Challenges for Future Energy Usage

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Survey

1. Glance into the history of energy usage

2. Present situation
   Population growth
   Shortage of resources
   Environmental damages and hazards

3. Identification of the biggest energy spenders

4. Boom of renewable energies

5. Promising options

6. Challenges
1. Glance into history of energy usage

Energy sources in past times: renewable (plants, animals, wood, charcoal, water, wind)

Power and heat from fire and muscles → slavery

Unusually benign climate for the last 12 thousand years → cultural evolution

Population 12 thousand years ago: a few million
in 1700 AD: 600 million

Start of industrialization about 300 years ago
Start of coal era

1712 coal fired steam engine of Thomas Newcomen (0.5 % efficiency)
1769 steam engine of James Watt (2 % efficiency)

Advent of electricity

1866 dynamo of Werner von Siemens → breakthrough of electr. motor
1879 light bulb of Thomas Alva Edison
1882 first electric power station (New York)
1890 first electrically driven subway (London)

Start of oil era

1859 first drilling for oil (Edwin L. Drake)
1870 foundation of Standard Oil Company (John Rockefeller)
Advent of the automobile

1877 *Otto engine* (Nikolaus A. Otto)
1886 *first automobile with combustion engine* (Call Benz)

Advent of natural gas

1785 *first working gas lamp* (Johannes P. Minckeleers)
1812 *first gas company* (London, Friedrich A. Winzer)
1814 *first public gas illumination* (London)

Broader use of gas started about 50 years ago

Advent of nuclear energy

1954 *first nuclear power station* in Obninsk (Russia)
1956 *nuclear power station* in Calder Hall (England)
1986 *Chernobyl catastrophe*
# Growth of world population

<table>
<thead>
<tr>
<th>population</th>
<th>year</th>
<th>time difference</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.25 billion</td>
<td>1</td>
<td>1650</td>
</tr>
<tr>
<td>0.5 billion</td>
<td>1650</td>
<td>200</td>
</tr>
<tr>
<td>1 billion</td>
<td>1850</td>
<td>75</td>
</tr>
<tr>
<td>2 billion</td>
<td>1925</td>
<td>40</td>
</tr>
<tr>
<td>4 billion</td>
<td>1975</td>
<td></td>
</tr>
</tbody>
</table>
Worldwide energy consumption grew even faster

<table>
<thead>
<tr>
<th>Year</th>
<th>World population</th>
<th>E/EJ</th>
<th>P/W</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.25 billion</td>
<td>1.5</td>
<td>190</td>
</tr>
<tr>
<td>1650</td>
<td>0.5 billion</td>
<td>10</td>
<td>635</td>
</tr>
<tr>
<td>2004</td>
<td>6.4 billion</td>
<td>472</td>
<td>2340</td>
</tr>
</tbody>
</table>

E = total energy consumption per year
P = energy consumption per capita per second
EJ = exajoule = $10^{18}$ J, $W = $watt
2. Present situation

Evolution of world population

2045 about 9 billion, maximum 10 – 11 billion
Energy consumption grew faster than population
Daily energy requirement of one person:

2700 kcal corresponding to 130 W permanent power supply (75 W radiated away)

Regional differences in power usage per capita

<table>
<thead>
<tr>
<th>Region</th>
<th>USA</th>
<th>BRD</th>
<th>China</th>
<th>Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>[W]</td>
<td>10 000</td>
<td>5 100</td>
<td>1 500</td>
<td>385 (170 without South Africa)</td>
</tr>
</tbody>
</table>
Running short of energy resources

85% of energy consumption from fossil combustion

Peak oil problem and oil supply

Today 0.7 billion automobiles, fuel essentially from oil

2040 1.4 billion automobiles expected

Regional differences in annual per capita oil consumption

<table>
<thead>
<tr>
<th>Region</th>
<th>USA</th>
<th>BRD</th>
<th>China</th>
<th>India</th>
</tr>
</thead>
<tbody>
<tr>
<td>barrels</td>
<td>26</td>
<td>11.7</td>
<td>1.7</td>
<td>0.8</td>
</tr>
</tbody>
</table>
Annual oil production and oil discoveries

