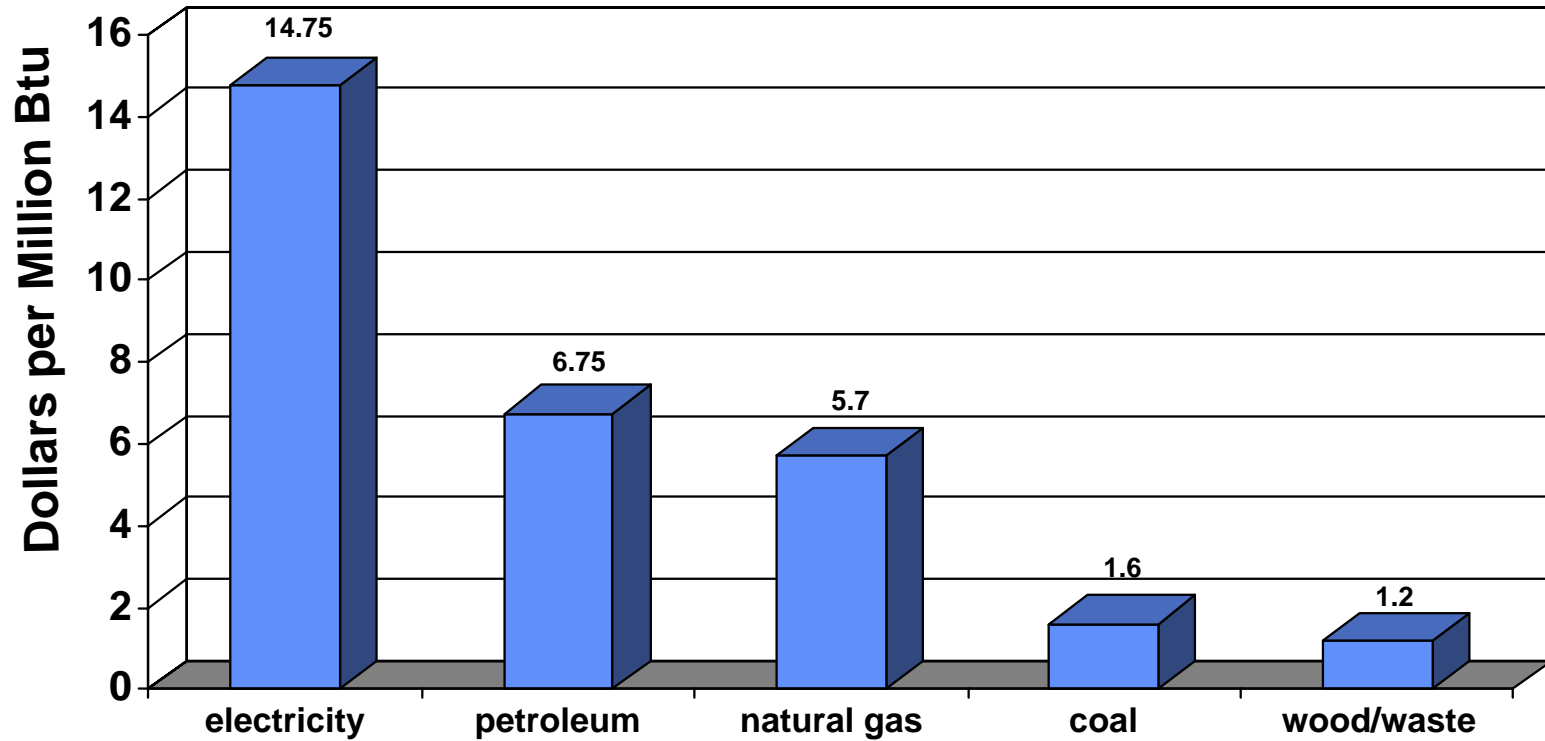
Energy Density



Most batteries
Flywheel
Compressed air
