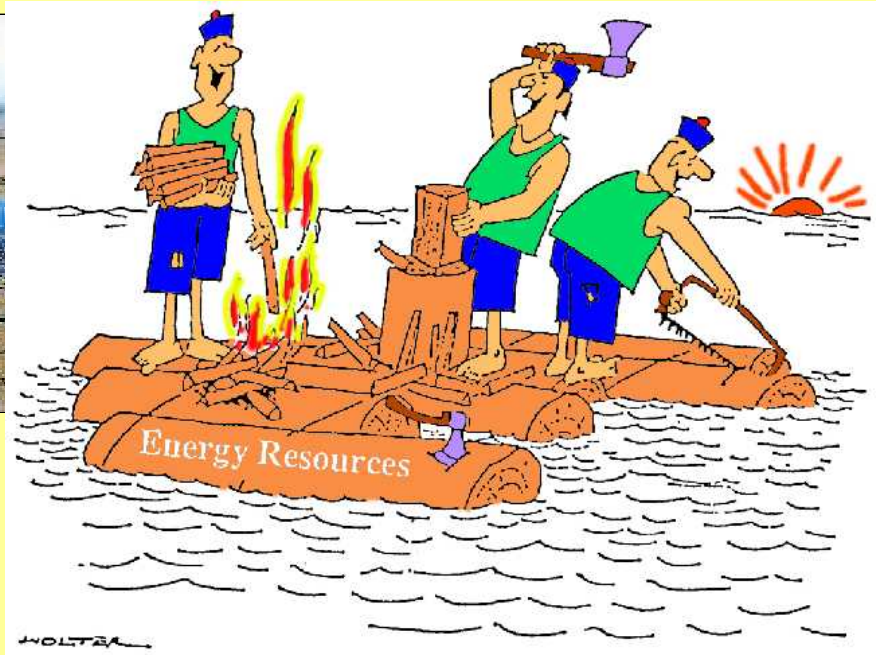
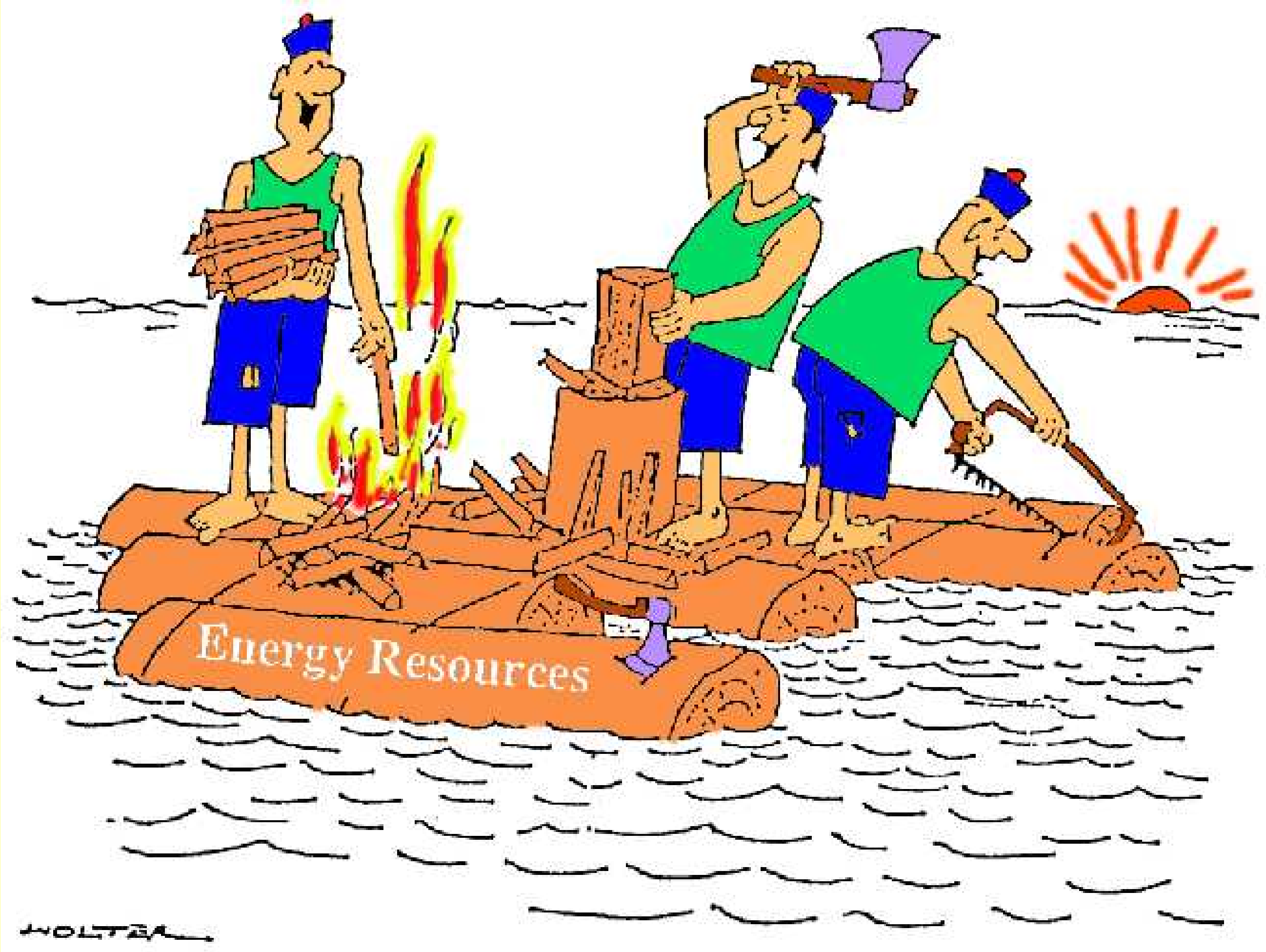
Chemical Sciences for Energy Storage: A Societal Challenge



Niyazi Serdar SARICIFTCI
Linz Institute for Organic Solar Cells (LIOS),
Institute for Physical Chemistry, Johannes Kepler University Linz, Austria
www.lios.at

