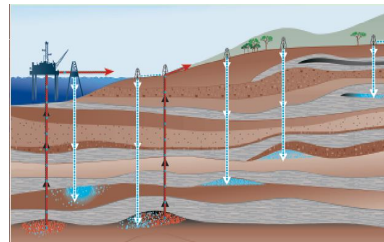




Energy futures

Jonas Åkerman



How to reduce emissions of carbon dioxide fossil fuels

(1) Less carbon intensive energy supply

(2) Improved end-use technology (*more energy efficient cars, aircraft etc*)

(3) Decrease need for car and air travel and truck transport.

May be achieved by urban planning, modal shift to cycle, rail, bus, IT-communication, local production etc)

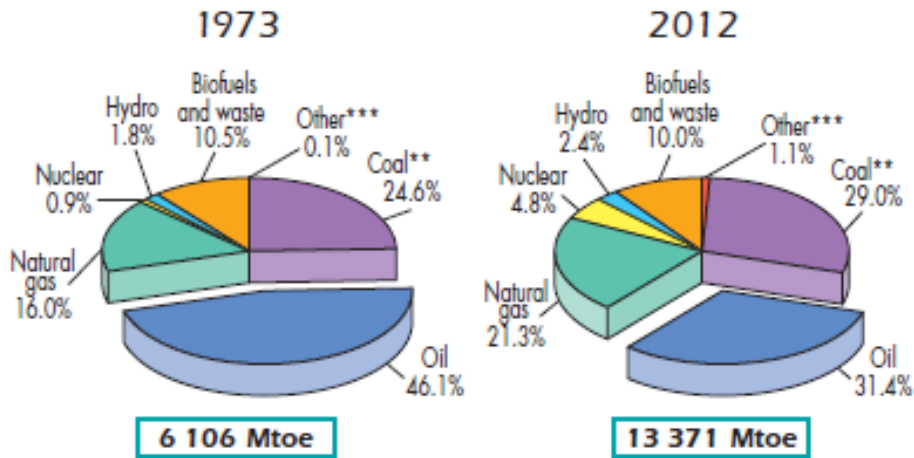
Emissions= Activity * Energy efficiency * Carbon intensity* Population

Example: (passenger-km) (kWh/p-km) (kg CO₂/kWh)



