

Energy 101: Ten Things Everyone Should Know About Energy

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The List

1. Energy cannot be created, destroyed or recycled.
2. Energy from the sun--past and present--create the conditions necessary for life to exist.
3. The climate of Earth is determined by the balance between energy entering and leaving the atmosphere.
4. Natural selection operates on evolutionary strategies that capture and allocate energy among competing uses.
5. Energy transitions are social transitions.

The List

6. Energy and economic well-being go hand-in-hand.
7. Struggle for the control of energy generates violent conflict.
8. Energy is a fundamental driver of environmental change and human health at local, regional, and global scales.
9. Energy quality varies markedly among sources.
10. Net energy is an ultimate limit to energy supply.

Principle #1: Energy Cannot be Created, Destroyed or Recycled

- First Law: Conservation of energy
- Second Law
 - Energy conversion $< 100\%$ efficient
 - Entropy
 - Direction to energy conversion

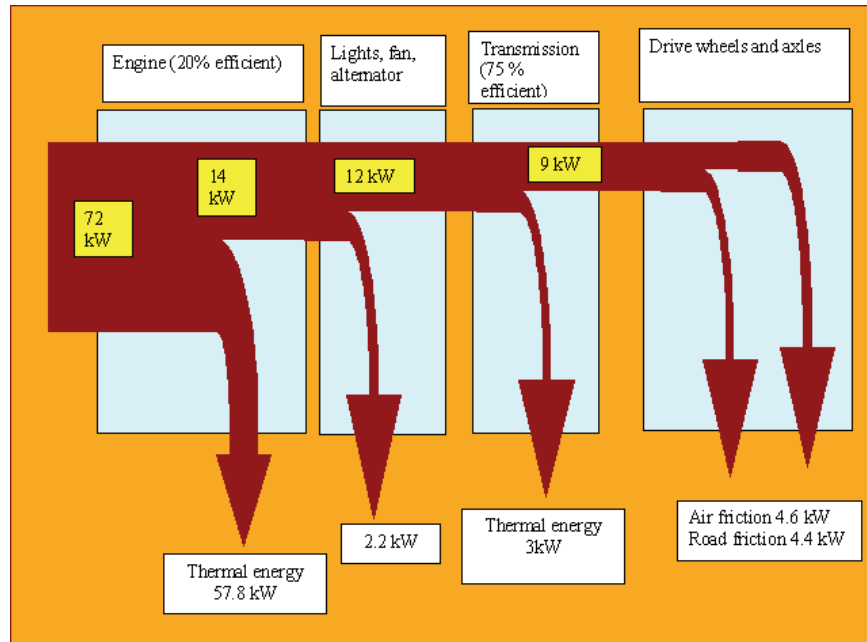


Rudolph Clausius (1822-1888)



Sadi Carnot (1796-1832)

