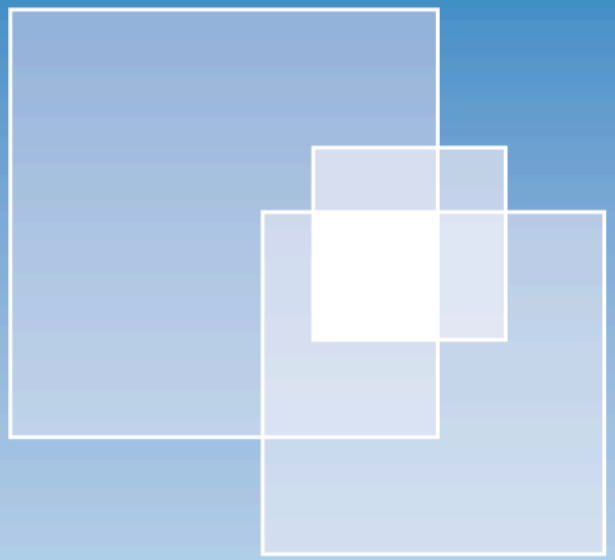

CEEDATA

energy analysis

Future energy supply, a physical view

Bunschoten, 11 September 2008

J.W. Storm van Leeuwen

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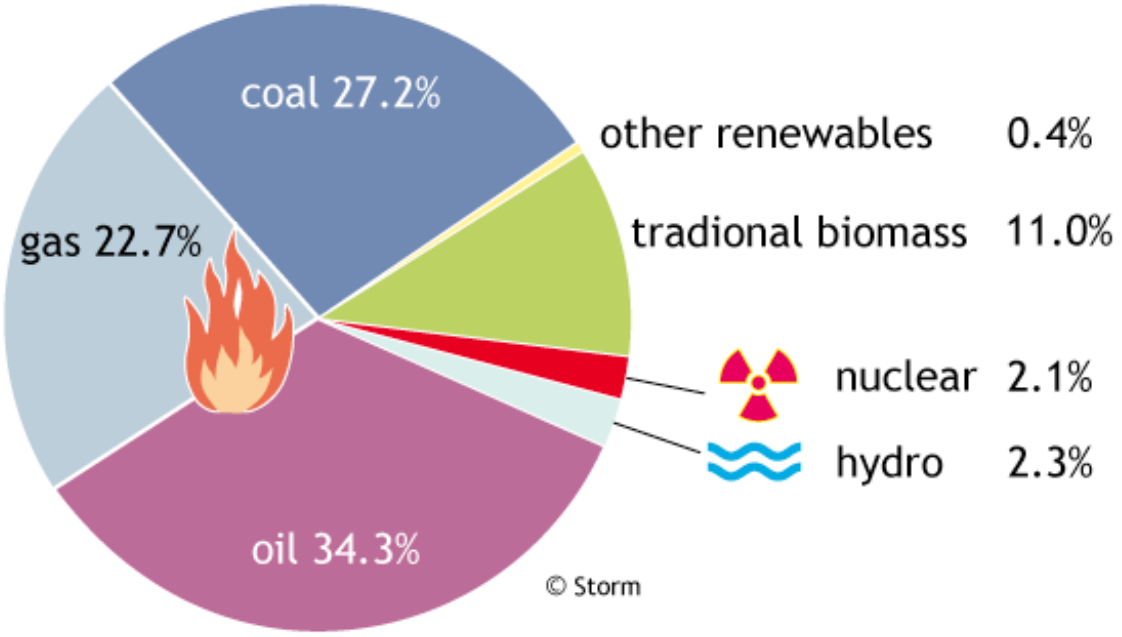
outline

- current world energy supply
- quantity and quality
  - basic notions: ecosphere and Second Law
  - free energy generation
  - entropy in the biosphere
- future energy supply, the only way out
  - sun-based energy systems
  - energy services
- Flamco's question
- some trends