Liquid N2

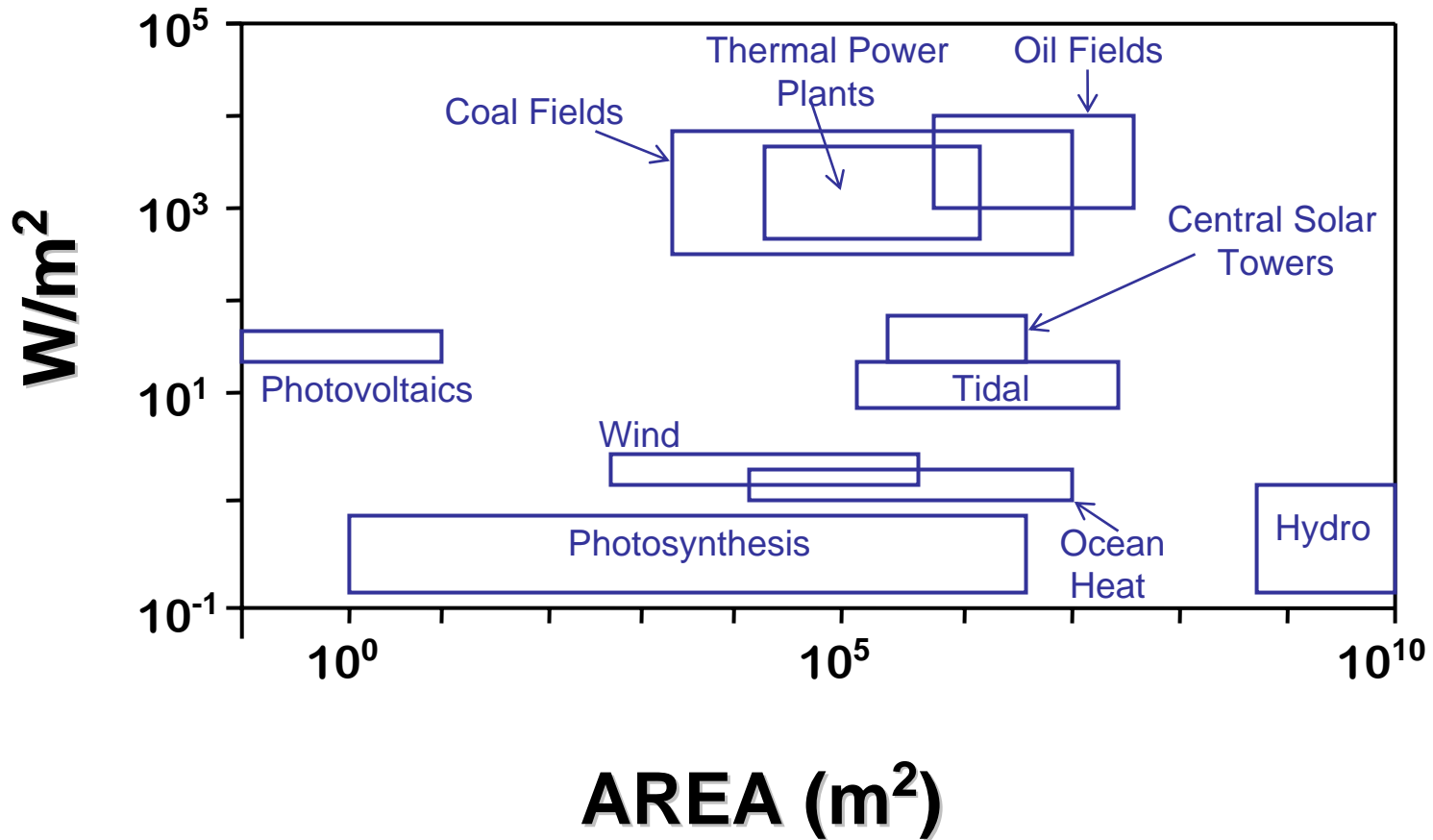
Energy Prices

(U.S. Industrial End Use Prices)

