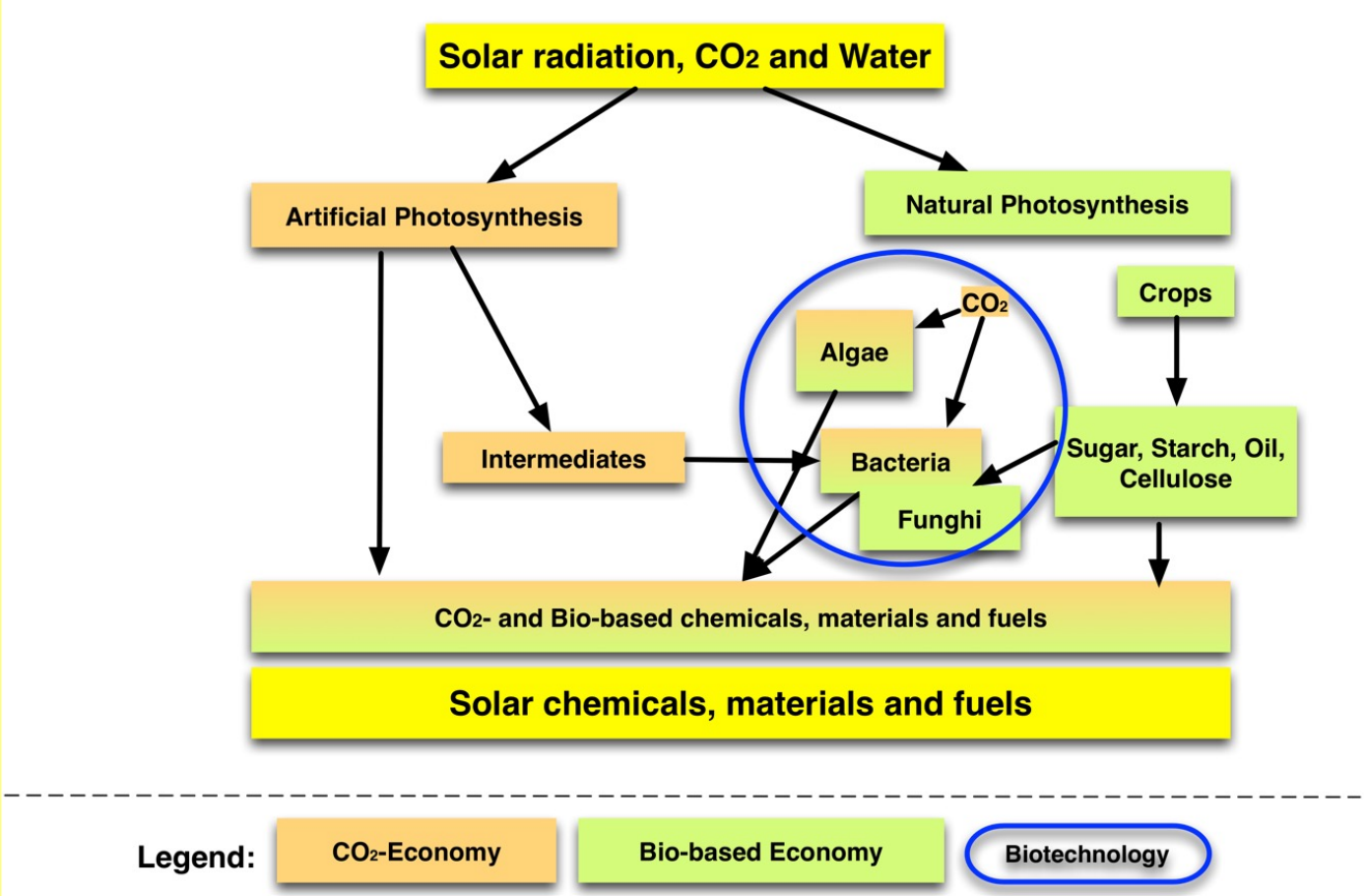
Traunkirchen Akademie Lecture 12th of April, 2024

KRAFTSTOFFE AUS SONNENLICHT

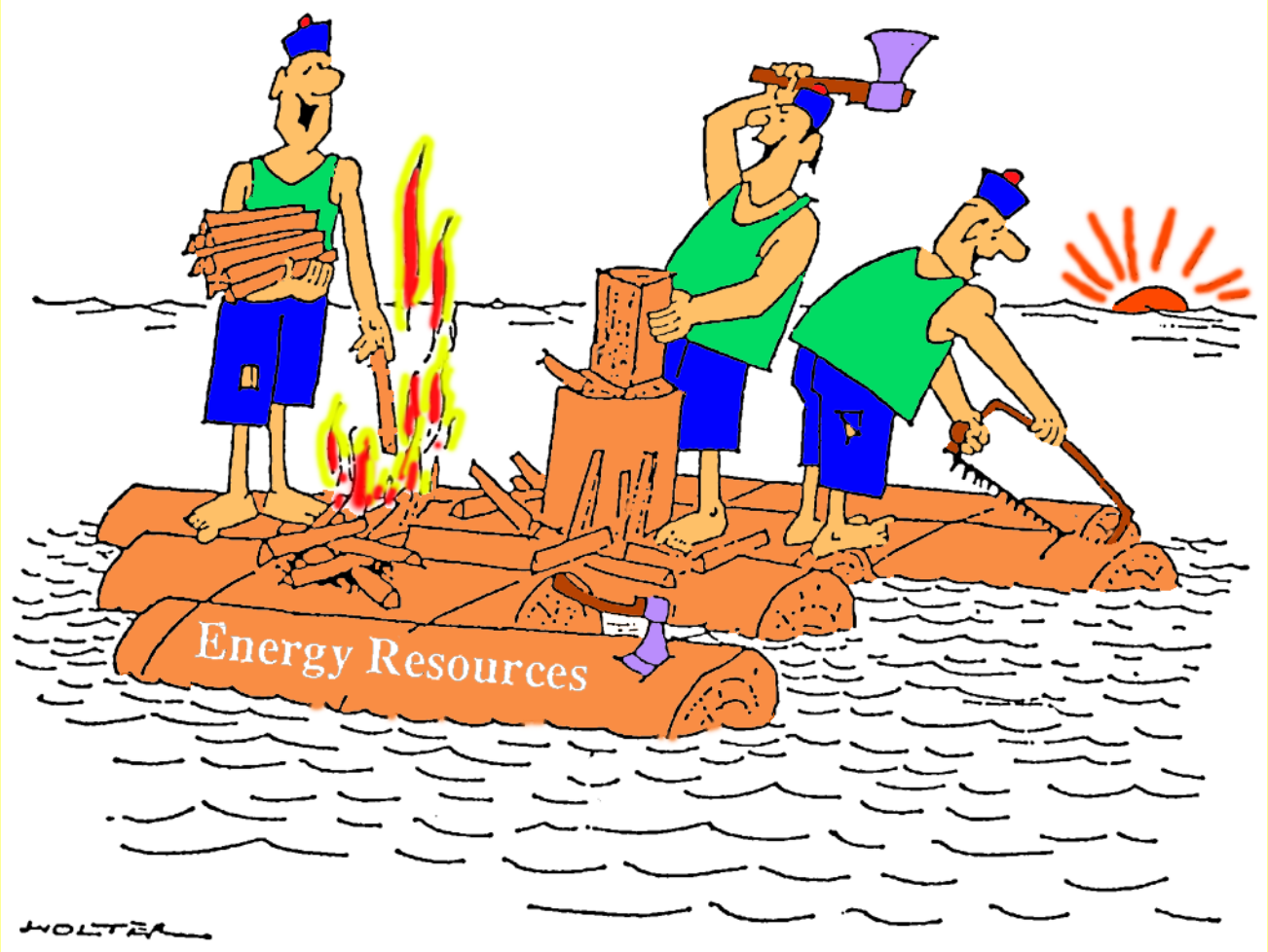


o.Univ.Prof.Dr.DDr.h.c. Niyazi Serdar Sariciftci

Institut für physikalische Chemie an der

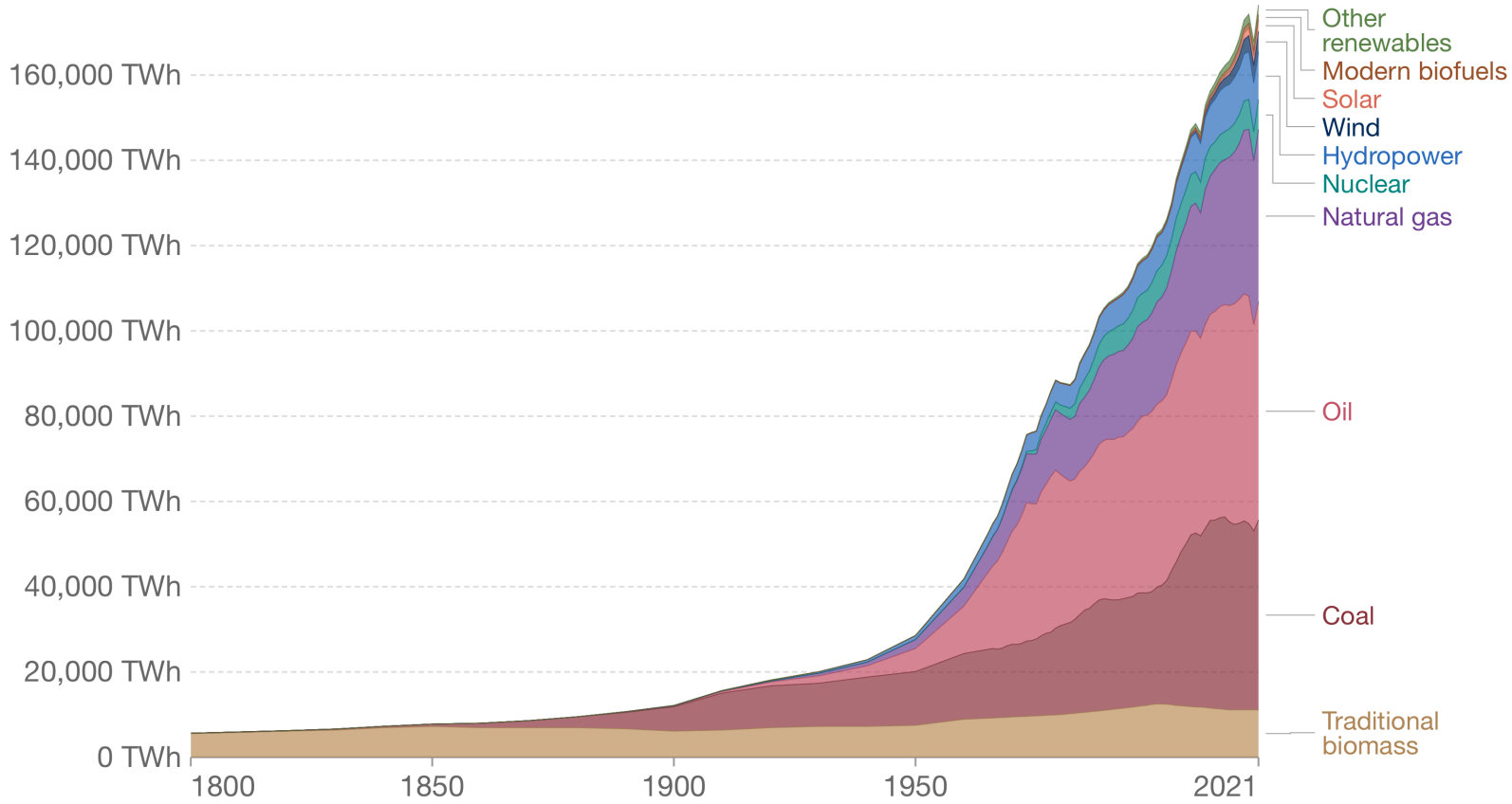
Johannes Kepler Universität Linz

Happy Life



Global primary energy consumption by source

Primary energy is calculated based on the 'substitution method' which takes account of the inefficiencies in fossil fuel production by converting non-fossil energy into the energy inputs required if they had the same conversion losses as fossil fuels.



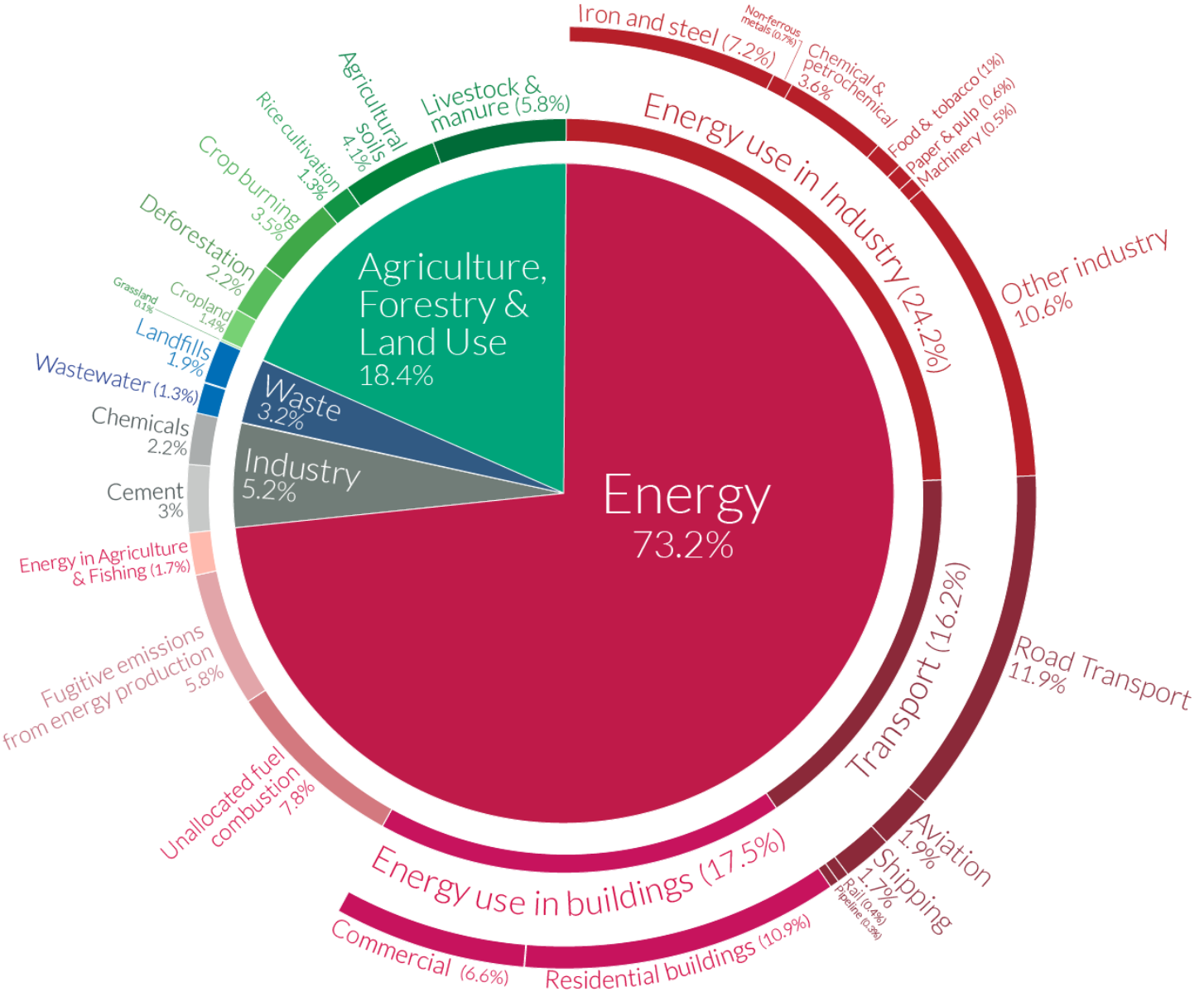
Source: Our World in Data based on Vaclav Smil (2017) and BP Statistical Review of World Energy