Second Law

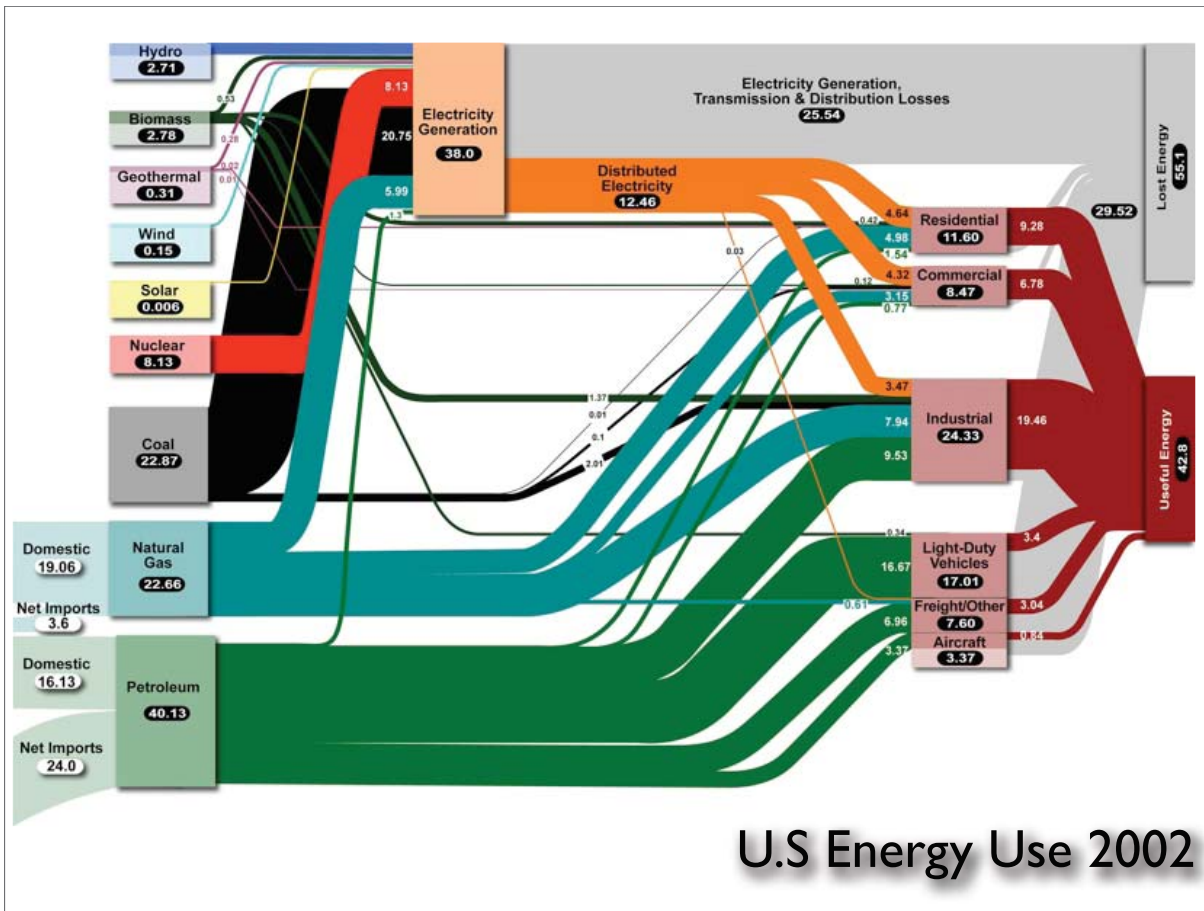


Entropy

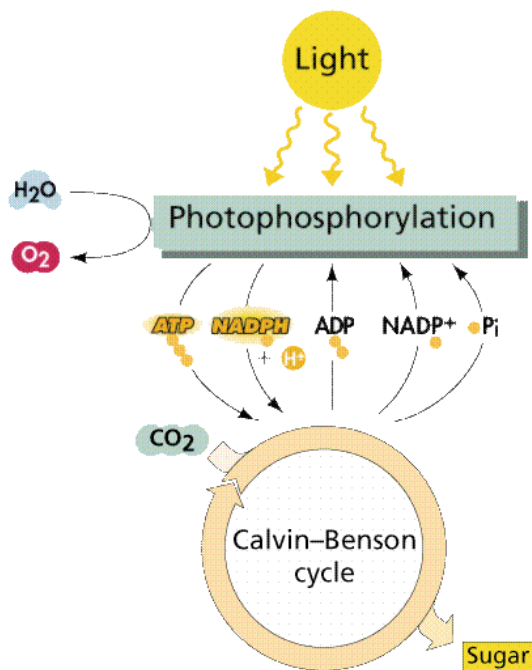
