

## FUTURE ENERGY DEVELOPMENT AND EMPA'S ENERGY RESEARCH PROGRAM

V. Zakaznova-Herzog and A. Züttel



## SECTION HYDROGEN & ENERGY

# ETH DOMAIN

## Federal Board of Ministers



D. Leuthard



M. Leuenberger



M. Calmy-Rey



H.-R. Merz



E. Widmer-Schlumpf



P. Couchepin



U. Maurer

## Board of the Swiss Federal Institutes of Technology



Fritz Schiesser



Paul L. Herring



Janet Hering



Hans Hess



Patrick Aebischer



Ralph Eichler



Thierry Lombard



Barbara Haering



Beth Krasna



Markus Stauffacher

### ETH

Eidgenössische Technische Hochschule Zürich  
Swiss Federal Institute of Technology Zurich

Ralph  
Eichler



### ETH Zürich

### EPFL

ÉCOLE POLYTECHNIQUE  
FÉDÉRALE DE LAUSANNE

Patrick  
Aebischer



### EPF Lausanne

### EMPA

Gian-Luca Bona



Janet Hering



PAUL SCHERRER INSTITUT  
PSI

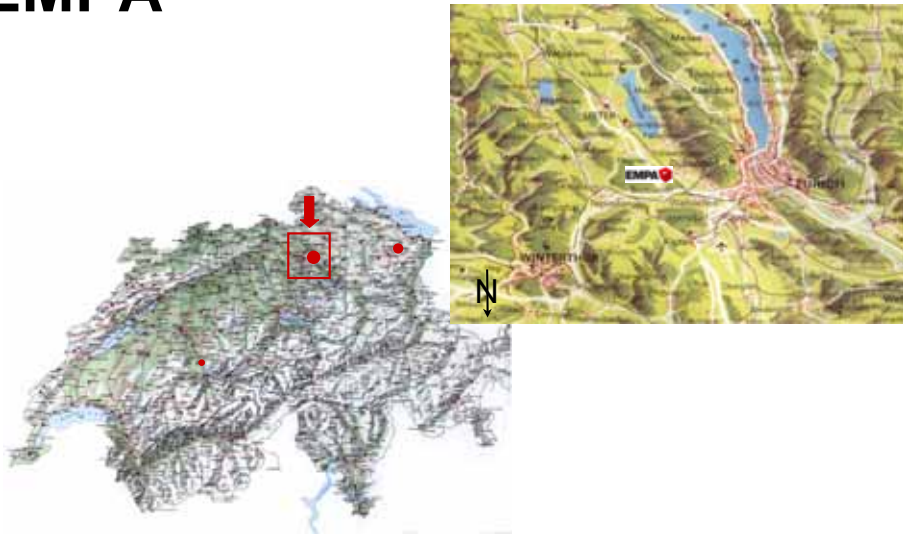
Joël Mesot



James W. Kirchner



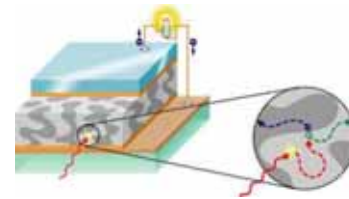
# EMPA



The «Building materials test institute» started work in 1880 in the cellars of Zürich's Polytechnical University, the forerunner of ETH Zürich.



Prof. Dr. Ludwig von Tetmajer (1850-1905)