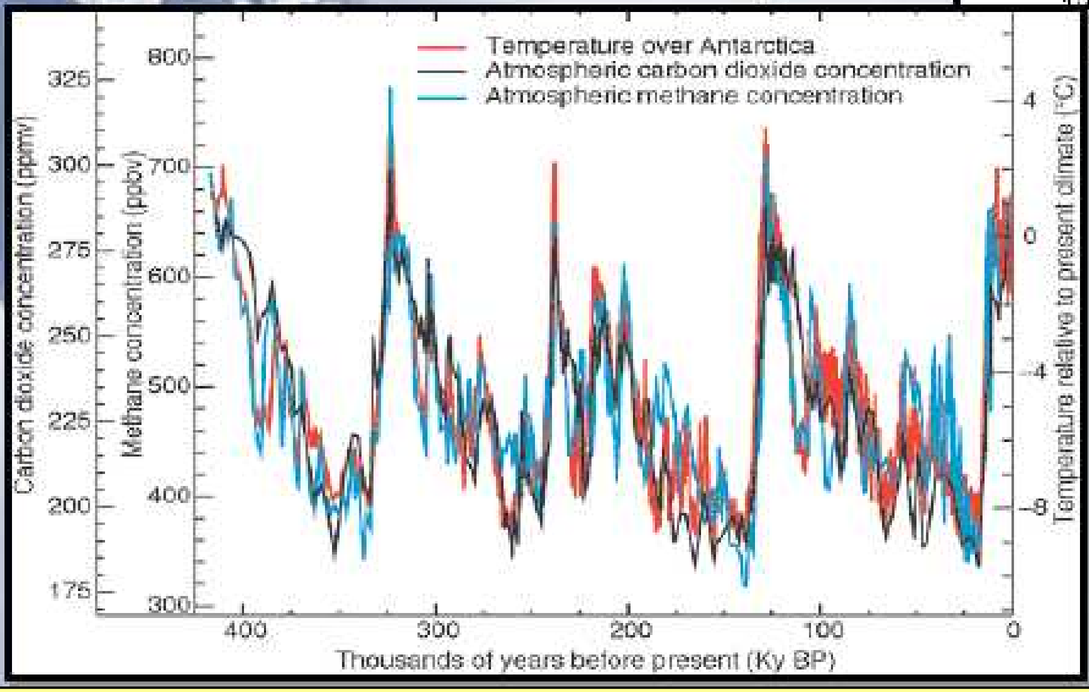
Happy Life

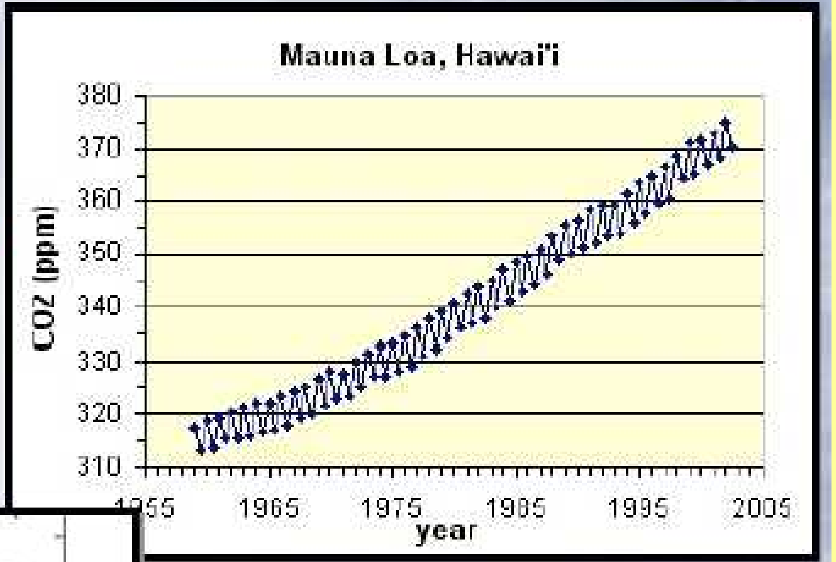


Our planet will be warmer

CO_2 Konzentrationen

Daten aus Vostok-Eisbohrungen

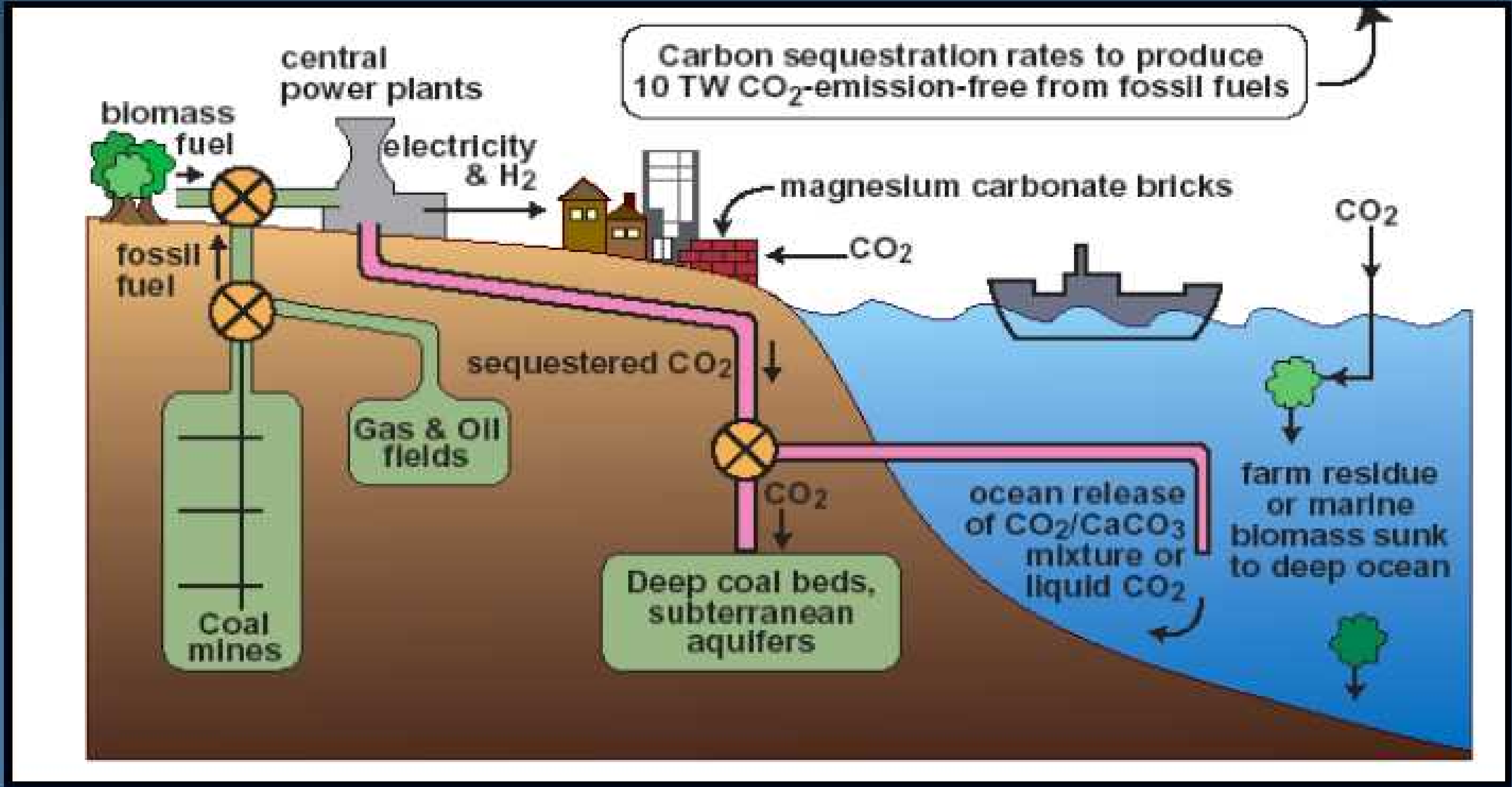




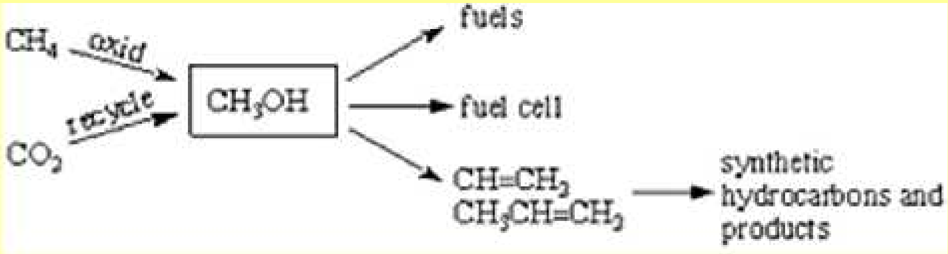
Keeling Atmospheric Data Set

Can we get rid of CO2?

CO_2-Einlagerung



RECYCLING CO2



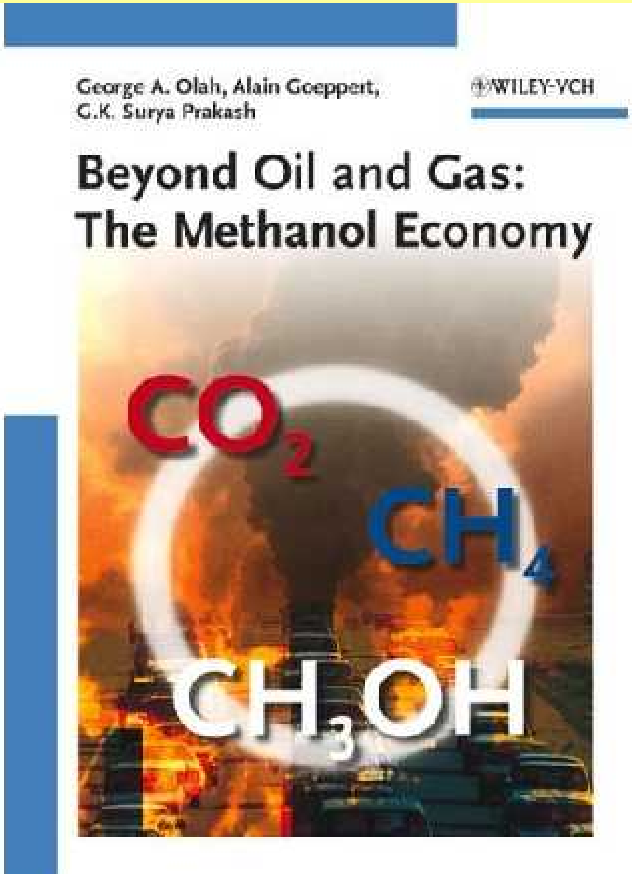
Methanol as carrier and storage of energy