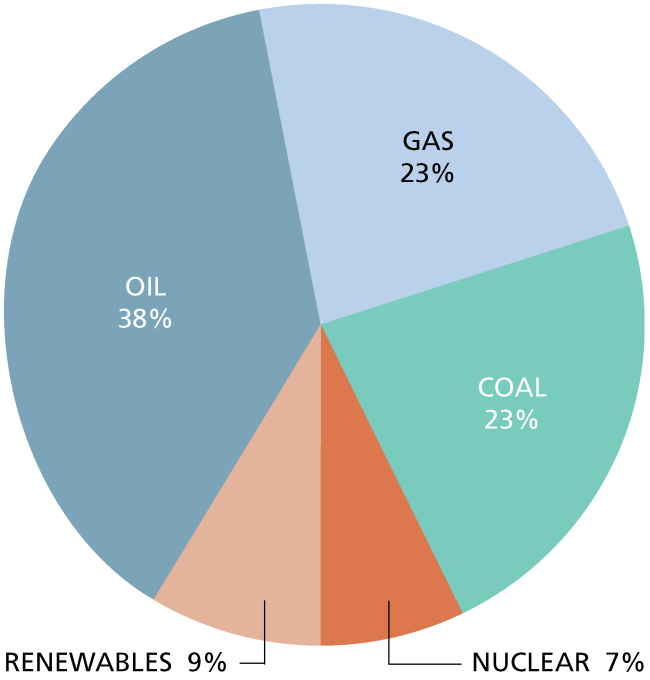
world energy supply 2006



world energy consumption in 2006: ~476 EJ

traded energy: 422 EJ

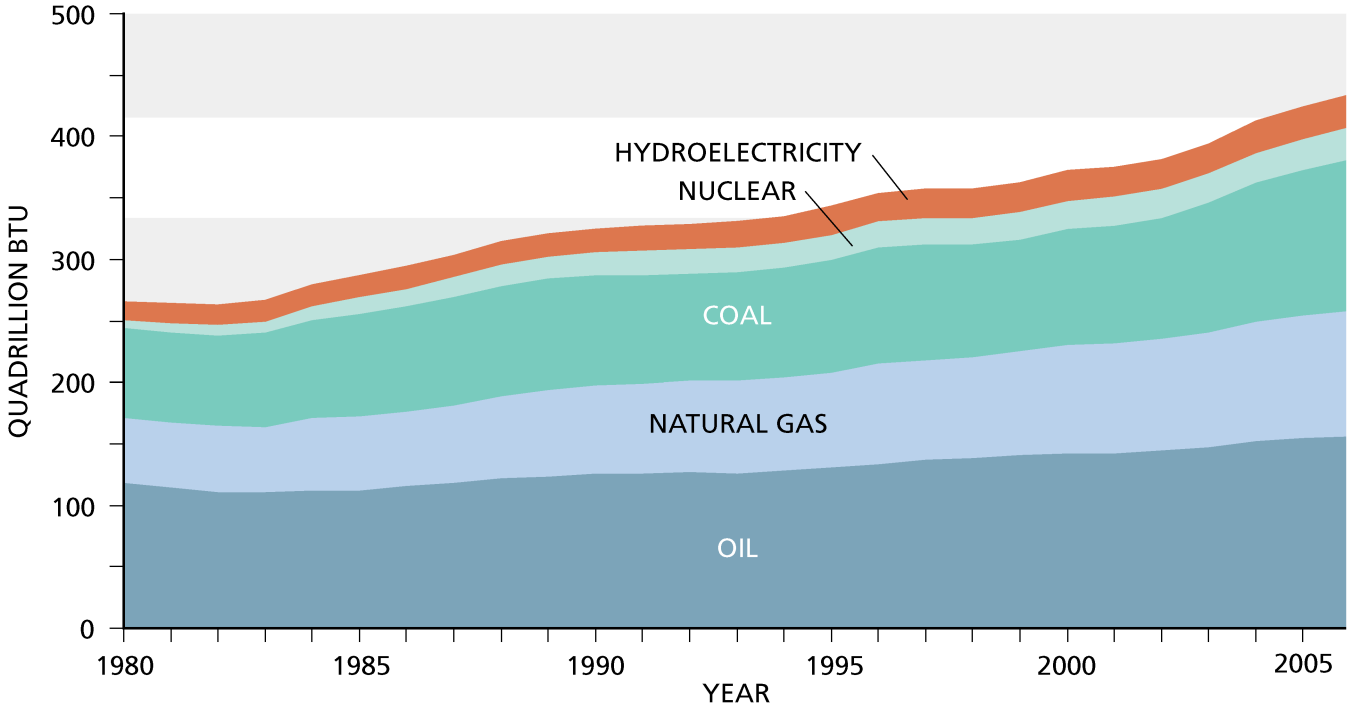
traded primary energy



Source: International Energy Agency, *World Energy Outlook 2006.*

FIGURE 2-10. *Global Energy Consumption Shares in 2005*

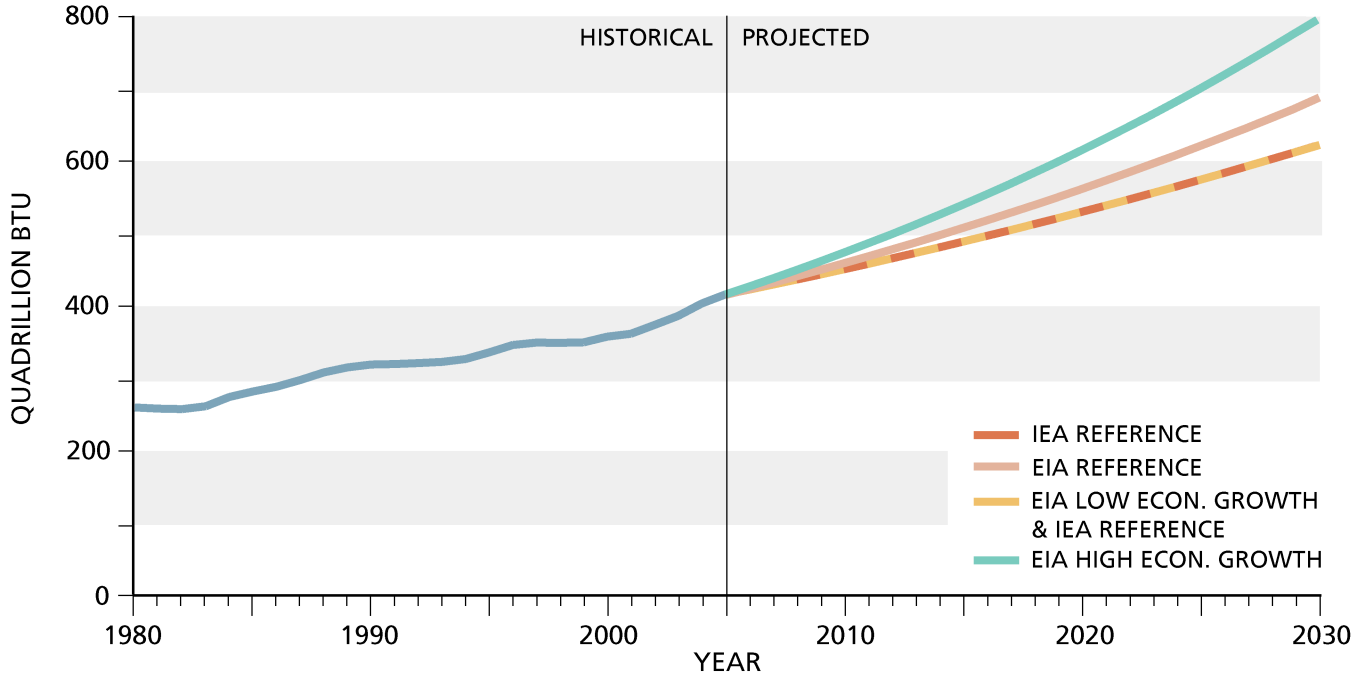
world primary (traded) energy consumption