Materials Sciences & Technology for Energy



Nanotechnology



Natural Resources and Pollutants



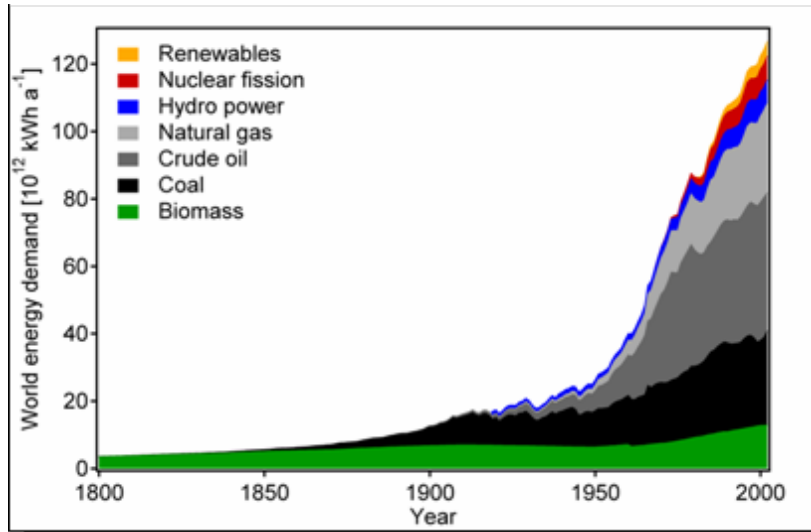
Materials for Health & Performance



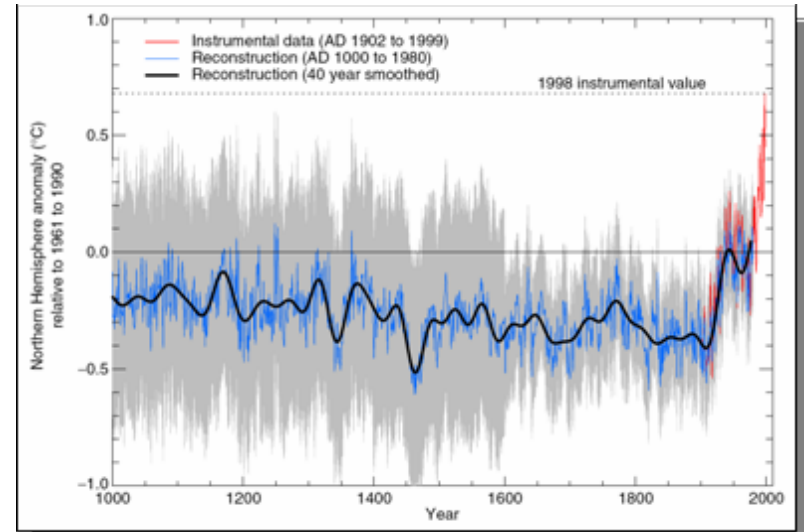
Adaptive Material Systems

# MAJOR CHALLENGES OF THE 21<sup>st</sup> CENTURY

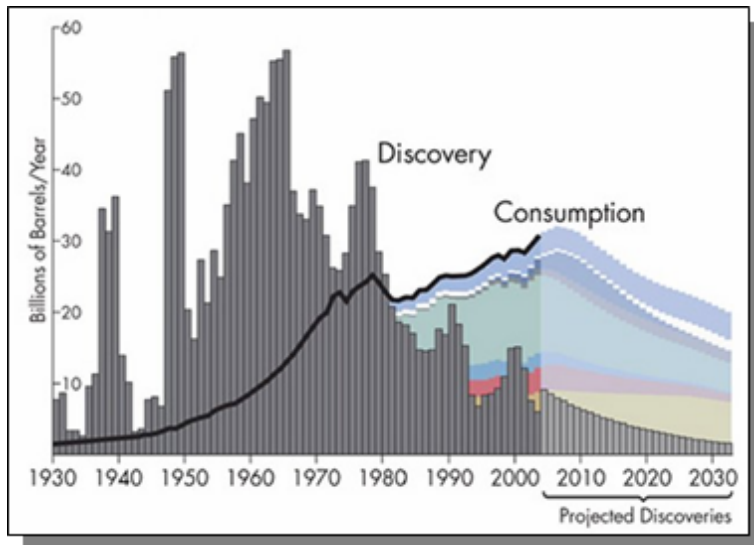
## ENERGY DEMAND



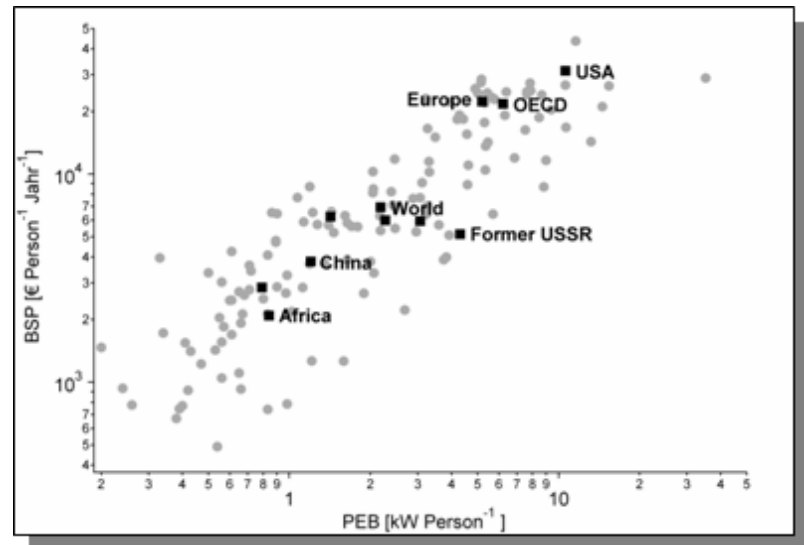
## CLIMATE CHANGE



## LIMITED RESOURCES

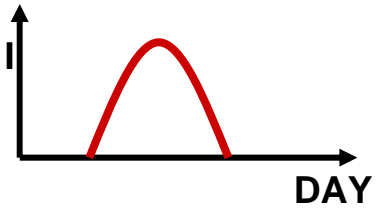


## ECONOMIC DEPENDENCY

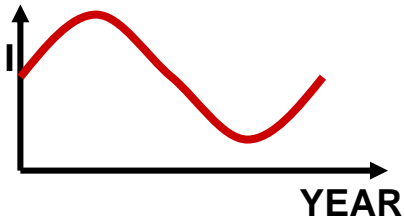


# RENEWABLE ENERGY

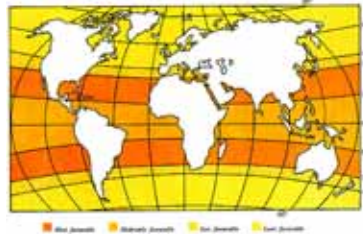
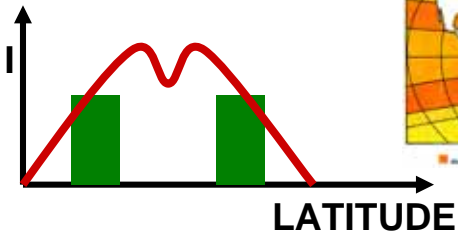
## DAY-NIGHT CYCLE



## SEASONAL CYCLE



## SPATIAL ENERGY DISTRIBUTION



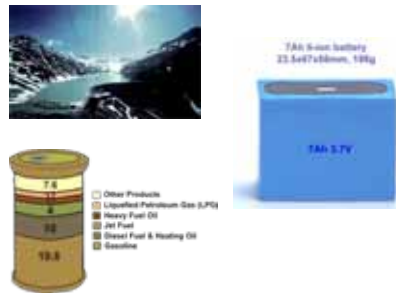
## CONVERSION



## RESIDENTIAL Heat



## STORAGE



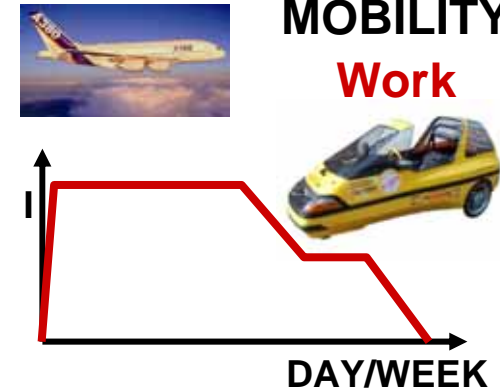
## INDUSTRY Heat & Work



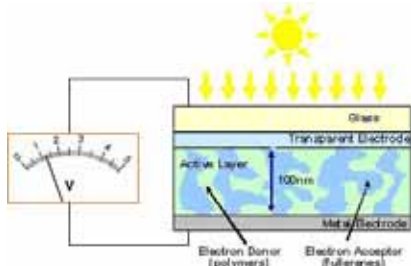
## TRANSPORT



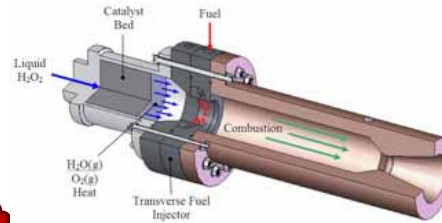
## MOBILITY Work



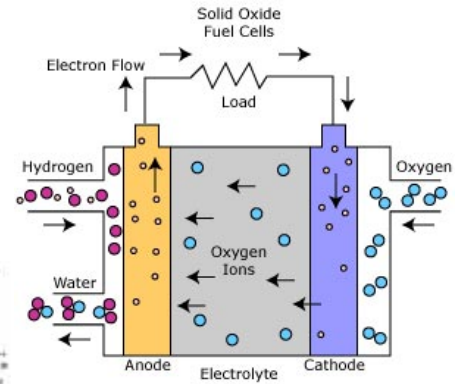
# EMPA RESEARCH ON ENERGY AND ENVIRONMENT



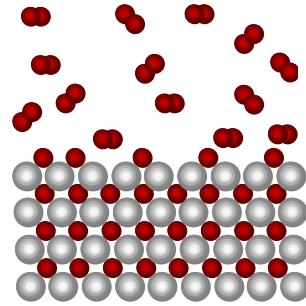
Polymer Photovoltaics



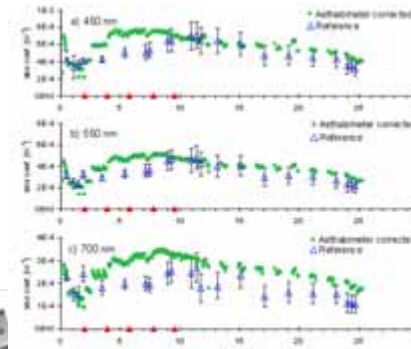
Fuel ( $H_2$ ) Combustion



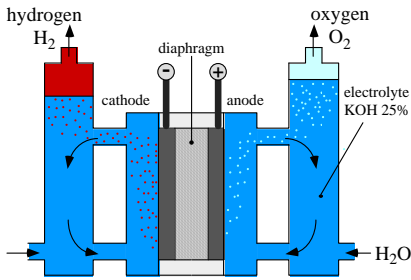
Solid Oxid Fuel Cells



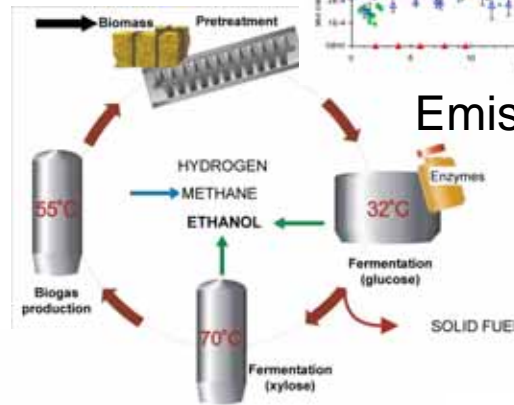
Hydrogen Storage



Emissions