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



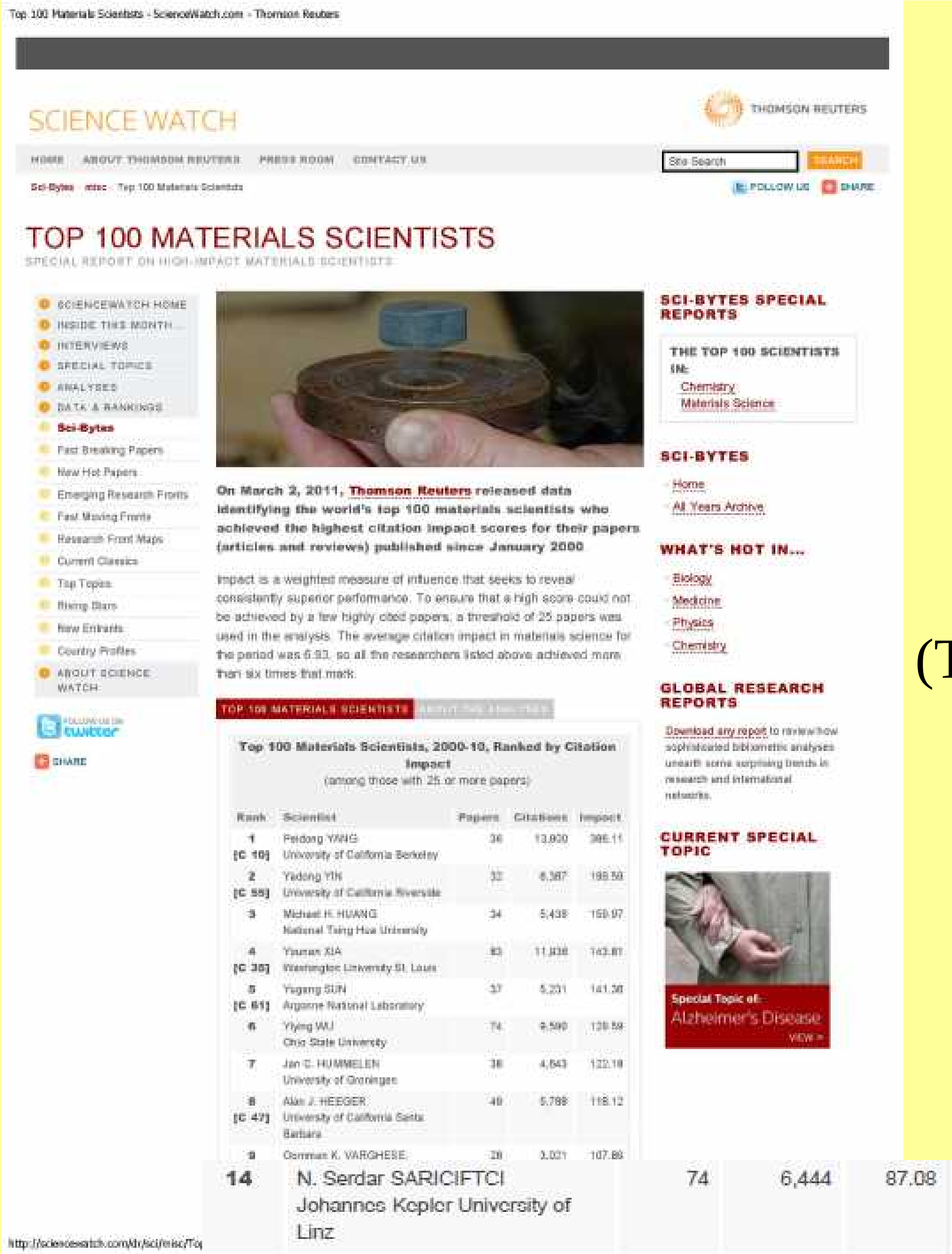
Linz Institute for Organic Solar Cells

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

- Organic/Hybrid Solar Cells
- CO2 Recycling into Synthetic Fuels
- Spectroscopy and Electrochemistry
- Bio-Organic Electronic Devices

„Incubator“ for small high tech spin-off companies



Top 100 Materials Scientists - ScienceWatch.com - Thomson Reuters

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On March 2, 2011, Thomson Reuters released data identifying the world's top 100 materials scientists who achieved the highest citation impact scores for their papers (articles and reviews) published since January 2000

Impact is a weighted measure of influence that seeks to reveal consistently superior performance. To ensure that a high score could not be achieved by a few highly cited papers, a threshold of 25 papers was used in the analysis. The average citation impact in materials science for the period was 6.93, so all the researchers listed above achieved more than six times that mark.

TOP 100 MATERIALS SCIENTISTS

Top 100 Materials Scientists, 2000-10, Ranked by Citation Impact
(among those with 25 or more papers)

Rank	Scientist	Papers	Citations	Impact
1 [C 10]	Peidong YANG University of California Berkeley	36	13,900	386.11
2 [C 55]	Yadong YIN University of California Riverside	32	6,387	199.59
3	Michael H. HUANG National Tsing Hua University	34	5,438	159.97
4 [C 38]	Younan XIA Washington University St. Louis	83	11,938	143.83
5 [C 61]	Yugang SUN Argonne National Laboratory	37	5,231	141.38
6	Yiying WU Ohio State University	74	9,590	129.59
7	Jan C. HUMMELEN University of Groningen	38	4,643	122.18
8 [C 47]	Alan J. HEEGER University of California Santa Barbara	49	5,788	118.12
9	Oomman K. VARGHESE	28	3,021	107.89
14	N. Serdar SARICIFTCI Johannes Kepler University of Linz	74	6,444	87.08

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http://sciencewatch.com/dr/sci/misc/To

LIOS @ JKU is #14
in the world ranking of
material scientists
(Thomson Reuters, March 2011)

Acknowledgements

Members of LIOS:
Helmut Neugebauer, Markus Scharber, Mathew White, Mihai Irimia-Vladu, Philipp Stadler, Jacek Gasiorovski, Daniel Egbe, Stefanie Schlager, Engelbert Portenkirchner, Eric Glowacki, Lucia Leonat, Marek Havlicek, Patrick Denk, Gerda Kalab, Christine Hinterberger, Dogukan Apaydin, Katheryna Gutnichenko, Elisa Tordin, Christine and Sandra Enengl, Halime Coskun, Zeynep Bozkurt, Daniel Voglhuber, Daniela Hiemetsberger, Cigdem Yumusak, many long term visitors …

Uni. Linz, Collaborators.: Siegfried Bauer, Martin Kaltenbrunner, Helmut Sitter, G. Knoer, Uwe Monkowius, Kerstin Oppelt, Achim Hassel…

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Austrian Foundation for Advancement of Science (FWF) Wittgenstein Prize, Indigo Project
EU Projects, FFG Projects

Sariciftci Heeger Patents at UCSB

US005331183A

United States Patent [19]

Sariciftci et al.

[11] **Patent Number: 5,331,183**

[45] **Date of Patent: Jul. 19, 1994**

[54] **CONJUGATED POLYMER - ACCEPTOR HETEROJUNCTIONS; DIODES, PHOTODIODES, AND PHOTOVOLTAIC CELLS**

[75] Inventors: **N. S. Sariciftci; Alan J. Heeger**, both of Santa Barbara, Calif.

[73] Assignee: **The Regents of the University of California**, Oakland, Calif.

[21] Appl. No.: **930,161**

[22] Filed: **Aug. 17, 1992**

[51] **Int. Cl.**[5] **H01L 29/28**

[52] **U.S. Cl.** **257/40**; 257/184; 257/461; 136/263

[58] **Field of Search** 257/40, 184, 461; 365/215; 136/263

[56] **References Cited**

U.S. PATENT DOCUMENTS

5,171,373 12/1992 Hebard et al. 257/40

OTHER PUBLICATIONS

Kamat, P. "Photoinduced Charge Transfer Between Fullerenes and Semiconductor ZnO Colloids" J. Am. Chem. Soc., 1991, 113, pp. 9705–9707.

Wang, Y. "Photoconductivity of Fullurene-Doped Polymers" Nature, Apr. 16, 1992, pp. 585–587.

Arbogast, J. W., et al., "Photophysical Properties of C_{60}" J. Phys. Chem., Jan. 10, 1991, pp. 11–12.

Sze, M. S., *Physics of Semiconductor Laser Devices*, (1981) Wiley–Interscience, New York, Chapter 13, "Photodetectors" pp. 743–789.

Sze, M. S., *Physics of Semiconductor Laser Devices*, (1981) Wiley–Interscience, New York, Chapter 14, "Solar Cells" pp. 790–838.

Primary Examiner—Sara W. Crane
Attorney, Agent, or Firm—Morrison & Foerster

[57] **ABSTRACT**

This invention relates generally to the fabrication of heterojunction diodes from semiconducting (conjugated) polymers and acceptors such as, for example, fullerenes, particularly Buckminsterfullerenes, C_{60}, and more particularly to the use of such heterojunction structures as photodiodes and as photovoltaic cells.

15 Claims, 3 Drawing Sheets

Sariciftci Heeger Patents at UCSB

We claim as our Invention:

1. A heterojunction device comprising
a. a layer of a conjugated polymer which serves as a donor, and adjacent thereto, a
b. layer of an acceptor material comprising an acceptor selected from the group consisting of the group of fullerenes, substituted fullerenes, fullerene derivatives, polymers comprising fullerenes or substituted fullerenes or of organic or polymeric acceptors having electronegativity in the range to enable a photoinitiated charge separation process defined

3. A heterojunction device comprising
a. a conjugated polymer which serves as a donor, and adjacent thereto,
b. an acceptor material comprising an acceptor selected from the group consisting of fullerenes or fullerene derivatives, polymers comprising fullerenes or fullerene derivatives, organic and or polymeric acceptors having electronegativity in the range to enable a photoinitiated charge separation

where

donor (D) and acceptor (A) units are either covalently bound (intramolecular), or spatially close but not covalently bonded (intermolecular);

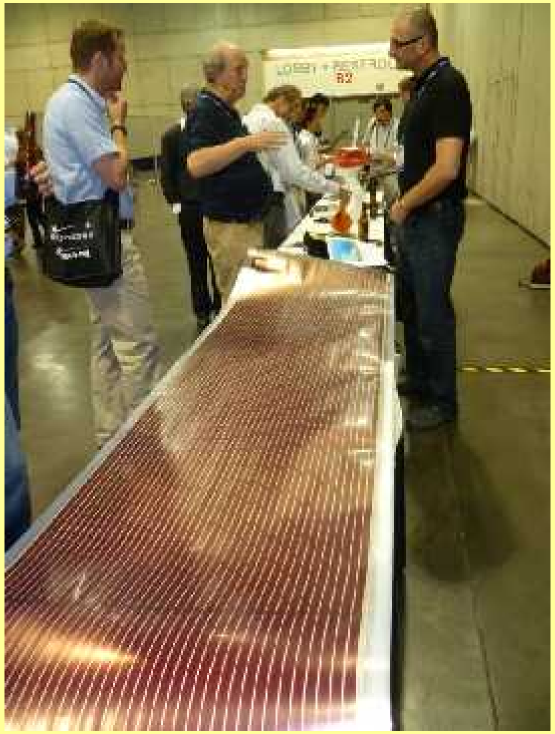
"1,3" denotes singlet or triplet excited states, respectively,

and where a heterojunction between the conjugated polymer and acceptor material is formed in situ by controlled segregation during solidification from a solution containing both the donor and the acceptor moieties.