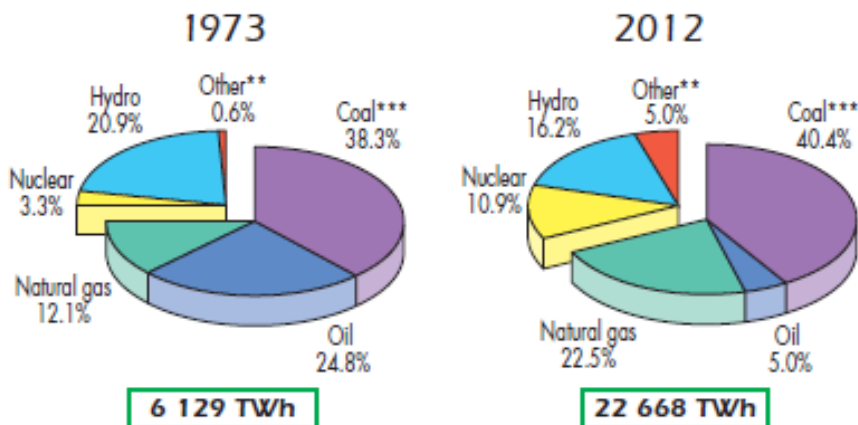
Global energy supply

1973 and 2012 fuel shares of TPES



Global electricity supply

1973 and 2012 fuel shares of electricity generation*



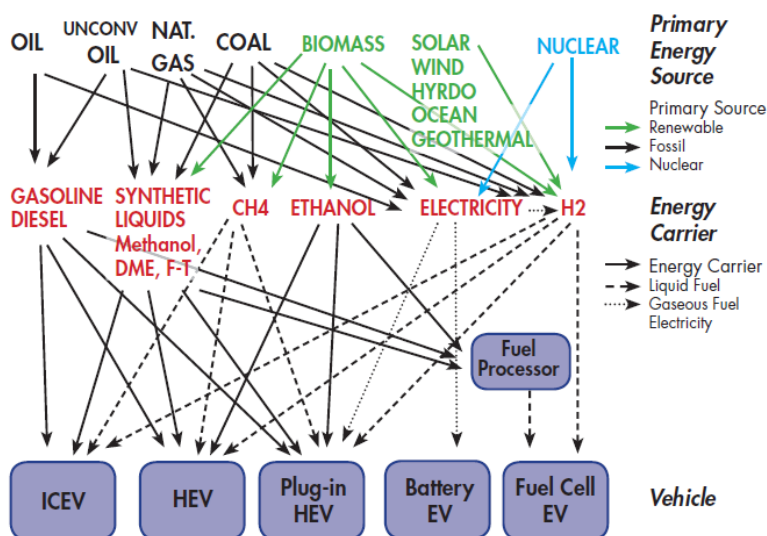


Possible fuels for transport

- **Diesel/gasoline**
- **Methane** (biogas, natural gas)
- **Ethanol**
- **Synthetic liquids** (methanol, DME, F-T diesel)
- **Hydrogen**
- **Electricity**



Possible fuel pathways: Primary energy → Energy carrier → Vehicle type



Source: Ogden & Anderson, 2011. Sustainable transportation energy pathways



Criteria for selecting alternative energy sources

- Low climate impact
- Small other effects on health or the environmental
- Small negative impact on ecosystem services.
- Reasonable cost
- Easy to handle
- Possibility to significantly contribute to global energy supply (*total solar energy reaching the earth correspond to more than 5000 times present total global energy use*)



Bioenergy

Bioenergy is the most important renewable energy source at present (<10% of total global energy supply)

- Future potential for bioenergy depend on several factors:
 - Global demand for food (especially the share for meat)
 - Efficiency in agriculture
 - The need to keep natural ecosystems intact to preserve ecosystem services
 - Future availability of productive land and water supply (given climate change, pollution, erosion etc)



How much are greenhouse gas emissions reduced if oil is replaced by bioenergy?



How much are greenhouse gas emissions reduced if oil is replaced by bioenergy?

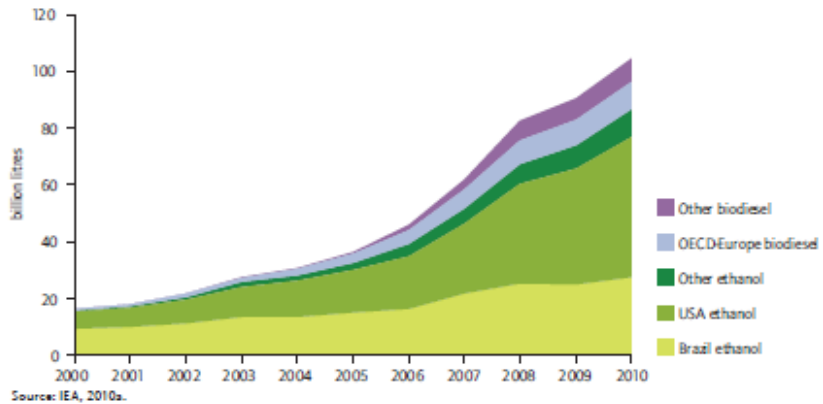
Much, but often less than 100%.

Need to consider:

- That **fossil fuels** may be used in the process of producing fuel out of primary biomass (e.g. Forest residues) and for transport.
- **Land use changes:** If natural land is converted to crop land (for growing energy crops) there may be substantial carbon emissions from the soil.
- For biogas from manure reduction may be more than 100%



Figure 1: Global biofuel production 2000-10



Hydro power

- At present the second biggest renewable energy source (2% of global energy, 16% of global electricity supply).
- Some potential for increased production but the sometimes big impact of dams on settlements and natural environment may limit increase.