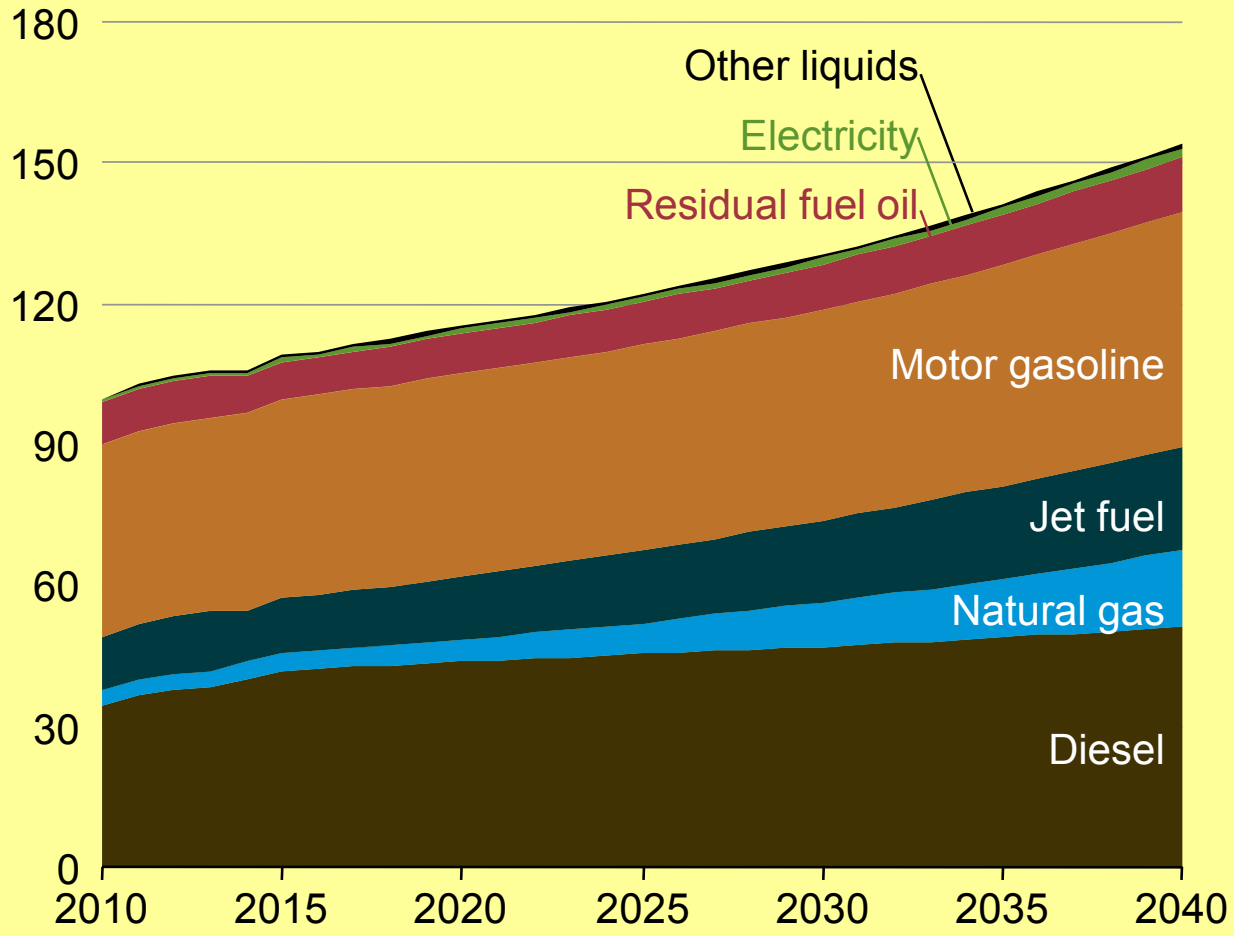
OurWorldInData.org/energy • CC BY

Global greenhouse gas emissions by sector

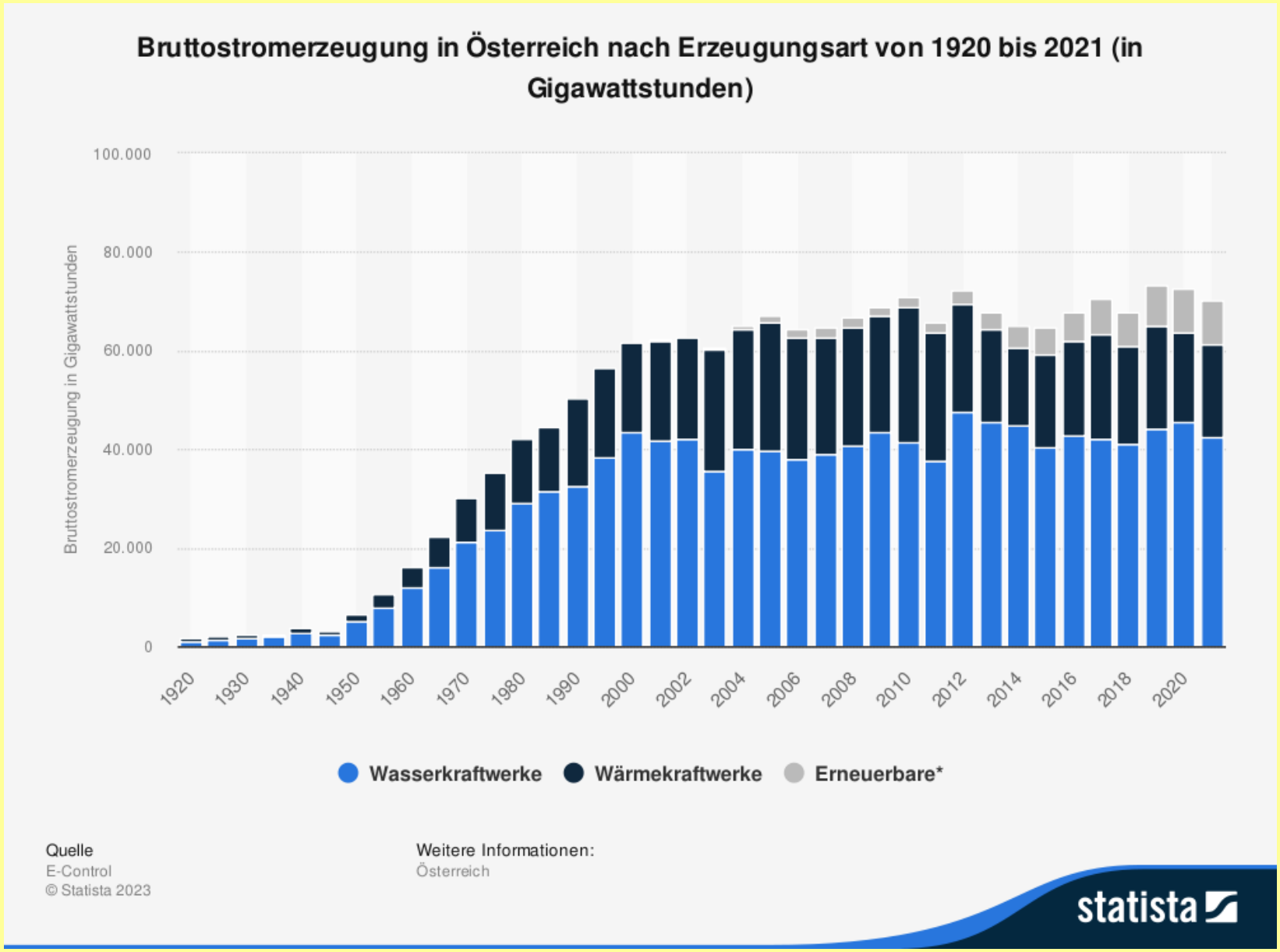
This is shown for the year 2016 – global greenhouse gas emissions were 49.4 billion tonnes CO_2eq.

Our World in Data

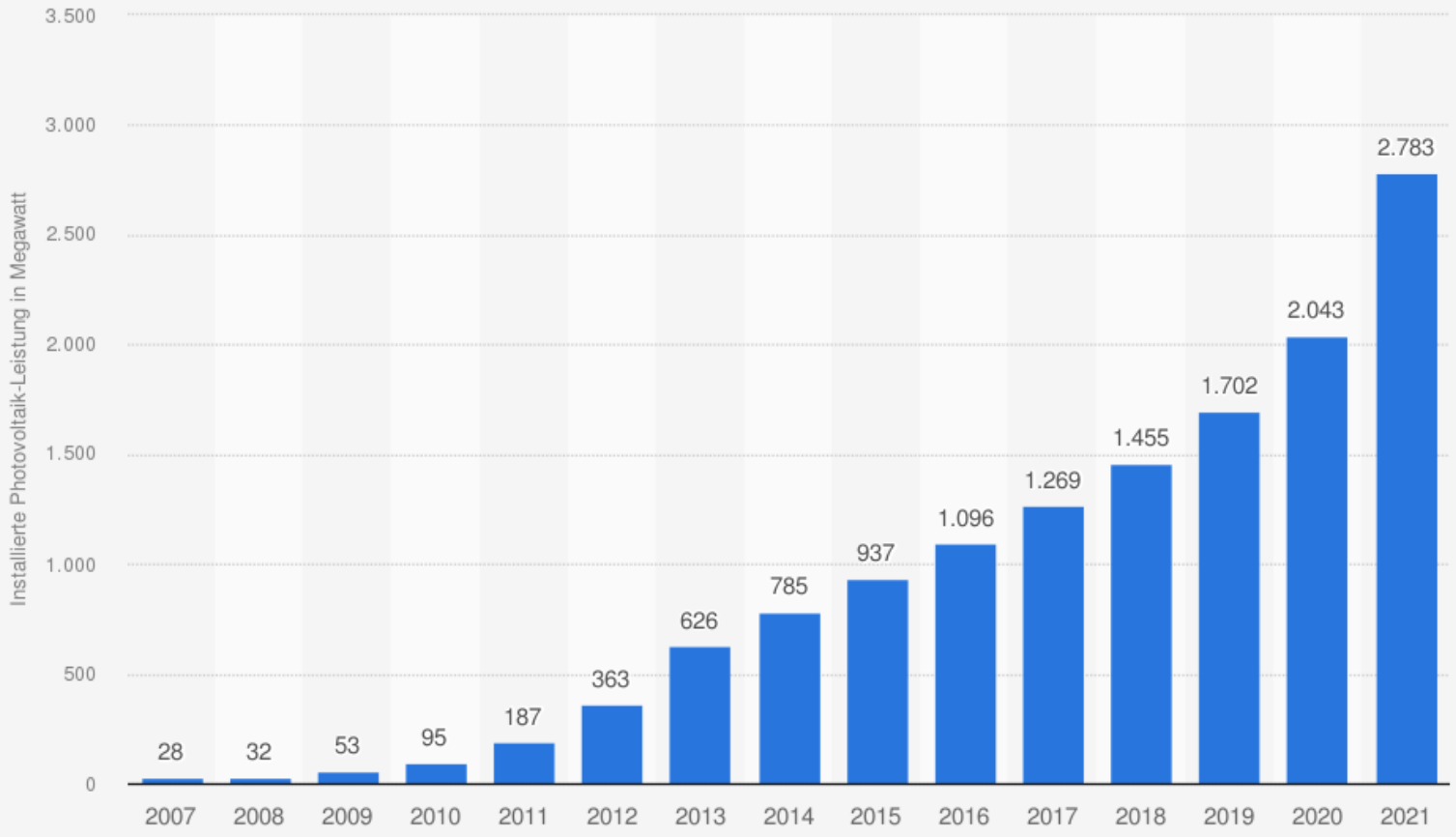




World transportation sector delivered energy consumption 2010-2040 (quadrillion Btu).
Reproduced from International Energy Outlook 2016,
p. 127, U.S. Energy Information Administration.
Other liquid fuels include natural gas plant liquids, biofuels, gas-to-liquids and coal-to-liquids.


Bruttostromerzeugung in Österreich nach Erzeugungsart von 1920 bis 2021 (in Gigawattstunden)
Bruttostromerzeugung in Gigawattstunden
100.000
80.000
60.000
40.000
20.000
0
1920
1930
1940
1950
1960
1970
1980
1990
2000
2002
2004
2006
2008
2010
2012
2014
2016
2018
2020
Wasserkraftwerke
Wärmekraftwerke
Erneuerbare*
Quelle
E-Control
© Statista 2023
Weitere Informationen:
Österreich
statista

Installierte Photovoltaik-Leistung in Österreich von 2007 bis 2021 (in Megawatt)

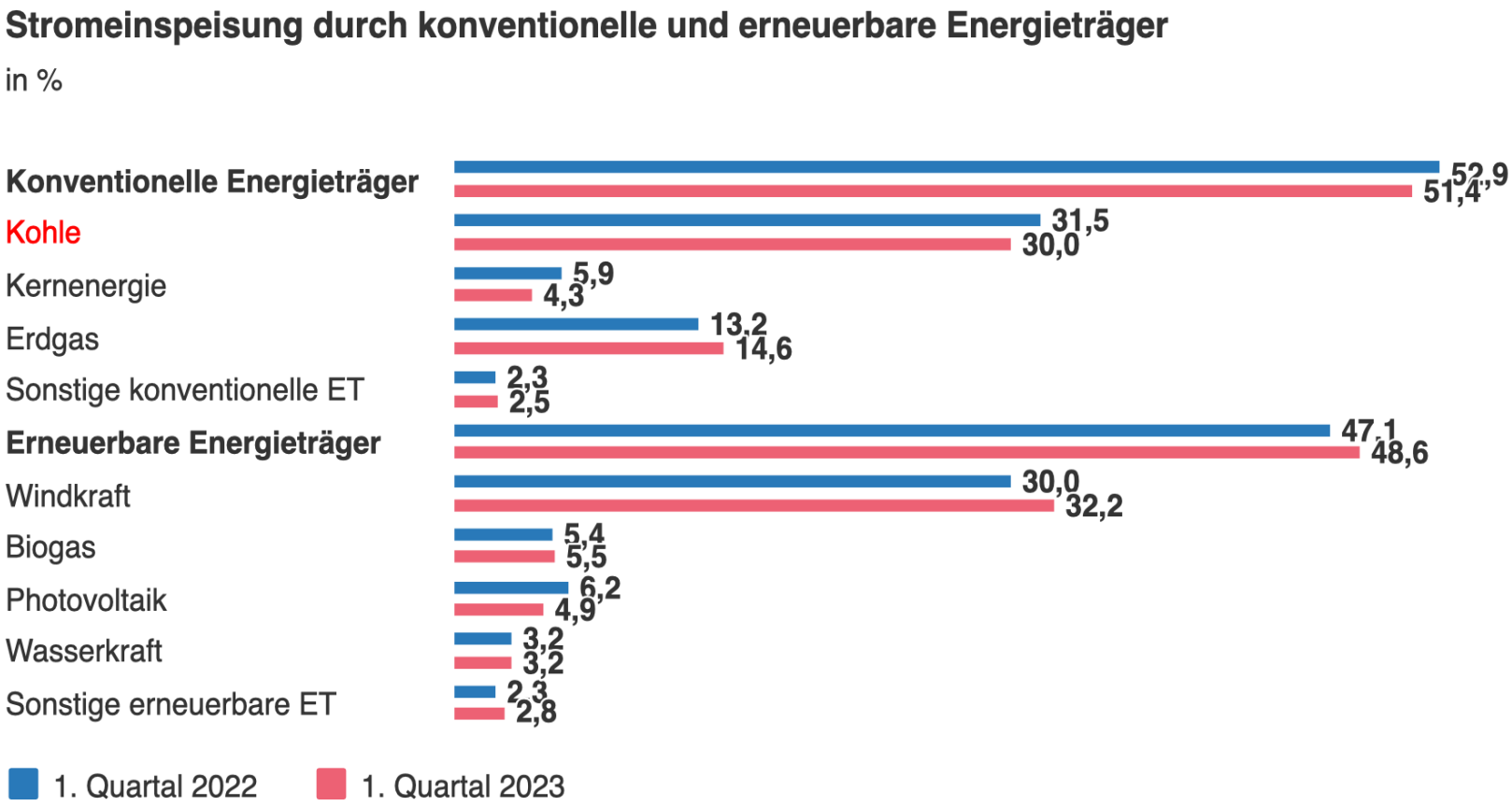


Quelle
Technikum Wien
© Statista 2023

Weitere Informationen:
Österreich; 2007 bis 2021

statista

Deutschland's Energie Mix



tagesschau Sendung verpasst?

illiarden für Elektromobilität

örderung von E-Autos auf Rekordhoch

and: 21.12.2022 10:57 Uhr

Der Bund hat in diesem Jahr so viele Förderprämien an Besitzer von Elektroautos ausgeschüttet wie noch nie. 3,2 Milliarden Euro zahlte er an Subventionen. 2023 dürfte

Future of Mobility and Transport

Primary Energy	Conversion	Distribution Infrastructure

E-Mobility:	Renewable	Not necessary	Grid has to be built worldwide

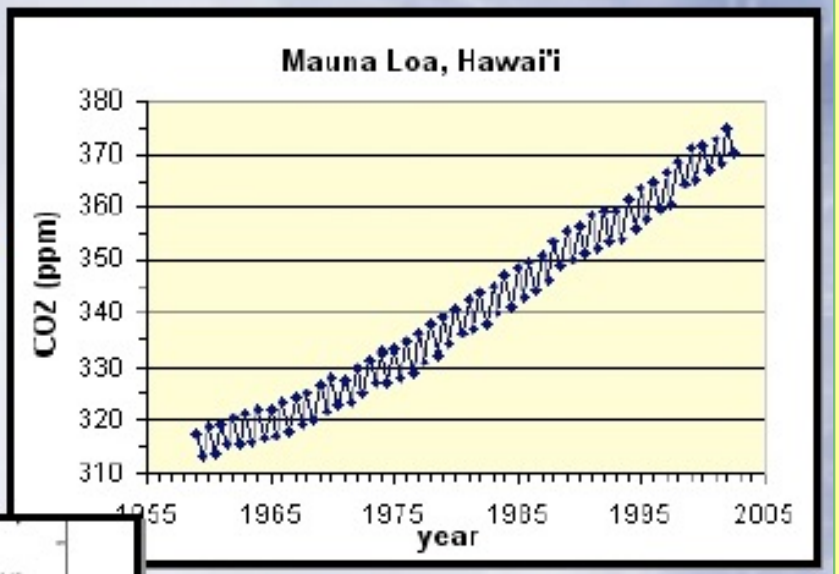
→ Needs global and transcontinental distribution infrastructure of high power electrical grid

E-Fuel Mobility:	Renewable	Conversion needed E2Fuel	Entire infrastructure is existent

→ Needs efficient and economical conversion technology of renewable energy to synthetic fuels

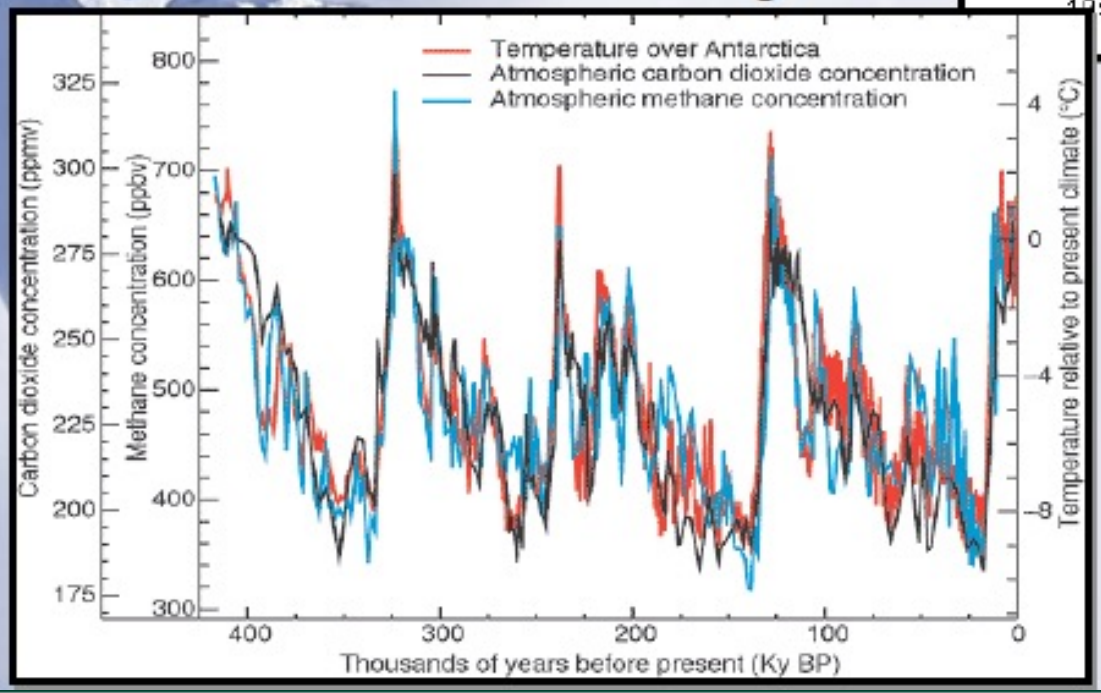
Our planet will be warmer

CO_2 Konzentrationen



Keeling Atmospheric Data Set

Daten aus Vostok-Eisbohrungen



Global warming was predicted

On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground

Svante Arrhenius

Philosophical Magazine and Journal of Science
Series 5, Volume 41, April 1896, pages 237-276.