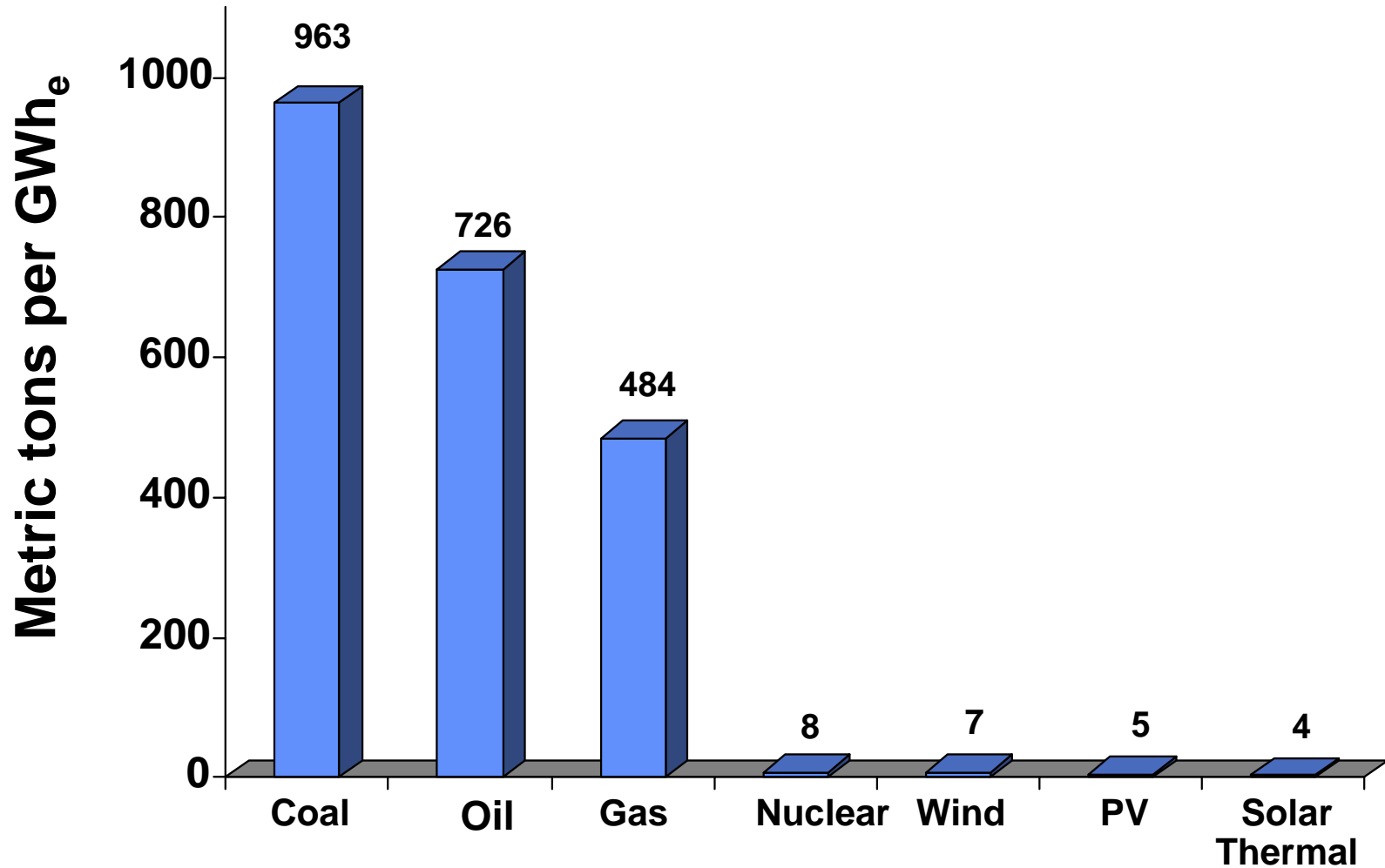


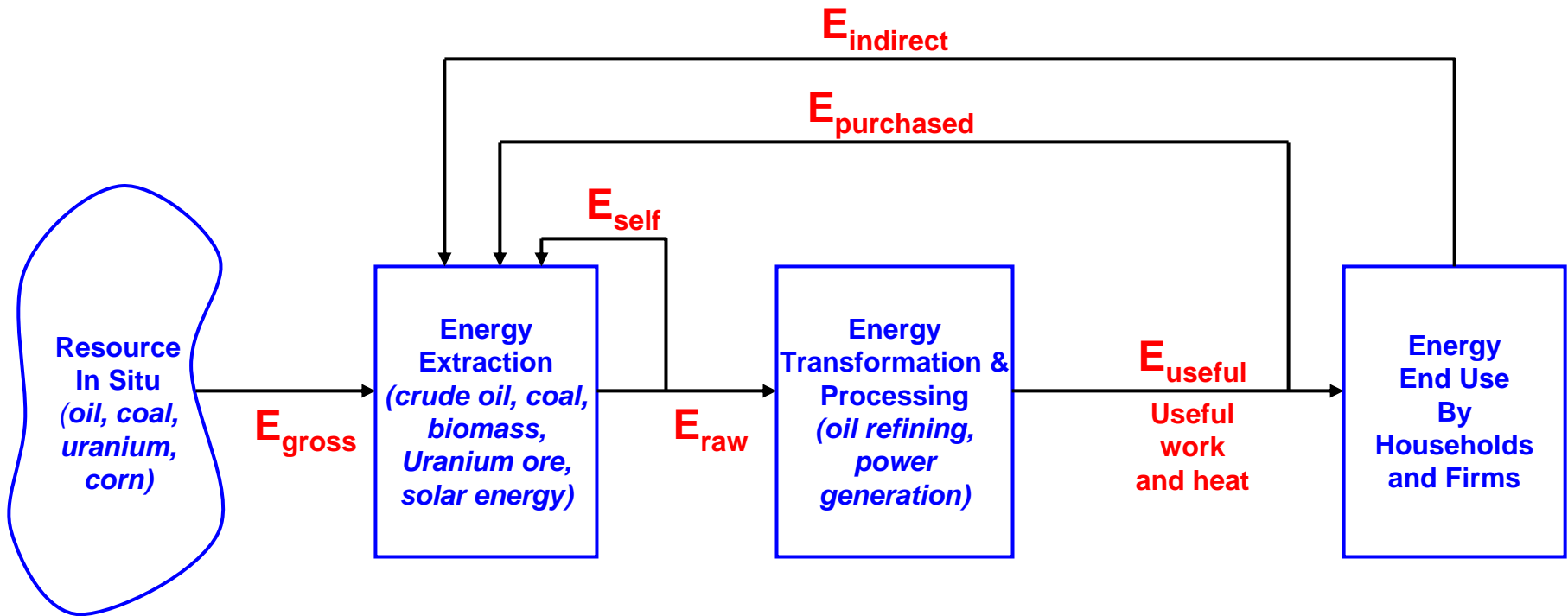
Power Densities

Source: Smil (1991)