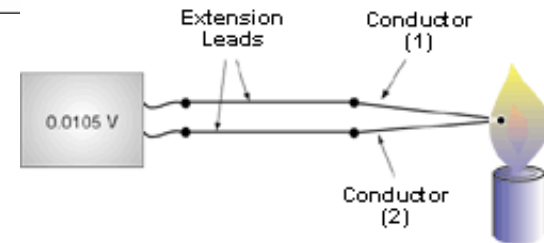
Hydrogen Production



Biofuels



Municipal FC vehicle



Thermoelectricity



Integrated Energy Systems for Buildings

# ORGANISATION

## BOARD: STRATEGY



Chairman  
Prof. Dr. Andreas Züttel



Vice Chair  
Dr. Frank Nüesch



Dr. Rainer Zah



Mark Zimmermann



Dr. Patrik Soltic



Dr. Peter Richner

# PROJECT EXPERTS



Org. photovoltaic  
Dr. Frank Nüesch



Thin film photovoltaics  
Prof. Dr. Ayodhya Tiwari



Si photovoltaics  
Dr. Laetizia Philippe



Photoelectrolysis  
Dr. Arthur Braun



Life cycle assessment  
Dr. Rainer Zah



Hydrogen storage  
Prof. Dr. Andreas Züttel



SOEC  
Dr. Ulrich Vogt



Electrolysis  
Dr. Valentina Herzog



Batteries  
Dr. Andreas Borgschulte



Synthetic fuels  
Dr. Oliver Friedrichs



Building Technologies  
Mark Zimmermann



Building Technologies  
Viktor Dorer



SOFC  
Dr. Peter Holtappels



Combustion  
Dr. Ulrich Vogt



IC Engines  
Christian Bach



Thermoelectricity  
Dr. Anke Weidenkaff



Mechanics of Materials  
Dr. Johann Michler



Turbines  
Prof. Dr. Eduardo Mazza

→ [energy@empa.ch](mailto:energy@empa.ch)

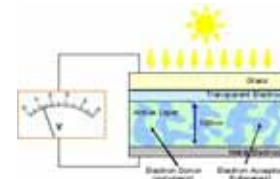
# MATERIALS SCIENCES FOR ENERGY TECHNOLOGY

**GOAL:** Elaboration of the scientific basis in order to sustainably secure the future energy demand of the humanity by innovative technical solutions.