- Universal tendency towards disorder



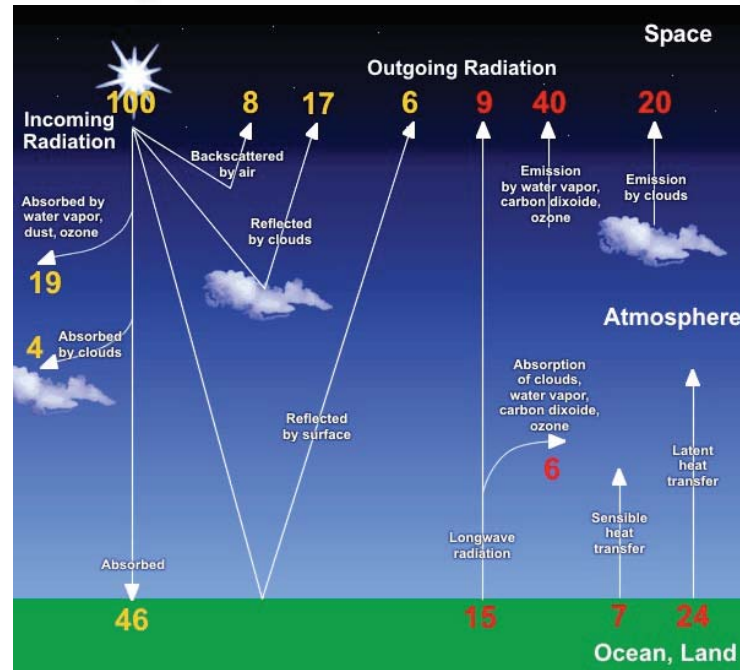
- Directionality to energy conversion processes