Definition

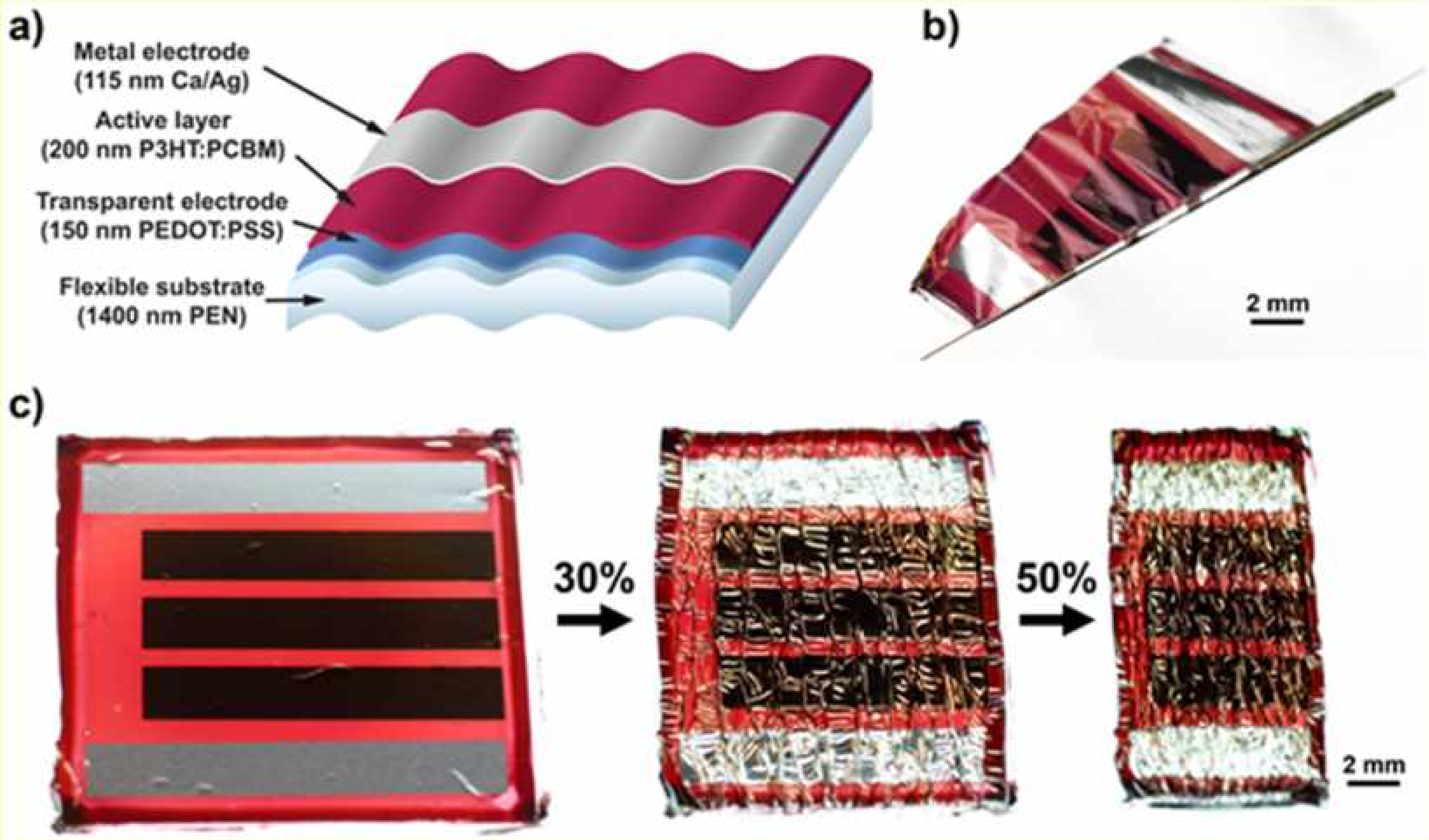
Birth of Bulk Heterojunction, 1992

Roll to roll produced solar cells



Konarka Inc.

Ultrathin, shrinkable, strechable organic solar cells



Martin Kaltenbrunner, Matthew White *et al*. *Nature Comm*. **DOI: 10.1038/ncomms1772 April, 2012**

nature COMMUNICATIONS

OPEN

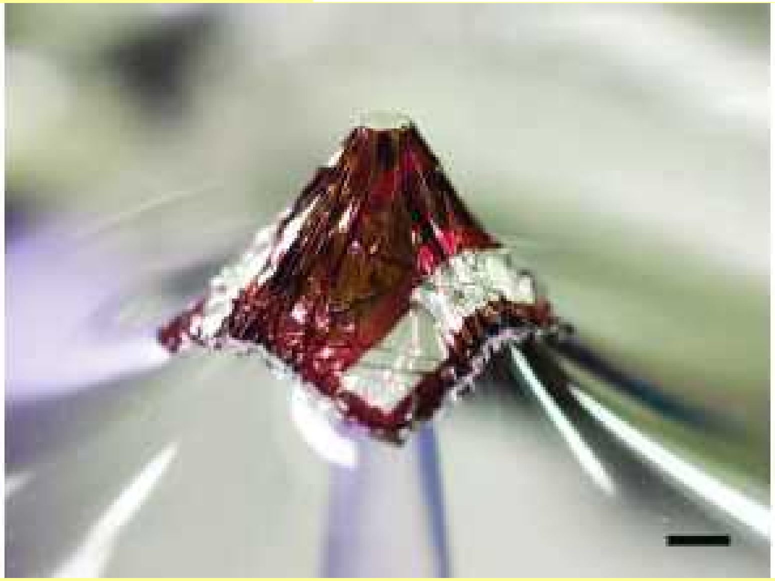
ARTICLE

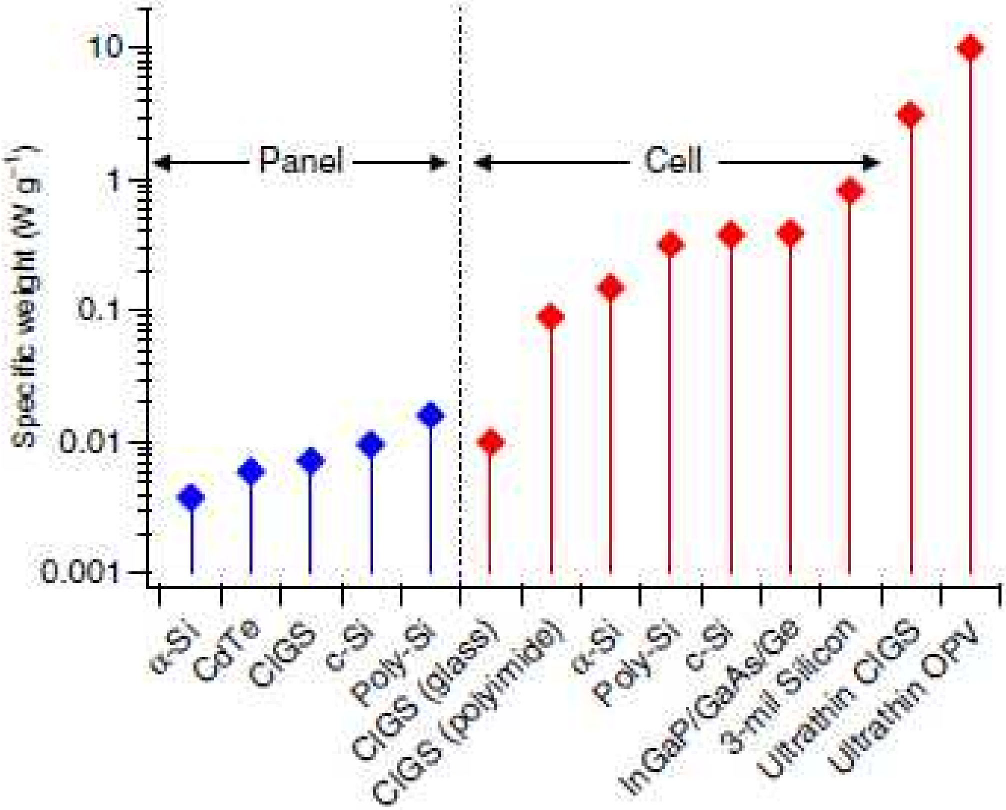
Received 17 Nov 2011 | Accepted 2 Mar 2012 | Published 3 Apr 2012