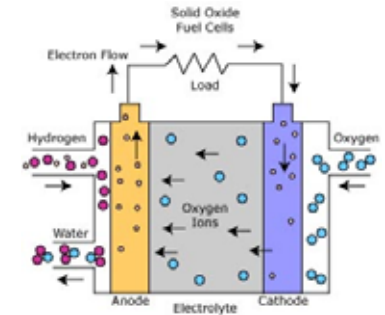
**ZIEL:** Die wissenschaftlichen Grundlagen zu erarbeiten um den zukünftigen Energiebedarf der Menschheit durch innovative technische Lösungen nachhaltig zu decken.

**STRATEGY:** We do **research** on relevant problems, **develop** creative ideas and **establish** realistic solutions for the future energy technology.

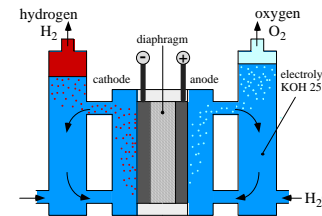
**STRATEGIE:** Wir forschen an **relevanten** Problemen, entwickeln **kreative** Ansätze und etablieren **realistische** Lösungen für die zukünftige Energietechnologie.



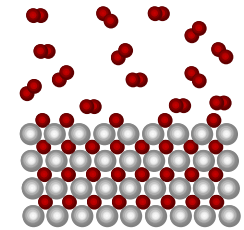
Polymer Photovoltaics



Solid Oxide Fuel Cells



Hydrogen Production



Hydrogen Storage

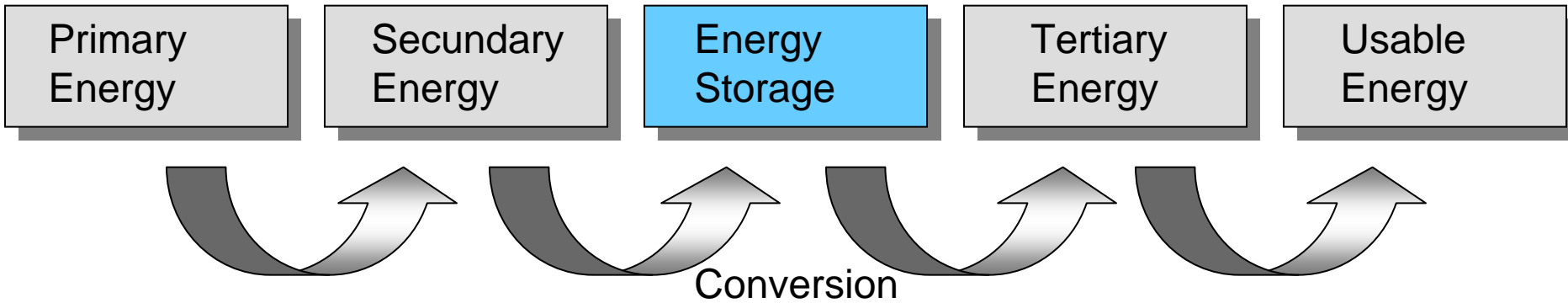


Biofuels



Integrated Energy Systems for Buildings

# MATERIALS FOR ENERGY TECHNOLOGY



## Life cycle and Technology Assessment

### Primary Energy Conv.

- Photovoltaic
- Solarthermal Power
- Windpower
- Hydropower
- Geothermal Heat

- Intensity
- Efficiency
- Continuity

### Energy Storage

- Biomass
- Coal, Oil, Gas
- Batteries
- Hydrogen
- Ammonia
- synth. -CH<sub>2</sub>-
- Methanol

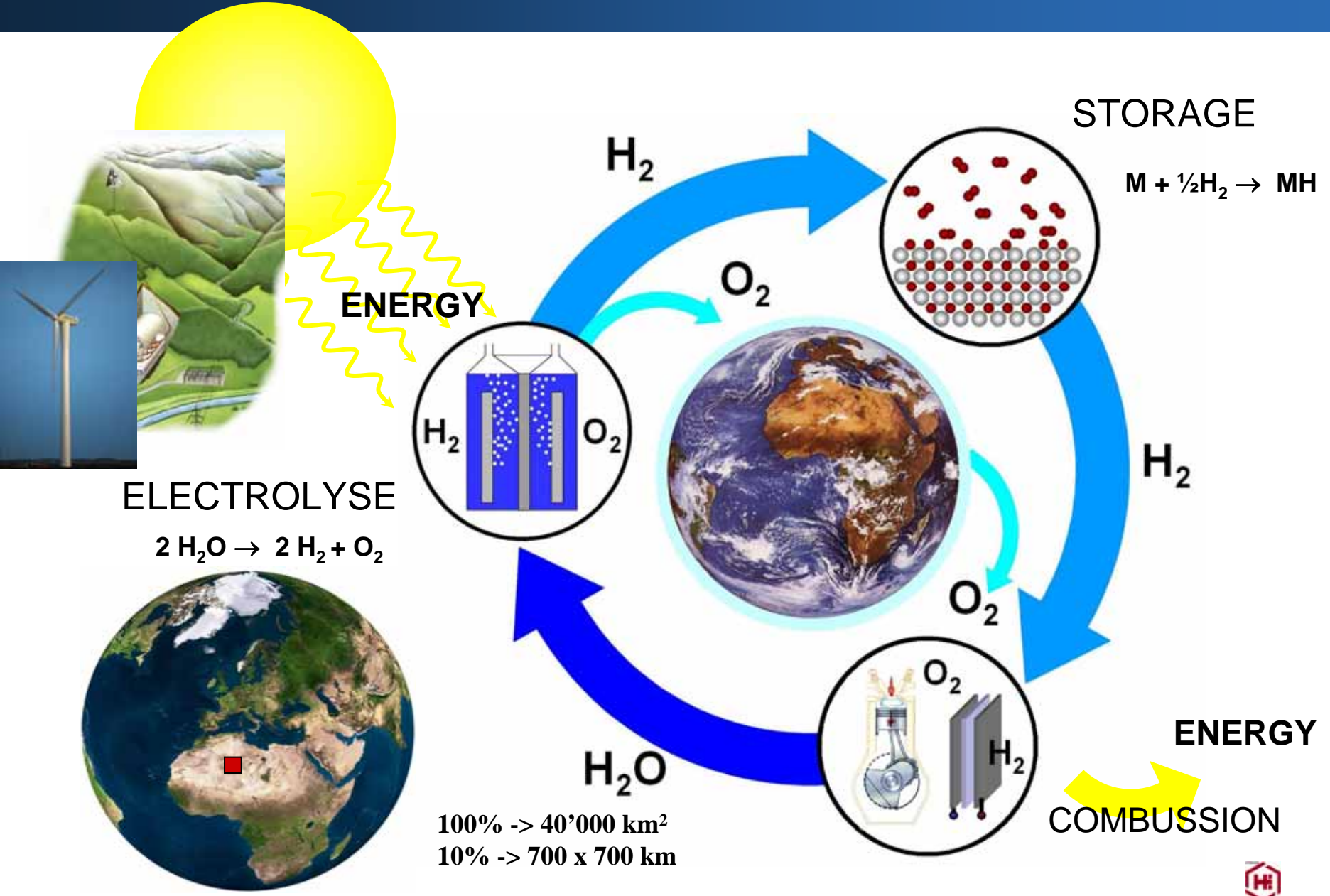
- vol. Energy Density
- grav. Energy Density
- Efficiency

### Use of Energy

- Engines
- Turbines
- Heat & Heattransport
- Light
- Fuel Cells
- Thermoelectricity