Principle #2: Solar Energy and Life



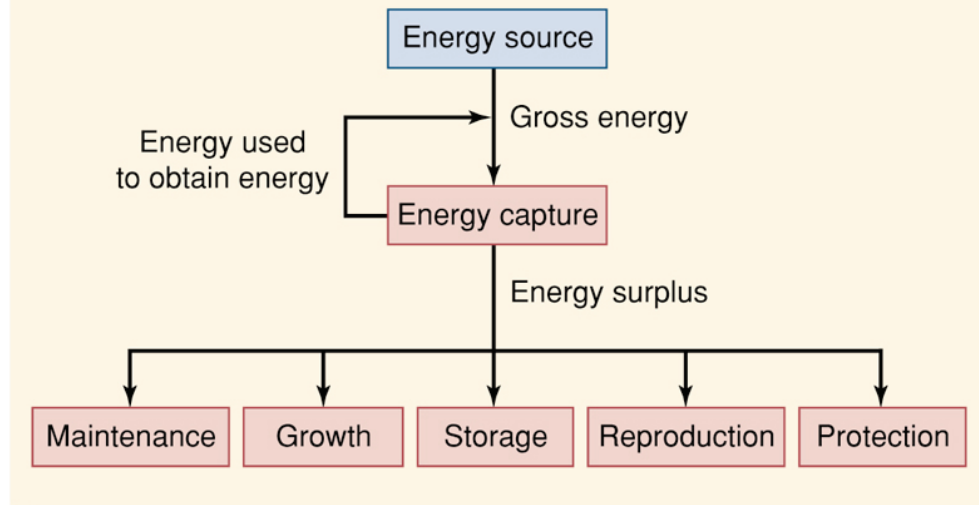
Principle #3: Climate and Energy



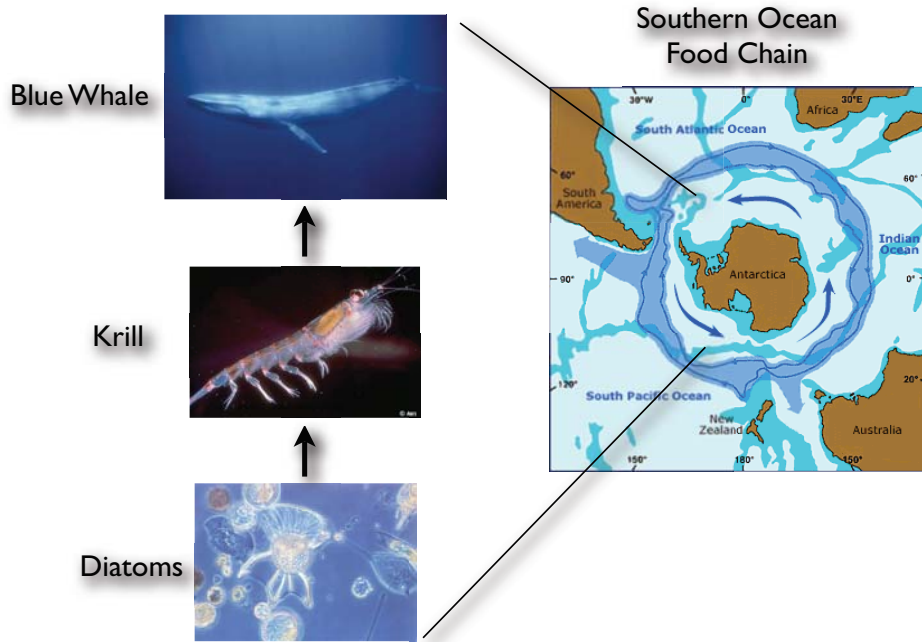
Principle #4: Energy and Evolution

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$$\text{Energy return on investment} = \frac{\text{Gross energy}}{\text{Energy used to obtain energy}}$$

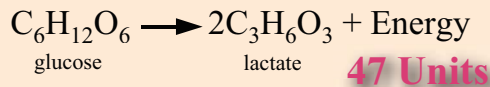


Principle #4: Energy and Evolution

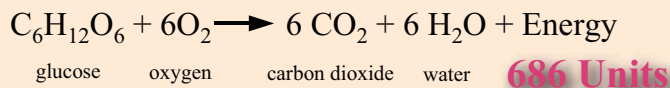


Principle #4: Energy and Evolution

Why Breathe Oxygen?