Carbon Intensity of Power Generation

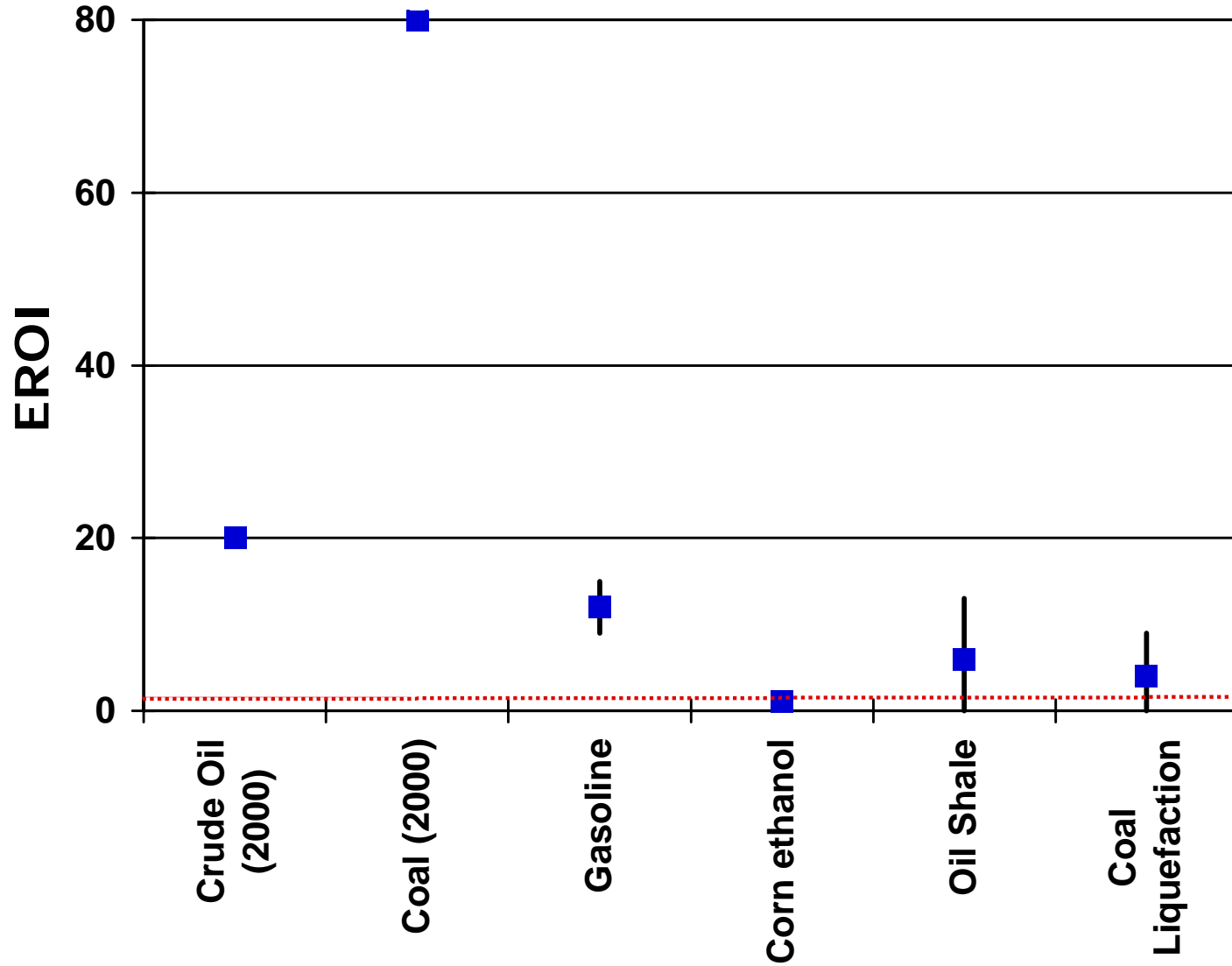




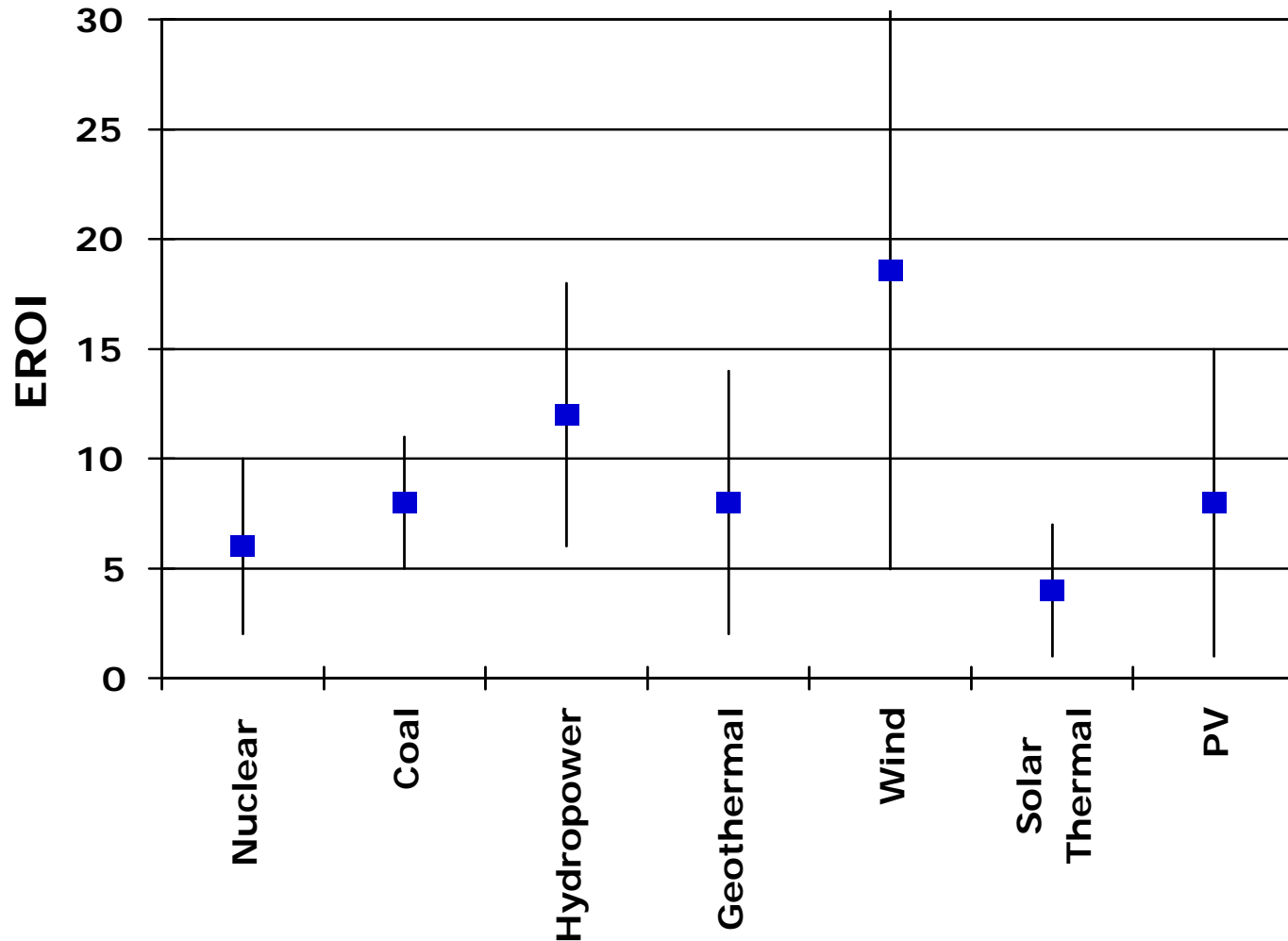
$$\text{Energy Return on Investment} = \frac{E_{useful}}{E_{self} + E_{purchased} + E_{indirect}}$$