- Efficiency
- Dynamics
- Power Density

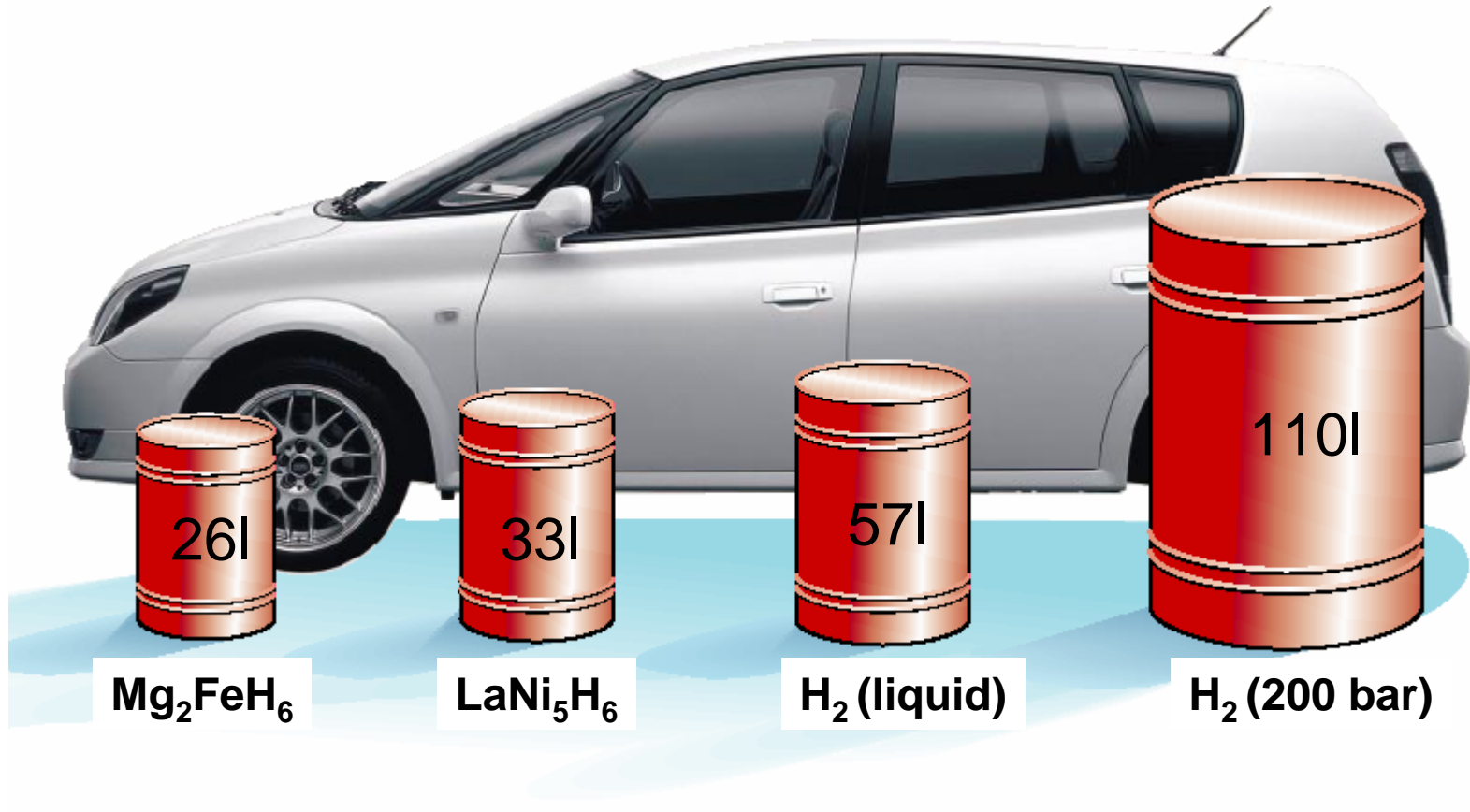
# HYDROGEN AS AN ENERGY CARRIER



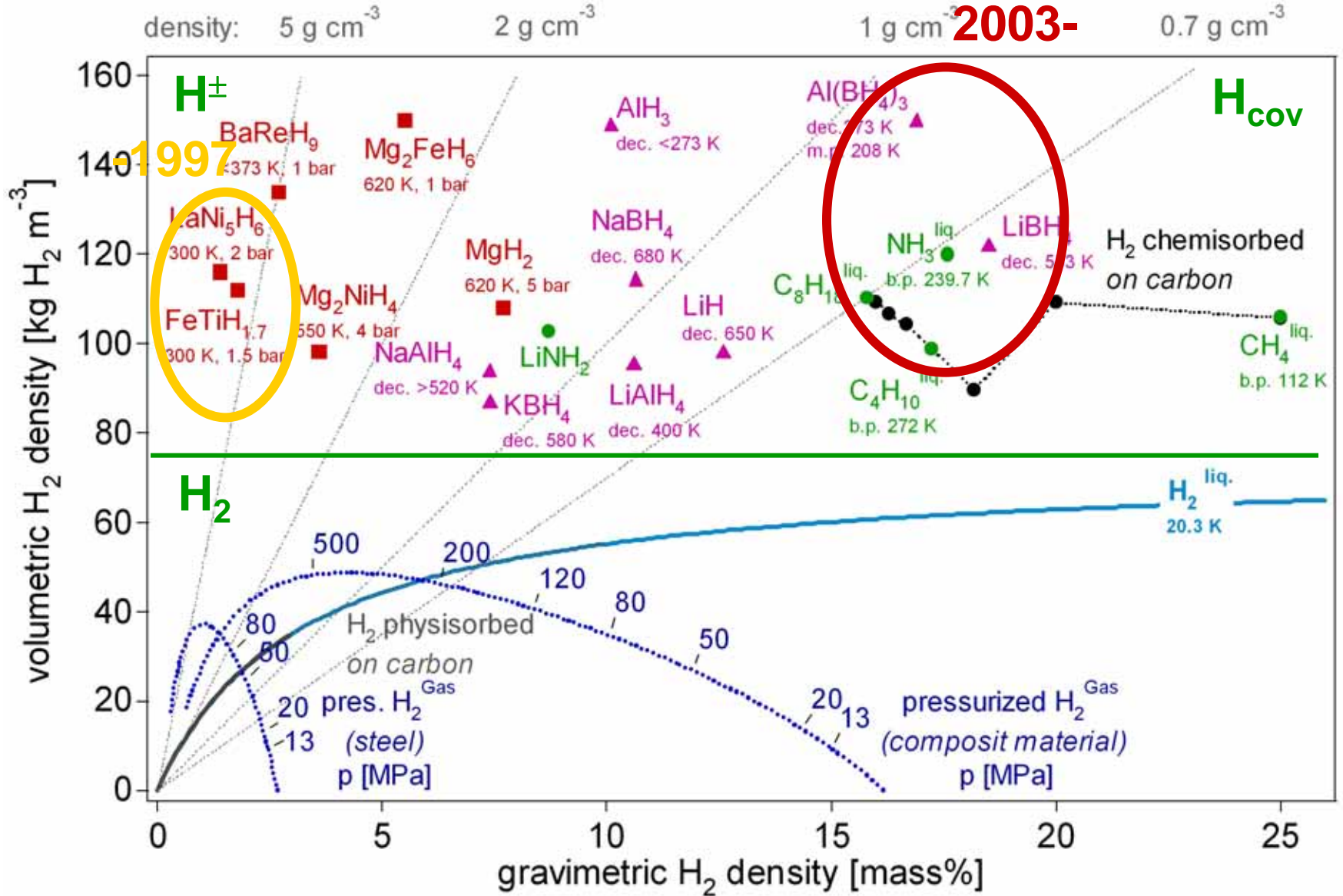
# VOLUMEN DER WASSERSTOFF SPEICHER

**4 kg Wasserstoff**

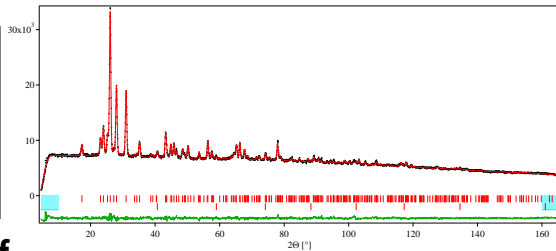
3 l Benzin / 100 km = 0.3 kWh / km



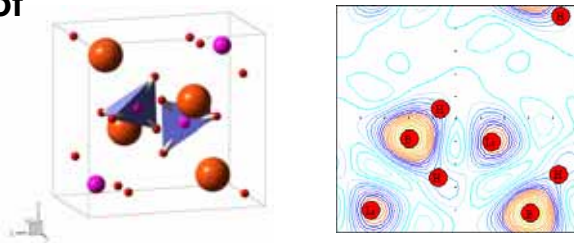
# HYDROGEN DENSITY



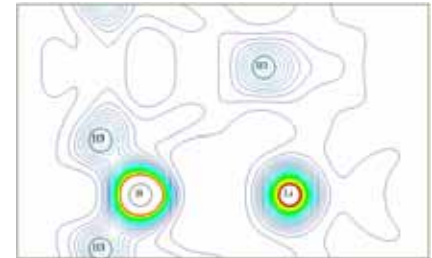
## STRUCTURE AND DYNAMICS



A. Remhof



## THEORETICAL MODELLING

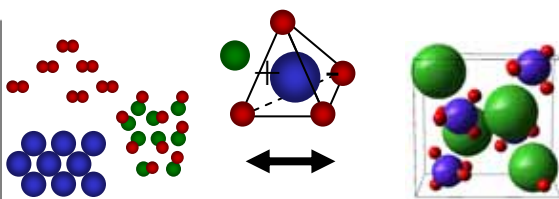


Z. Lodziana R. Caputo

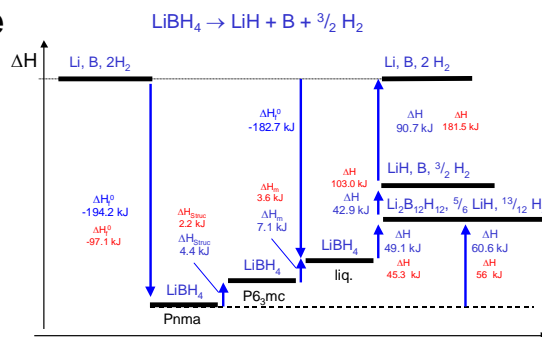


$$G(T, p) = H(S, V) - TS(T, p) + pV$$

## STABILITY AND KINETICS



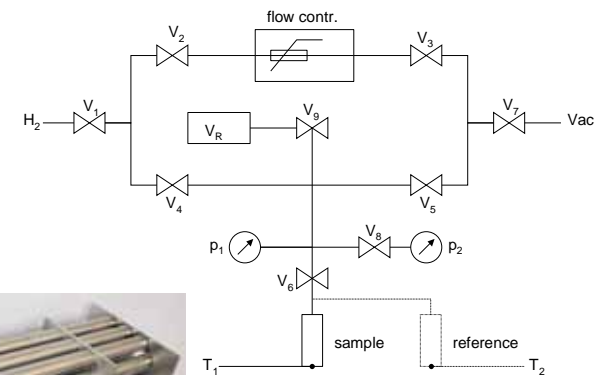
A. Borgschulte



## SAFETY & INSTRUMENTS



M. Biemann



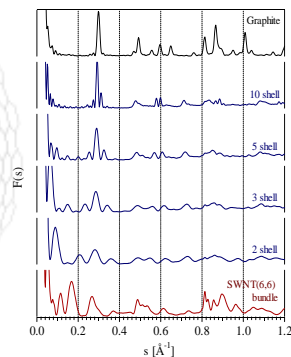
# DEVELOPING AREAS

## NANO-DIFFRACTION



$$F(s) = I_0 \cdot N \cdot f^2(s) \cdot \left\{ 1 + \frac{D}{N} \sum_{n \neq m} \frac{\sin(2 \cdot \pi \cdot s \cdot r_{n,m})}{2 \cdot \pi \cdot s \cdot r_{n,m}} \right\}$$

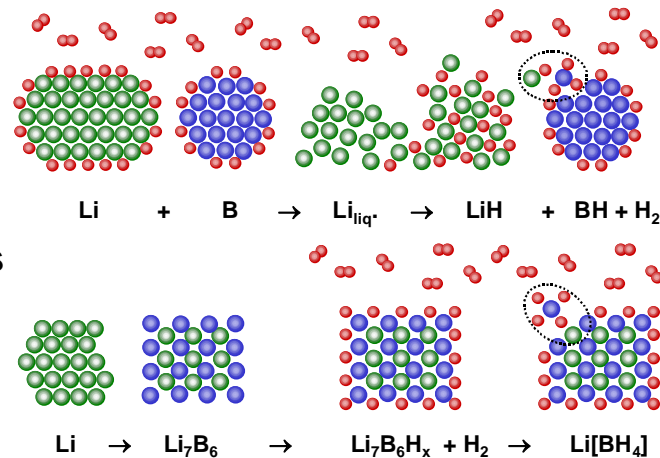
Ph. Mauron



## SYNTHESIS



O. Friedrichs



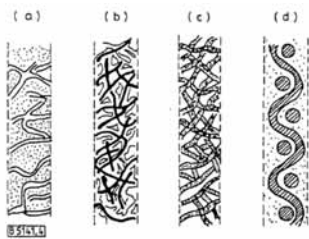
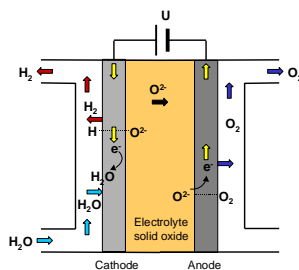
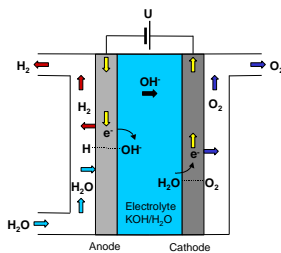
## ELECTROCHEMISTRY