DOI: 10.1038/ncomms1772

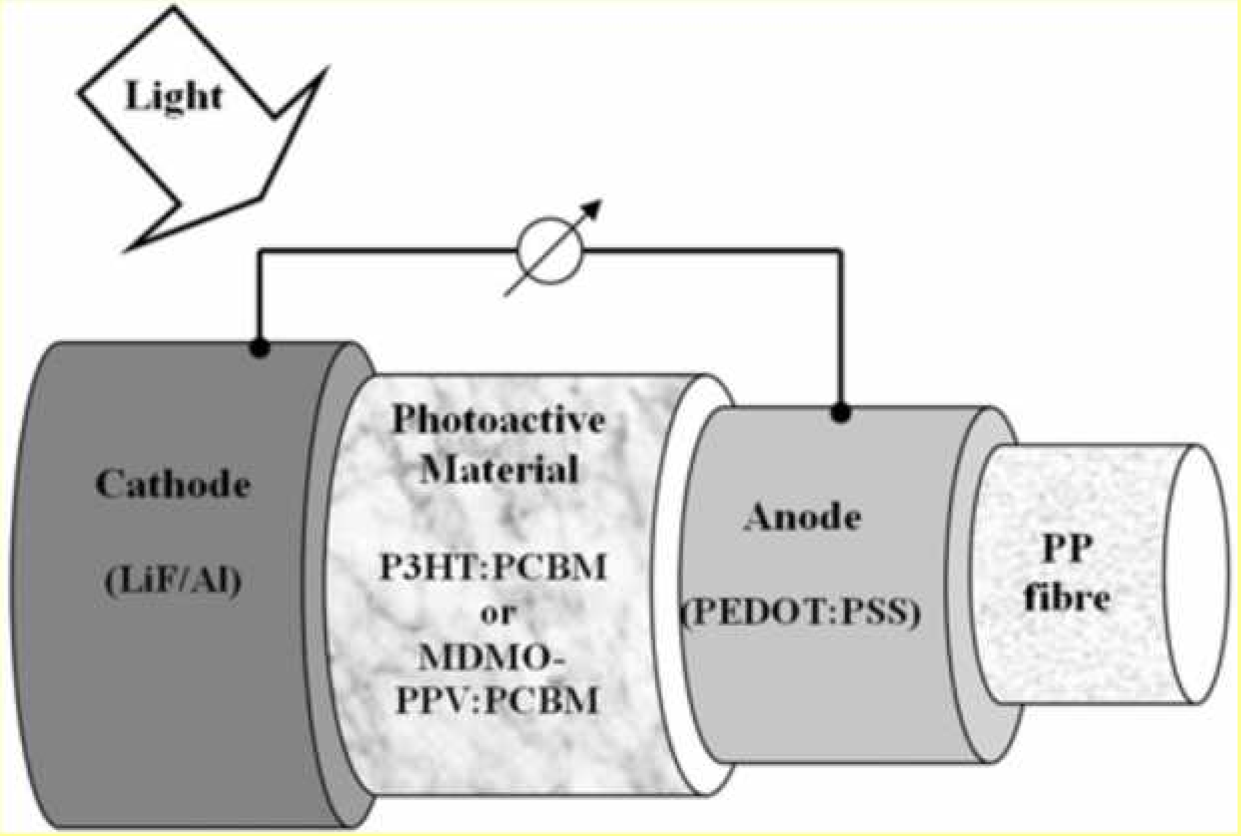
Ultrathin and lightweight organic solar cells with high flexibility

Martin Kaltenbrunner[1,2,3], Matthew S. White[4], Eric D. Głowacki[4], Tsuyoshi Sekitani[2,3], Takao Someya[2,3], Niyazi Serdar Sariciftci[4] & Siegfried Bauer[1]





Textile integrated organic solar cells fibers



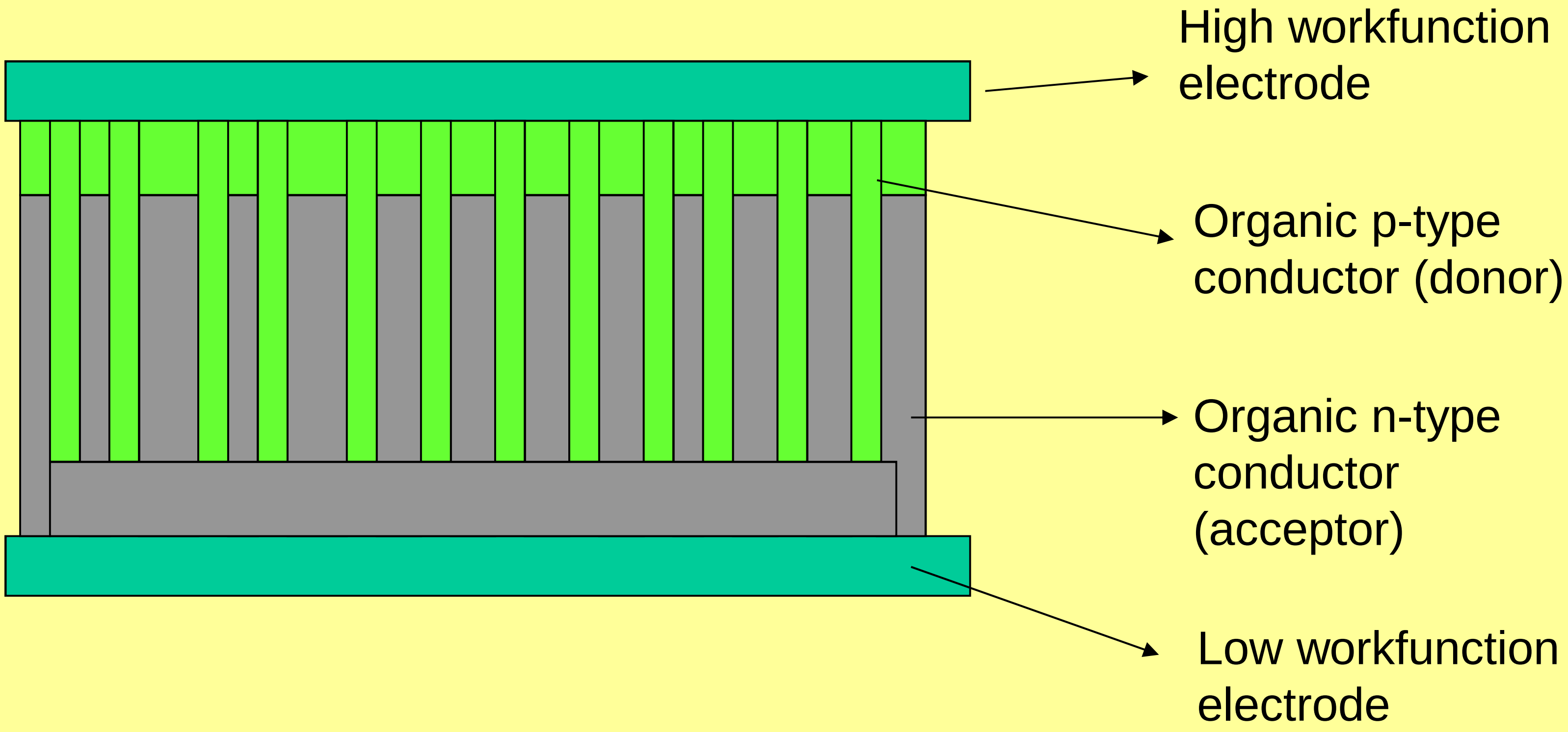
Ayse Bedeloglu *et al*, Textile Research Journal (2009)

