

Technology and transition scenarios on the road to 2050

Which energy carriers are needed and how to include the
mobility sector ?

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Global Challenges

The European Council and the European Parliament have both confirmed the EU's objective to limit average global temperature increase to a maximum of 2°C compared to pre-industrial level.

Commission of the European Communities, January 2007

Based on general accepted climate models the following consequence are inevitable:

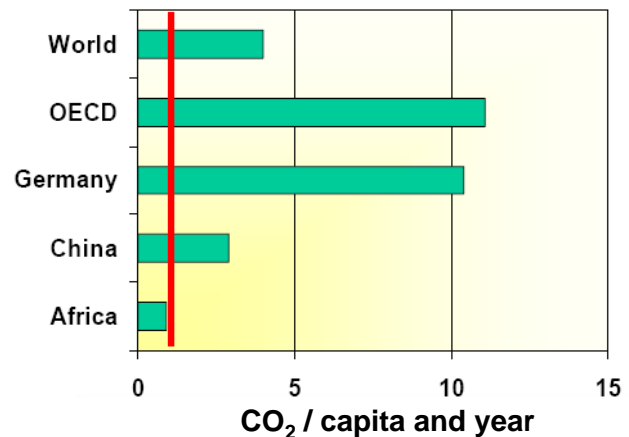
- **Stabilisation of global CO₂ concentration below 450 ppm**
- **Reduction of man-made CO₂ emissions for energy supply from 27 Gt/year to 10 Gt/year in 2050**
- **Mean emission quota per person in 2050: ~ 1 t CO₂/year**
- **Reduction of CO₂ emissions in Germany below one tenth compared with today**

How does this get along with the actual goals defined by politician all over the world?

Politics is aiming for a reduction of today's CO₂ emissions until 2050 by 50%

This would be sufficient, if

- population would grow
- All countries would decrease their emissions by 50%.



But ...

- based on prognoses world population will increase from 6 to 10 billion people in 2050
- there will be no justification for a five times higher CO₂ emission in today's OECD countries compared with the rest of the world

Entrepreneurial and economics challenges

- How will energy supply and power plants mix look like in 2050?
- Which end energy will be used in different applications and what are the consequences for the energy supply infrastructure?
- Do we need quantum leaps which require a parallel installation of a new supply infrastructure?
- Can we develop further existing infrastructures to enhance them for the new challenges?
- Which investments are necessary into long-living supply infrastructures?

Preliminary remarks

- Technology scenarios are based on the assumption that necessary CO₂ reductions must be achieved until 2050.
- Assumption is to maintain the energy service as it is today in OECD countries
- On the road to 2050 also transition technologies will be used which have no major role in 2050 anymore.
- Transition of the energy supply can not be achieved without strong guidance and decisions from politics and society.
- Not all areas of energy consumption are explicitly mentioned (e.g. cargo transport, air traffic).
- Energy per unit will cost more money in the future.
- But increased energy efficiency can keep the expenses for energy constant for the end user.

CO₂-free energy sources and power plant mix in 2050

- **Energy savings**
- **Electrical power**
 - Renewable Energies (wind, photovoltaics, solar thermal, tidal and stream energy, geothermal, hydro power, biomass)
 - Coal and gas with CO₂ sequestration (??)
 - Nuclear fission and fusion (??)
 - Transnational and regional electricity networks
- **Gas**

... details are not in the focus of this analysis ...

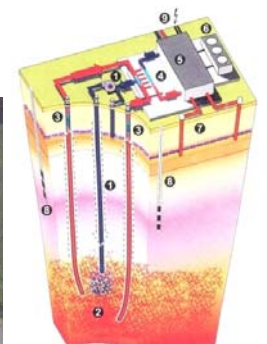
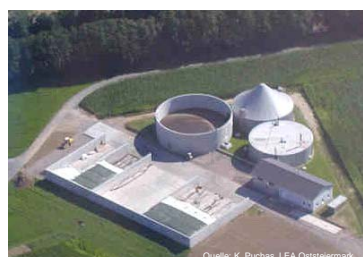
 - Transition from natural gas to a mixture of natural gas / biogas / hydrogen
 - Hydrogen only in case of significant surplus of energy from renewable sources
- **Fuel**
 - Liquefied or compressed gas (mixture as above)
 - Synthetic bio fuels ("biomass to liquid" BTL), world-wide trading