Wind power

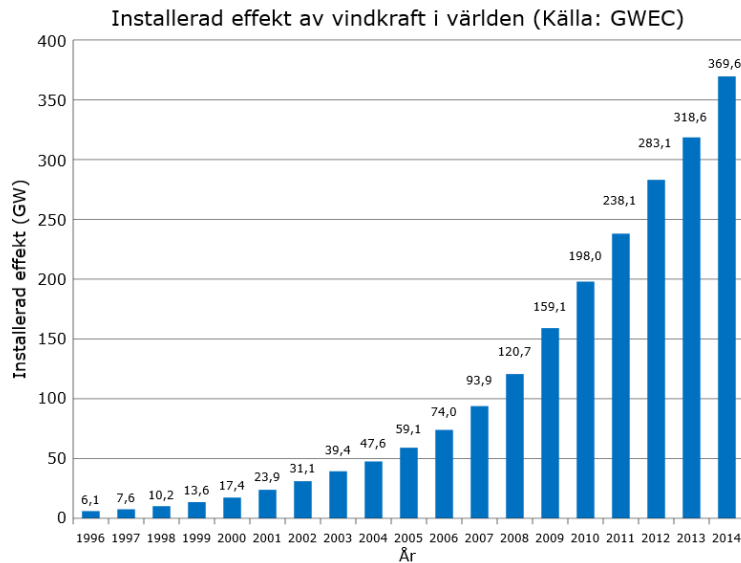


Wind power

- Quite big long term potential
- Very fast increase in production.
- Now globally more than 600 TWh electricity (3% of global electricity production)
- Between 2009 and 2014 wind power more than doubled it's capacity.
- Wind power is gradually becoming competitive without subsidies
- Small negative environmental effects (mainly visual intrusion).
- Small land requirement, but some noise close to the windmills.
- Wind power need to be balanced by other energy sources (such as hydropower) OR well developed grid



Installed global wind power capacity



Wind capacity in different countries in 2011

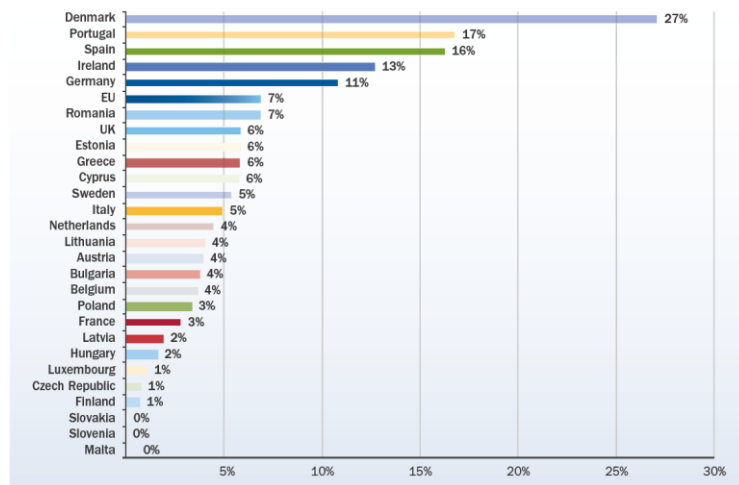
Country	Total Capacity end of 2011 [MW]
China *	62.733
USA	46.919
Germany	29.075
Spain	21.673
India *	15.800
Italy *	6.747
France	6.640
United Kingdom	6.018
Canada	5.265
Portugal *	4.290
Denmark	3.927
Sweden	2.816
Japan	2.501
Rest of the World*	24.200
Total*	238.604

*- Preliminary Data



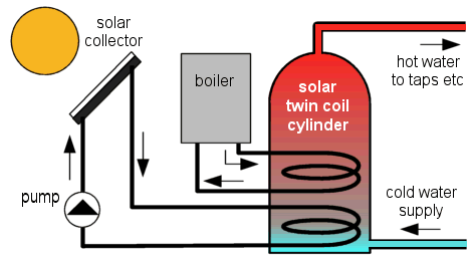
Wind power share of electricity consumption