Source: *BP Statistical Review of World Energy 2007.*

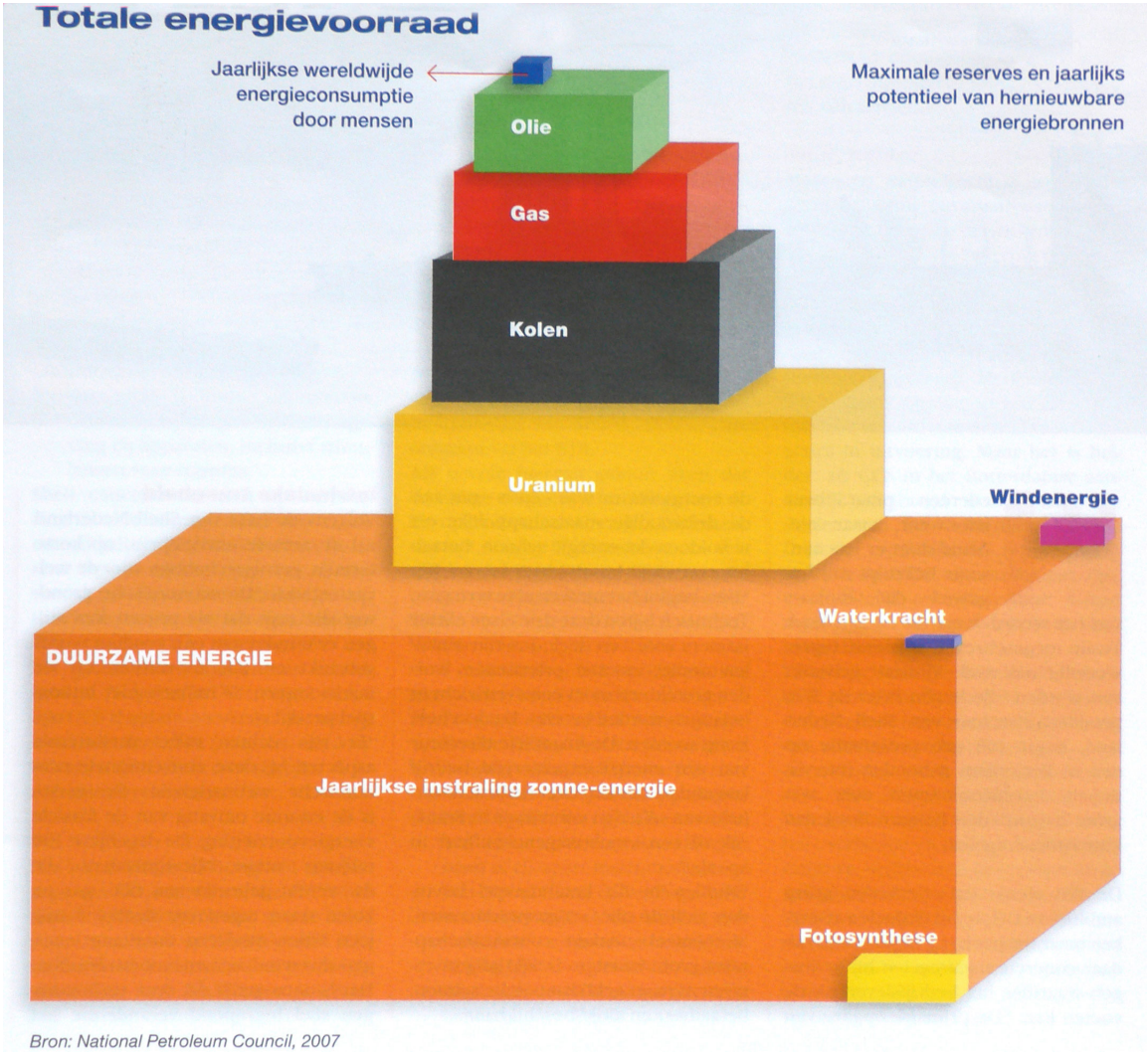
FIGURE 2-8. *Global Primary Energy Consumption, 1980-2006*

world energy consumption scenarios (IEA & EIA)