Arrhenius's paper is the first to quantify the contribution of carbon dioxide to the greenhouse effect (Sections I-IV) and to speculate about whether variations in the atmospheric concentration of carbon dioxide have contributed to long-term variations in climate (Section V). Throughout this paper, Arrhenius refers to carbon dioxide as "carbonic acid" in accordance with the convention at the time he was writing.

Contrary to some misunderstandings, Arrhenius does not explicitly suggest in this paper that the burning of fossil fuels will cause global warming, though it is clear that he is aware that fossil fuels are a potentially significant source of carbon dioxide (page 270), and he does explicitly suggest this outcome in later work.

THE
LONDON, EDINBURGH, AND DUBLIN
PHILOSOPHICAL MAGAZINE
AND
JOURNAL OF SCIENCE.

[FIFTH SERIES.]

APRIL 1896.

XXXI. *On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground.* By Prof. SVANTE ARRHENIUS *.

I. *Introduction: Observations of* Langley *on Atmospherical Absorption.*

A GREAT deal has been written on the influence of the absorption of the atmosphere upon the climate. Tyndall † in particular has pointed out the enormous importance of this question. To him it was chiefly the diurnal and annual variations of the temperature that were lessened by this circumstance. Another side of the question, that has long attracted the attention of physicists, is this: Is the mean temperature of the ground in any way influenced by the presence of heat-absorbing gases in the atmosphere? Fourier‡ maintained that the atmosphere acts like the glass of a hot-house, because it lets through the light rays of the sun but retains the dark rays from the ground. This idea was elaborated by Pouillet §; and Langley was by some of his researches led to the view, that "the temperature of the earth under direct sunshine, even though our atmosphere were present as now, would probably fall to −200° C., if that atmosphere did not possess the quality of selective

* Extract from a paper presented to the Royal Swedish Academy of Sciences, 11th December, 1895. Communicated by the Author.
† 'Heat a Mode of Motion,' 2nd ed. p. 405 (Lond., 1865).
‡ *Mém. de l'Ac. R. d. Sci. de l'Inst. de France*, t. vii. 1827.
§ *Comptes rendus*, t. xii. p. 41 (1838).

Global warming was predicted

Svante August Arrhenius was a Swedish scientist (1858-1927)

Originally a physicist,
but often referred to as a chemist
was the founder of physical chemistry

Nobel Prize for Chemistry in 1903

Global warming was predicted

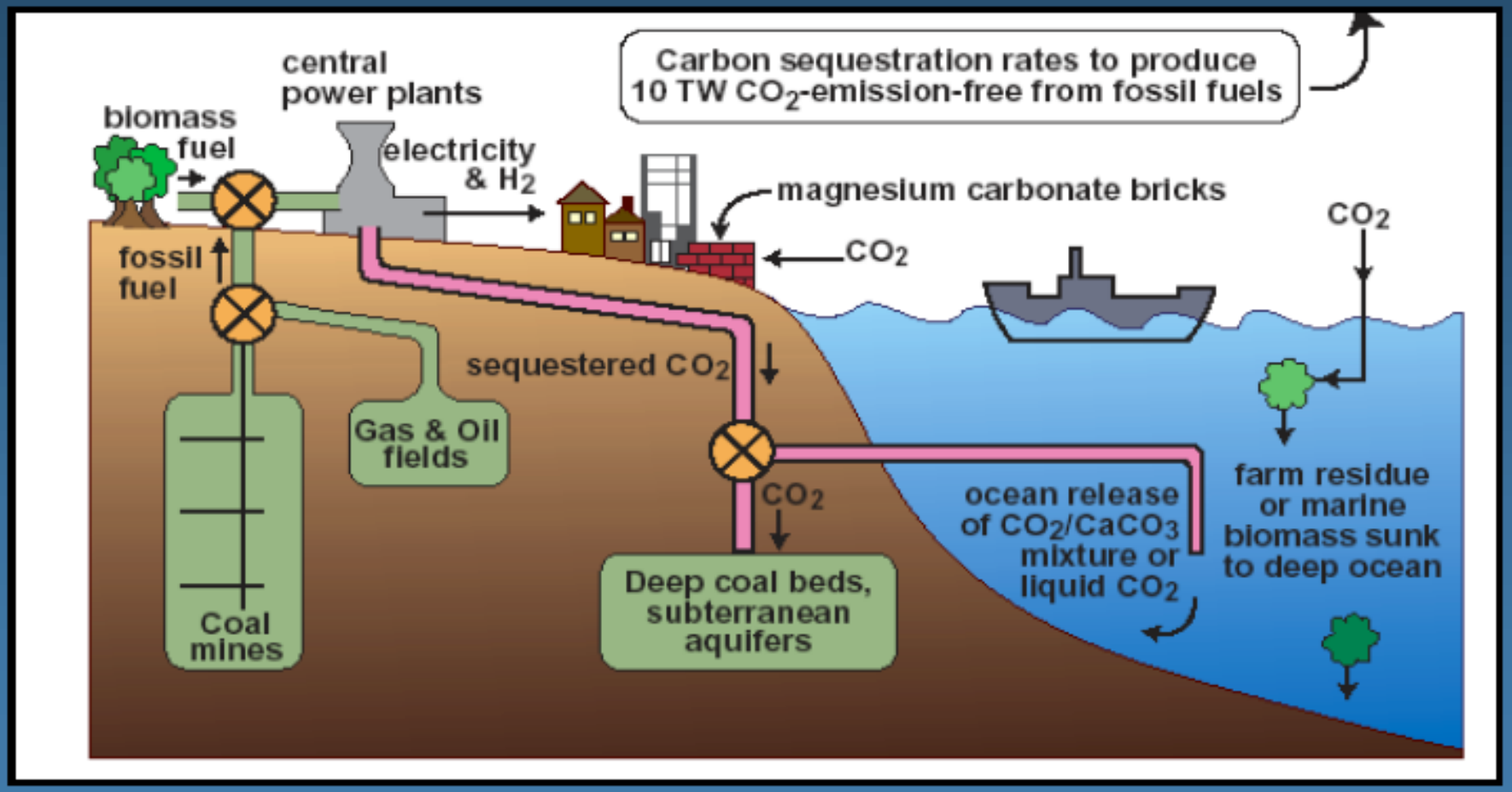
One may now ask, How much must the carbonic acid vary according to our figures, in order that the temperature should attain the same values as in the Tertiary and Ice ages respectively? A simple calculation shows that the temperature in the arctic regions would rise about 8° to 9° C., if the carbonic acid increased to 2·5 or 3 times its present value. In order to get the temperature of the ice age between the 40th and 50th parallels, the carbonic acid in the air should sink to 0·62—0·55 of its present value (lowering of temperature 4°–5° C.). The demands of the geologists, that at the genial epochs the climate should be more uniform than now, accords

The CO_2 level at those days was 300 ppm which corresponds to K=1

Today we have 400 ppm, K=1.3

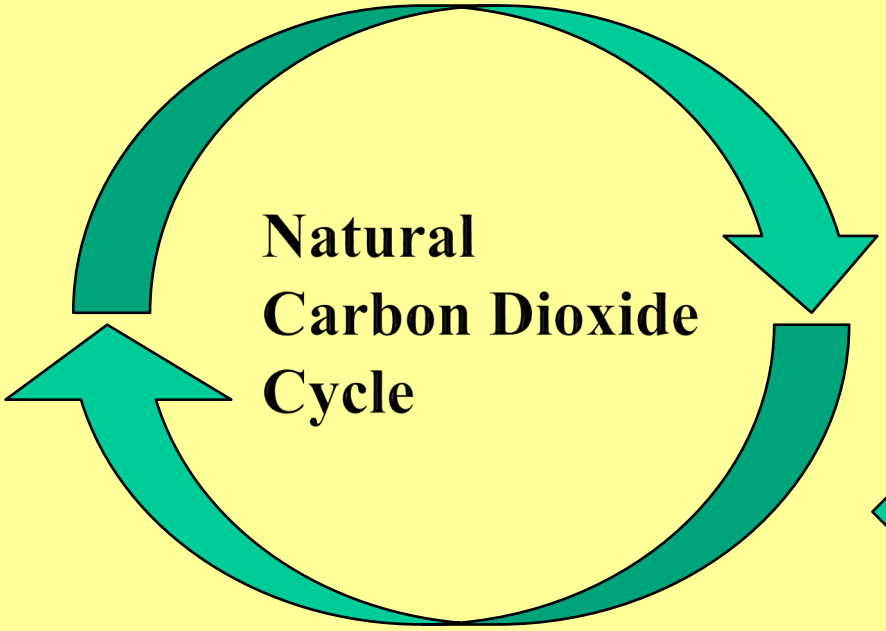
Can we get rid of CO2?

CO_2-Einlagerung



Carbon Cycle and Recycling in Nature

Photosynthese:

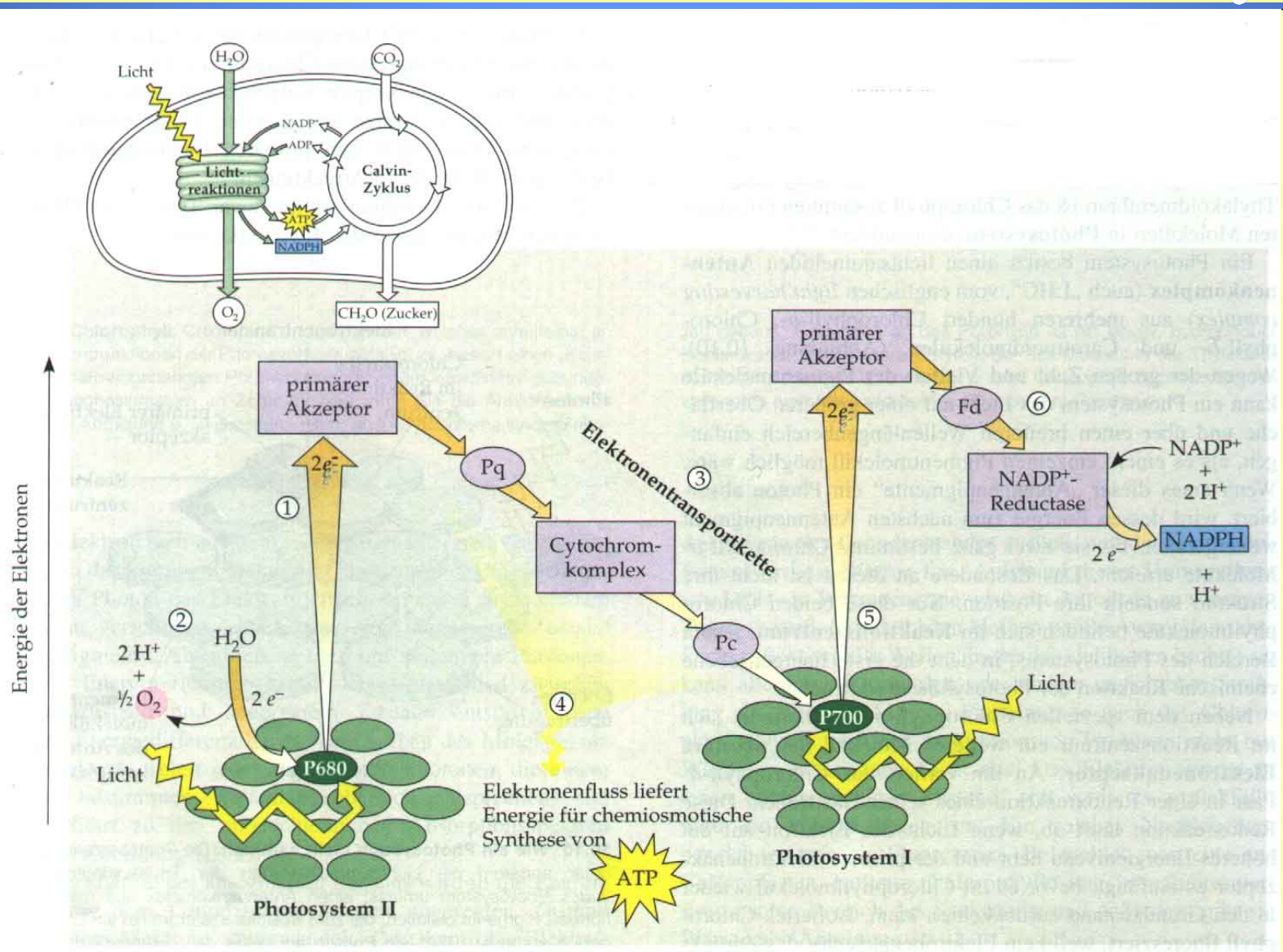


Metabolism:

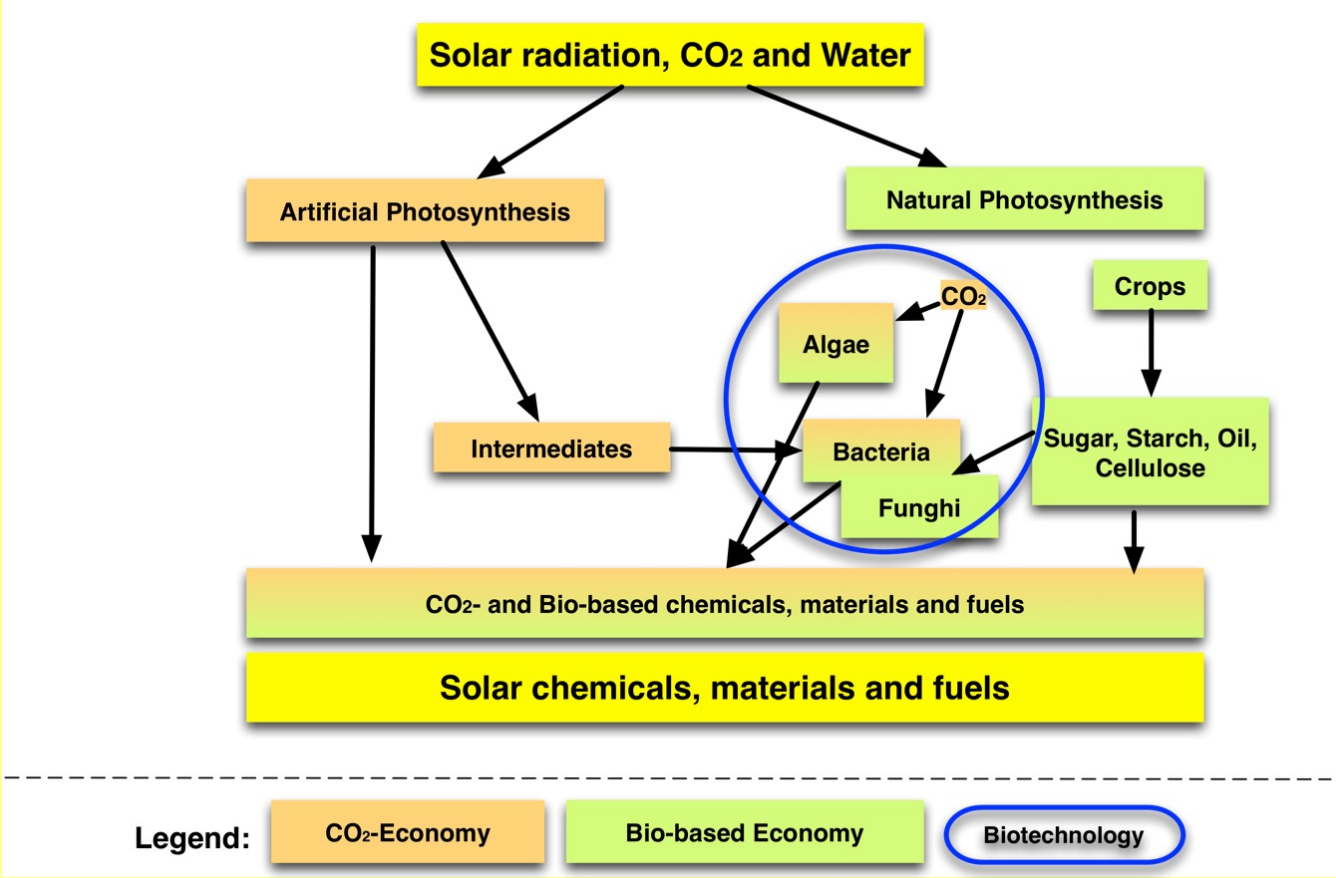
Carbondioxide + Water + Energy → Carbohydrates + Oxygen