V. Herzog



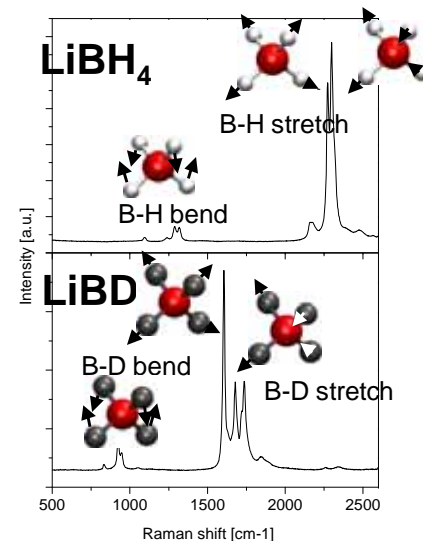
U. Vogt



## RAMAN, UV and IR SPECTROSCOPY



R. Gremaud



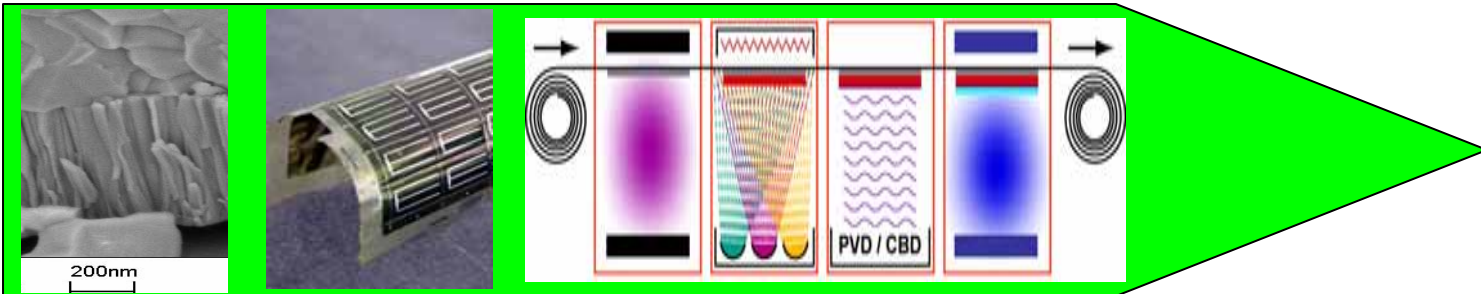
# THIN FILM AND ORGANIC PHOTOVOLTAICS

silicon



GOAL: Costs down  $< 1 \text{€}/\text{W}_p$

ClGS



short term

medium term

long term

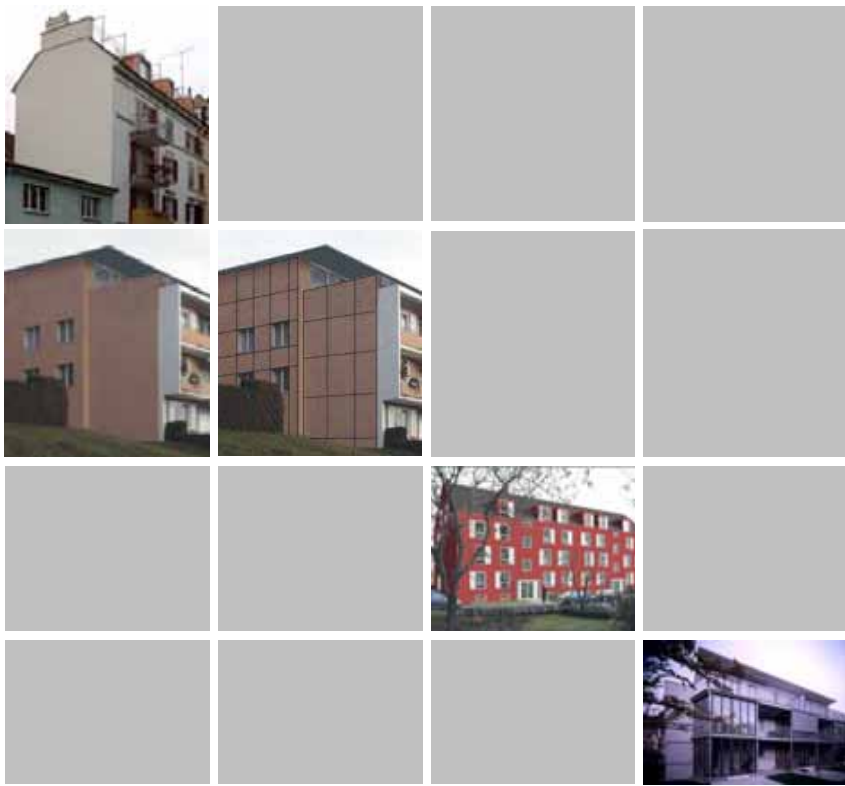


# ADVANCED ENERGY-EFFICIENT BUILDING

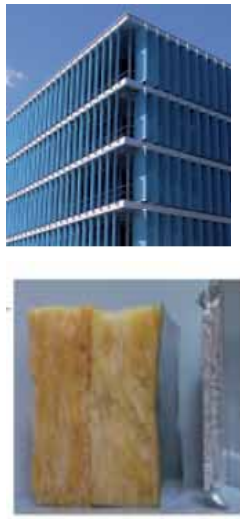
## Existing Situation



## Retrofit Design Options



## New Buildings



**Solutions** Typical solutions for façades, roofs and HVAC

# ENERGY CYCLE ASSESSMENT



**Erosion**



**Toxicity**



**Airpollution**



**Resources**



**Climatechange**



**Waterpollution**

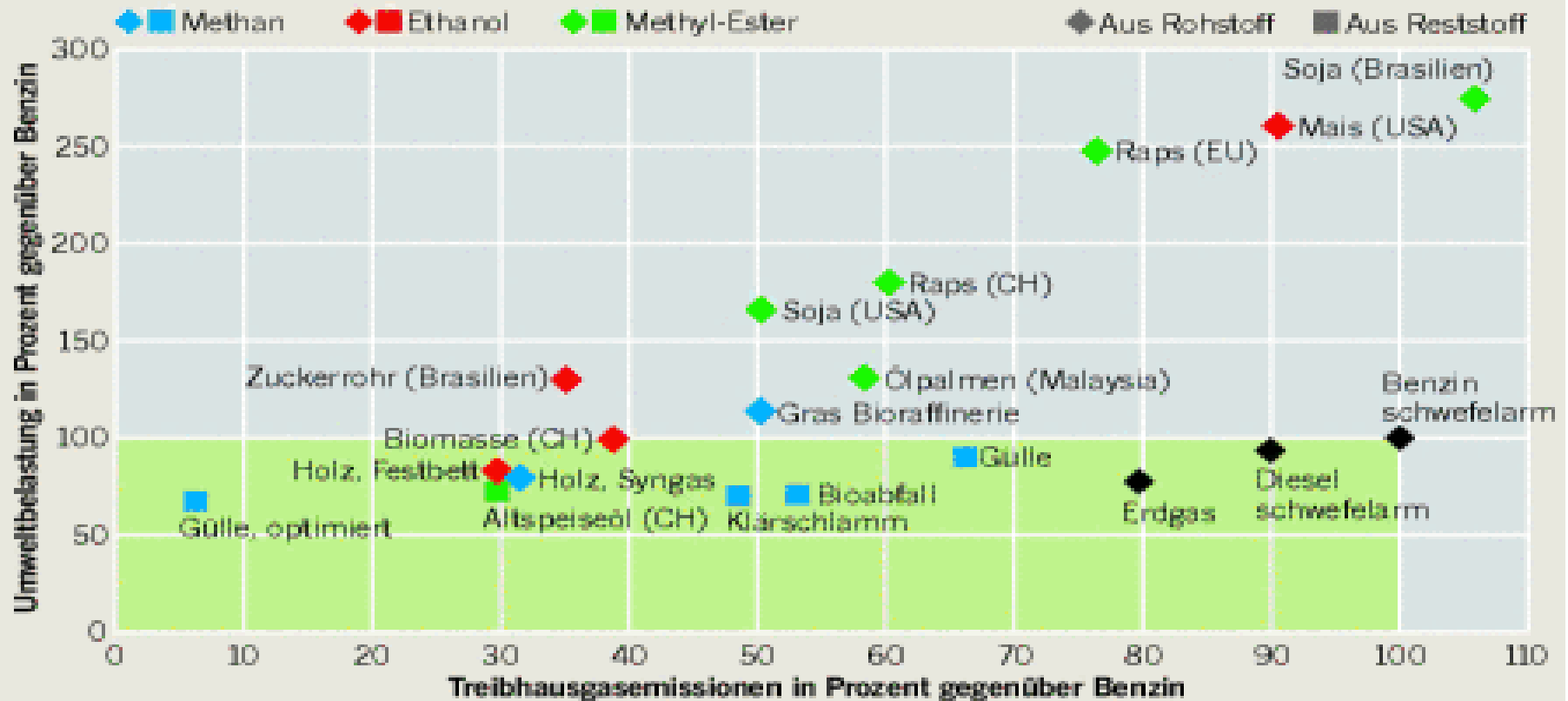


**Extinction**

# ENVIRONMENTAL IMPACT OF FUELS

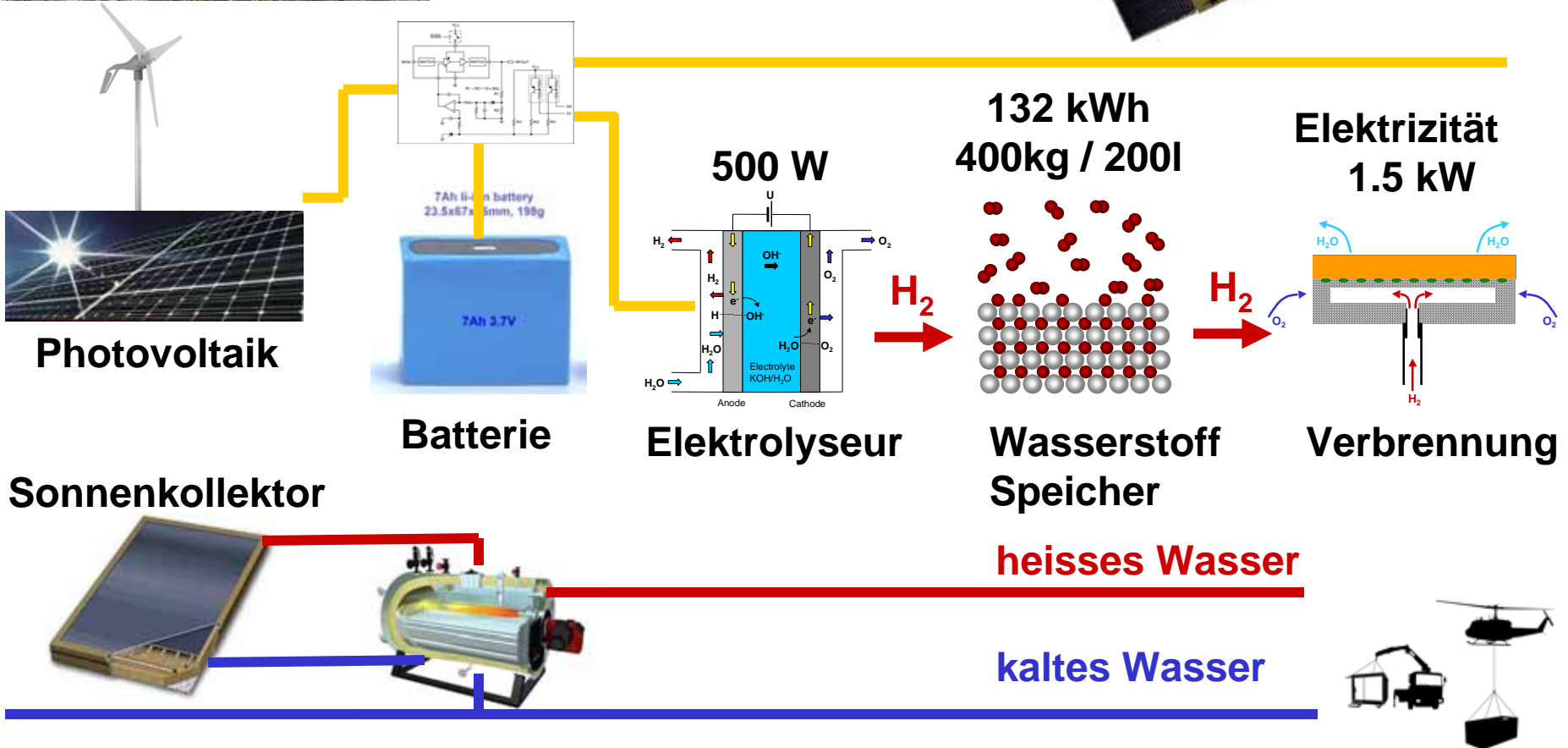
## Treibhausgasemissionen und Umweltbelastung von Biotreibstoffen

Nur die Treibstoffe im grünen Bereich schneiden sowohl bei Treibhausgasen als auch bei Umweltbelastung besser ab als Benzin