Solar cell integrated textiles

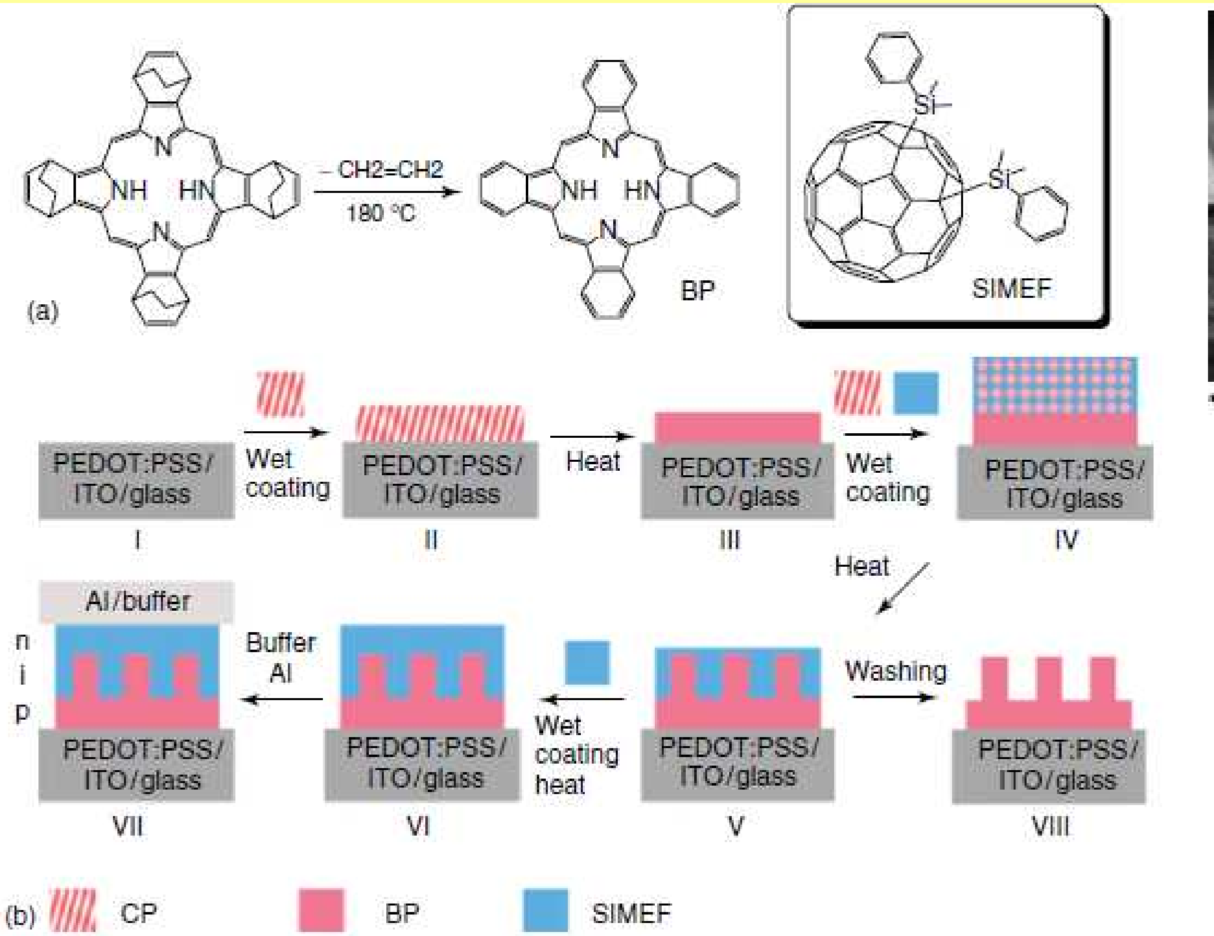
A commercial solar jacket and bag

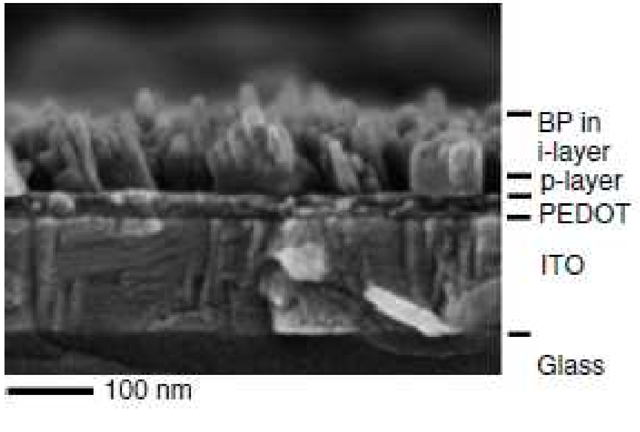
www.scottevest.com www.neubers.de

„Optimum“ Geometry for Organic and Hybrid Solar Cells



CHEMISTRY BASED SOLAR CELLS REACH >10 %





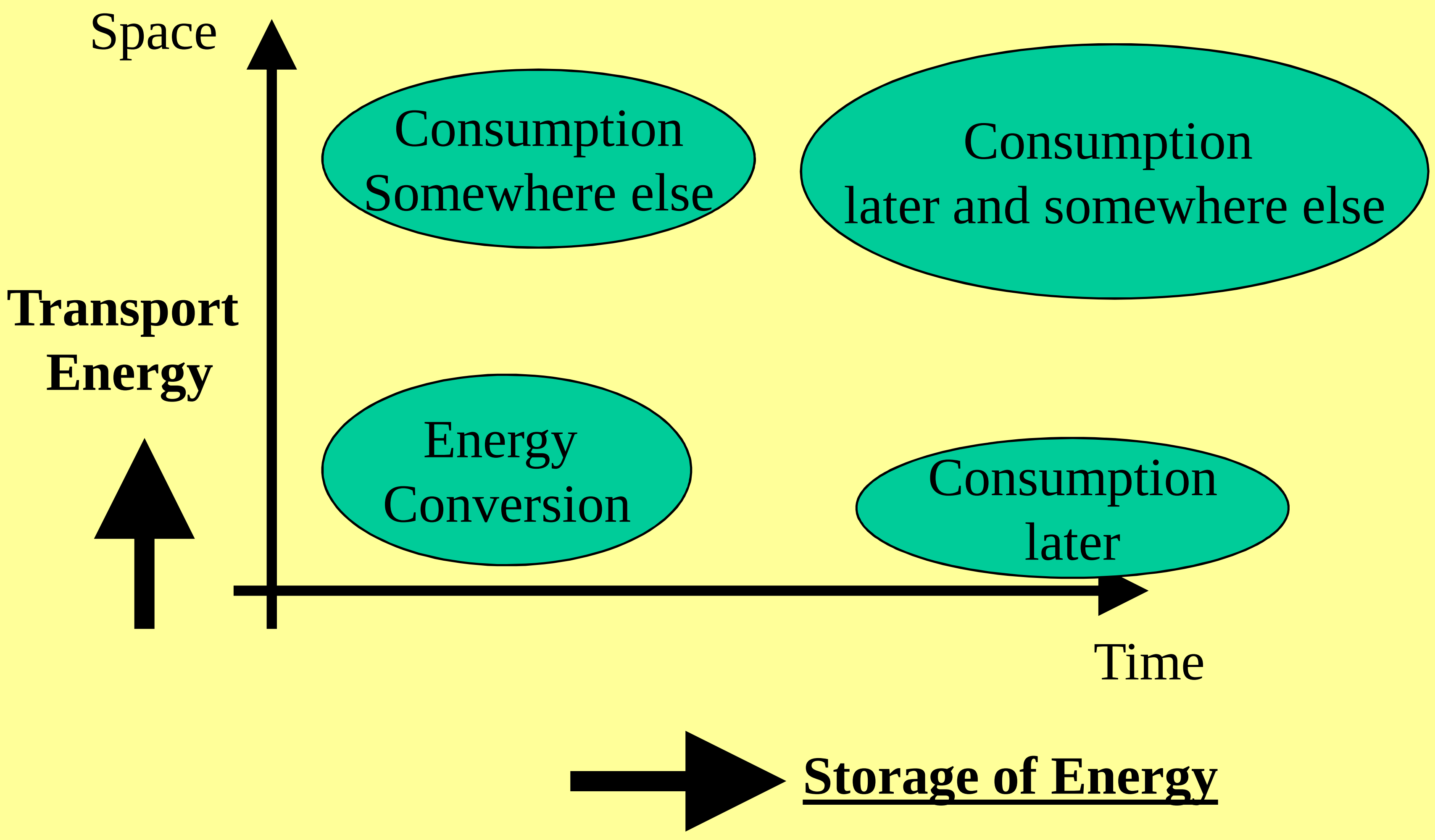
Aramaki et al,
Mitsubishi Chemicals Labs, Tokyo

What is the next challenge in

Solar Energy Conversion?

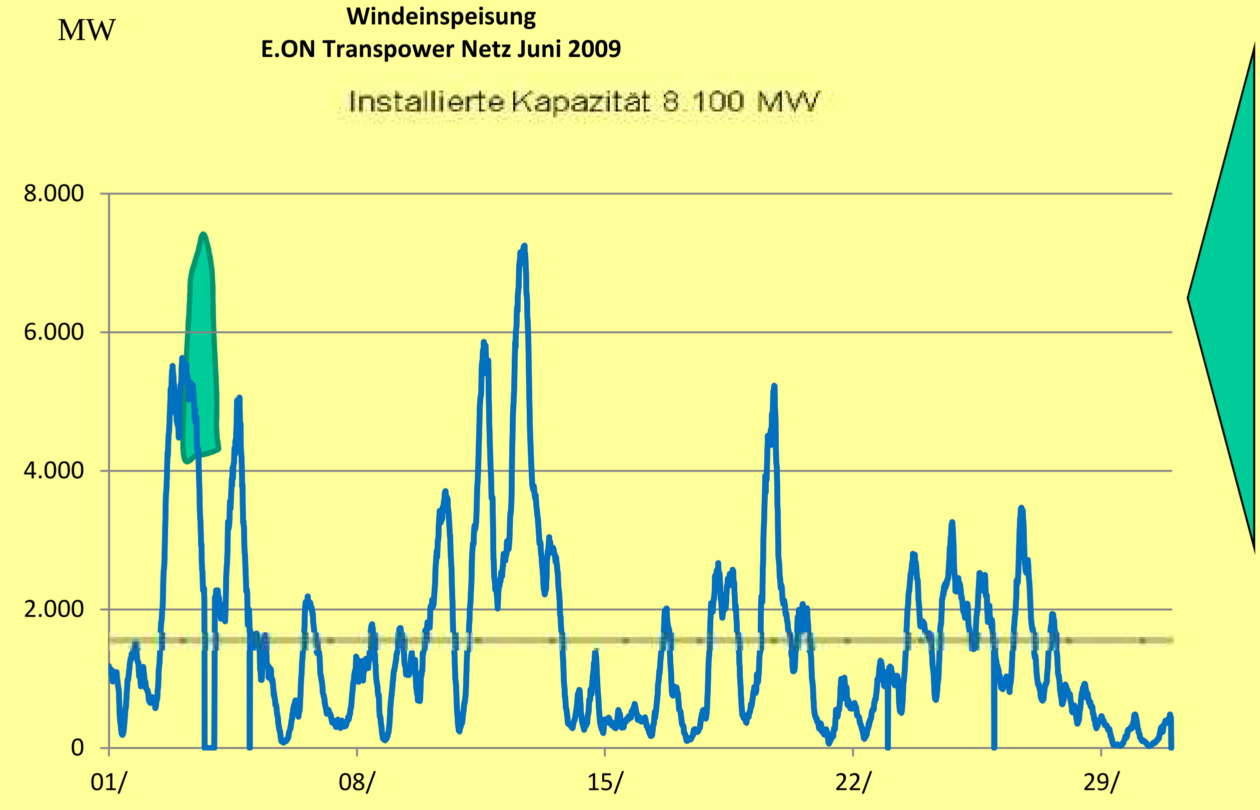
Solar energy STORAGE into chemical energy

Storage-Transport Problem



Transportable fuel created by solar energy conversion !!!