FIGURE 3.6 WIND POWER SHARE OF TOTAL ELECTRICITY CONSUMPTION IN EU (7%) AND IN MEMBER STATES





Solar energy – Three main types

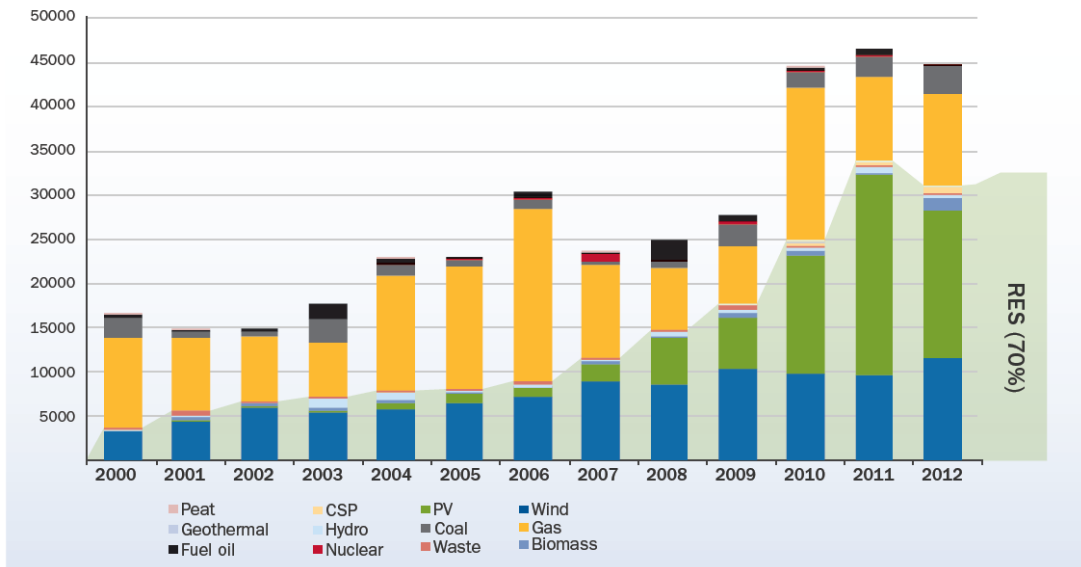


Solar electricity

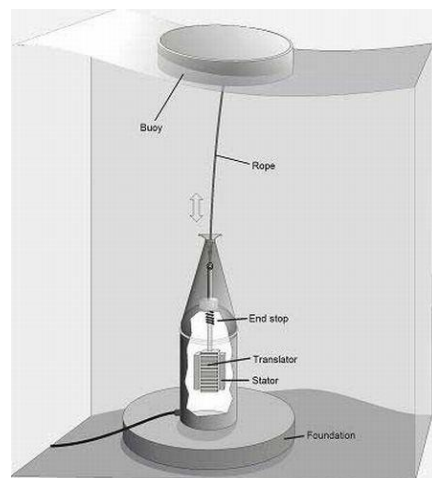
- The amount of solar radiation reaching the surface of the earth is huge
- The cost of solar cell electricity is decreasing quite rapidly, but still subsidies are needed.
- In the long term probably a substantial potential.
- Solar power need to be balanced by other energy sources and/or



FIGURE 2.1 INSTALLED POWER GENERATING CAPACITY PER YEAR IN MW AND RES SHARE (%)



Wave energy





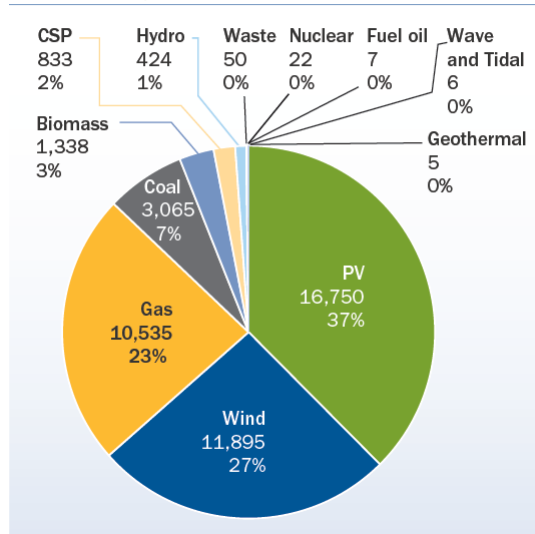
Other renewable energy

- Geothermal energy
- Ocean currents



New power installations in EU in 2012

FIGURE 1.2 SHARE OF NEW POWER CAPACITY INSTALLATIONS IN EU. TOTAL 44,601 MW





EU power mix (Installed capacity)

FIGURE 2.3 EU POWER MIX 2000

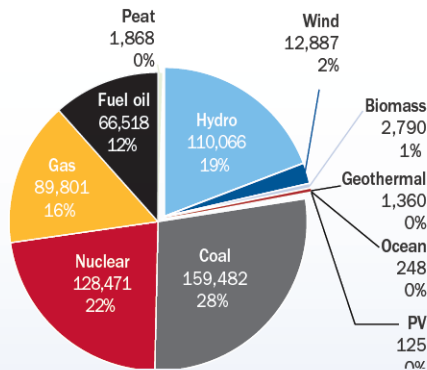
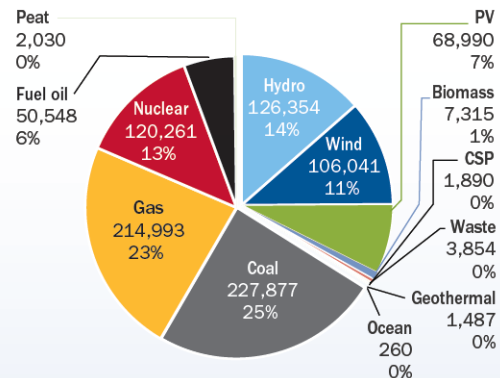