Gb = gigabarel

1980 reversal point

past discoveries based on data from ExxonMobil (2002)
Hubbert curve

depletion-mid-point
Peak oil

1967 in Germany

1971 in USA

2004 worldwide with OPEC and former SU excluded

not yet in Iraq, Kuwait and Saudi Arabia

Worldwide peak oil expected between 2005 and 2020

Expected consequences: sharp rise in price and energy crisis
Peak oil of nations

OGJ, 9 Feb 2004 (Jan-Nov 2003)
Oil Prices, 1994-March 2008
(NYMEX Light Sweet/WTI)

Present price x

Dollars per Barrel


SOURCE: http://ectane.niimt.edu/igatev/Marketplace/Prices.aspx
Per capita oil production rate

Per consumer oil peak even before 1980
Oil reserves in 2004: 1200 gigabarrels (BP Statist. Rev. of World Energy)
Annual production rate: 27 gigabarrels
Projected reserve life time: 40 years (22 years taking account of rising demand)

Crude oil consists of about 17,000 chemical constituents
→ pharmaceuticals, solvents, fertilizers, pesticides, paints and coatings, detergents, plastics, .....

What a shame to just burn it!

Supply of coal, gas and uranium

<table>
<thead>
<tr>
<th>energy carrier</th>
<th>peak of production in</th>
<th>reserve life span</th>
</tr>
</thead>
<tbody>
<tr>
<td>oil</td>
<td>2005 - 2020</td>
<td>40 y</td>
</tr>
<tr>
<td>natural gas</td>
<td>2015 - 2035</td>
<td>65 y</td>
</tr>
<tr>
<td>coal</td>
<td>2020 – 2035</td>
<td>165 y</td>
</tr>
<tr>
<td>uranium</td>
<td>?</td>
<td>70 – 220 y</td>
</tr>
</tbody>
</table>
Environmental problems caused by conventional energy usage

- Pollution, erosion, contamination and flooding of soils
- Pollution and contamination of waters
- Local and global pollution + contamination of atmosphere with consequential damage to fauna and flora
- Environmental burdens through the release of heat
- Local and global climate changes, especially through man made enhancement of greenhouse effect
Since 1850 in atmosphere concentration of methane doubled, of CO\textsubscript{2} increased by 30%.

Temperature and CO\textsubscript{2} concentration correlated.
Increase of temperature and sea level

<table>
<thead>
<tr>
<th></th>
<th>Temperature</th>
<th>Sea Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>last 100 years</td>
<td>0.7 °C</td>
<td>18.5 cm</td>
</tr>
<tr>
<td>next 100 years</td>
<td>2 – 6 °C</td>
<td>20 – 90 cm</td>
</tr>
</tbody>
</table>

**Ice Age Temperature Changes**

- **EPICA**
- **Vostok**
- **Ice Volume**

*Time (kyr BP)*
### 3. Identification of the biggest energy spenders

#### Percentage of the different kinds of primary energy (worldwide)

<table>
<thead>
<tr>
<th>Energy Source</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil</td>
<td>38 %</td>
</tr>
<tr>
<td>Gas</td>
<td>23.2 %</td>
</tr>
<tr>
<td>Coal</td>
<td>25.3 %</td>
</tr>
<tr>
<td>Hydroelectric</td>
<td>6.3 %</td>
</tr>
<tr>
<td>Nuclear</td>
<td>6.3 %</td>
</tr>
<tr>
<td>Renewables</td>
<td>0.9 %</td>
</tr>
</tbody>
</table>

#### Percentage of the different forms of energy (Germany in 2000)

<table>
<thead>
<tr>
<th>Energy Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mechanical energy</td>
<td>40 %</td>
</tr>
<tr>
<td>Industrial heat</td>
<td>26 %</td>
</tr>
<tr>
<td>Room heating</td>
<td>31 %</td>
</tr>
<tr>
<td>Light, information + communication</td>
<td>4 %</td>
</tr>
</tbody>
</table>

#### Percentage of end energy consumed by different users (Germany in 2000)

<table>
<thead>
<tr>
<th>User Type</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic</td>
<td>30 %</td>
</tr>
<tr>
<td>Homes</td>
<td>28.5 %</td>
</tr>
<tr>
<td>Small-scale consumers</td>
<td>16 %</td>
</tr>
<tr>
<td>Industry</td>
<td>25.5 %</td>
</tr>
</tbody>
</table>
Traffic: biggest spender, only 20% end energy finally used (14% of primary energy) (Other fields: about 50%)

More than 50% of end energy → heat

1. 2/3 energy losses from source to final usage → energy saving!