Unstability in Wind Energy Supply

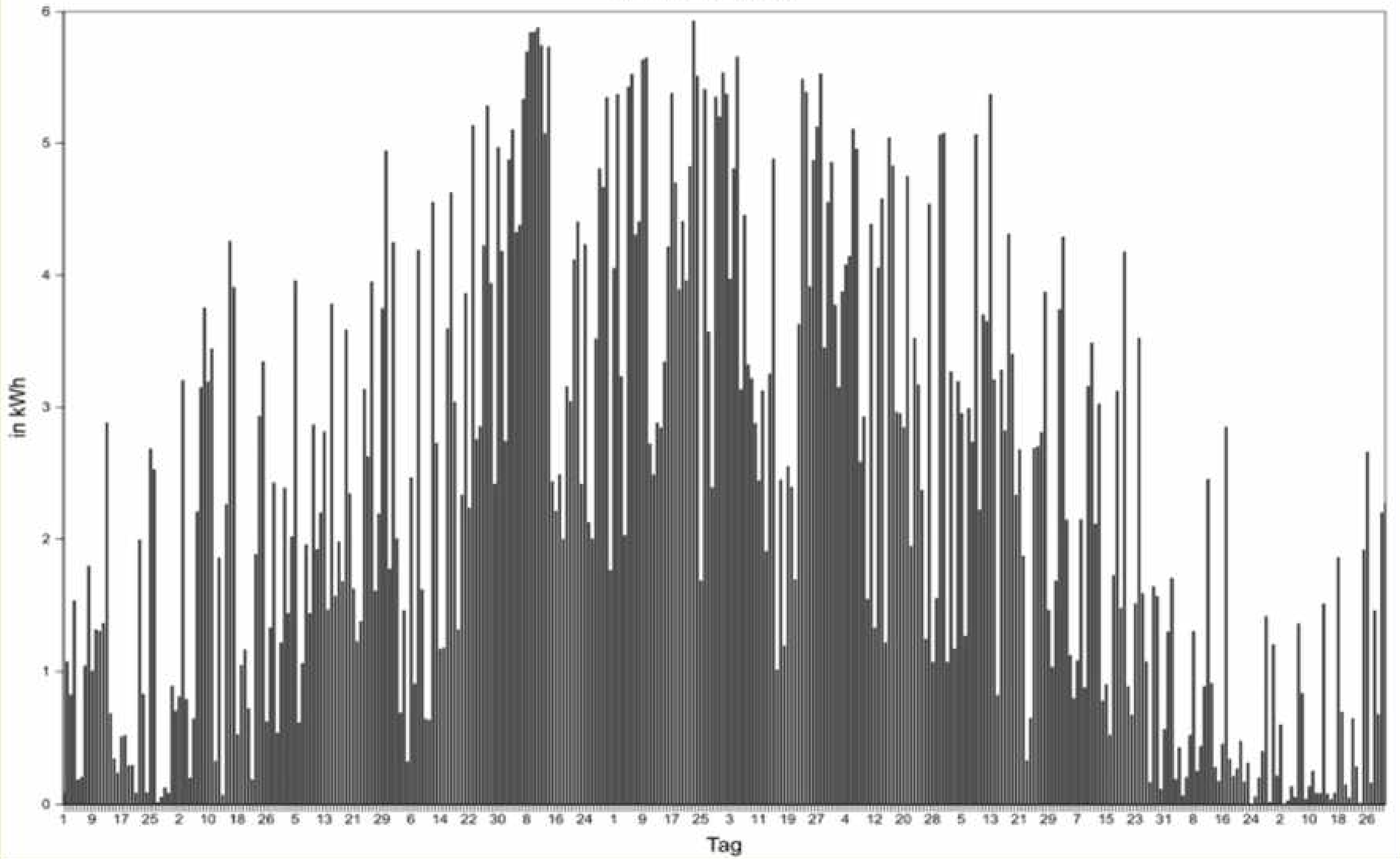


Needs Buffering

Jahresgang 2008

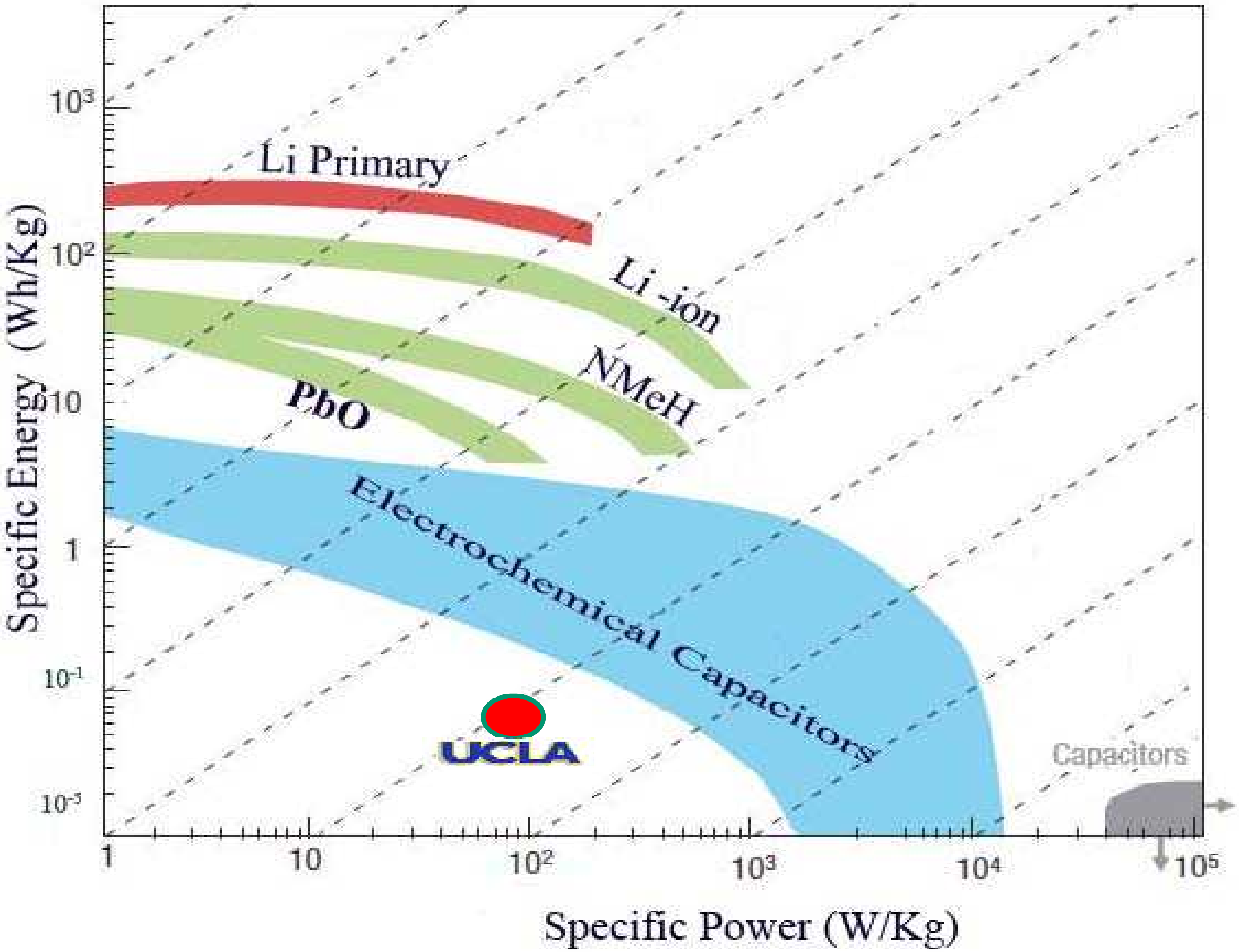
Norddeutschland: Kreis 3xxxx

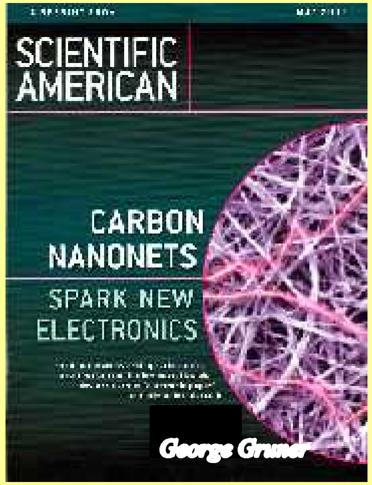
(normiert auf 1 kWp)