←

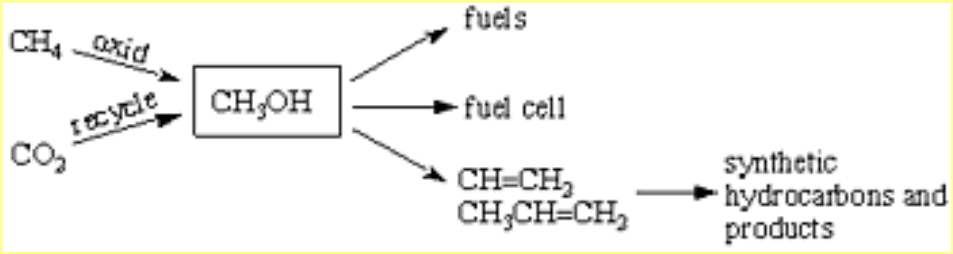
Natural Photosynthesis



Carbon Capture and Utilization: CO_2 Recycling



RECYCLING CO2



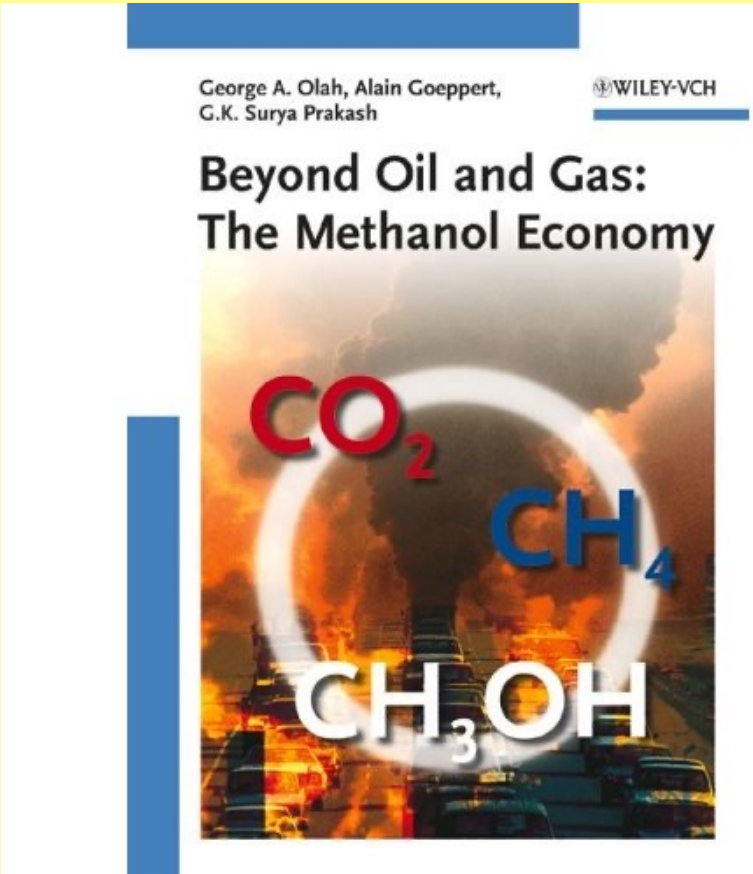
Methanol as carrier and storage of energy

a.) Methanol can be mixed to gasoline

b.) Methanol is used in fuel cells

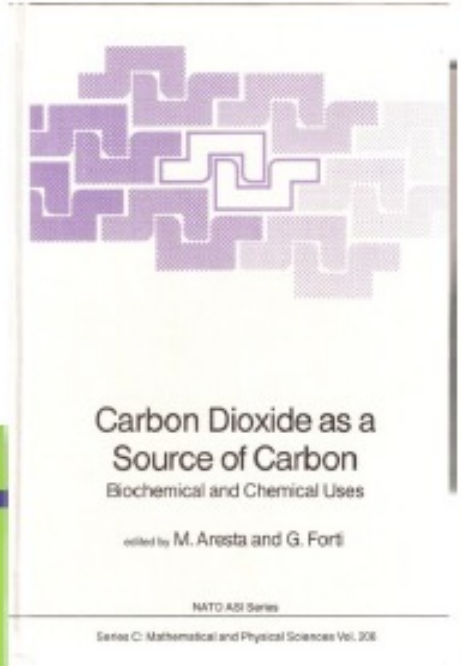
c.) Methanol is starting chemical for
Many other derivatives

George Olah, Nobel Prize 1994
Univ. of Southern California, USA

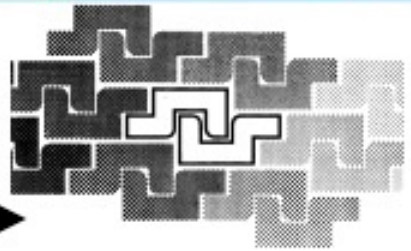


From the basket of published Books.....

1986



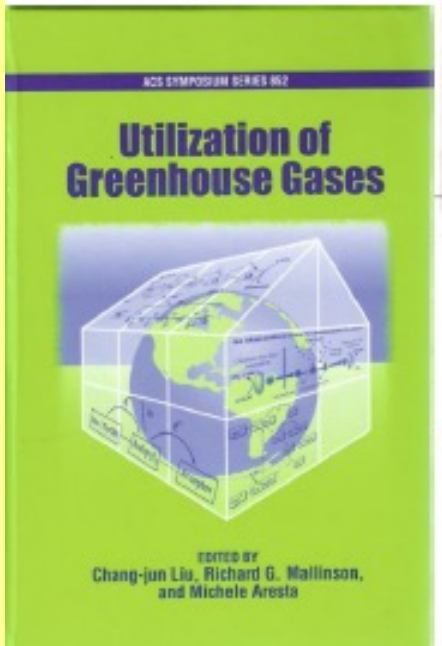
1989



Enzymatic and
Model Carboxylation
and Reduction Reactions
for Carbon Dioxide Utilization

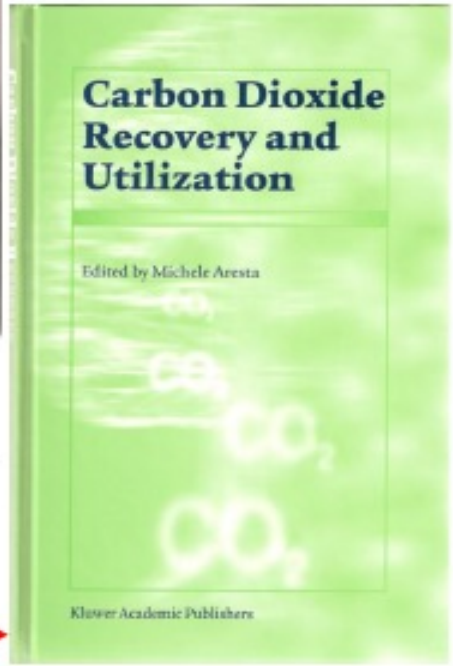
Edited by
M. Aresta and J. V. Schloss

NATO ASI Series

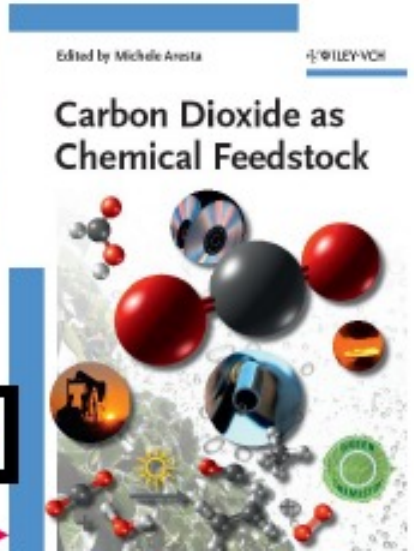


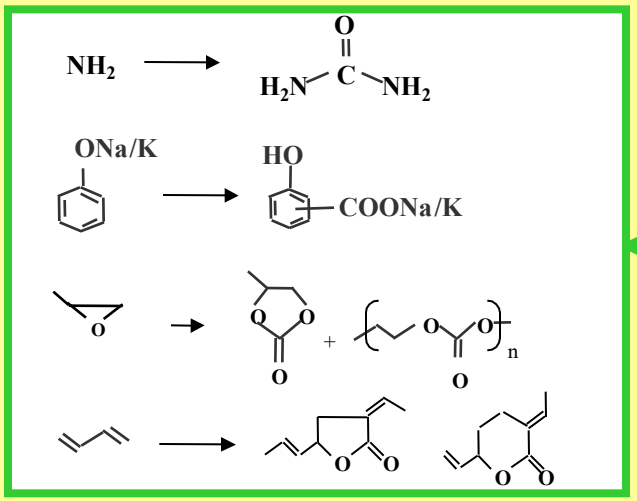
2003

2003

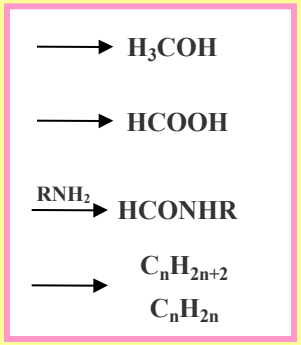


2009





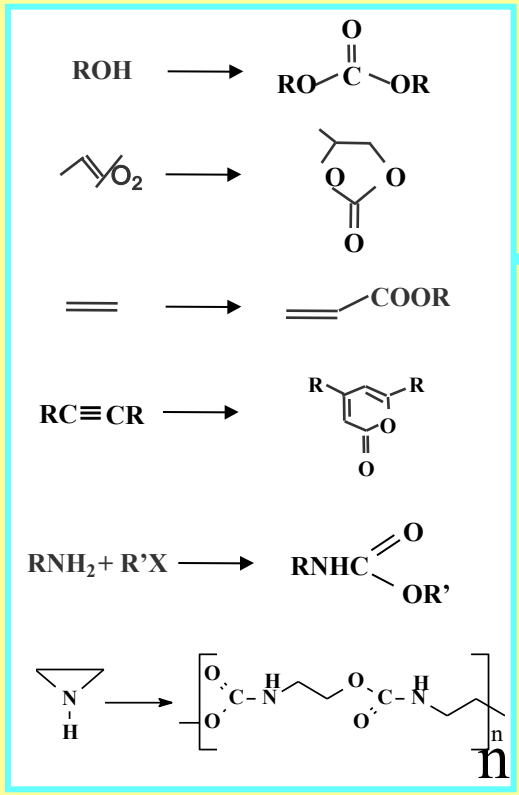
A



D

H2

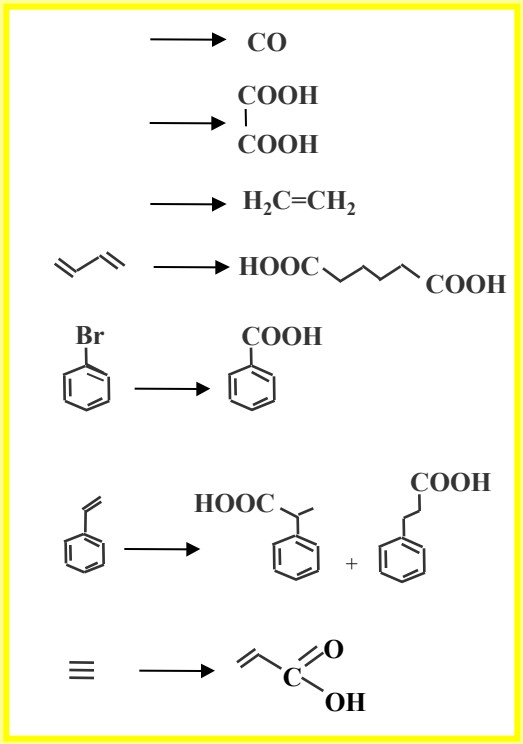
CO_2



B

C

e-, H+



IS IT POSSIBLE TO RECYCLE CO_2? The answer is yes!

$$CO_2 + 2e^- + 2H^+ \rightarrow HCOOH \quad (1)$$

$$HCOOH + 2e^- + 2H^+ \rightarrow CH_2O + H_2O \quad (2)$$

$$CH_2O + 2e^- + 2H^+ \rightarrow CH_3OH \quad (3)$$

$$CH_3OH + 2e^- + 2H^+ \rightarrow CH_4 + H_2O \quad (4)$$

Steps in methanol oxidation/production.

Overall: 6e- process

$CH3OH + H2O \rightarrow CO2 + 6H+ + 6e-$

Biocatalysis

Photocatalysis

Electrocatalysis

Sabatier Reaction:

$$CO_2 + 4H_2 \rightarrow CH_4 + 2\ H_2O$$

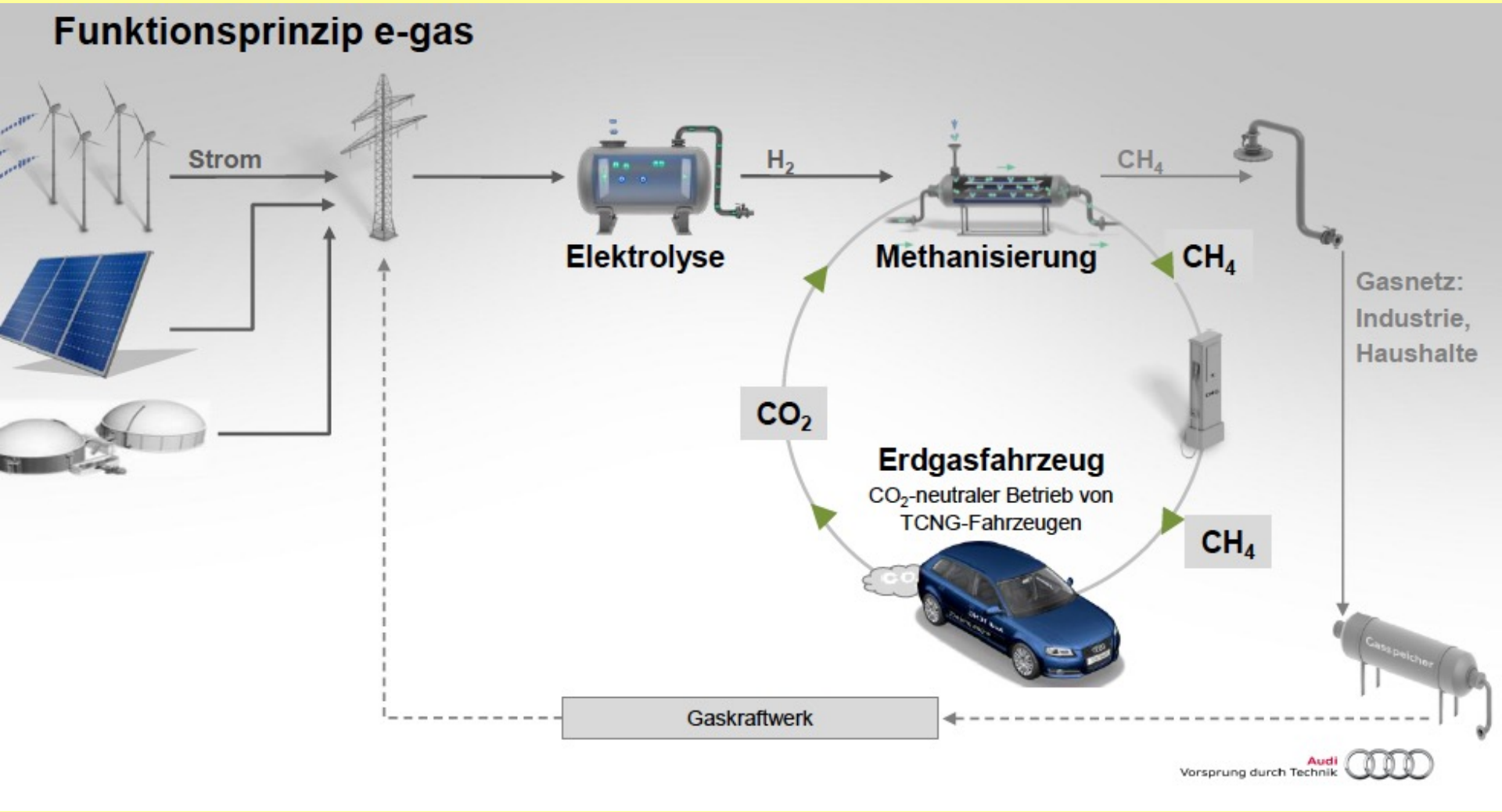
400 C, pressure + catalyst

$\Delta H = -165$ kJ/mol

Methanisation of carbon dioxide with hydrogen gas

Paul Sabatier (1854-1941)
Nobel Prize 1912

http://www.solar-fuel.net/



Courtesy of Dr. Pengg, Audi Corp.

The ETOGAS 6.3MW beta plant was completed in time and in budget

Impressions from the opening ceremony, June 2013

Mr. Hollerweger (Head of Total Vehicle Development, Audi) and Mr. Flasbarth (President Federal Environment Agency) at the opening ceremony

Source: ETOGAS, Audi

ETOGAS
smart energy conversion

WHY SOLAR ENERGY?