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

EROI for Fuel Systems

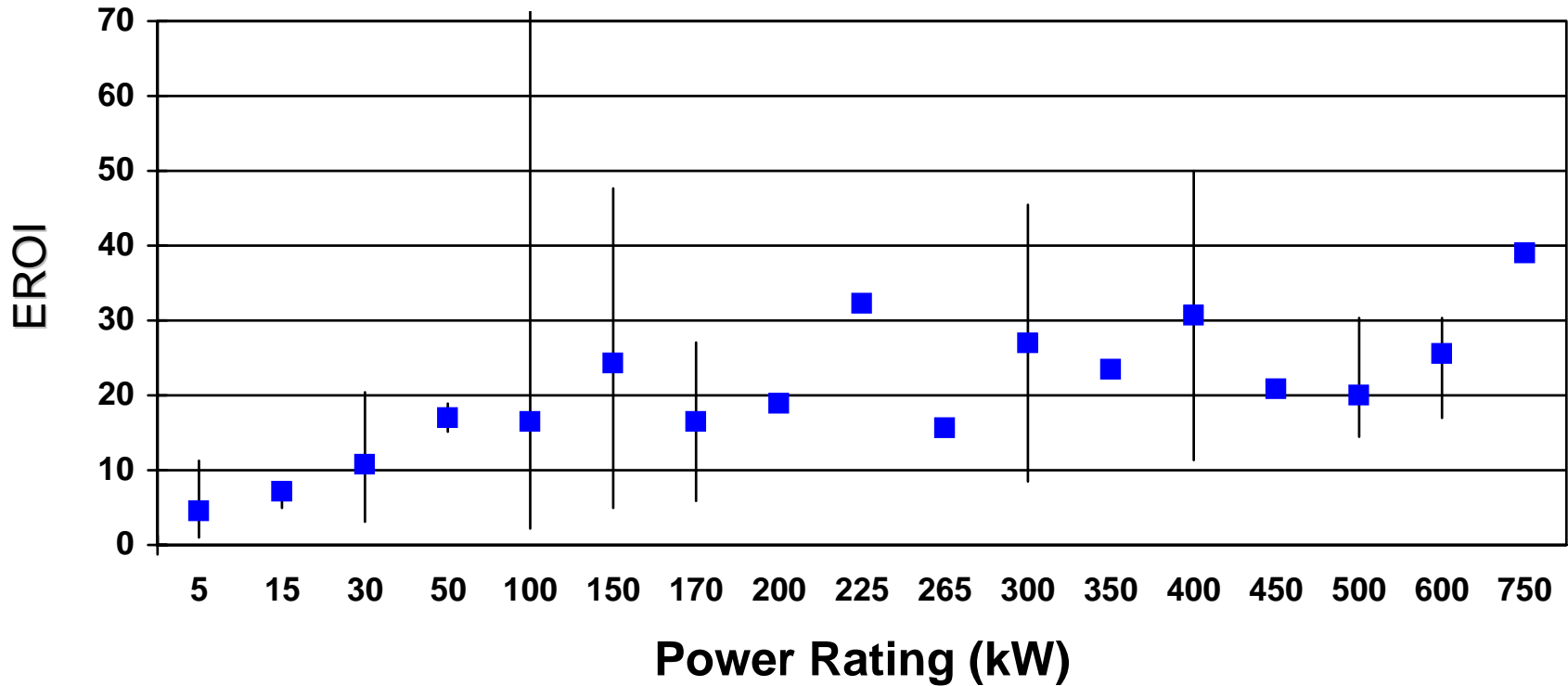


EROI for Electric Power Systems



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).