FIGURE 2.4 EU POWER MIX 2012

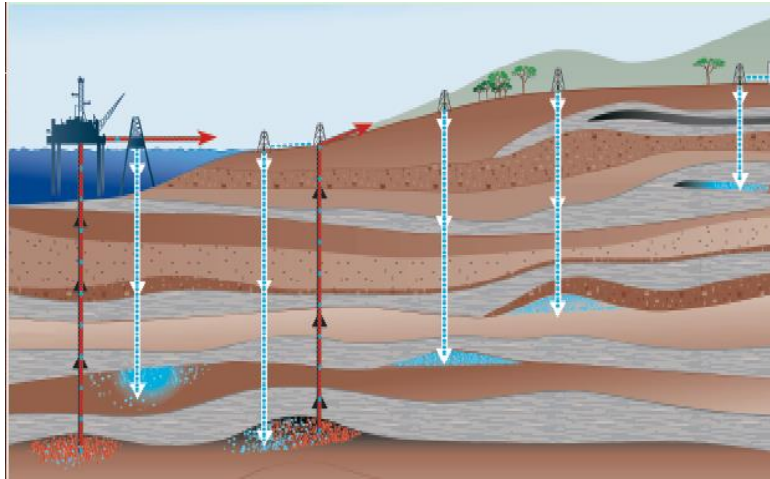


Carbon capture and storage

- CO₂ is captured in power plants or industrial plants.
- Transported to suitable areas where it is pumped to underground storages
- The technology is under development
- Uncertainty about leak profeness of storages
- Additional cost is uncertain but may be acceptable
- Only possible to apply to big stationary plants which will limit use.
- **Conclusion:** Big uncertainty, but may give a significant contribution to emission reduction within a couple of decades



Carbon capture and storage



Could carbon capture and storage be used for transport?

If so, in what way?



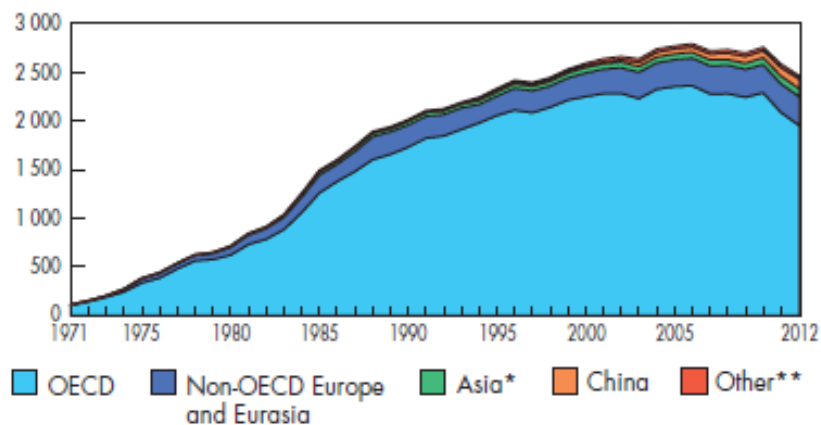
Nuclear power

- Stands for about 2 % of total global energy supply and 15% of global electricity.
- Problems associated with nuclear power:
 - Safety in plants (Tjernobyl, Fukushima)
 - Safe storage of radioactive waste
 - Civil nuclear energy might facilitate the spread of nuclear weapons
 - Limited supply of uranium
- Even if safety concerns would be solved, cost for electricity from new nuclear plants is about the same as for new wind power plants at good sites.



Nuclear Production

Nuclear production from 1971 to 2012
by region (TWh)





Conclusions

- There is not a single energy source that can replace fossil fuels (oil in particular)
 - All alternative energy sources have their advantages and disadvantages.
 - But, if different alternative energy sources are combined there is **a good opportunity to replace most fossil fuels** before 2050
- ...if we can stop the growth of global energy use.



Two alternatives for world energy supply in 2050 that reach the 2-degree target.