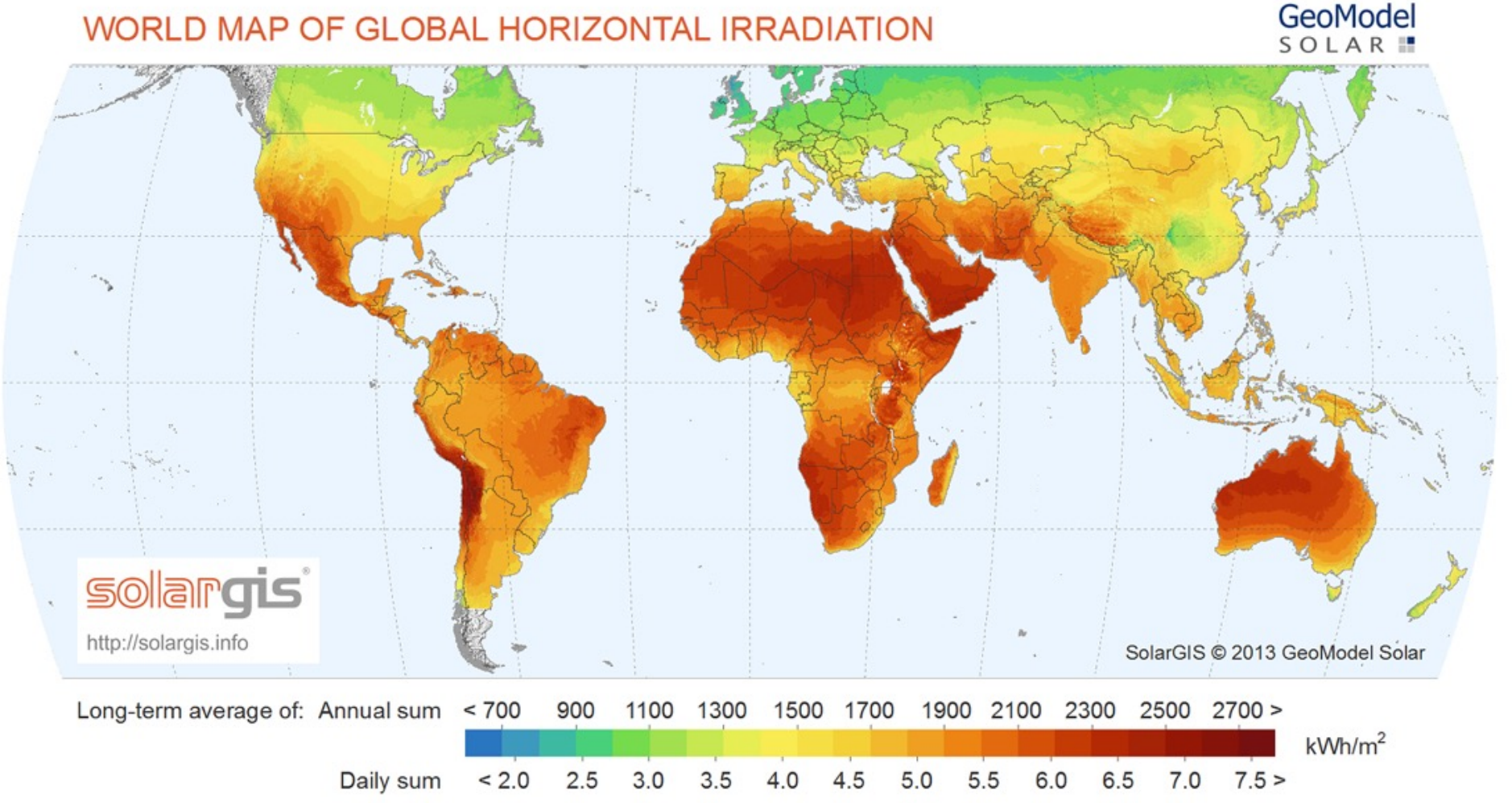
170.000 TERAWATTS

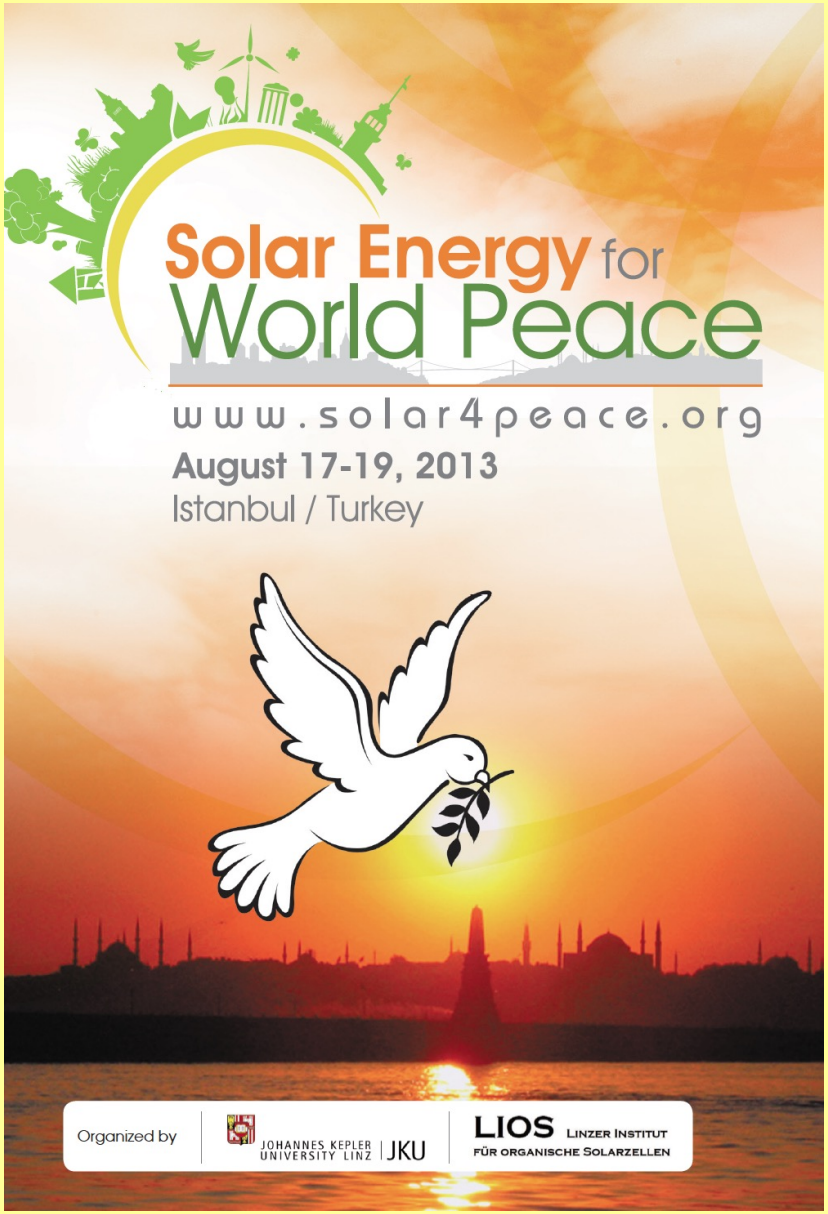
OF SOLAR POWER ARRIVES ON EARTH

Human civilization consumes today around

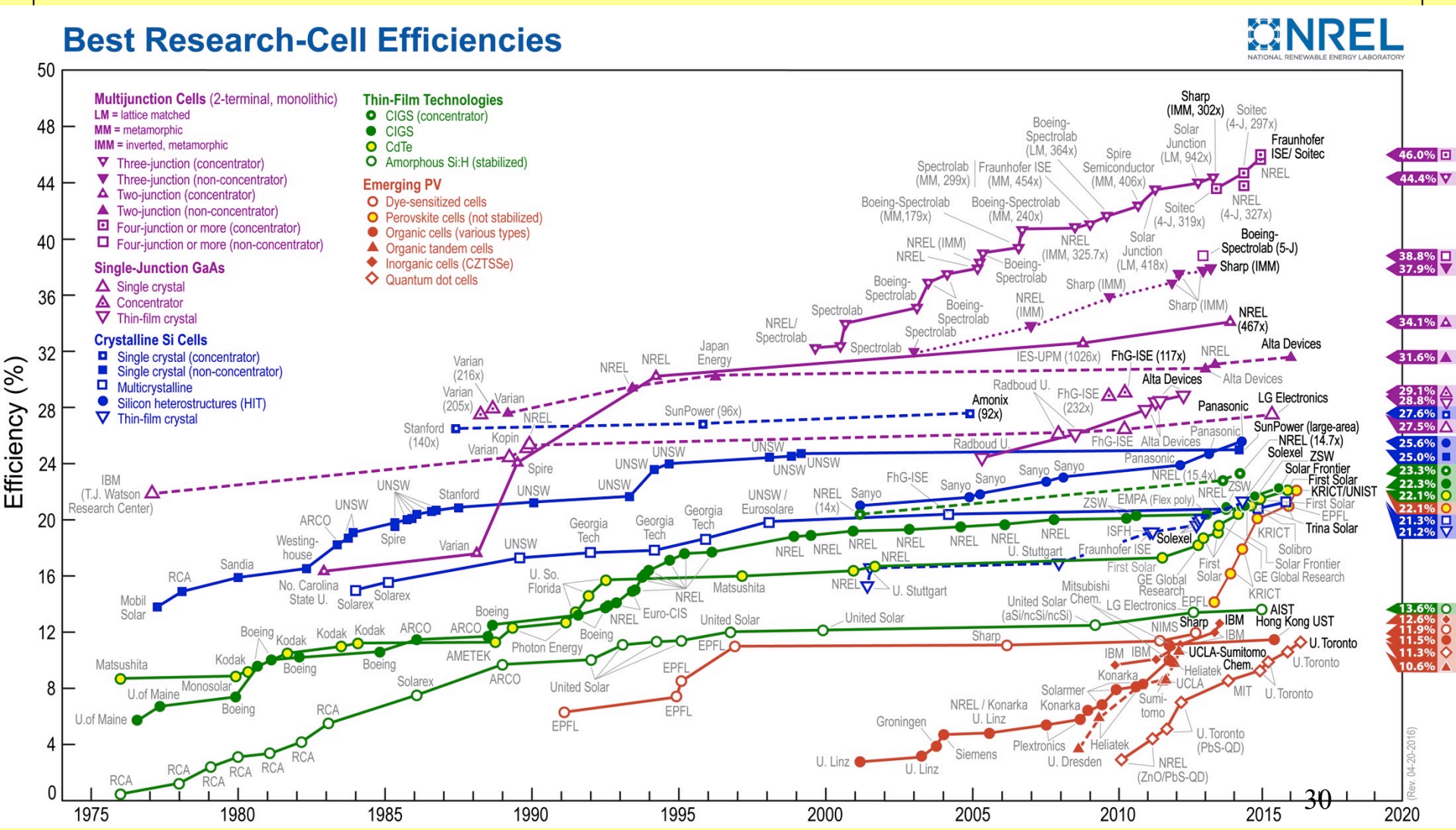
17 Terawatts

Solar Energy Distribution

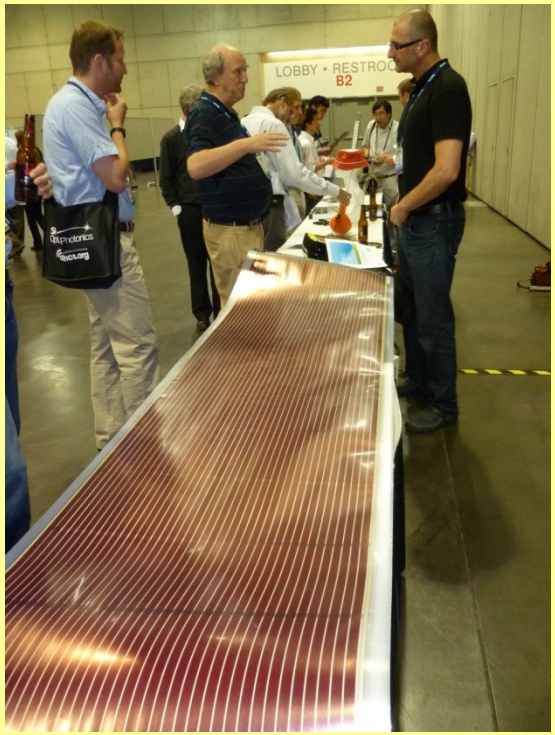


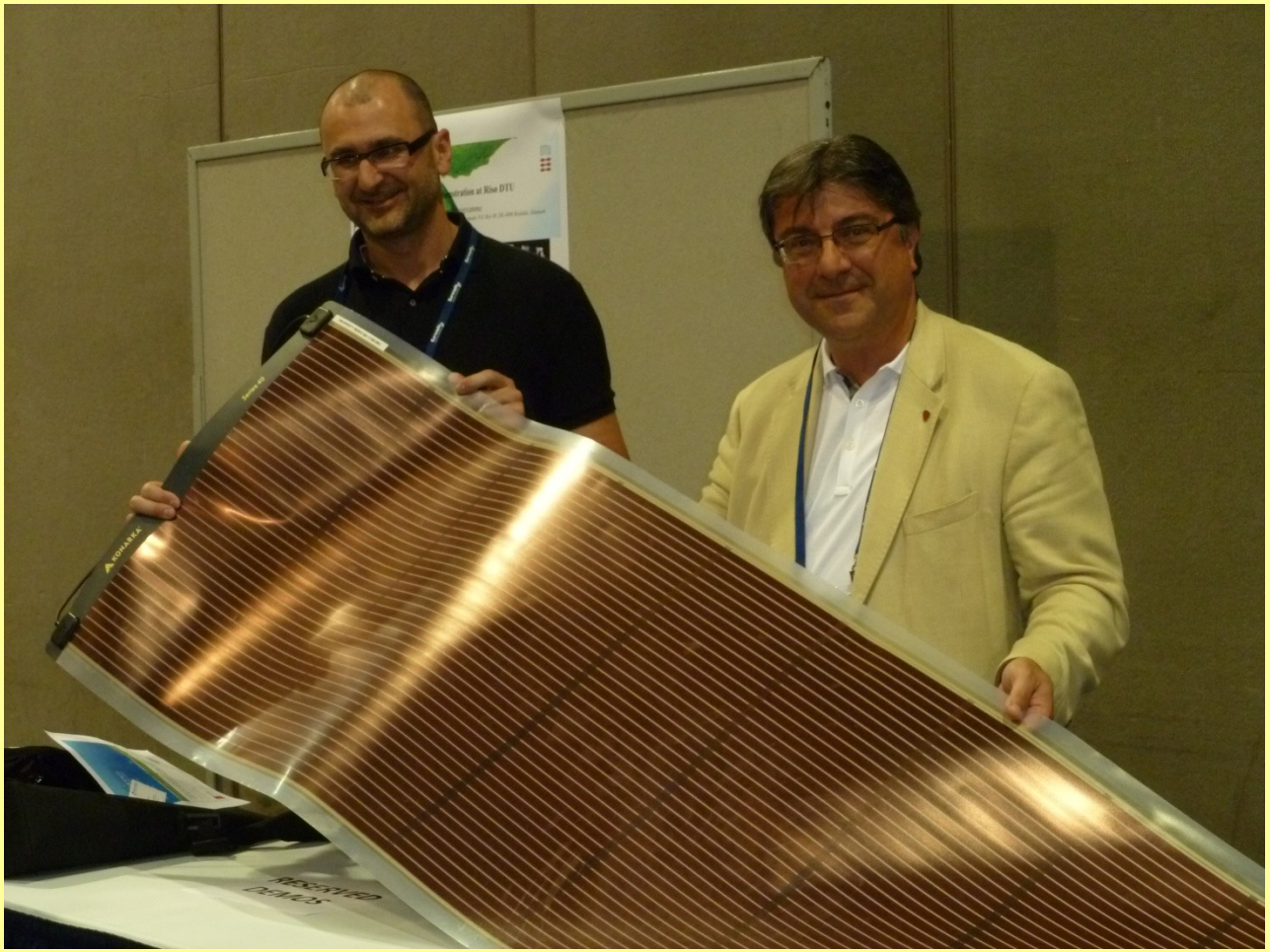

Solar Energy for World Peace
www.solar4peace.org
August 17-19, 2013
Istanbul / Turkey
Organized by
JOHANNES KEPLER UNIVERSITY LINZ | JKU
LIOS LINZER INSTITUT FÜR ORGANISCHE SOLARZELLEN