2. Energy saving especially important in traffic and heating
4. Boom of renewable energies
Hydroelectric power

- Water storage power plants
- Damless hydraulic power stations

Worldwide 17 %, Germany 4 % electricity production water powered

Worldwide big enhancement possible (not in Germany)

Wind power

Worldwide 1 %, Germany 6 %, Denmark 19 % electricity prod. wind powered

Up to 5 mW per turbine

Within 15 years wind energy price reduction by factor 2.5, but still subsidized

Financial break even expected in 2010 – 2015

1991 first offshore wind farm in Denmark → high potential expected
**Solar power**

**Solarthermal applications** (non-electric)
- Heating of air in homes and greenhouses
- Heating of water in solar thermal collectors
- Cooking
- Water distillation, desalination and disinfection
- Solar chemical processes

**Solar electricity**
- Photovoltaic electricity
- Solar thermal power plants
Photovoltaic electricity

No direct sunlight needed, very flexible
--> from pocket calculator to multi-MW PV-station
Cell efficiency 15 %, durability 20 – 40 years
Energetic amortisation after 1.5 – 6 years --> PV not completely CO2 free
Cost reduction by factor > 2 since 1990, still too expensive (high subsidy)
New materials (organic polymers, metal alloys) --> higher efficiency,
        lower costs

Concentrator cells --> large power from small systems

Solar thermal power plants

Direct sunlight needed --> southern countries
High efficiency, energetic amortization after few months
Medium subventions,
Higher manufacturing numbers --> steep reduction in costs
Photovoltaic electricity generation in Germany
Bioenergy

Energy in 3 tons biomass = energy in 1 ton petroleum

Biomass --> production of heat, electricity, liquid fuels and biogas

First generation biofuels: not sufficient and sustainable (shugar cane, corn etc.) --> food versus fuel debate

Second generation biofuels: sustainable, (non-food crops, waste biomass) financially not yet competitive (subsidy) --> biogas and liquid fuel (sundiesel)

Third generation biofuels: algae
Geothermal heat (widely neglected)

Close to Earth’s surface heat from Sun → heat pumps

In deeper layers heat from radioactivity → electric power + industrial process heat

Concentrated to areas of geothermal anomaly

Appropriate for base load power plants

High drilling costs → high financial risks

Contribution to worldwide power supply < 1 %

High potential: supply of whole mankind for 30 000 years
5. Promising options

CO₂ sequestration

Role of coal will increase, but highest CO₂ emissions, exceeding those of oil by factor 1.4 and of gas by factor 1.8

Enhancing efficiency not sufficient: same emissions as gas fired plant of 58% efficiency requires efficiency of 96% → CO₂ sequestration

Energy penalty of sequestration: efficiency reduction by about 10%

CO₂ deposition + enhancement of oil recovery → cost reduction
Successful example: Sleipner platform (Norway)

Nuclear fusion

Fuels: Lithium + Deuterium from stones and water
First fusion power plant in 50 years → too late for present problems

June 2005 decision: ITER will be built in Cadarache (France)
Further options

- Pebble bed reactor
- Transmutation
- Combined heat and power production in homes
- Hydropowered fuel cells: for cars?
  Stationary fuel cells for small scale heat and power production (more promising)
6. Challenges

- Highest priority: reduction of greenhouse gases
  Hard to achieve →

Example of Germany
• Limitation of temperature rise to < 2°C in one century only for cut down of CO₂ emissions worldwide by 50 %, in industrialized countries by 80 % until 2050 (IPCC)

• Immediate action required, waiting for climatic damage raises cost by factor up to 20 (Stern report)

• Decoupling of energy consumption from economic growth

• Energy saving by
  Raising efficiency
  Streamlined energy usage → energy management
  Substitution of energy sources and energy consuming devices
  Sacrificing energy use wherever possible

• Global dimension of energy shortage and environmental hazards → avoid wars!