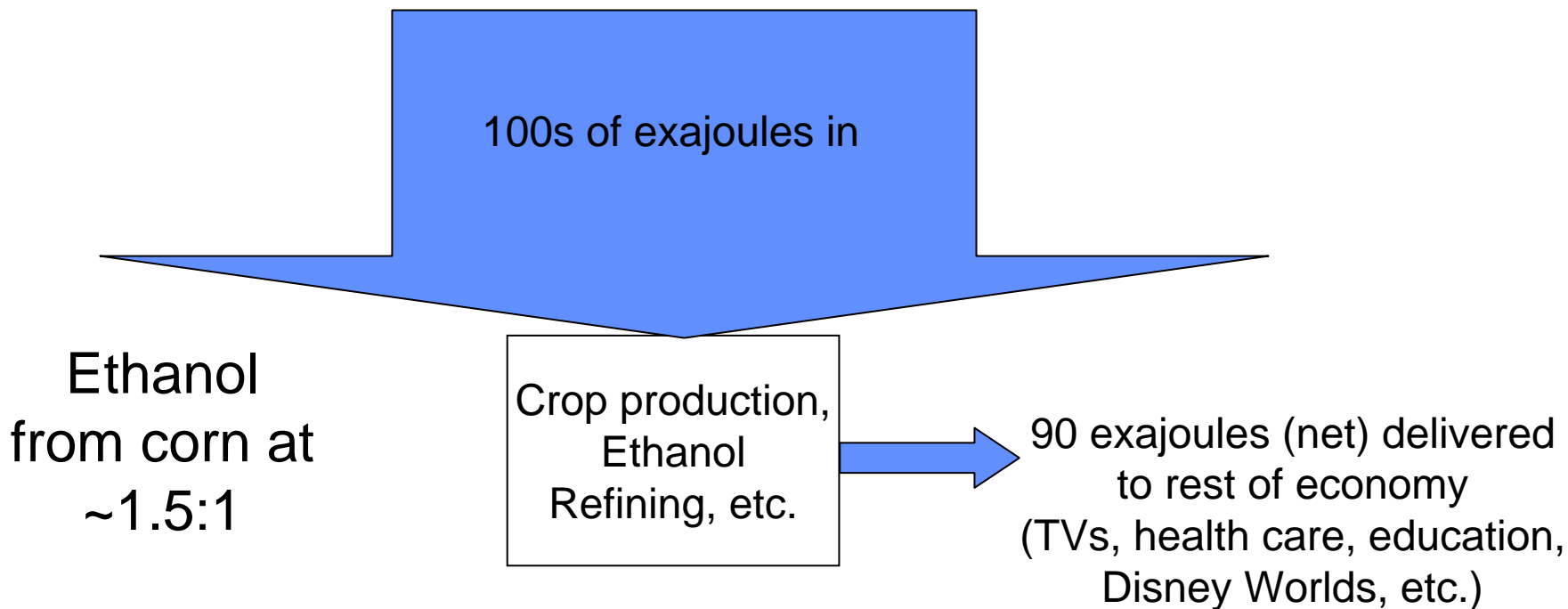
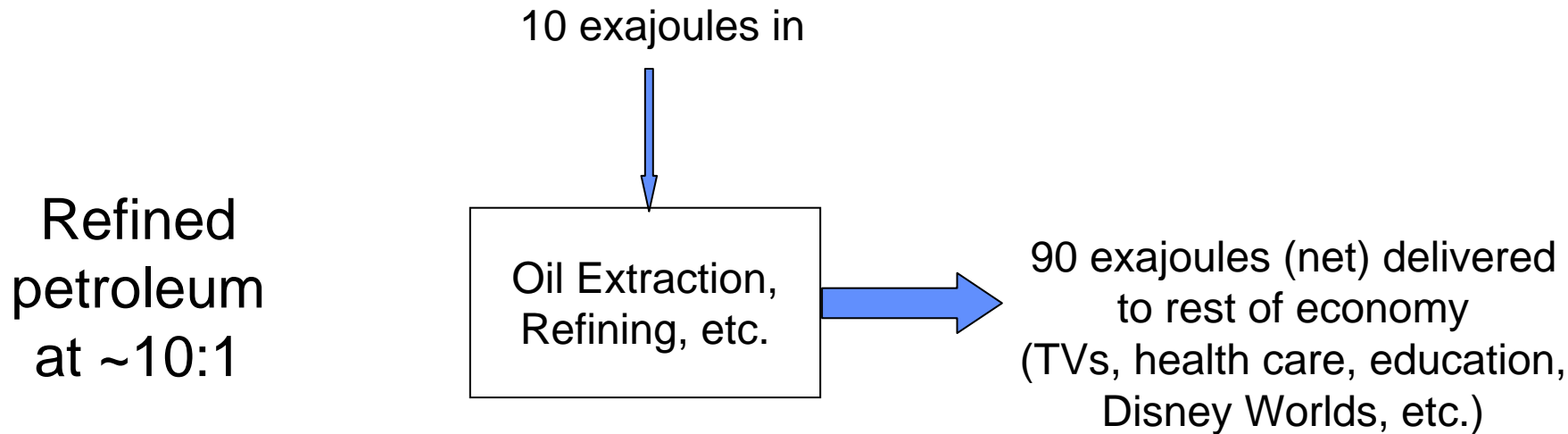
EROI for Wind Power



Source: 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).