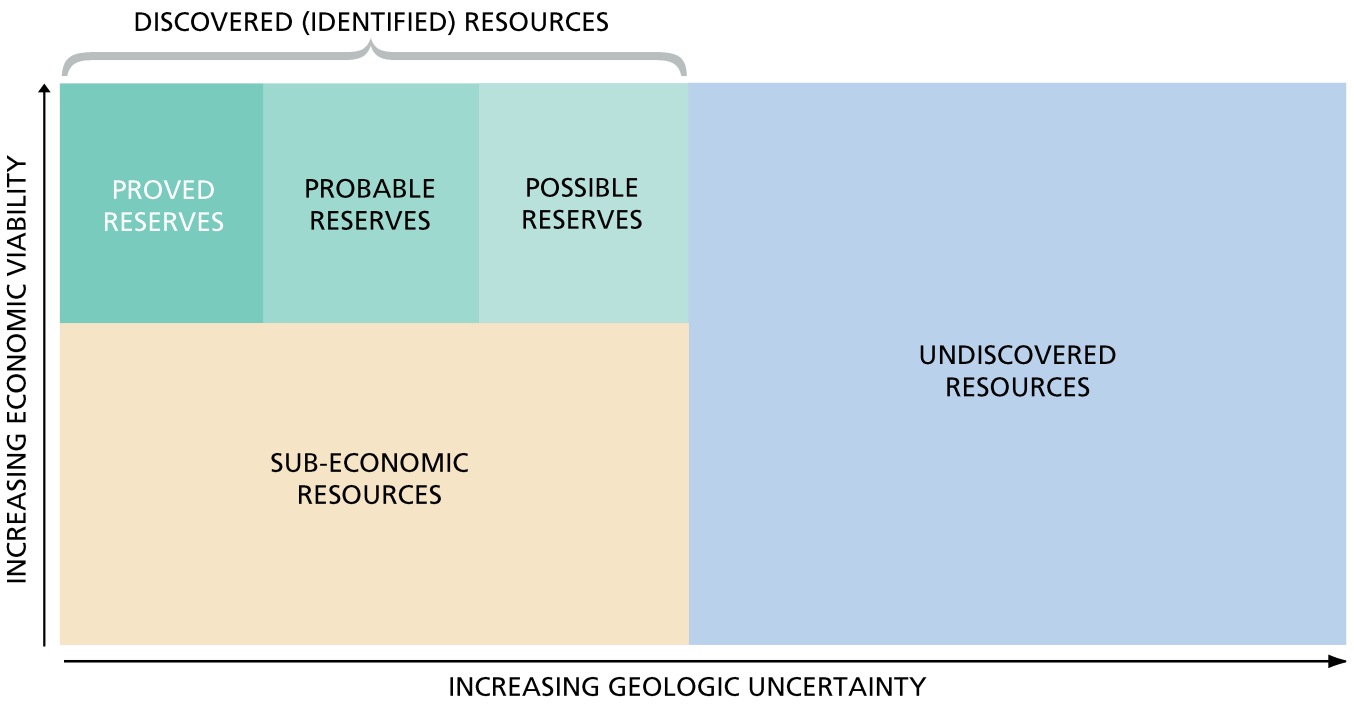


Sources: International Energy Agency (IEA) *World Energy Outlook 2006;*
and Energy Information Administration (EIA) *International Energy Outlook 2006.*

energy resources (NPC)

