Significant Contributions of Chemistry in the Field of Energy

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Future of energy supply and migration from fossil fuels to renewable energy sources is one of the greatest challenges of the 21st century

Chemistry is a key technology and a significant contributor to the

- **conversion (generation)**
- **storage and**
- **efficient use of energy.**

New technologies to address the energy challenge almost always require significant innovations from chemistry

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Conversion of energy

Fuels

- **Conventional fuels from coal, oil, gas and biomass**
  - Improvements in conventional refinery techniques
  - Efficient methods for generating syn gas (CO + H_2) from natural gas
  - Direct transformation of methane into higher hydrocarbons
  - New methods for processing of tar sands and oil shale
  - BTL: 2nd generation biofuels, e.g., enzymatic generation of bioethanol / biobutanol from cellulose and hemicellulose
- **Methanol, dimethyl carbonate, dimethyl ether as fuels**
  - Direct oxidation of methane to methanol or DME
  - Direct synthesis of dimethyl ether from CO_2 and H_2
  - Of dimethyl carbonate from CO_2 and CH_3OH
  - **CO_2 not as waste but as feedstock!**

Fuels

- **Hydrogen as fuel**
  - Not a naturally occurring energy source, must first be generated
  - Today mostly from fossil fuels (natural gas). Not CO_2 neutral
  - Alternatives: electrolysis – but needs electricity
  - Medium term: catalytic water cleavage, bioreactors
  - Ultimate goal: artificial photosynthesis
  - Hydrogen as fuel has additional challenges

Developments depend on new (bio)catalytic approaches

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Light to Biomass

- Efficient production of biomass is important prerequisite for many new applications as fuel and feedstock (⇒ biorefinery)
- Requires innovative and new approaches for
  - Fertilizers
  - Plant breeding, including genetic engineering
  - Pest management
  - Protection of soil
  - water management

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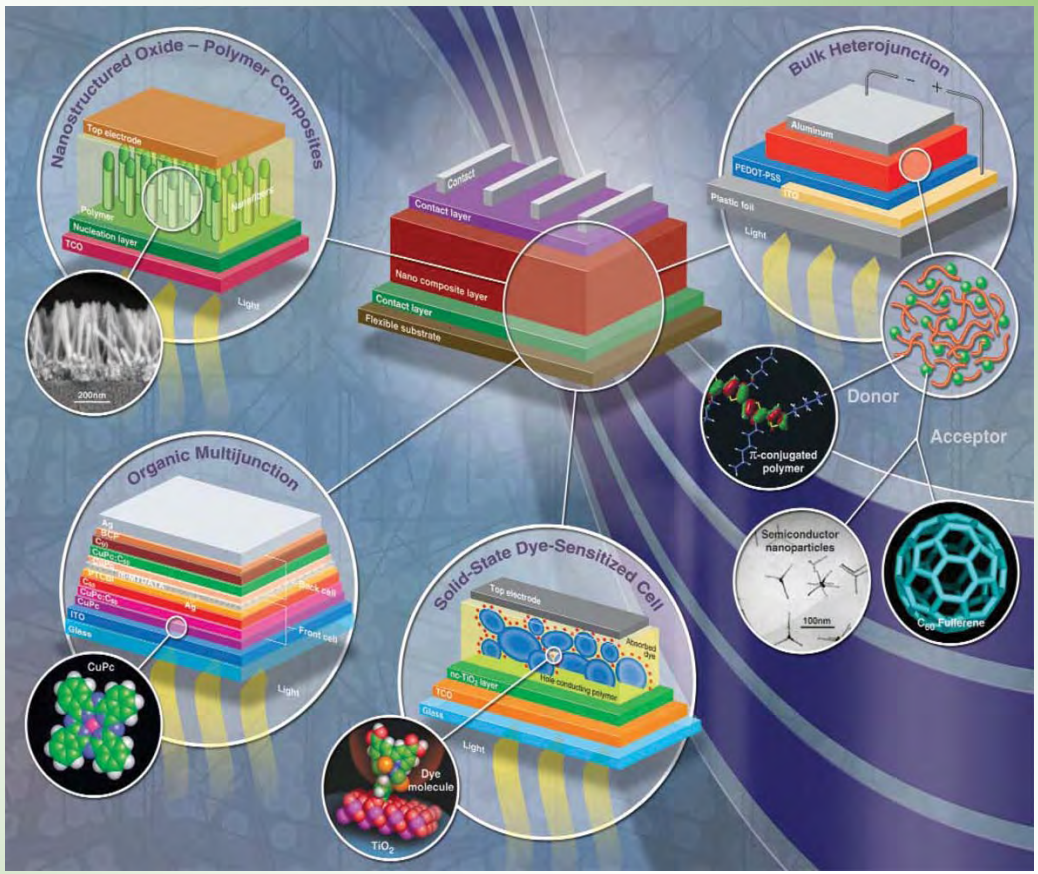
***** which is chemistry