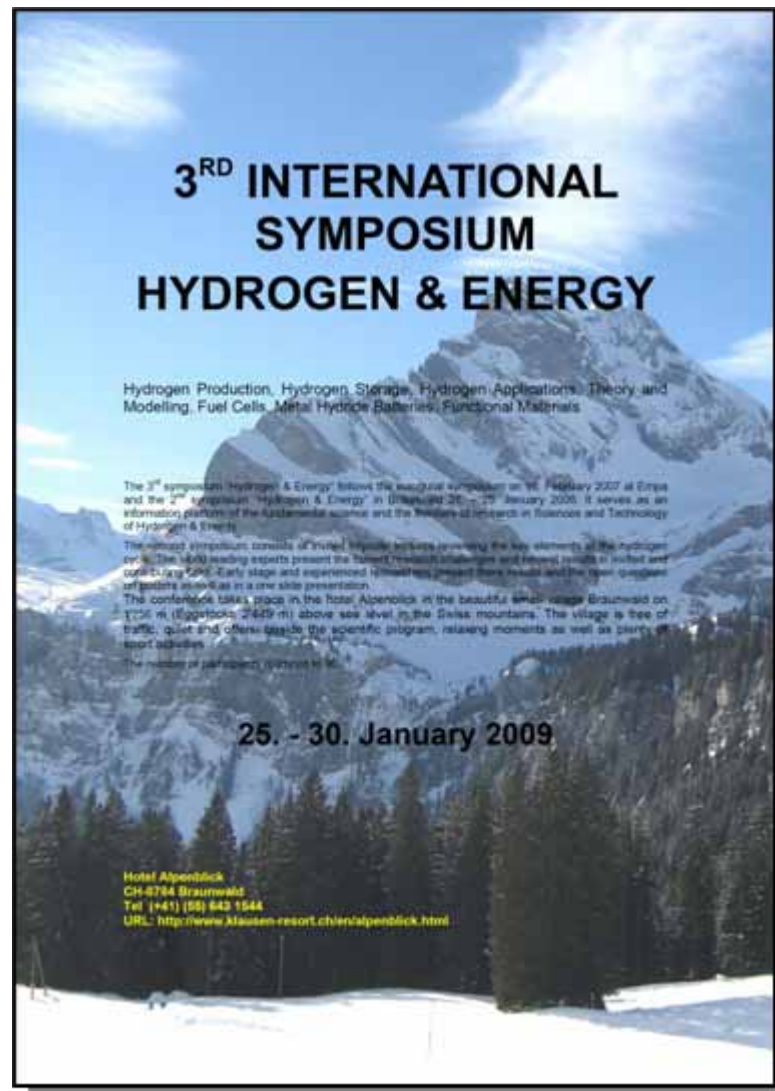
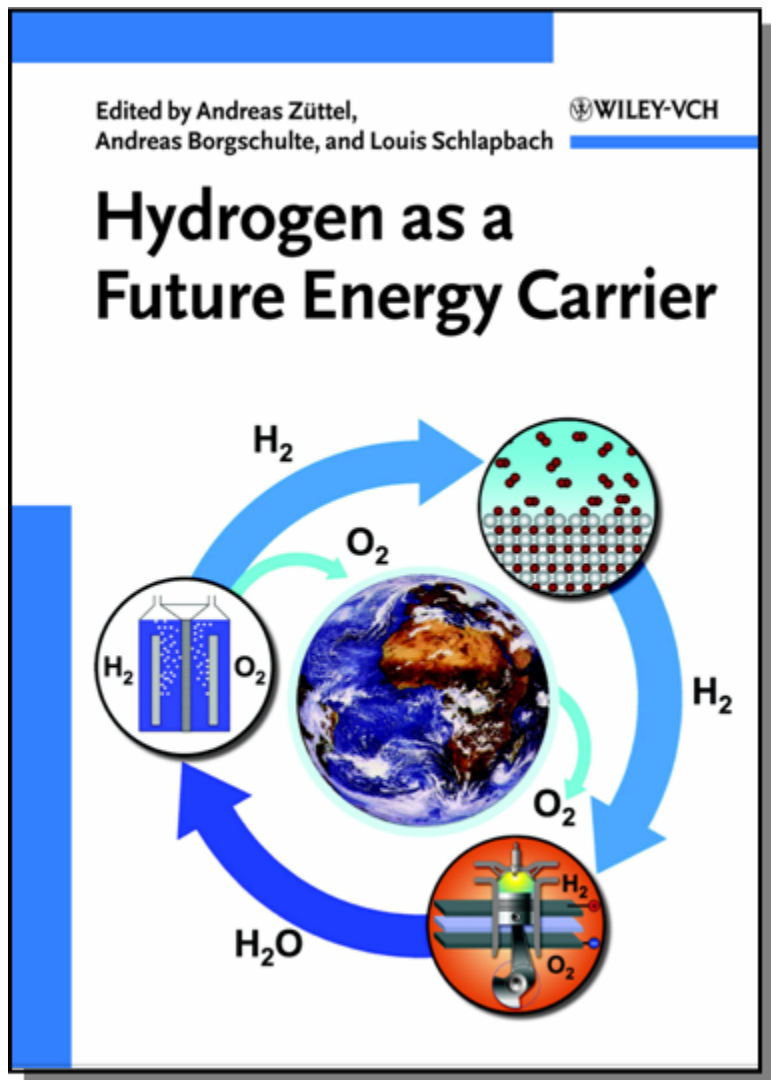


Quelle: Empa, eigene Vereinfachungen

# DEMONSTRATION DEVELOPMENT

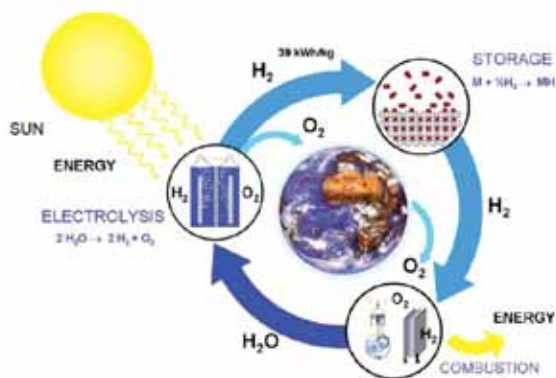


# BOOK & SYMPOSIUM



Announcement

# 4th Symposium Hydrogen & Energy



January 24–29, 2010

Hotel Hirschen, Wildhaus, Switzerland

Registration online:

[www.empa.ch/h2e-symposium](http://www.empa.ch/h2e-symposium)

■ Subjects

- Hydrogen production
- Hydrogen storage
- Fuel Cells
- Applications
- Theory and Modelling

■ Steering Committee

Maximilian Fichtner	Germany
Ronald Griessen	The Netherlands
Jens Nørskov	Denmark
Shin-Ichi Orimo	Japan
Andreas Züttel	Switzerland

■ Invited Speakers

Peter Edwards	Great Britain
Rainer Kirchheim	Germany
Krijn P. de Jong	The Netherlands
Rüdiger Bormann	Germany
Rex Harris	Great Britain
YoungWhan Cho	South Korea
Etsuo Akiba	Japan
Konstantinos Boulouchos	Switzerland
Ewa Ronnebro	USA
Duncan Gregory	Great Britain
Jean-Marie Tarascon	France

■ Program

	So	Mo	Tu	We	Th	Fr
09:00						
12:00						
14:00		Lunch				
17:00	Recept.		Social event	free		Depart.
18:00	Dinner	Dinner	Dinner	Dinner	Conf. dinner	
21:00		Poster	Poster			

inv. lec. inv. talk, talk

■ Registration

Conference fee CHF 200.– (ca. Euro 130.–)

incl. proceedings and social event

Participants

Single room p.P. CHF 1090.– (ca. Euro 725.–)

Double room p.P. CHF 990.– (ca. Euro 660.–)

special rates incl. hotel room for 5 nights, coffee breaks, breakfast, lunch, dinner and conference dinner excl. beverages

Deadline

Registration and abstract submission: October 31, 2009

Registration online: [www.empa.ch/h2e-symposium](http://www.empa.ch/h2e-symposium)

■ Location



Hotel Hirschen, Wildhaus  
Phone +41 71 998 54 54  
info@hirschen-wildhaus.ch  
www.hirschen-wildhaus.ch

■ Organized by

Empa – Materials Sciences & Technology  
Department Environment, Energy and Mobility  
Laboratory for Hydrogen & Energy  
Überlandstrasse 129, CH-8600 Dübendorf