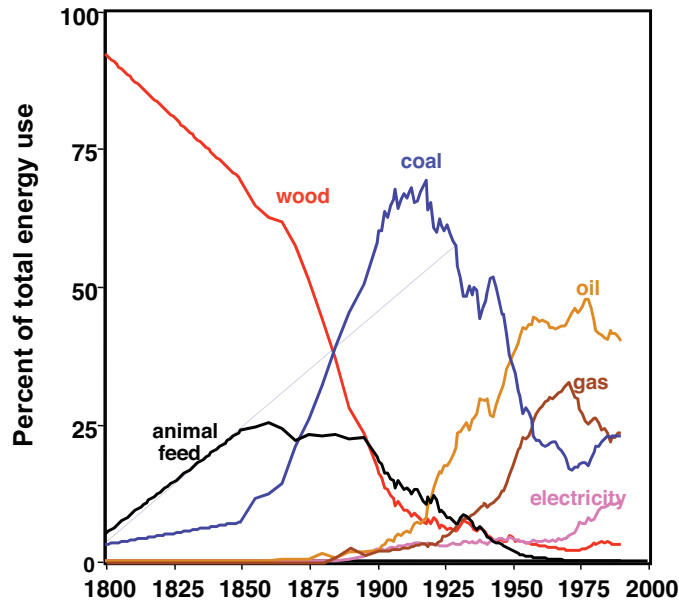
Anaerobic pathway



Aerobic pathway

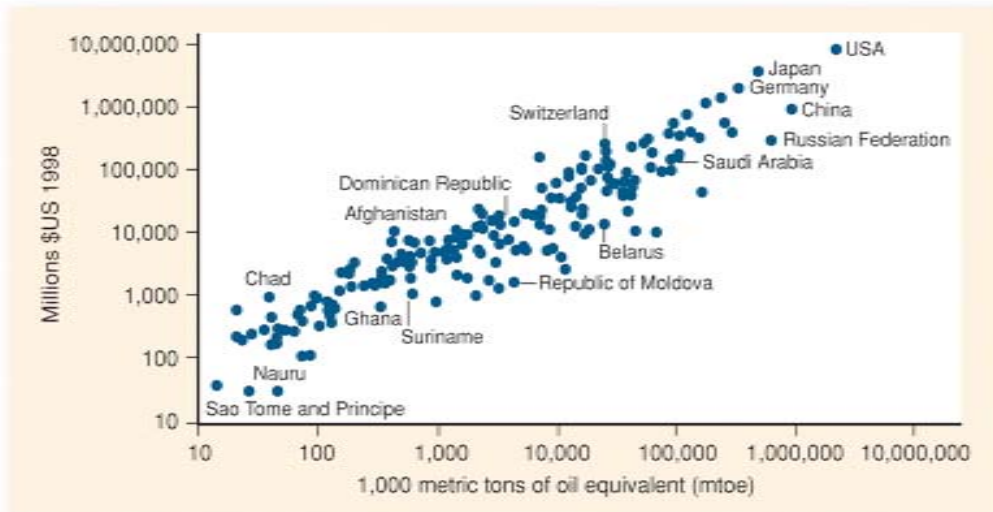


Principle #5: Energy Transitions Are Social Transitions

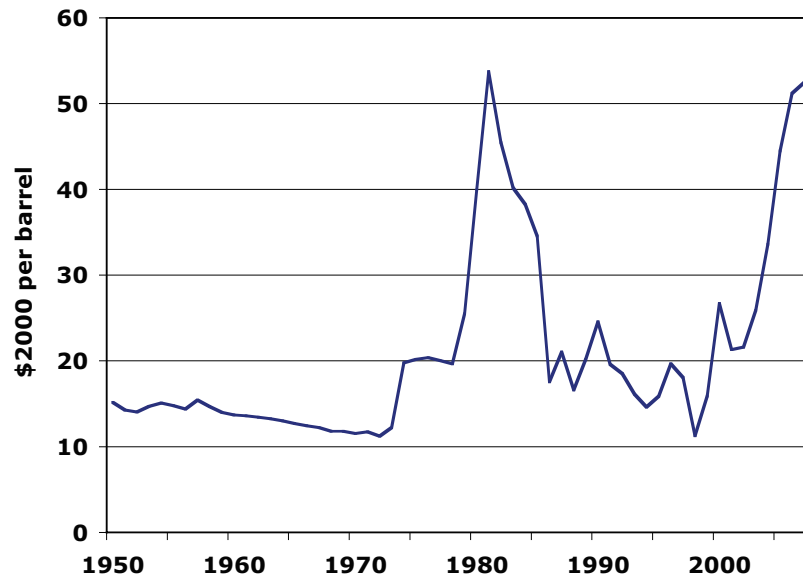


Principle #6: Energy & Economic Growth

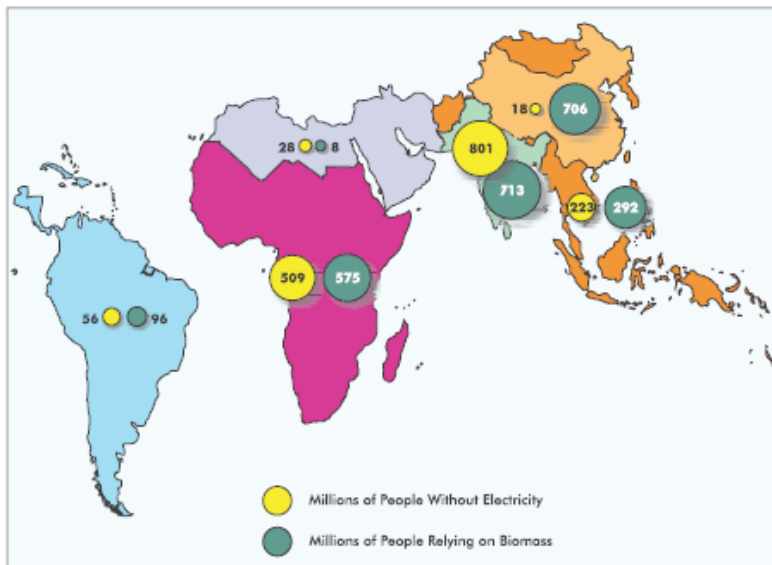
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Crude Oil Prices, 1950-2007



Energy and Well-Being



Source: IEA analysis.