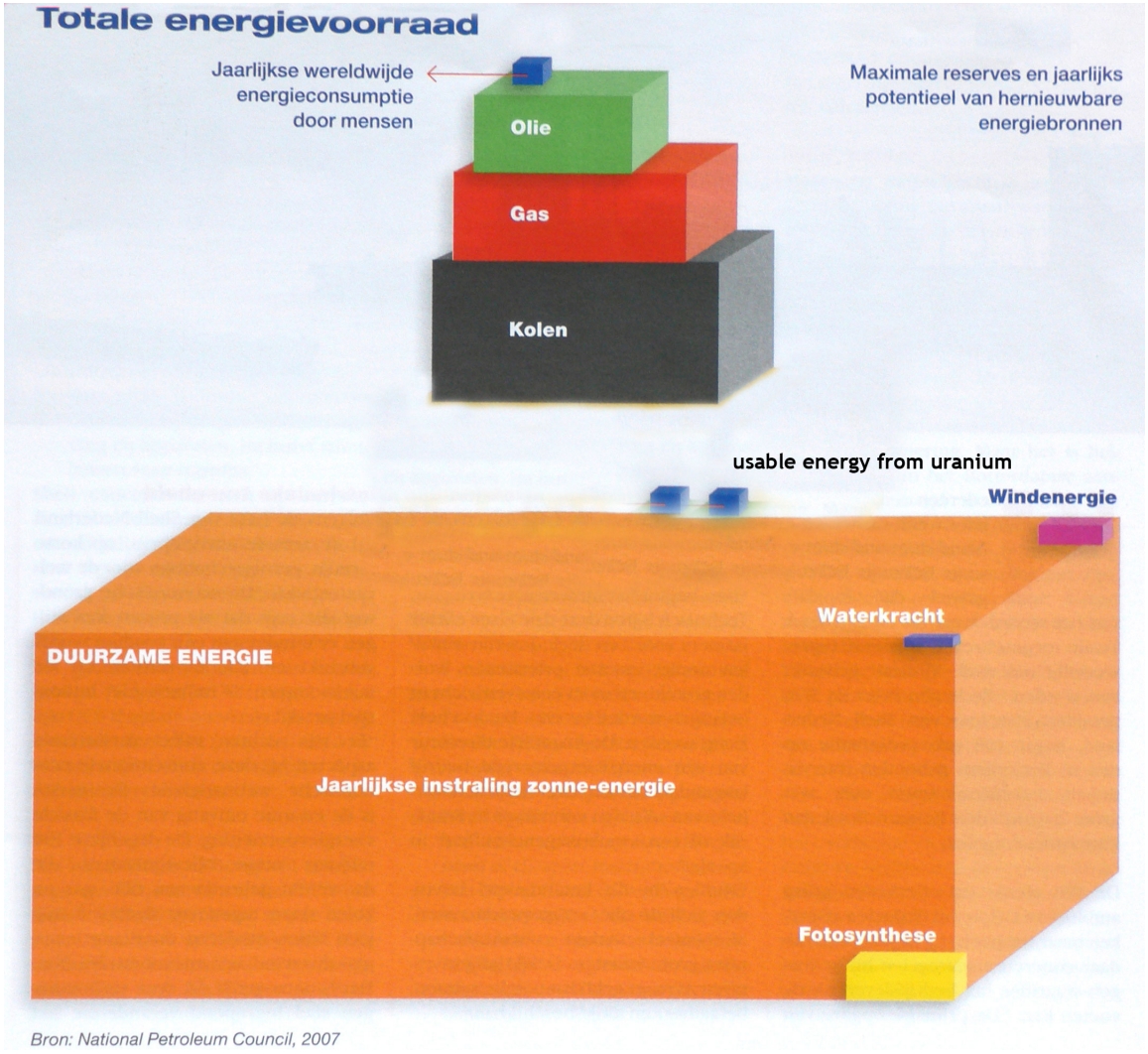


McKelvey diagram

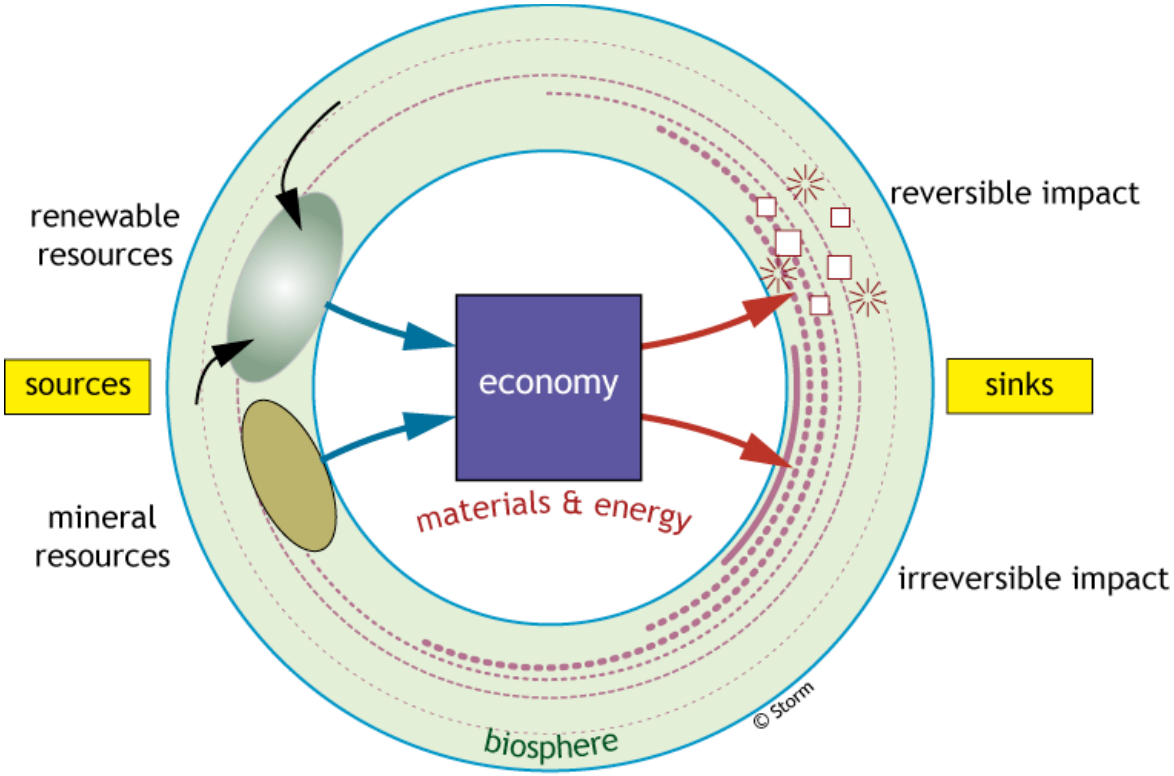


Source: McKelvey, V.E., "Mineral Resource Estimates and Public Policy," *American Scientist*, 1972.

energy resources, adjusted



the biosphere as system, with the economy as subsystem



The economy as a subsystem of the biosphere

humankind in a finite world

Humankind will face global disasters

- if one or more sources will get depleted,

and/or

- if one or more sinks will get full above a critical level

thermodynamics

- Every change in the observable universe is accompanied by an energy conversion.

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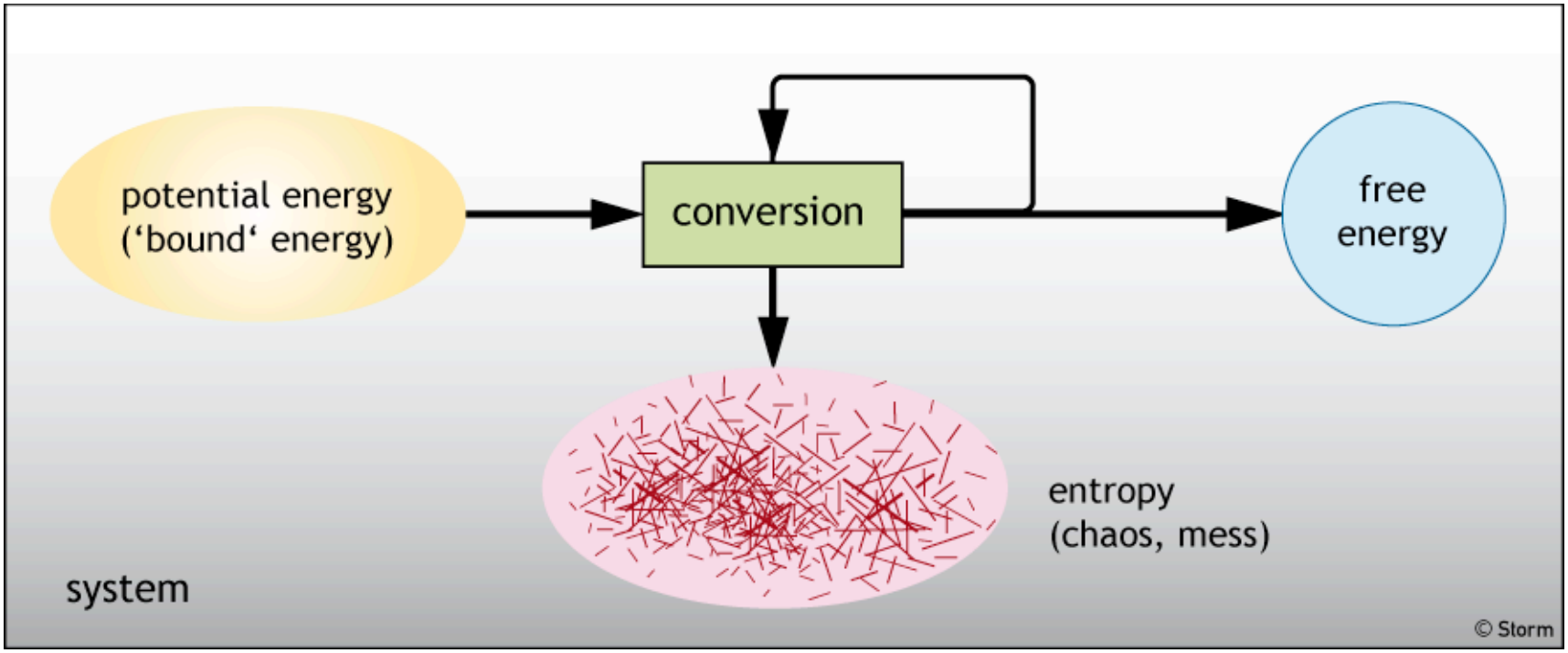
- First Law: energy conservation. ‘Energy consumption’ means energy conversion.