Efficiency Chart



Roll to roll produced solar cells

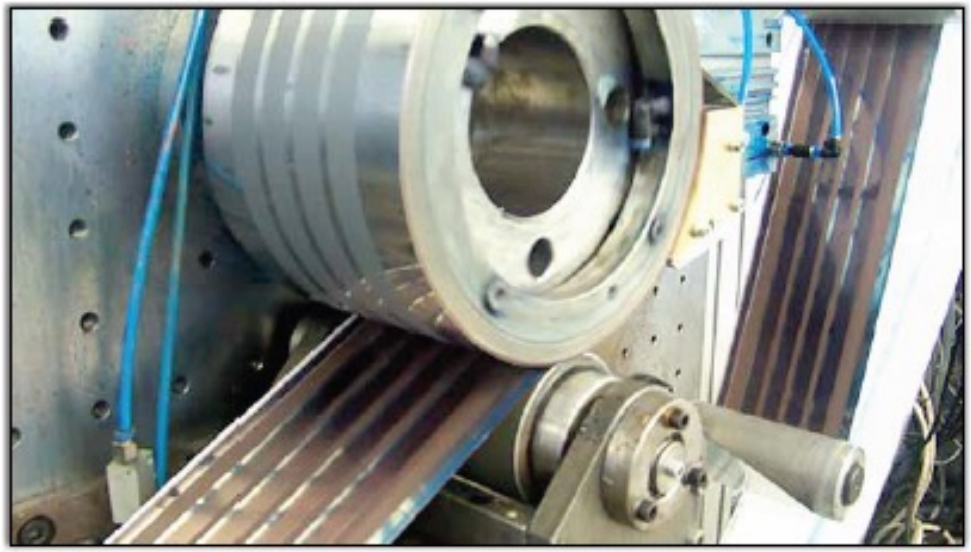


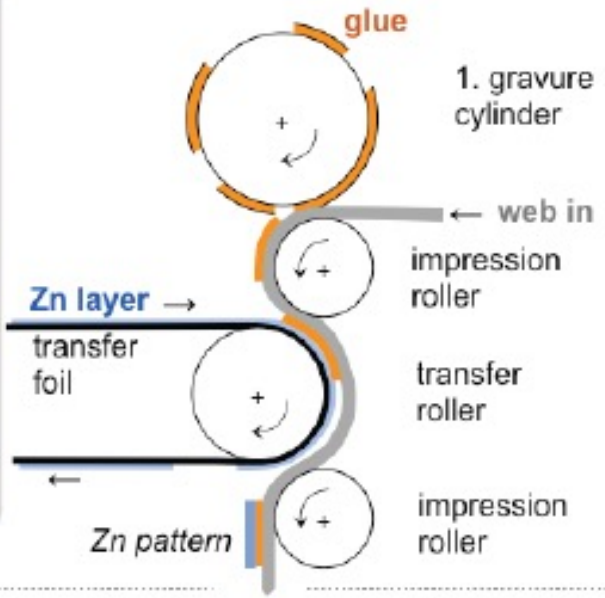


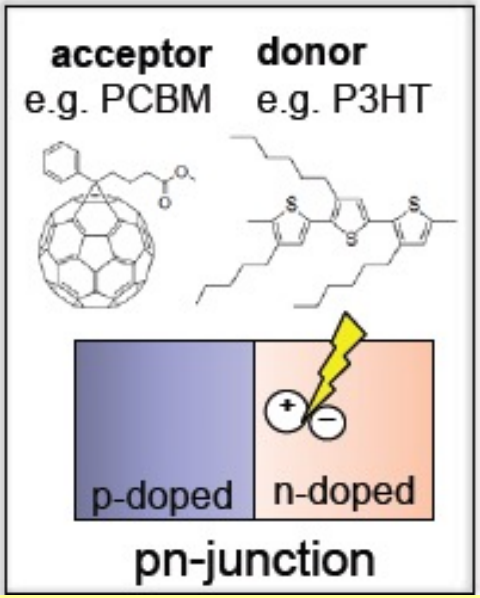
Courtesy of Konarka Inc.

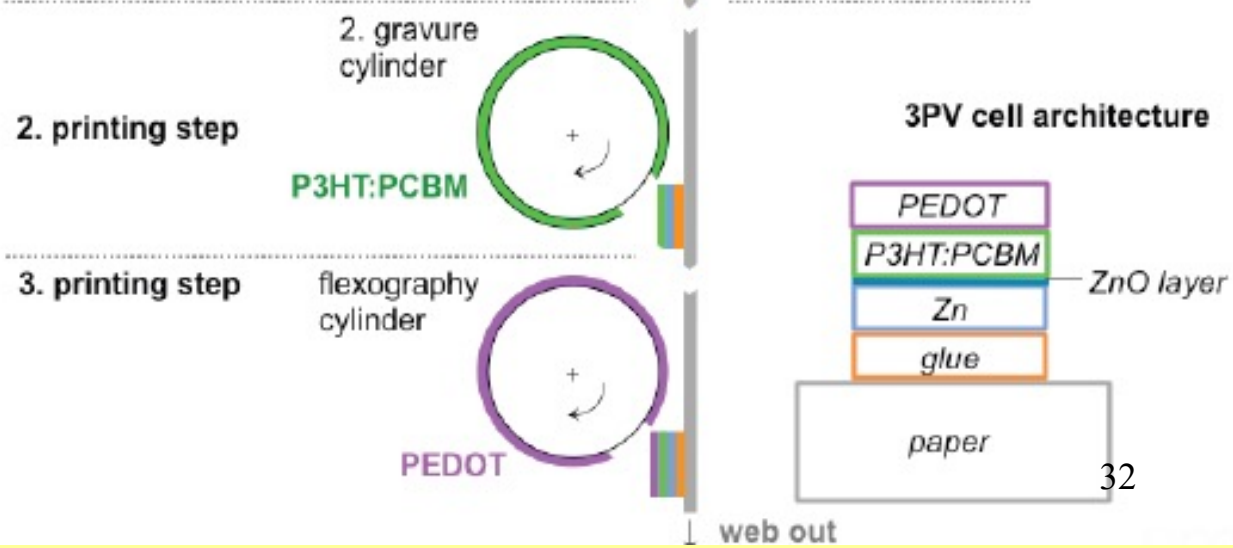
Paper solar cells, Arved Hübler et al.

technology approach: 3PV printed paper photovoltaics







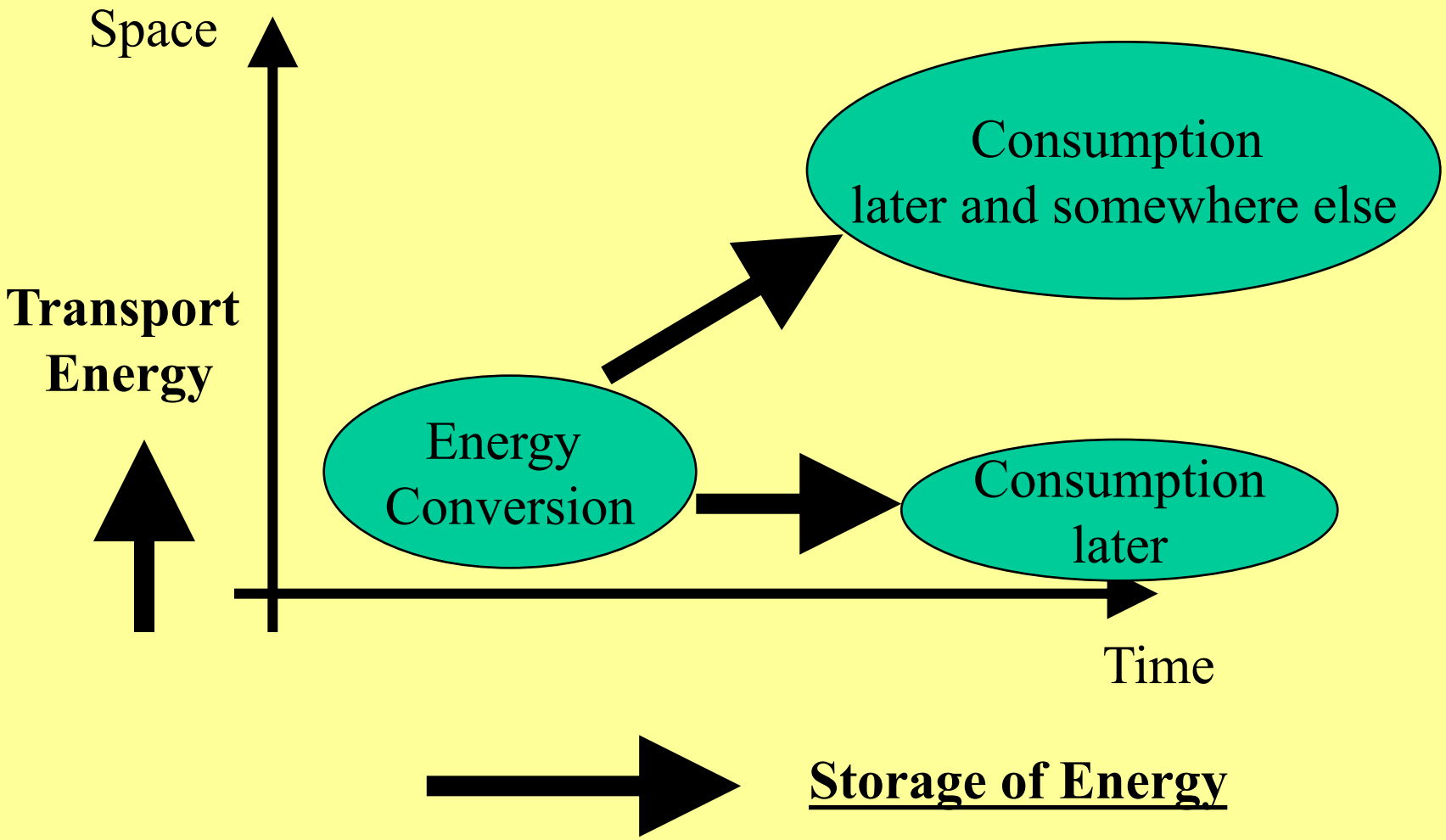


What is the next challenge in

Solar Energy Conversion?

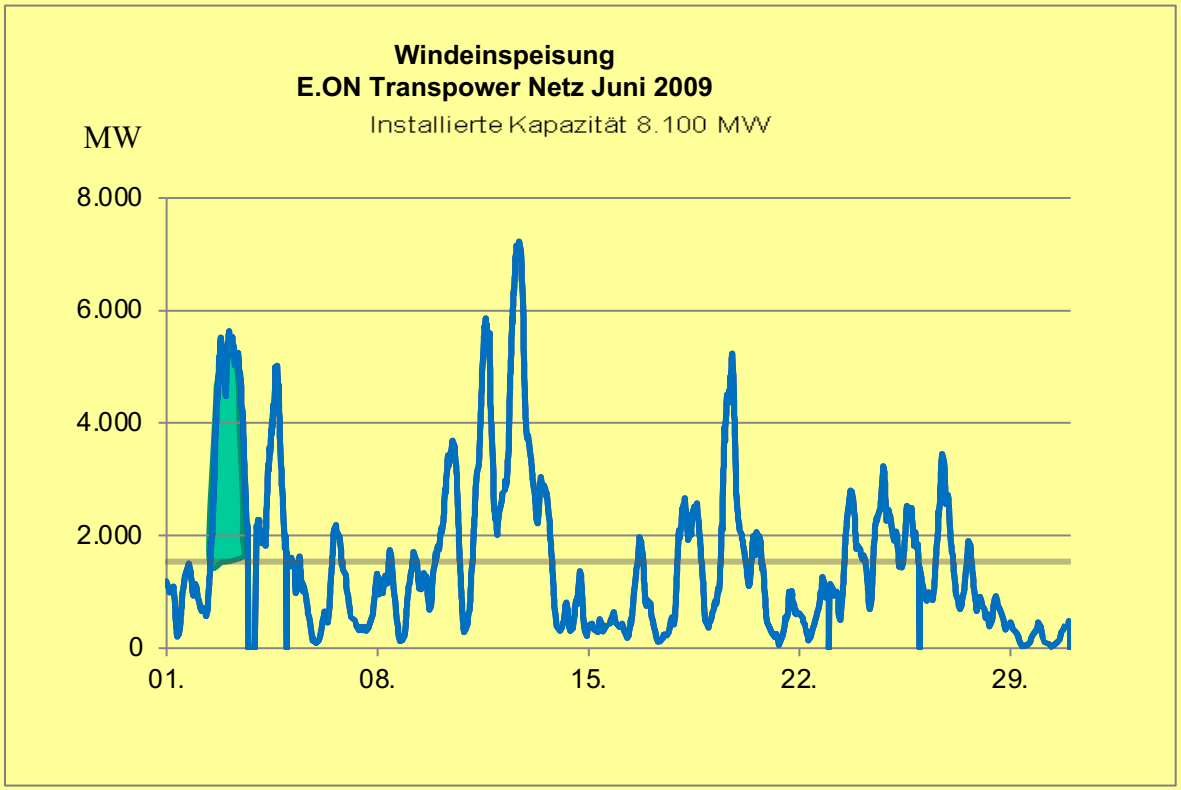
Solar energy into chemical energy

Storage-Transport Problem



Transportable fuel created by solar energy conversion !!!

These 2



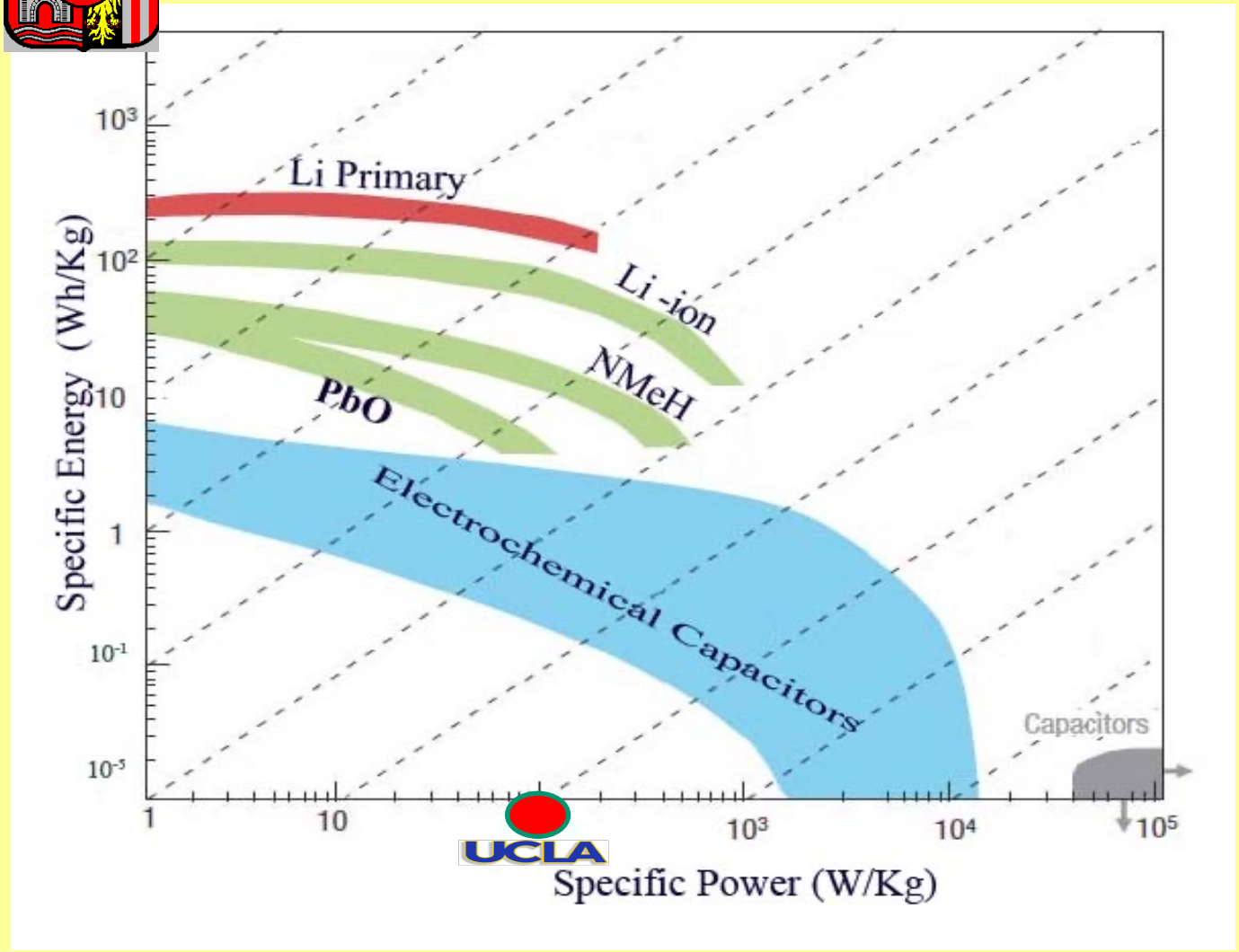
Breites nicht regelbares Schwankungspektrum stellt unlösbare Anforderung an Netzbetrieb

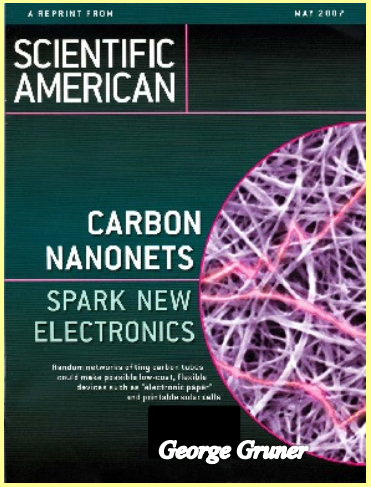
Strombeitrag kann daher nur kleinen Teil des Bedarfs decken