Principle #7: Energy and Conflict

Access to sufficient amounts and types of energy is a central strategic, economic and political goal for nations:

- land (ability to fuel people and animals)
- timber
- hydropower
- coal
- oil and gas

Energy and Conflict: “Spar” Timber



Energy and Conflict: Oil

- World War I: Armenian and British forces defend Baku oil fields for Russia against German and Turkish invaders
- World War II:
 - oil is central to the execution and strategy of war
 - Japan invades oil-rich Indonesian islands after U.S. export embargo
 - Germany invades USSR to gain possession of Russian oil fields in Caucasus mountains

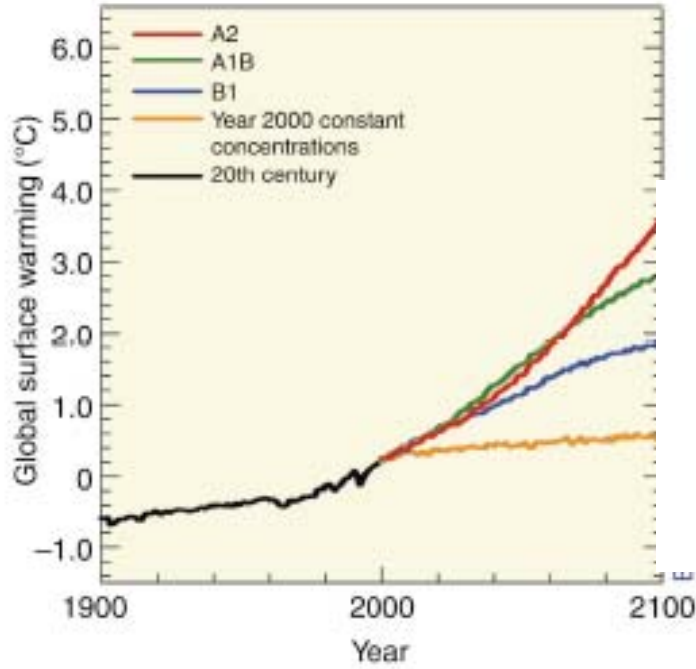


Energy and Conflict: Oil

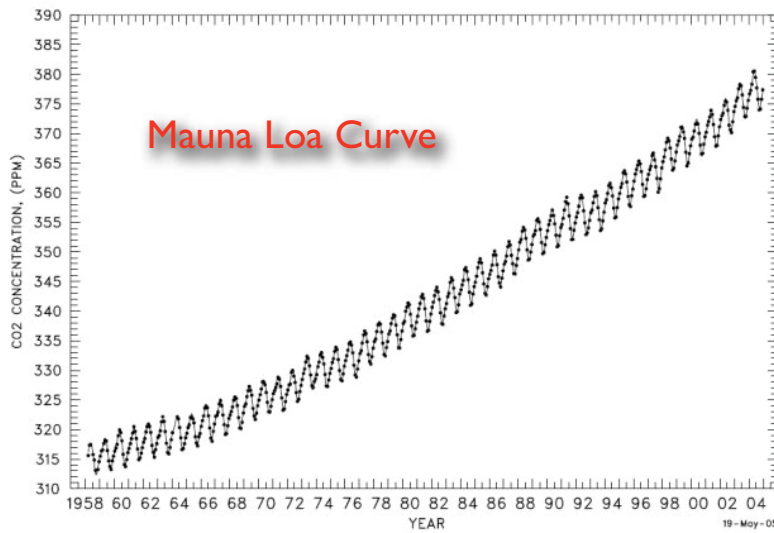
- U.S. and Britain orchestrate 1953 overthrow of Prime Minister Mohammed Mossadegh of Iran
- Gulf War erupts after Iraq invades Kuwait and seizes control of its oil fields
- In Nigeria, armed ethnic militias and government forces vie for spoils of oil rich Niger delta