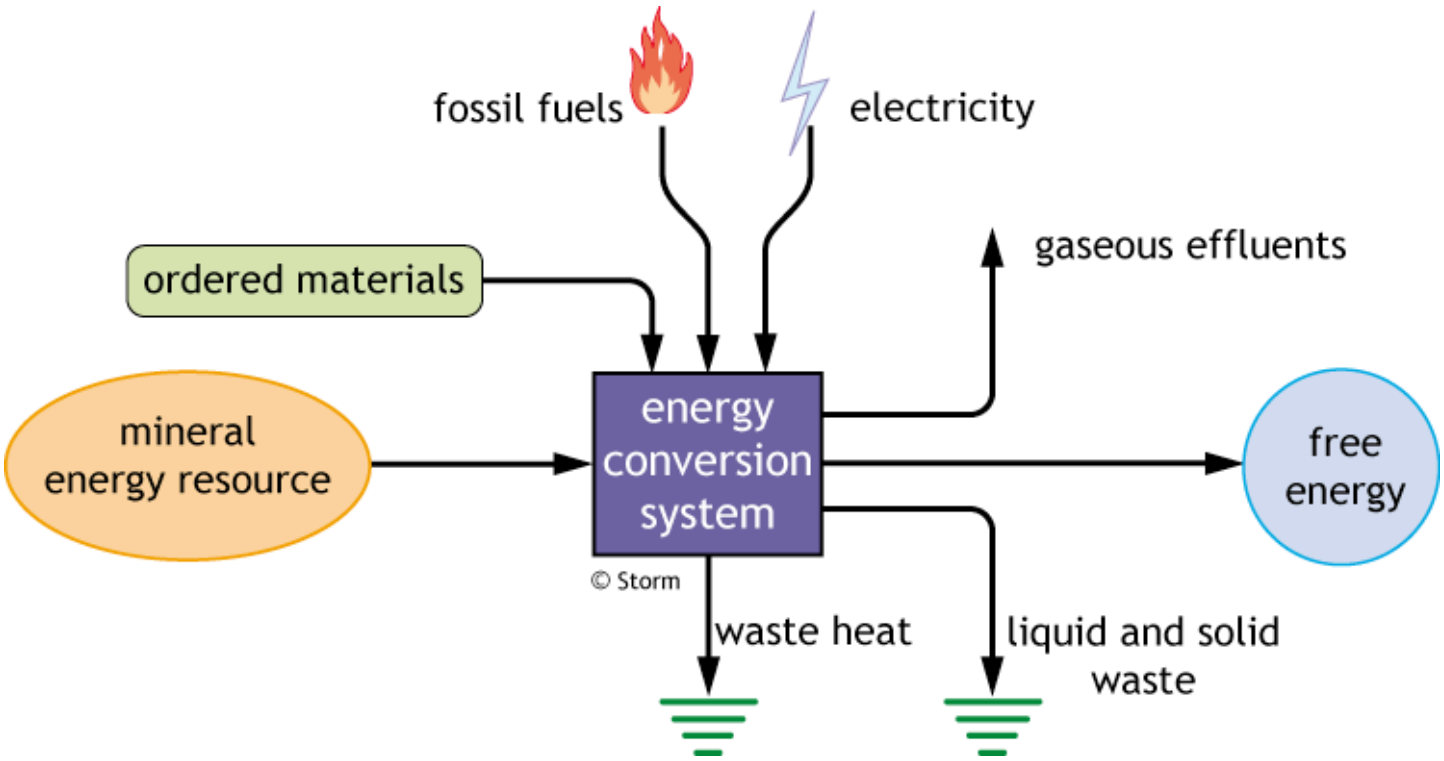
thermodynamics

- Every change in the observable universe is accompanied by an energy conversion.
- First Law: energy conservation. ‘Energy consumption’ means energy conversion.
- Second Law: every change in the observable universe increases its entropy.

generation of free energy in a system without input from outside



mineral-based free energy generation



Second Law

From the 2nd law follows:

the entropy released by the conversion of mineral energy sources from the biosphere into free energy is larger than can be compensated by the generated free energy.

Second Law

Conclusion 1

In the current situation the entropy of the biosphere increases

inevitably and irreversibly,

at an ever increasing rate.

Second Law

Conclusion 2

Dependency on mineral energy resources means a dead-end road in the long run.

Second Law

Fallacy

‘We need economic growth to cope succesfully with the environmental problems.’

Economic growth (today’s notion) implies the consumption of more materials and energy and consequently exponentially rising entropy.

increase of entropy, what does that mean?