Electrical Energy

- **Electricity from sunlight**
  - **Major source of energy (10,000 times more than annual worldwide energy consumption)**
  - **More efficient and cheaper solar cells (dye or organic solar cells)**
  - **With efficiency of 25 % only 0.3 % of earth's land surface is sufficient to cover the energy requirement predicted for 2050**



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Electrical Energy

- **Fuel cells**
  - Large variety of types (high / low T, H_2, CH_3OH, natural gas, etc.)
  - Need custom-made electrolytes, electrodes, membranes
  - Significant savings (Large stationary fuel cells with power-heat coupling: 20 - 50 % reduction of CO_2 and energy consumption
- **Thermoelectricity**
  - Today very inefficient (< 10 %) but large potential
  - Need materials with high electrical and low thermal conductivity
  - Reduction of thermal conductivity through nano technology
  - Phonon-glass, electron crystal (PGEC) approaches
  - Energy from waste heat and solar heat

New, tailor-made materials are needed

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Heat Energy

- **Collectors for solar and geothermic heat**
  - **Absorber materials must be black, thin and good heat conductors. Typically coated metal sheets or glass tubes**
  - **Insulation (polyurethane foam)**
  - **Covers (low-iron glass with extra high transmission rates)**
  - **Reflectors**
  - **Heat transfer media (water with ethylene or propylene glycol)**

Materials synthesis and thin layer deposition techniques

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Storage of energy

Electricity Storage

- **Mobile batteries (Ni-Cd, Ni-MH, Li-ion)**
  - Many applications (from personal devices to hybrid cars)
  - New electrodes, electrolytes, and additives
  - Optimization of solid-electrolyte-interface
  - Goal: higher energy density and cell voltage, longer life cycle
- **Stationary batteries (buffer for renewable energies)**
  - Need large storage capacities (multi-MW)
  - Large redoxflow batteries promising option
- **Supercaps (double layer capacitor)**
  - Electrostatic technique
  - Complementary to batteries
  - New materials for electrodes, electrolytes (ionic liquids)

Materials and electrochemical processes must be optimized

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Material-Related Energy Storage

- Today almost exclusively based on fossil sources
- New storage strategies are needed for the post fossil era
- Hydrogen
  - Storage in high-pressure / low temperature tanks problematic
  - Use of solid state materials
  - Chemisorption: metal hydrides or other complex hydrides
  - Physisorption: metal organic frameworks (MOF)
- Other possible energy carriers
  - Silicon, carbon, ...
  - However, solid state energy carriers more difficult to handle