Schwankung zwischen 0% und 100%
Wind Deutschland: Durchschnitt 18%

PV Deutschland: Durchschnitt 10%

Kaltfront 3.6.09:
~ 4 GW x 20 h = 80 Millionen kWh





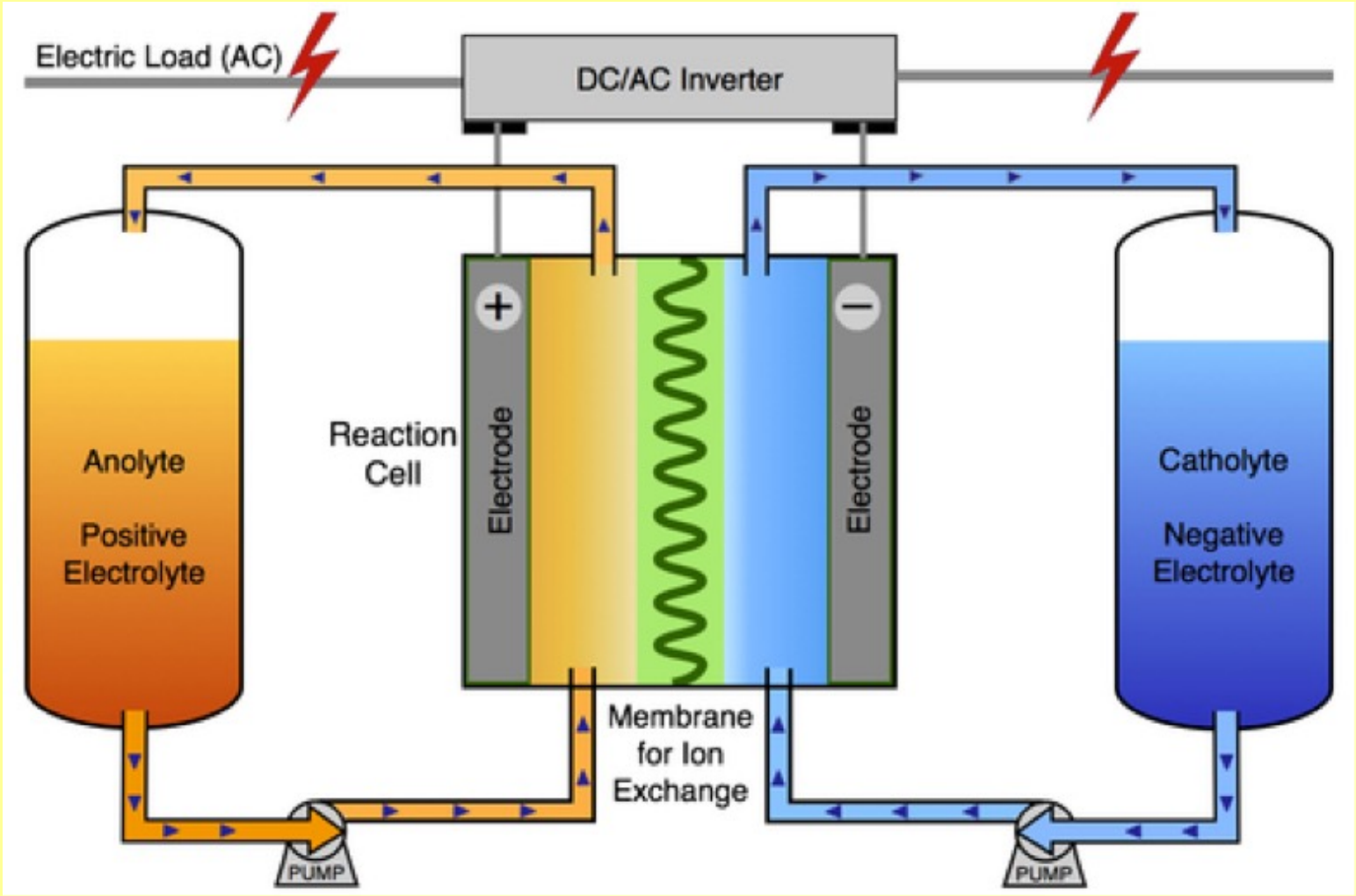
Batteries are slow, not suitable for power handling

The solution: Supercapacitors

G. Gruner, UCLA

By fuelling a typical gasoline car (~ 40 l ca 400 kWh) within 2 min (~ 10 MW)

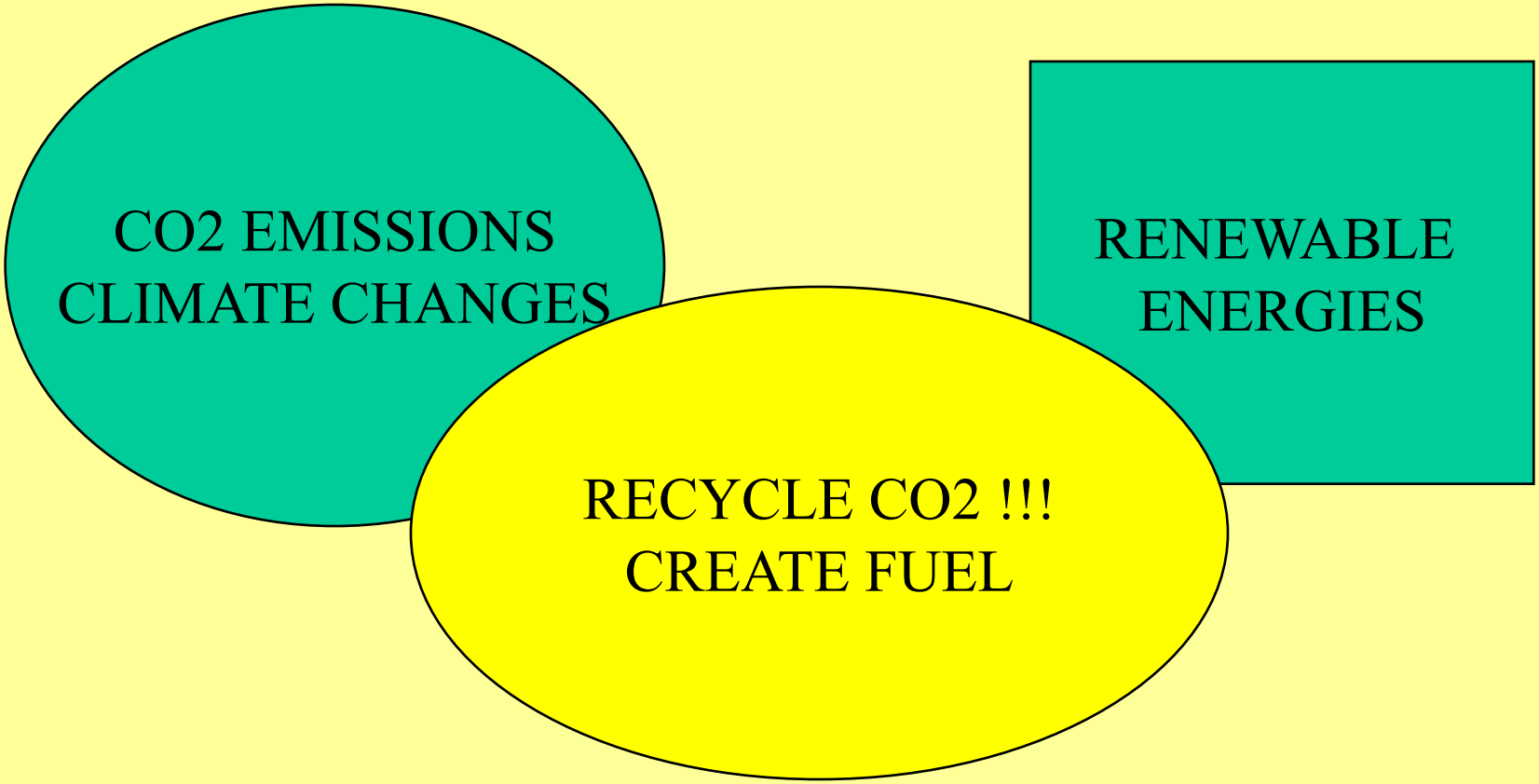
REDOX FLOW BATTERIES FOR HIGH CAPACITY



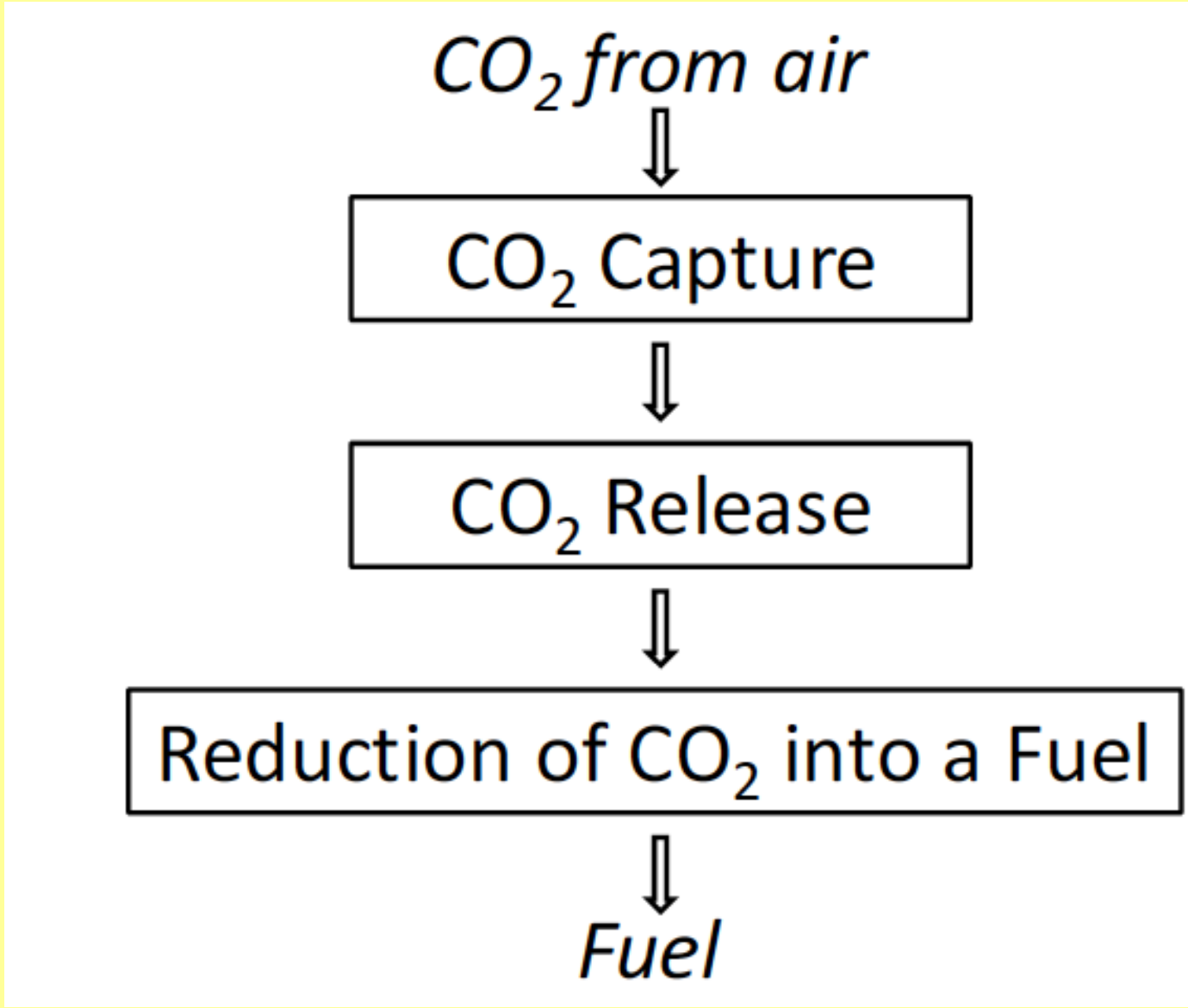
REDOX FLOW BATTERIES FOR HIGH ENERGY STORAGE

Vanadium based redox flow battery systems, CellCube, Wiener Neudorf

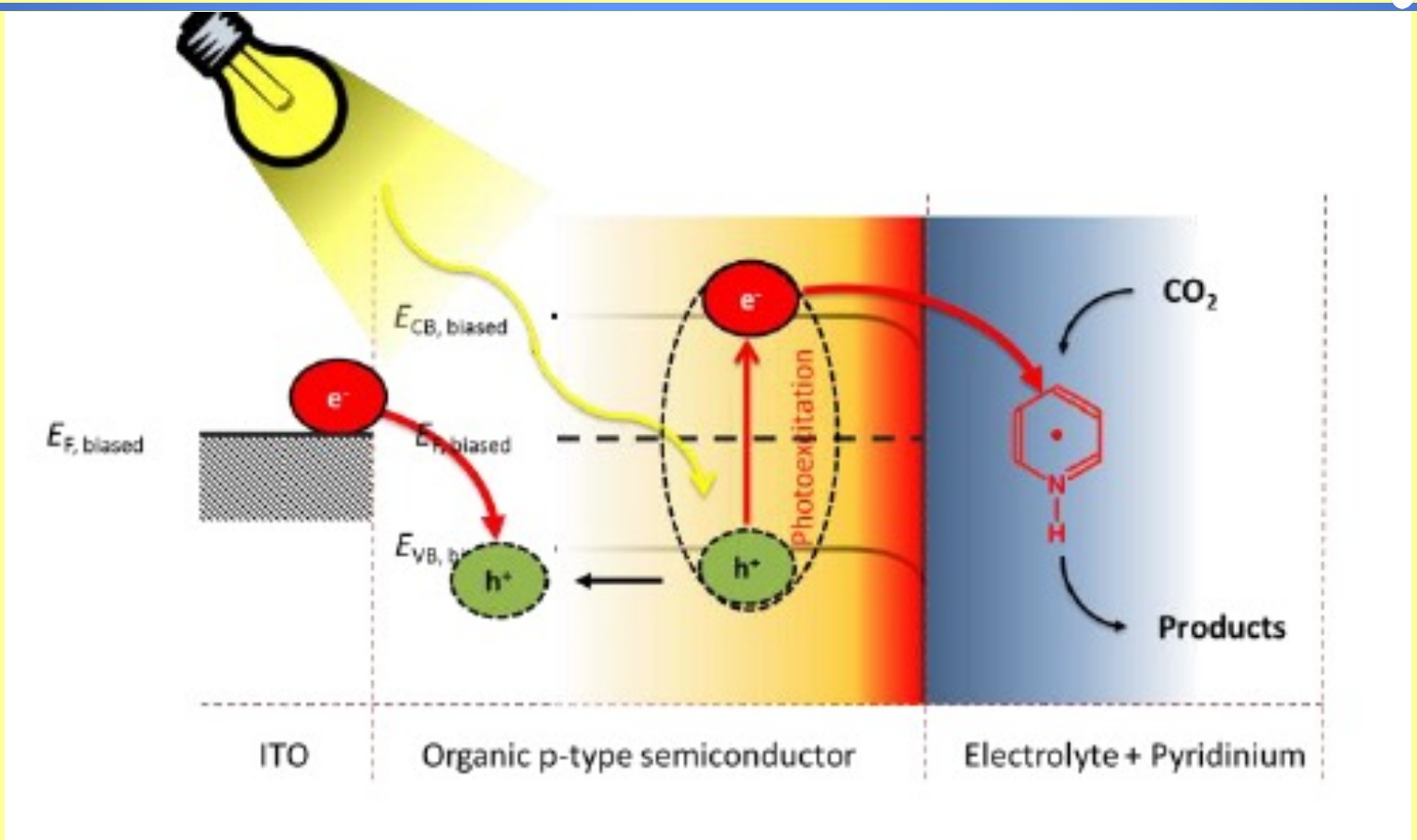
INTERFACE BETWEEN CO2 REDUCTION AND RENEWABLE ENERGY CREATION



Future recycling of CO2 as important mission of renewable energies


CO_2 from air
CO_2 Capture
CO_2 Release
Reduction of CO_2 into a Fuel
Fuel

Poly 3-hexylthiophene (P3HT) as Photocathode



For CO_2 reduction to Methanol

Engelbert Portenkirchner et.al 2013

Dopamin based polymers

COMMUNICATION Adv. Mater. 2020, 32, 1902177

ADVANCED MATERIALS www.advmat.de

Metal-Free Hydrogen-Bonded Polymers Mimic Noble Metal Electrocatalysts

*Halime Coskun, Abdalaziz Aljabour, Phil de Luna, He Sun, Nobuyuki Nishiumi, Tsukasa Yoshida, Georg Koller, Michael G. Ramsey, Theresia Greunz, David Stifter, Moritz Strobel, Sabine Hild, Achim Walter Hassel, Niyazi Serdar Sariciftci, Edward H. Sargent, and Philipp Stadler**

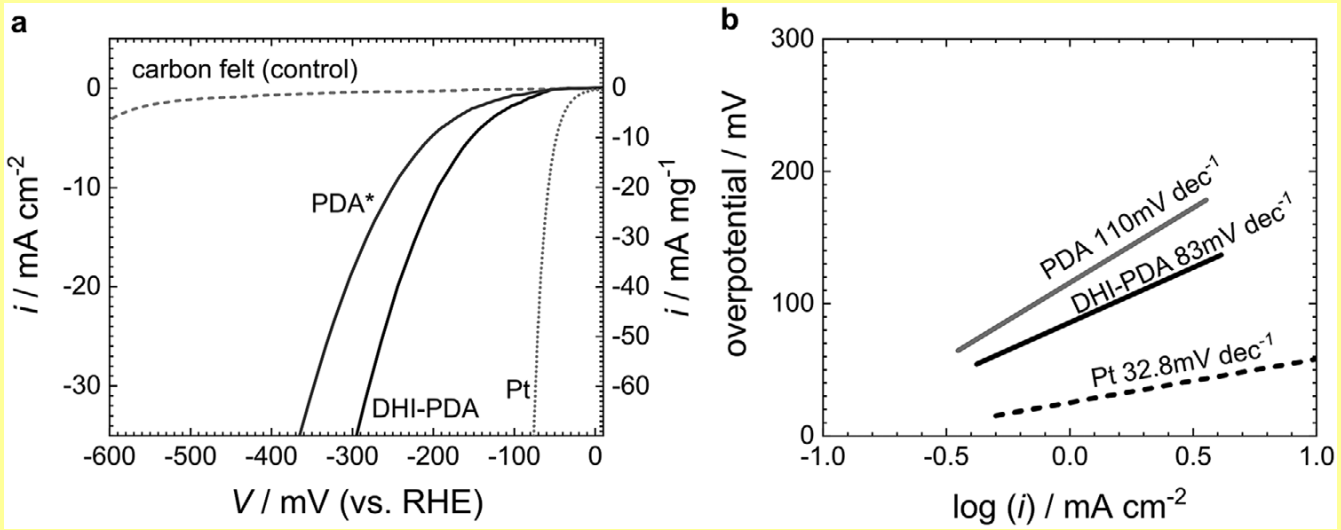


Figure 3. Electrochemical characterization. a) Voltammetric scans (10 mV s^{-1}, referred to active area and gravimetric) in 1 M TfOH electrolyte for HER showing the performance of PDA (standard) and DHI-PDA as compared to Pt (reference) and CF (blank control). b) Tafel plot (log (*i*) vs. η) with the slopes indicated in the graph. The reference overpotential η (at 10 mA cm^{-2} planar current density) is 190 mV (DHI-PDA) and 270 mV (PDA).