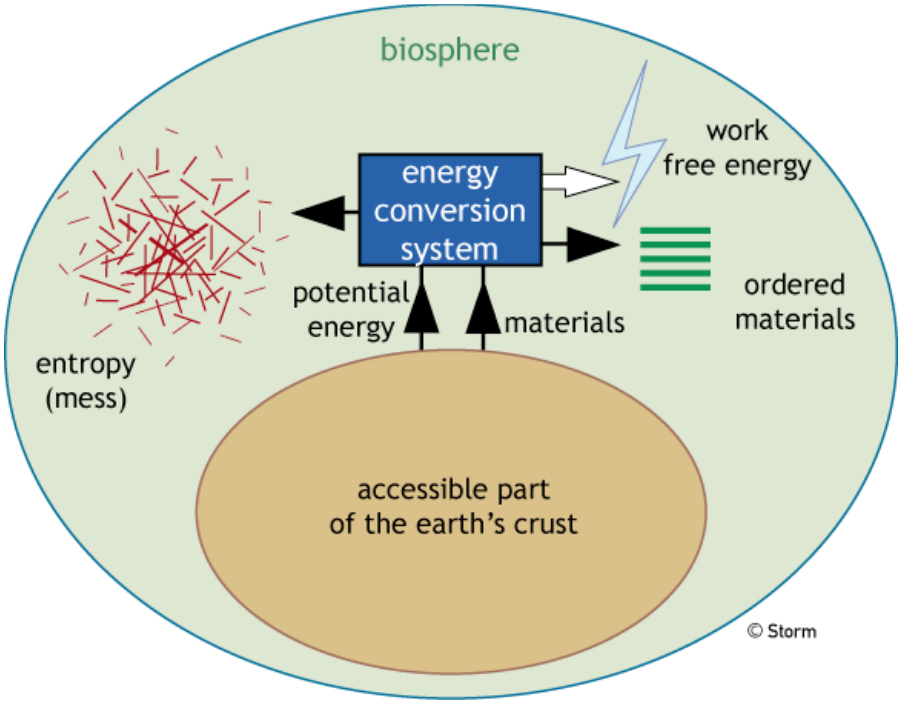
Increasing entropy of a system means:
declining quality,
declining usefulness to man,
less predictability of its behavior.

Basic mechanisms of entropy increase are:
scatter of matter
scatter of energy
scatter of oriented movement

manifestation of anthropogenic increase of entropy in the biosphere

- increasing amounts of CO_2 and other man-made greenhouse gases in the atmosphere.
- declining biodiversity
- increasing pollution of the air, soil, ground water, rivers, lakes and seas by abiotic chemicals and radioactive materials.
- erosion of arable land
- erosion of environmental services

mineral-based energy supply
entropy of the biosphere increases

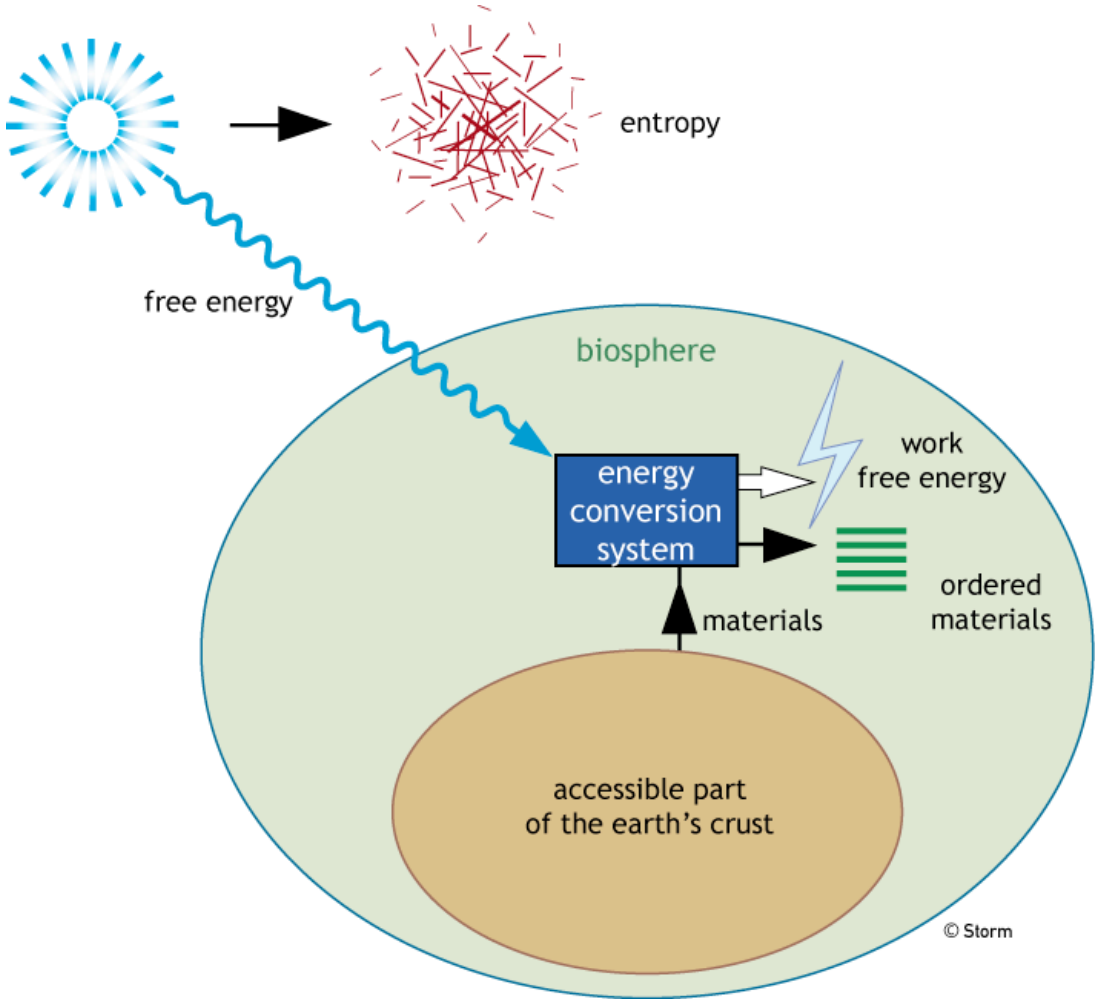


the only way out

The only way open to man for escaping an ‘entropy disaster’ is to power his activities with an energy source outside of the biosphere.