Principle #8: Energy and Environmental/ Human Health



Energy & Climate Change



Energy and Human Health

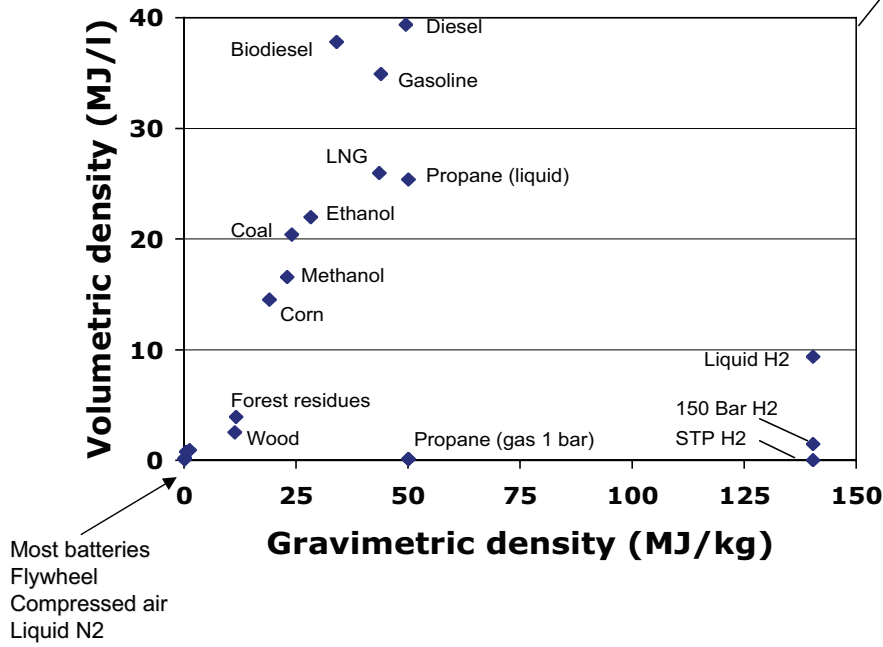


Principle #9: Energy Quality

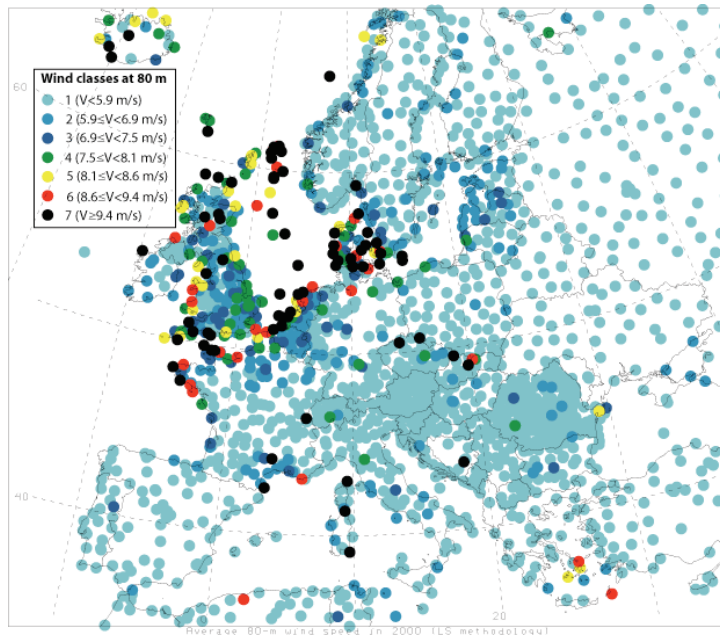
- The economic usefulness of a heat unit of fuel or electricity:
 - How much GDP can 1 joule produce? •
- What determines energy quality?
 - cost
 - weight
 - density
 - safety
 - amenability to storage
 - heat content
 - pollution intensity
 - conversion efficiency
 - ease of transport
 - intermittency
 - spatial distribution