CO₂-free energy sources and power plant mix in 2050

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Most relevant technologies for renewable energies

- **Electricity**
 - Wind
 - Solarthermal power plants (Southern Europe, North Africa)
 - Photovoltaics
 - Biogas
 - Geothermal
 - Hydro power
- **Heat**
 - Near surface geothermie
 - Solar thermal (non concentrating, passive and active)
 - Biomass
- **Fuel**
 - Bio fuels (BTL)
 - Hydrogen from thermo-chemical or biological processes



Transition of gas supply

- Beside electricity gas will be most important as energy carrier for the end user for CHP units, industrial processes, long-distance transport, or peak load power plants
- Infrastructure and end users for natural gas must be enhanced for increasing shares of
 - biogas – from decentralised plants and central plants using imported biomass
 - hydrogen – from surplus electricity from CO₂-free sources

Public transport

- In cities only with electricity – with catenaries, batteries, fuel cells



Public transport

- In cities only with electricity – with catenaries, batteries, fuel cells
- Required infrastructure
 - Battery charging stations at major bus stops (approx. 100 kW per charging point)
 - Catenaries
 - Gas supply and liquid bio fuels for high temperature fuel cells



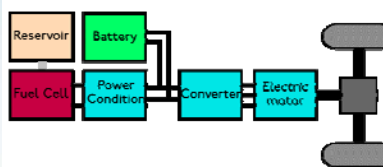
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Folie 11

Individual transport

- Inside cities only electric driving with battery (up to 60 - 100 km/day)
- suburban & highway with plug-in hybrids (batteries plus internal combustion engine or fuel cell) with bio fuels or gas



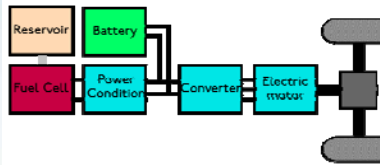
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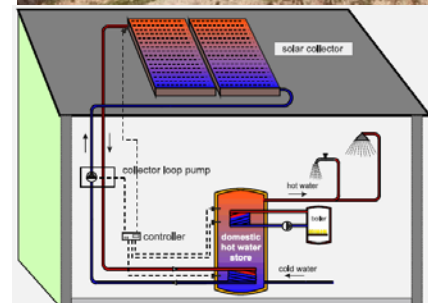
Individual transport

- Inside cities only electric driving with batt (up to 60 - 100 km/day)
- suburban & highway with plug-in hybrids (batteries plus internal combustion engine or fuel cell) with bio fuels or gas
- Required infrastructure
 - Bi-directional power flow in all grid segments
 - High power connection of public parking lots
 - Energy management and communication
 - Filling stations for bio fuels and gas



Single dwellings

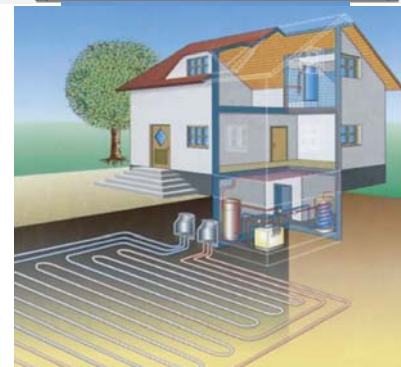
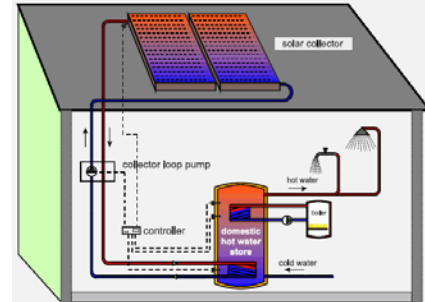
- Thermal isolation reduced heating demand below 20 kWh / m² / year
- Remaining heating energy from heat pumps (~ 600 kWh/year for 120 m²).
- Hot water from solar thermal collectors
- Additional electricity need for individual transport (~ 1500 kWh / 9.000 km/year)
- Reduction of electricity consumption by 50% due to savings (< 2000 kWh/year)