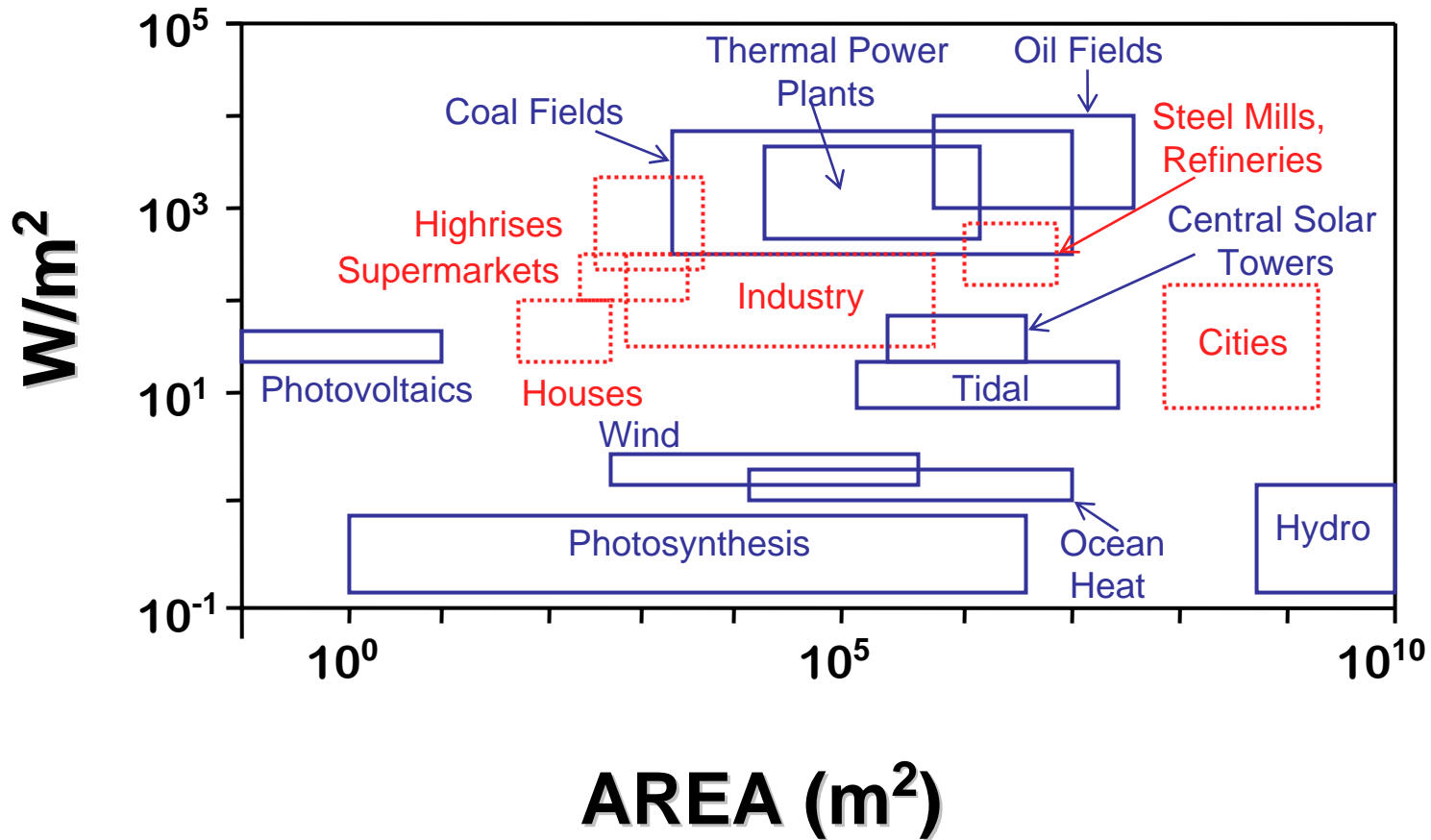
Ethanol Follies

- ◆ **Energy break-even is an irrelevant debate**
- ◆ **Relevant question: What is the EROI relative to the fuel it is replacing?**



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”**
- ◆ **We lack a unified framework and forum for the comprehensive assessment of energy systems**
- ◆ **Demand-side: the third rail of U.S. energy policy**
- ◆ **Market will not send socially optimal signals regarding transition**



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