Energy Quality: Density

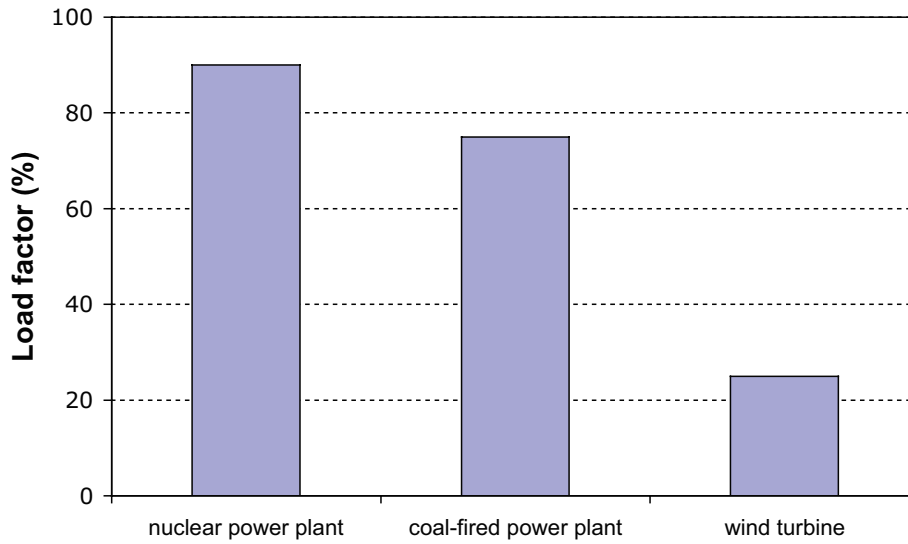
Nuclear fission of U-235:
 90,000,000 MJ/kg
 1,700,000,000 MJ/l



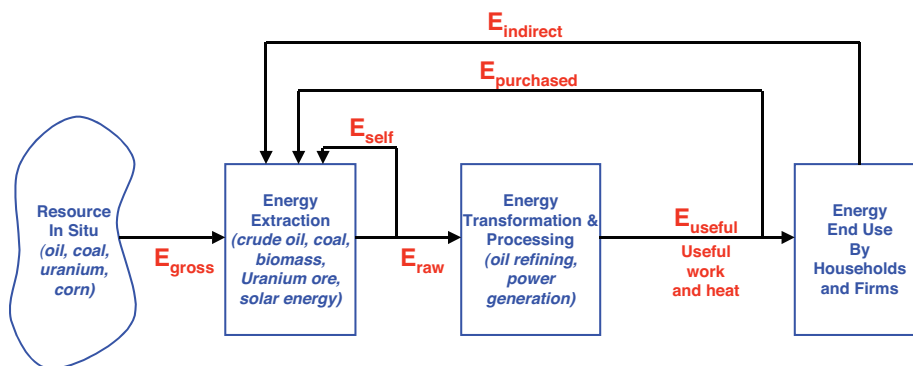
Energy Quality: Spatial Distribution



Energy Quality: Intermittency



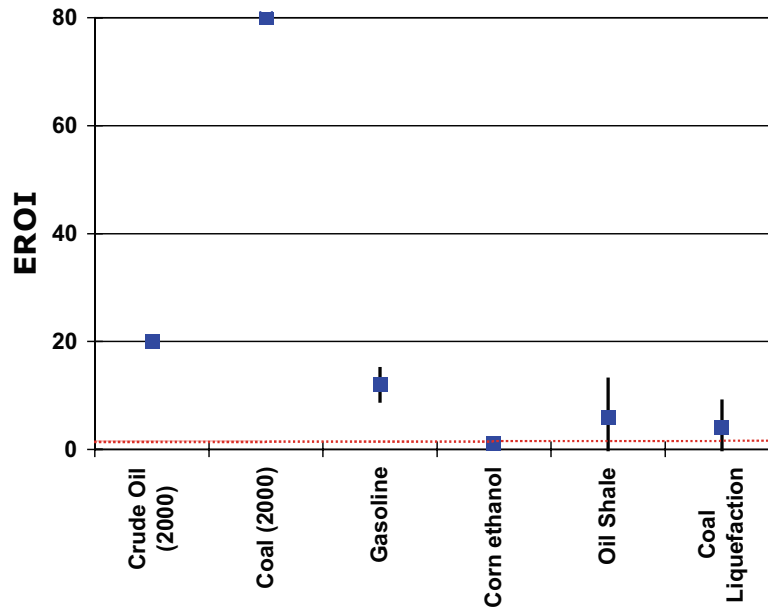
Principle #10: Net Energy is Ultimate Limit



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

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

EROI for Fuel Systems



Concluding Thoughts

- Attributes of future energy systems will constrain future economic and social aspirations
- The struggle for the control of remaining supplies of oil will intensify
- Carbon issue may trump everything