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- Required infrastructure
 - Existing electricity grids sufficient, but enhancement for bi-directional energy flow
 - Installation of heat pumps

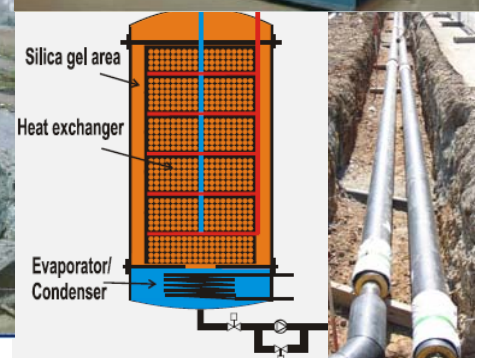


Apartment, business and public buildings

- Heating and cooling with combined heat and power (CHP) units
- CHP powered by gas
- Electricity for all other loads



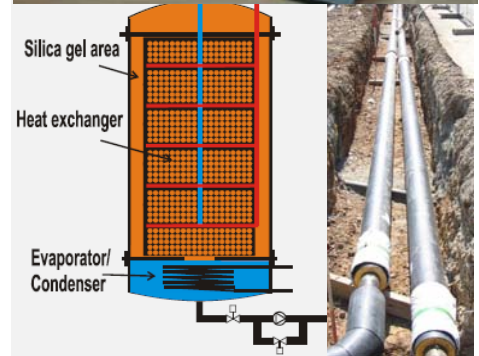
Decentralized CHP systems



Apartment, business and public buildings

- Heating and cooling with combined heat and power (CHP) units
- CHP powered by gas
- Electricity for all other loads

- Required infrastructure:
 - gas
 - electricity
 - energy management
 - local heat and cooling distribution systems
 - thermal storage (daily and seasonal)



Measures for the stabilisation of the electricity grid with high penetration of fluctuating power generators

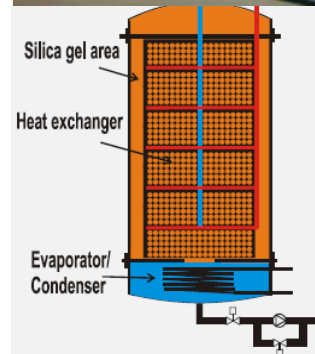
- Extension of transnational electricity transport capacities
- CHP operation at times of electricity demand
- Dual use of storage units for electricity grid and transport
- Additional storage systems (large to small call, various technologies)

Thermal storage in CHP units

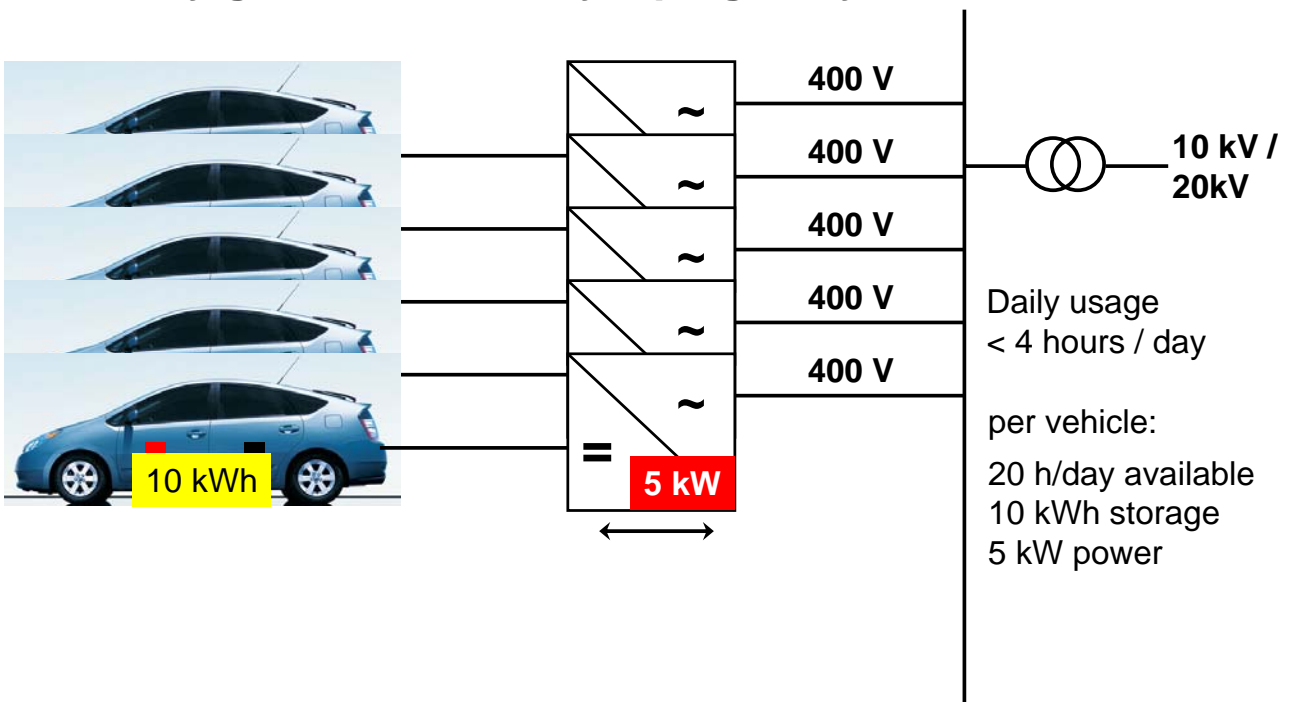
Forceful change-over to power controlled CHP units:

- Thermal storage systems are much cheaper compared with electricity storage systems
- Daily and seasonal storage device for thermal energy available
- Usage of CHP unit as virtual, distributed and controllable peak load power plants

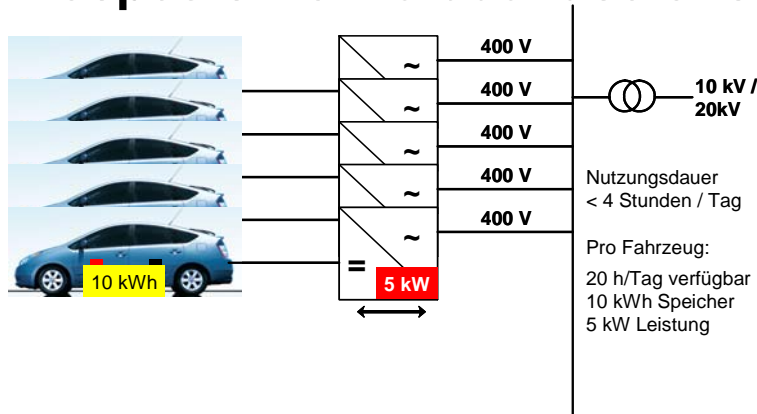
→ allows levelling of power demand in grids



Prospects from a dual use of storage systems for electricity grids and mobility – plug-in hybrids



Prospects from a dual use of storage systems



- Vehicle fleet in Germany: > 45 Million
- 4 Mill. vehicles (< 10% of fleet) as bi-directional connected plug-in hybrids result in
 - 20 GW power for 2 hours
 - or 8 hours with 5 GW power (exceeds today's installed capacity of pumped hydro storage systems in Germany)
- 35% of the vehicles can supply the average load in Germany for 3 hours

Electrical energy storage vs. transmission

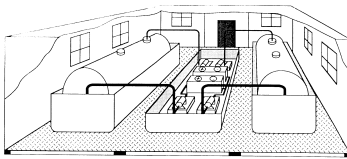
Storage systems

- Efficiency depends on technology (30 - 90% electricity to electricity)
- Very flexible power and energy sizing
- Reduced dependencies on third countries, increasing level of energy autonomy
- The smaller the grid segment the bigger the storage system
- Typically significant costs per kWh

Transmission network

- High efficiency (high voltage DC ~ 5% losses / 1000km)
- International co-operation and stability for transnational and transcontinental grids required
- DC cable technique allows underground and underwater lines
- Expensive in sparsely populated areas

Technologies for storing electrical energy



Redox-Flow batteries



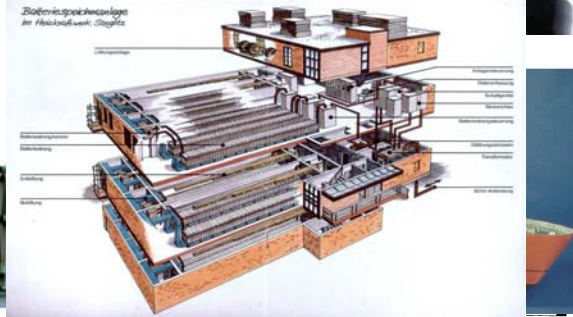
Hydrogen



Pumped hydro



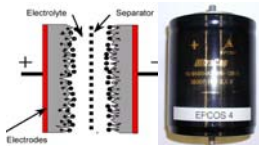
Superconductive coils



Batteries - Redox, Hydrogen, NiCd...