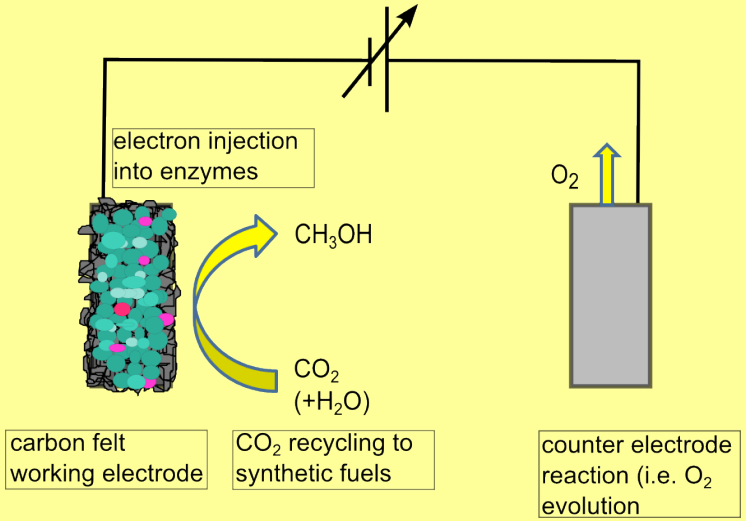
Coupling Chemistry and Biotechnology

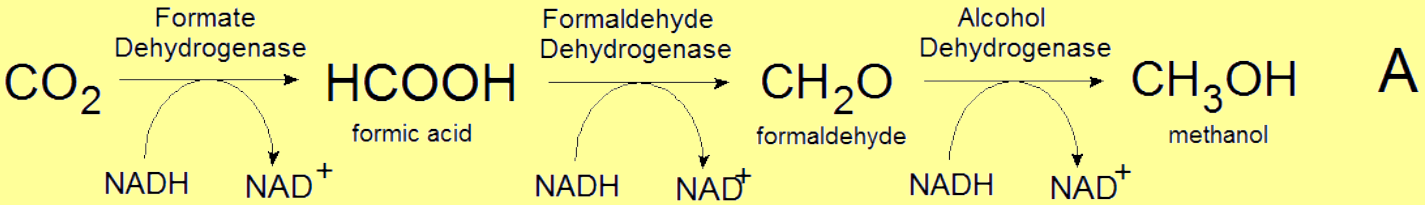
- $CO_{2\ aq} \rightarrow HCOO^-$ **Formate dehydrogenase**
- $HCOO^- \rightarrow H_2CO$ **Formaldehydedehydrogenase**
- $H_2CO \rightarrow CH_3OH$ **Methanoldehydrogenase**

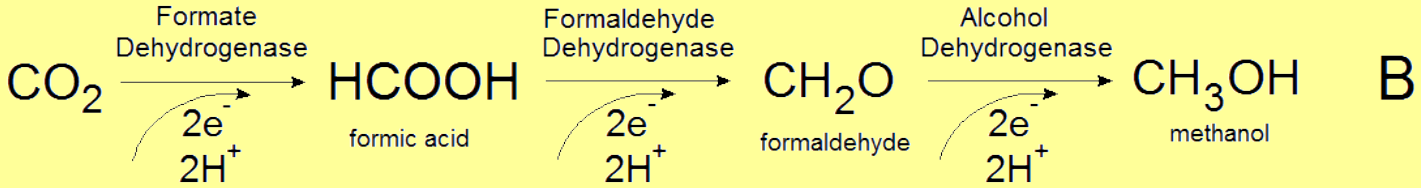
- **NAD^+/NADH is the source of energy .**
- **Key issue : how to reverse the NAD^+/NADH couple after oxidation ?**
- **Use of chemical systems for solar light harvesting and conversion**

Bio-electrochemical Catalysis

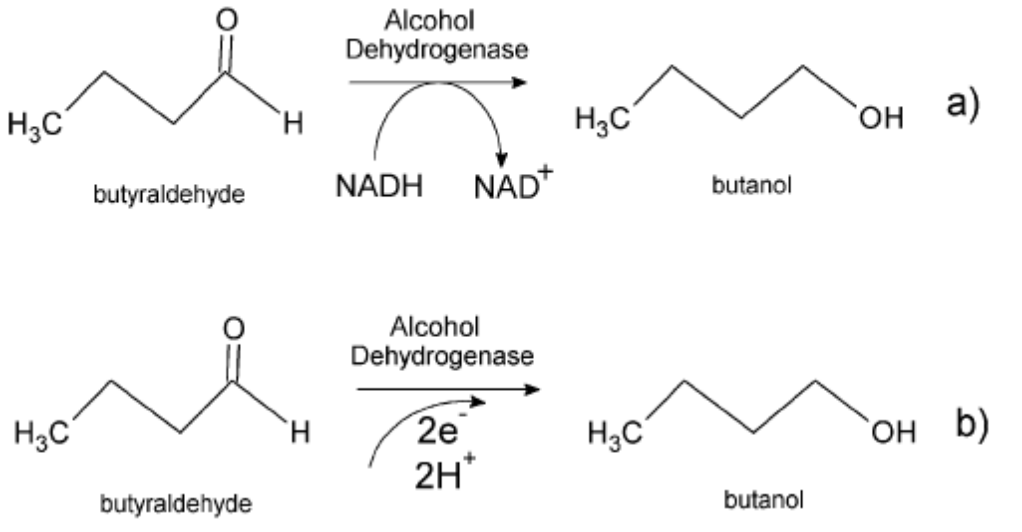
Stefanie Schlager *et al*;
ChemSusChem
Vol.9, p. 631 (2016)

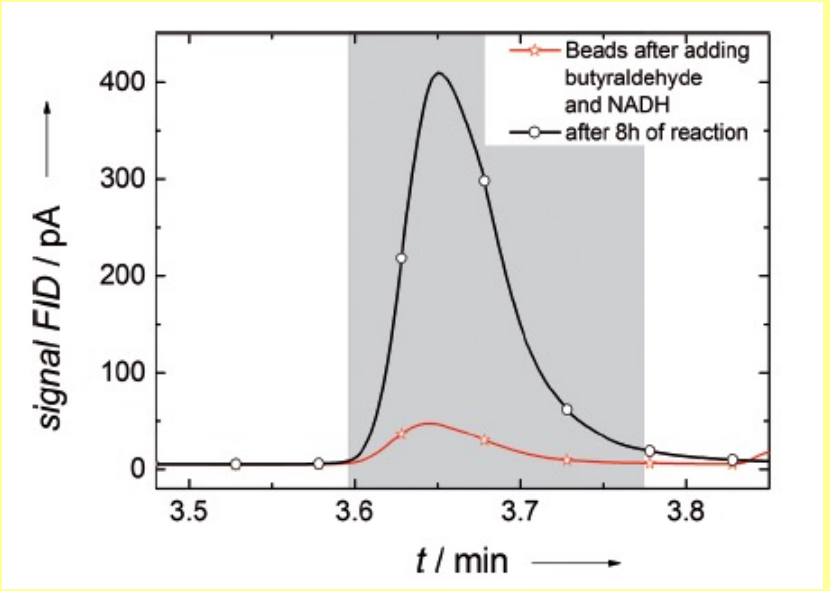


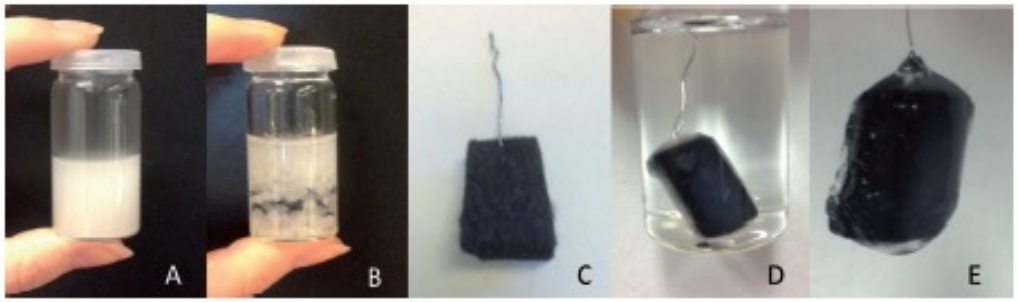


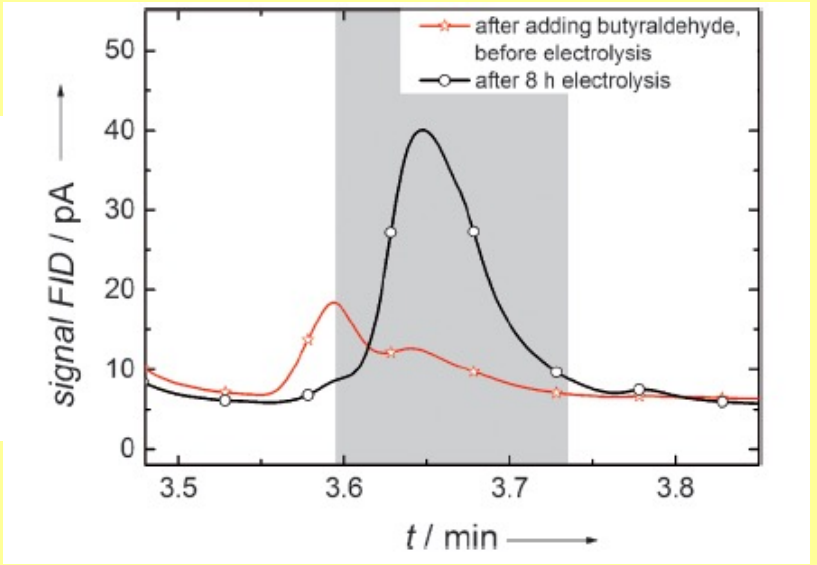


Bio-electrochemical Catalysis









Stefanie Schlager *et al*; ChemCatChem (2015), Vol. 7, 967

Bacterio-electrochemical Catalysis

CHEMSUSCHEM
Full Papers

ChemSusChem 2016, 9, 1 – 9

Bio-Electrocatalytic Application of Microorganisms for Carbon Dioxide Reduction to Methane

Stefanie Schlager,*[a] Marianne Haberbauer,[b] Anita Fuchsbauer,[c] Christine Hemmelmair,[b] Liviu Mihai Dumitru,[a] Gabriele Hinterberger,[a] Helmut Neugebauer,[a] and Niyazi Serdar Sariciftci[a]

$CO_2 + e^-$	⟶	$CO_2^{\bullet-}$	$E^0 = -1.90$ V
$CO_2 + 2e^- + 2H^+$	⟶	$CO + H_2O$	$E^0 = -0.53$ V
$CO_2 + 2e^- + 2H^+$	⟶	$HCOOH$	$E^0 = -0.61$ V
$CO_2 + 4e^- + 4H^+$	⟶	$H_2CO + H_2O$	$E^0 = -0.48$ V
$CO_2 + 6e^- + 6H^+$	⟶	$CH_3OH + H_2O$	$E^0 = -0.38$ V
$CO_2 + 8e^- + 8H^+$	⟶	$CH_4 + 2H_2O$	$E^0 = -0.24$ V

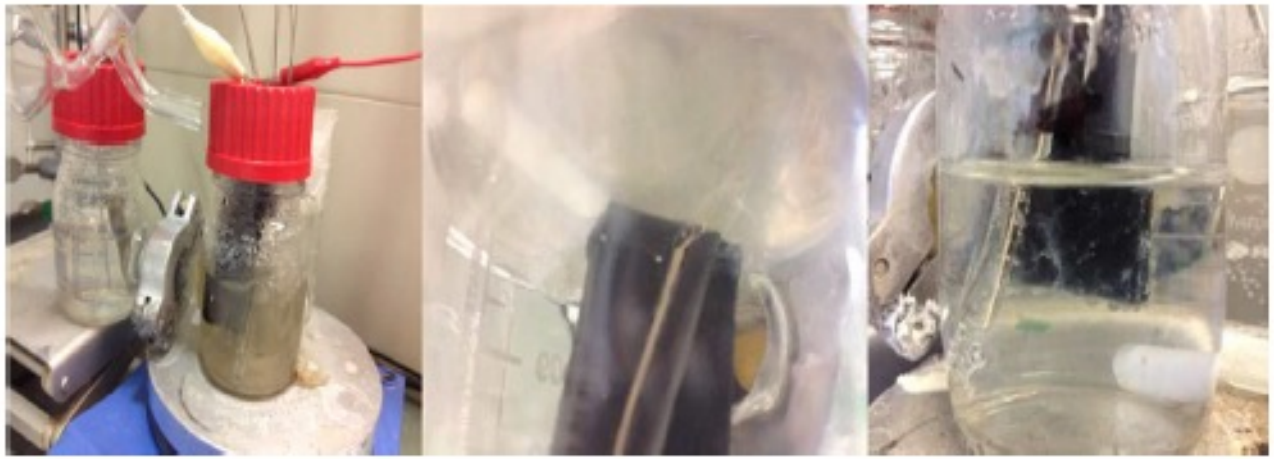
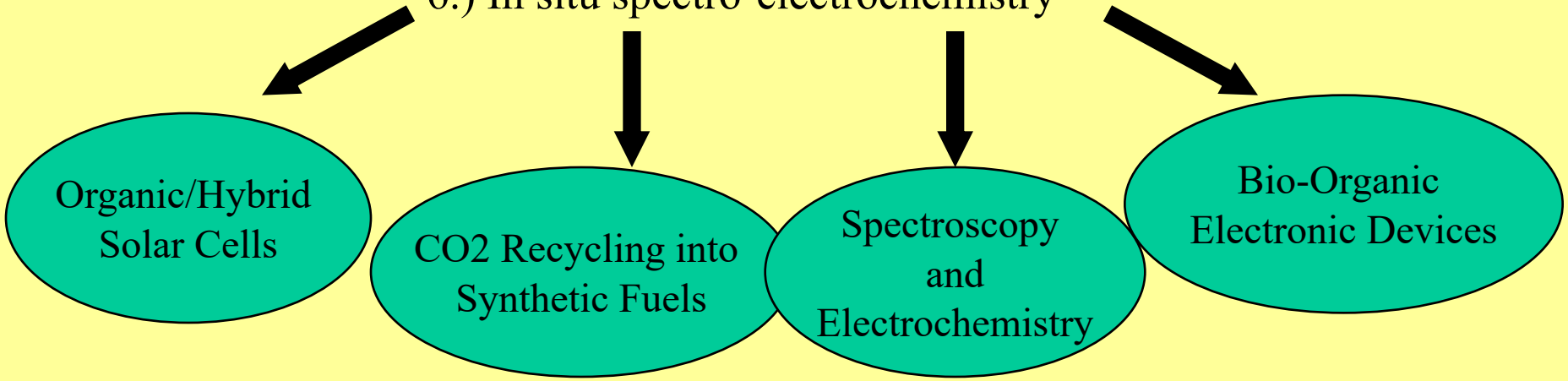


Figure 1. a) Cloudy medium after inoculation of microorganism suspension, b) biofilm formation after 24 h and clarified medium, c) and biofilm after 1 week (multiplying microorganisms) when the medium was exchanged.

Linz Institute for Organic Solar Cells

Physics of Organic Semiconductors:

1.) Photoexcited spectroscopy
2.) Photoconductivity
3.) Thin film characterization
4.) Nanoscale engineering
5.) Nanoscale microscopy (AFM, STM...)
6.) In situ spectro-electrochemistry



„Incubator“ for small high tech spin-off companies

Acknowledgements

Recent Members of LIOS:
Markus Scharber , (Philipp Stadler), Cigdem Yumusak, Christoph Ulbricht, (Patrick Dong Whang), Mihai Irimia-Vladu, Munise Cobet, (Gerda Kalab), Christine Hinterberger, (Dogukan Apaydin, Halime Coskun, Abdelaziz Aljabour, He Sun, Mateusz Bednorz), Stepan Demchyshyn, (Bekele Teklemariam, Herwig Heilbrunner), Serpil Tekoglu, (Hathaichanok Seelejaroen), Christoph Putz, (Jakob Hofinger, Dominik Wielend), Katarina Gugujonovic, (Hannah Rabl), Felix Mayr, Katharina Matura, Elisabeth Leeb, Corina Schimanofsky, Dominik Böhm, Stefano Favero Costa, (Stefan Pöllner) and many long term visitors from around the world …(Anna Prochazkova, Matousz Kratochvil, Lucia Ivanova...)
Recent Collaborators.: Siegfried Bauer ✝, Martin Kaltenbrunner, Thomas Klar, Yolanda Salinas, Jozef Krajcovic, Martin Weiter, Aristides Bakandritsos, Michal Opyetka

Funded by:
Austrian Foundation for Advancement of Science (FWF) Wittgenstein Prize, Indigo Project FFG Projects, EFRE Projects