As live did 3.8 billion years ago.

sun-based energy supply
entropy of the biosphere may decrease



sun-based energy supply

In a world with a sun-based energy supply, the availability of mineral materials may become a limiting factor, not energy

pros of sun-based energy supply

- constant flow (not counting short-term fluctuations)
- constant high quality
- very high capacity (but not limitless)

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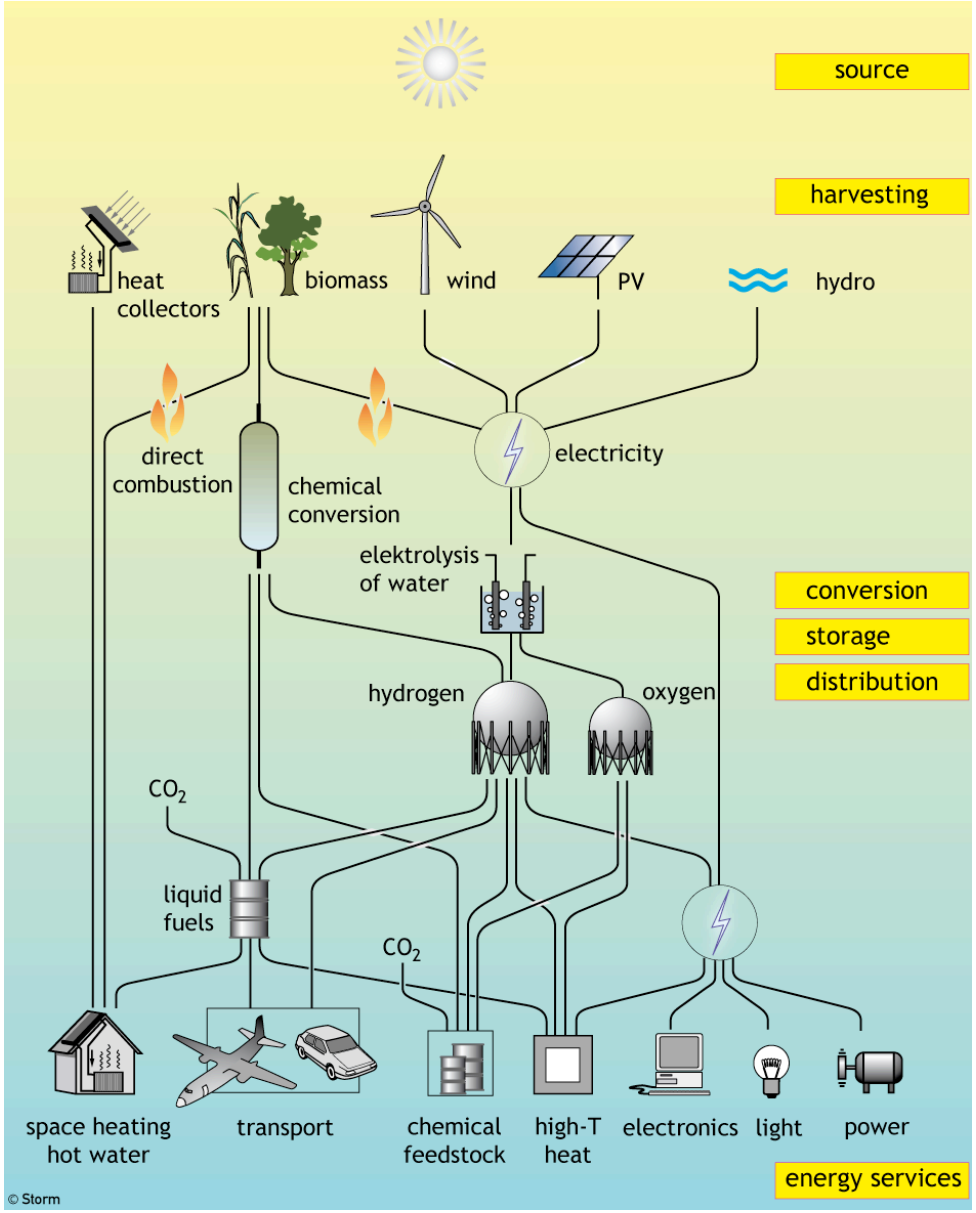
- improvement of environment (climate)
- low vulnerability

sun-based energy supply, problems to be solved

- storage: hydrogen
- reconversion: fuel cells
- fluctuations: can largely be solved by large and smart grids

outline of a renewable energy supply system



energy services

- mechanical energy (transport, machines)
- electricity (electronics, etc)
- heat, low-T and high-T
- light
- conversion of raw materials into useful, ordered materials by chemical reactions: steel, chemicals, etcetera.

Flamco's question

What about the future of water-based heat systems?

Flamco's question

Demand for low-T energy services likely will change only gradually.

At issue is: how to meet this demand?

- generation of low-T heat
- distribution of low-T heat

Flamco's question

Demand for low-T energy services can be met by:

- better insulation of dwellings and buildings (zero-E)
- gas-fired micro cogeneration
- heat pumps
- conventional fossil-fuelled (phase-out?)
- electric heat generation (not advisable)

some trends

- Electricity may get a larger share in a renewable energy scenario.

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- Electricity may get a larger share in a renewable energy scenario.
- Free energy may stay high-priced during the transition period from fossil to renewable.
- Mineral resources will go ever more energy-intensive, due to decreasing ore quality.
- Availability of a number of mineral resources likely may become a limiting factor for economic growth.

concluding remarks

- The discourse on future energy is dominated by economic viewpoints.
- A physical approach starting from the basic laws of nature may broaden the discourse and offer insights free of value judgements.

thank you