Flywheels



Supercapacitor

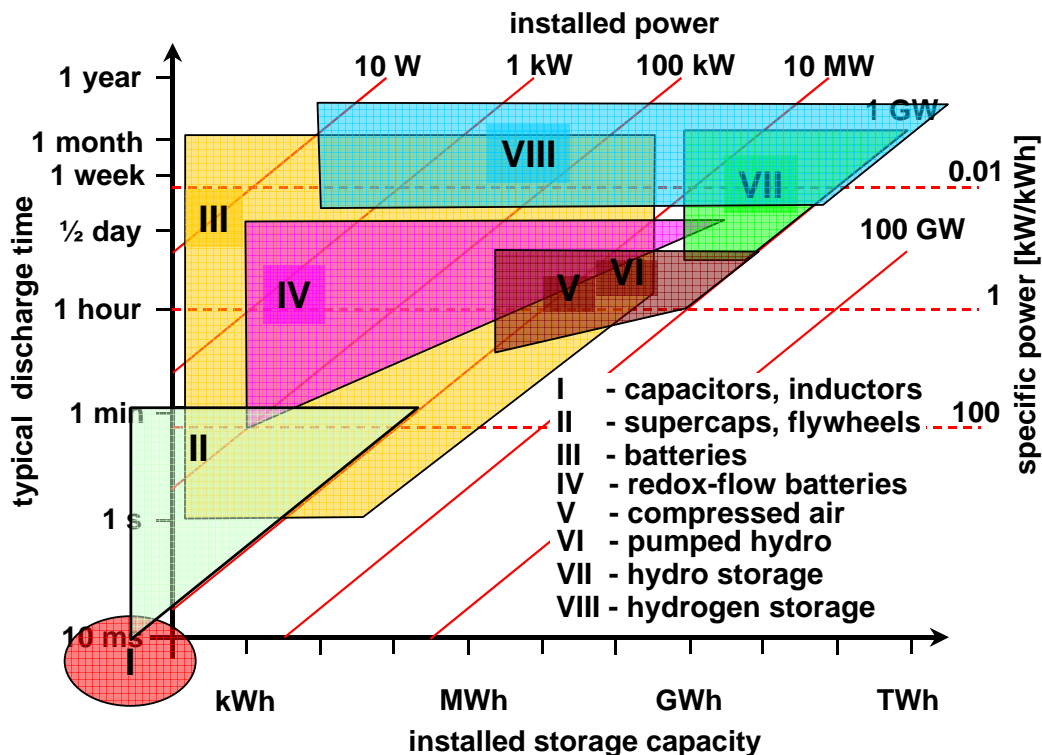


Batteries - lead-acid, lithium, NaS, NiCd ...



Compressed air

Betriebsbereich verschiedener Speichertechnologien



Conclusion

- Electricity will become the most important end-energy carrier.
- Even though energy savings will be realised, the need for electricity will increase in relative and absolute numbers.
- Existing infrastructures can be upgraded and developed further for future needs. No new infrastructures are needed.
- Merging of electricity supply and individual transport offers a huge technical and economic potential.

- Thermal and electrical storage systems are inevitable ...
 - for optimum mobile and stationary utilisation of electricity
 - for reduction of investments in peak power plants
 - for most efficient operation of heat and power co-generation plants
 - for energy efficiency measures especially in the industry

Finally ...

The conference will show ...

- technologies for storing electricity and heat are available
- there are more different technologies than typically recognised in official studies and future scenarios
- renewable energies for a sustainable energy supply will not be hindered by missing storage technologies

But also ...

- especially in Europe strong investments in technology development and demonstration projects are needed.