Requires progress in solid state research and hydride chemistry

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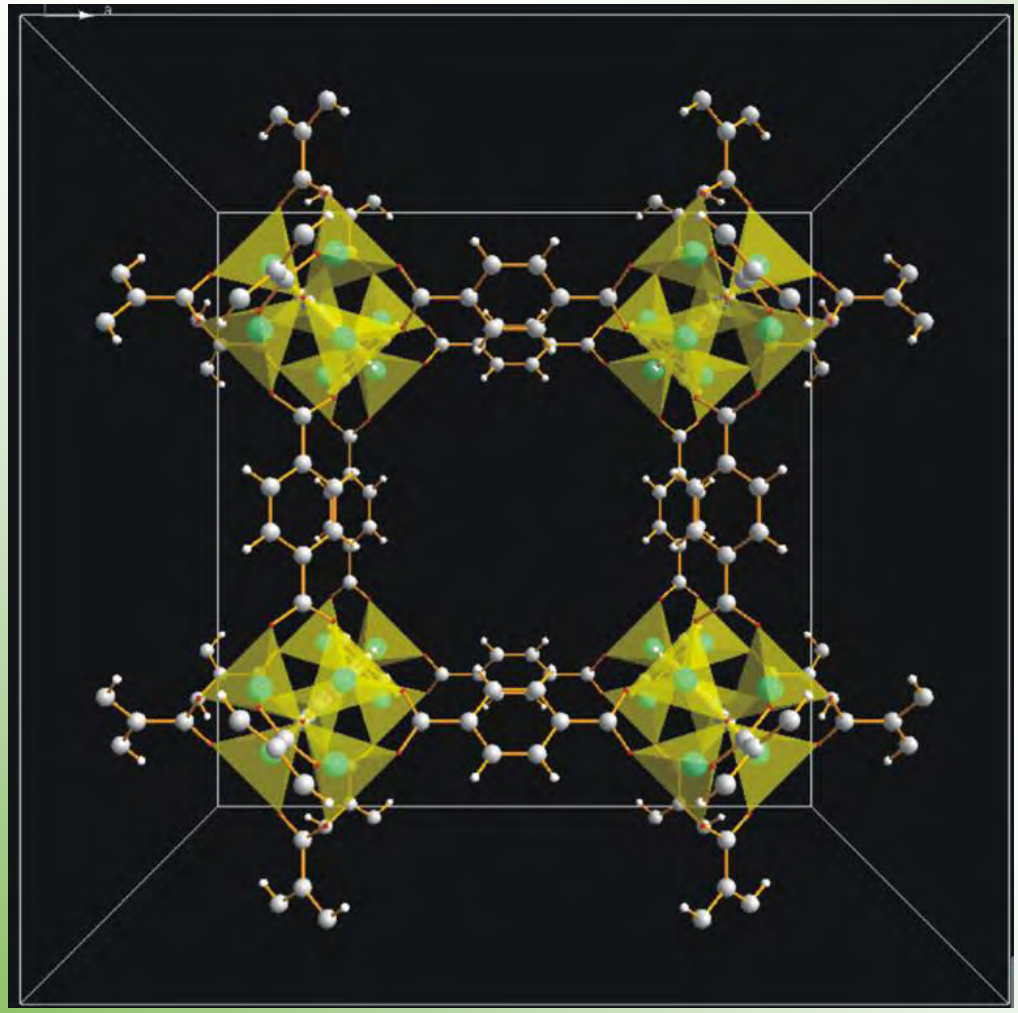

A typical metal-organic framework (MOF-5)

Specific surface ca. 4,000 m^2 per gram

contains up to 5.2 % H_2 by weight at 50 bar and 77 K

Advantages:
- **fast kinetics**
- **high reversibility**
- **small heat of adsorption**

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Efficient use of energy

Efficient Use of Energy

- One of the biggest energy "sources"
- Lighting
  - 10 % of electric power used for lighting
  - Traditional light bulbs very inefficient
  - Modern developments involve LEDs and organic LEDs (OLED)
  - New classes of luminants (e.g. nitridic compounds)
  - Emerging new applications
  - Increasing efficiency by at least a factor of 2 is realistic

Efficient Use of Energy

- **High performance materials**
  - Lightweight materials e.g. for cars, ships, planes, etc
  - New polymers and metallic materials with specific properties
  - Savings potential significant: weight reduction by 5 % in cars ⇒ 3 % saving in fuel consumption
- **Nano-porous foam materials**
  - Around 1 / 3 of energy is used for heating
  - New materials for thermal insulation
  - Small density and pore sizes of mean free path length

Innovations in material research and polymer chemistry

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Summary

"The struggle for existence is the struggle for available energy", Ludwig Boltzmann

Addressing the energy challenge needs a coordinated strategy extending from short term measures to fundamental investigations of alternative energy sources and an adapted energy infrastructure.

All these efforts depend to a large extent on innovative contributions from the chemical sciences