Phone +41 44 823 4692, 4038

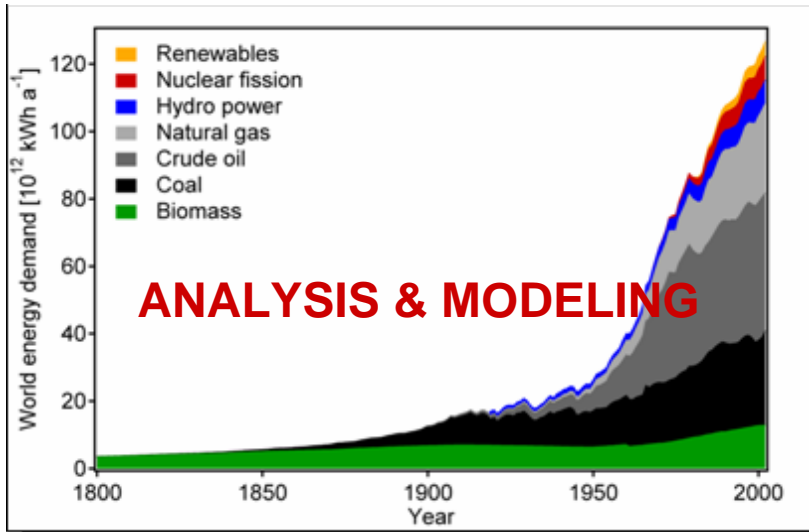
Fax +41 44 823 4022

E-mail [h2e@empa.ch](mailto:h2e@empa.ch)

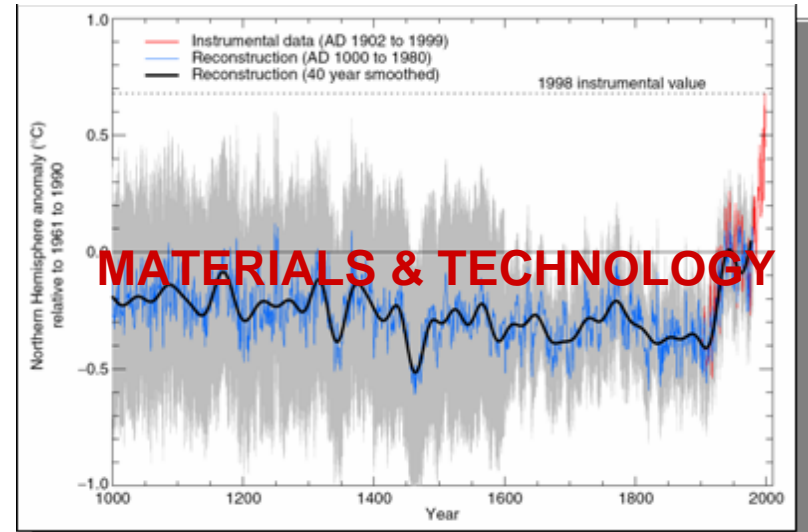
[www.empa.ch/h2e](http://www.empa.ch/h2e)

# MAJOR CHALLENGES OF THE 21<sup>st</sup> CENTURY

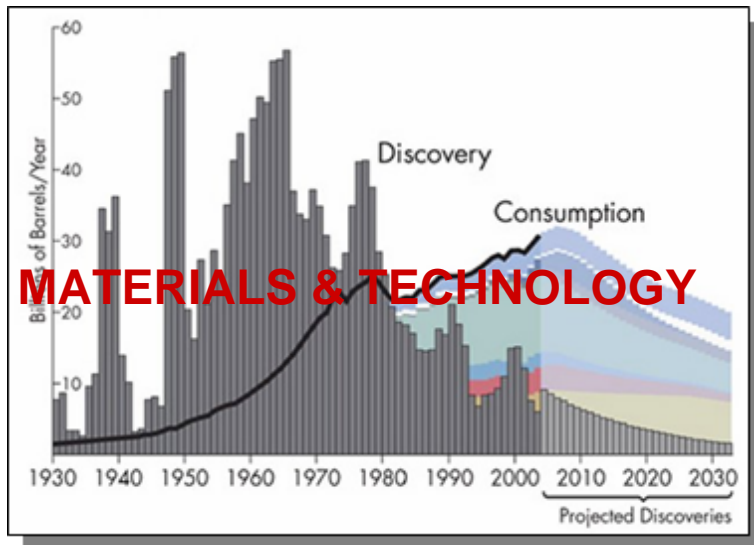
## ENERGY DEMAND



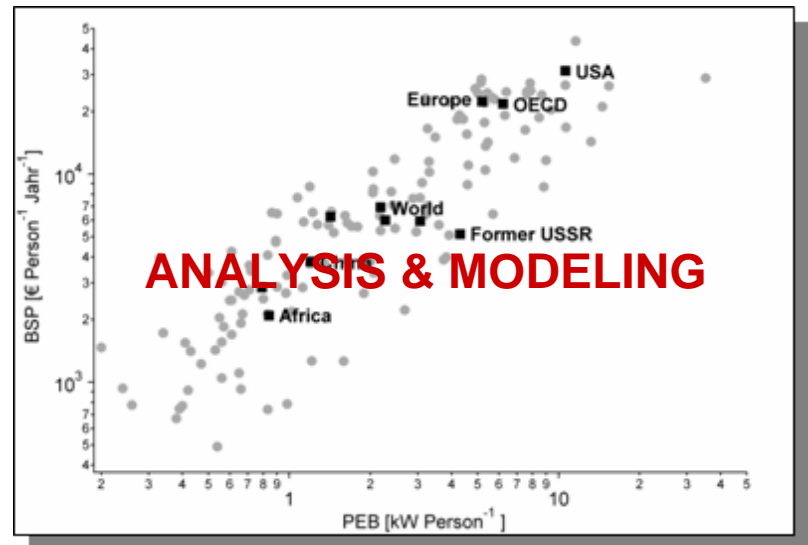
## CLIMATE CHANGE



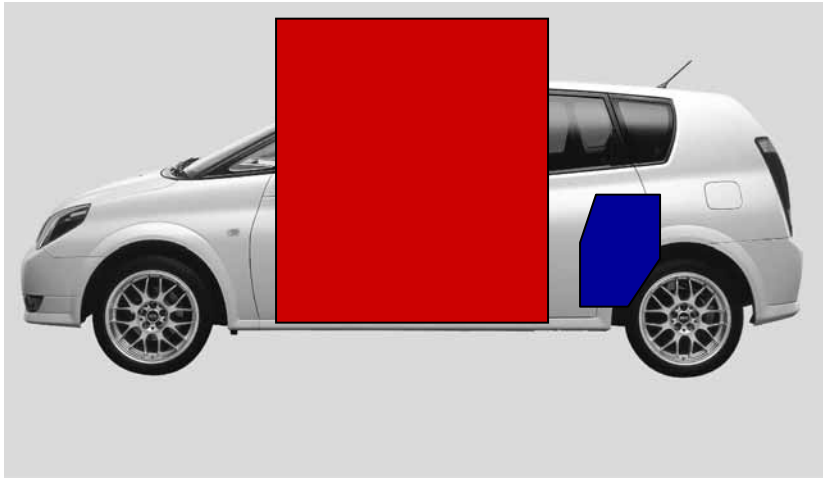
## LIMITED RESOURCES



## ECONOMIC DEPENDENCY



# SPACE FOR ENERGY CARRIERS



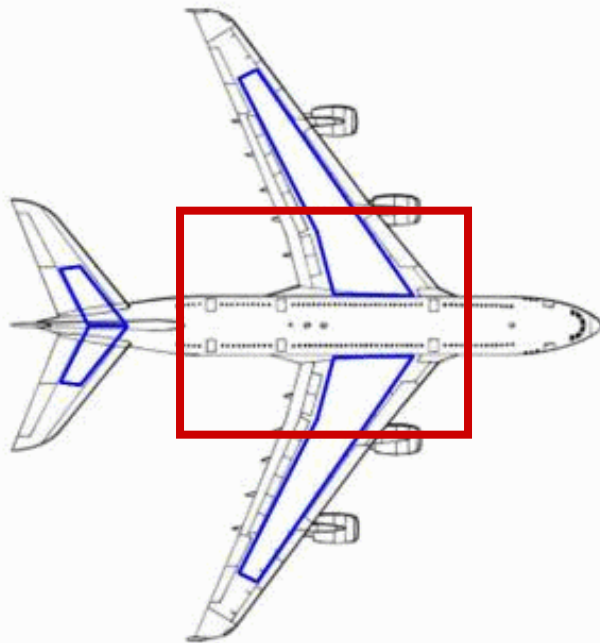
50 kg , 70 l Gasoline

$$Q = 650 \text{ kWh}_{\text{therm}} \quad W = 200 \text{ kWh}_{\text{mech}}$$

1000 kg , 1000 l Battery

$$W = 200 \text{ kWh}_{\text{mech}}$$

$$P = 30 \text{ kW} \quad P_{\text{max}} = 150 \text{ kW}$$



Airbus A380 Fuel Tank Locations

100 t, 130'000 l Gasoline

$$Q = 1300 \text{ MWh}_{\text{therm}} \quad W = 780 \text{ MWh}_{\text{mech}}$$

4'000 t , 4'000 m<sup>3</sup> Battery

$$W = 800 \text{ MWh}_{\text{mech}}$$

$$P = 50 \text{ MW} \quad P_{\text{max}} = 200 \text{ MW}$$

# ENERGY CARRIERS