The problem: power fluctuation during

generation and use



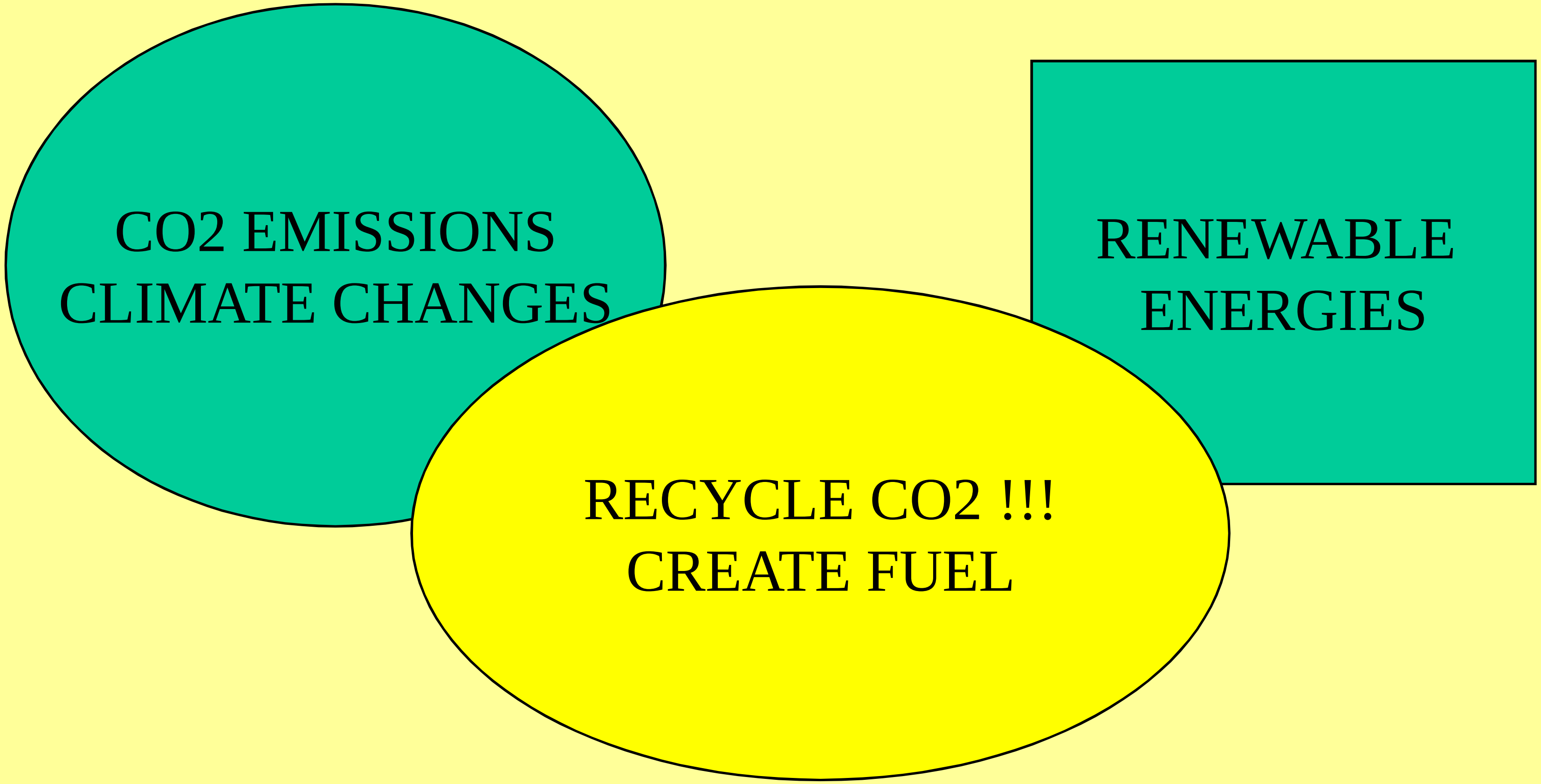


Batteries are slow, not suitable for power handling

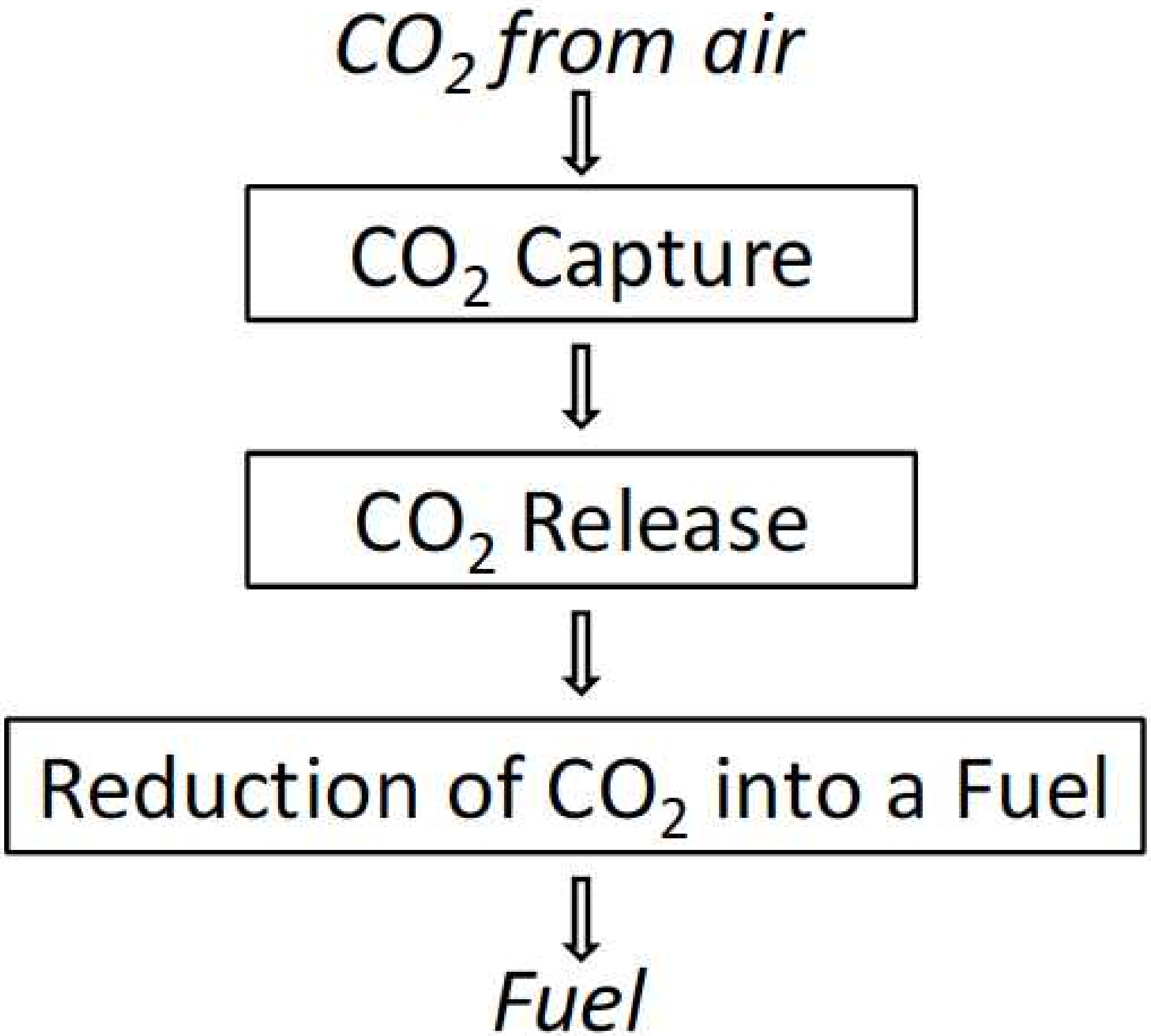
The solution: Supercapacitors

G. Gruner, UCLA

INTERFACE BETWEEN CO2 REDUCTION AND RENEWABLE ENERGY CREATION

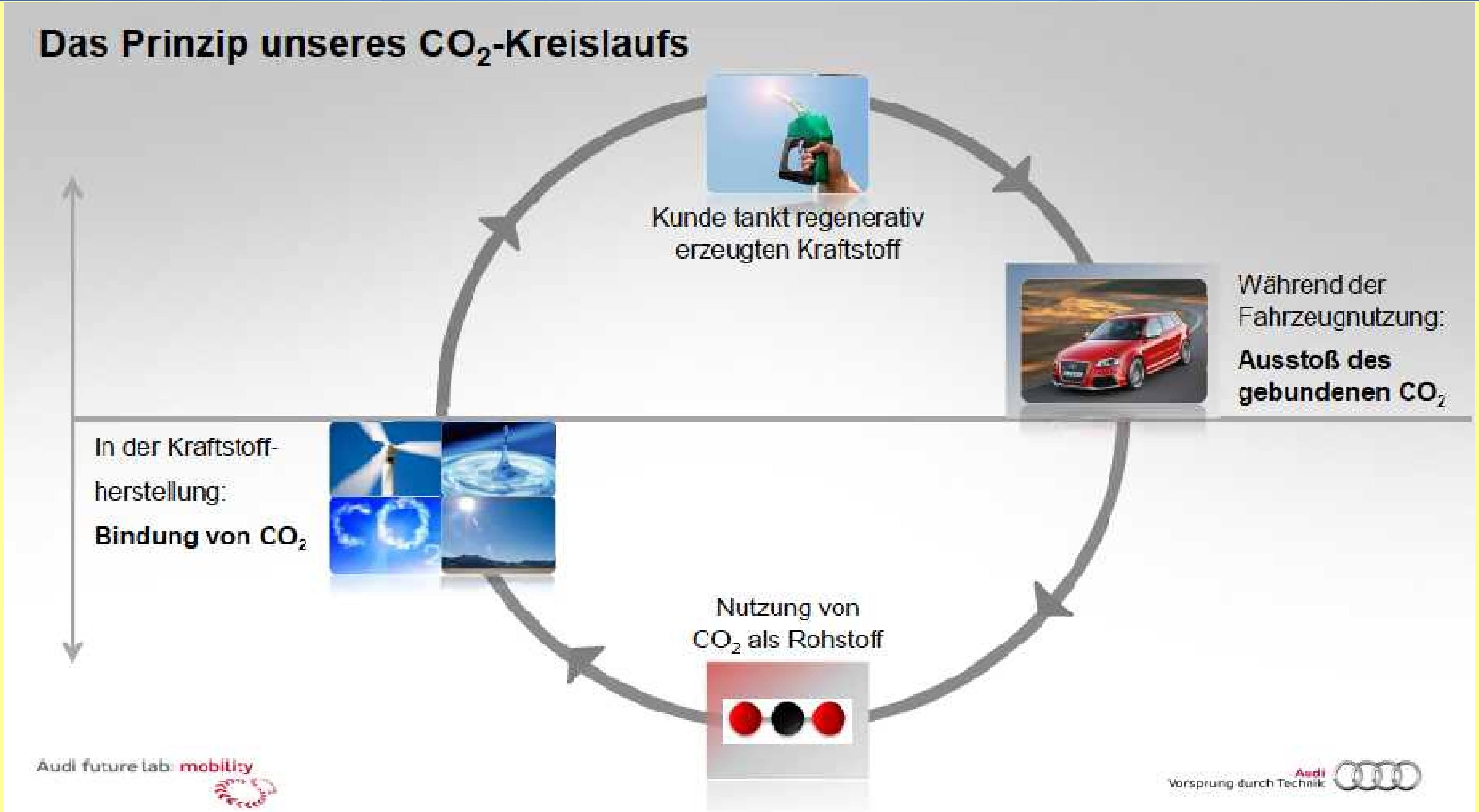


Future recycling of CO_2 as important mission of renewable energies


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

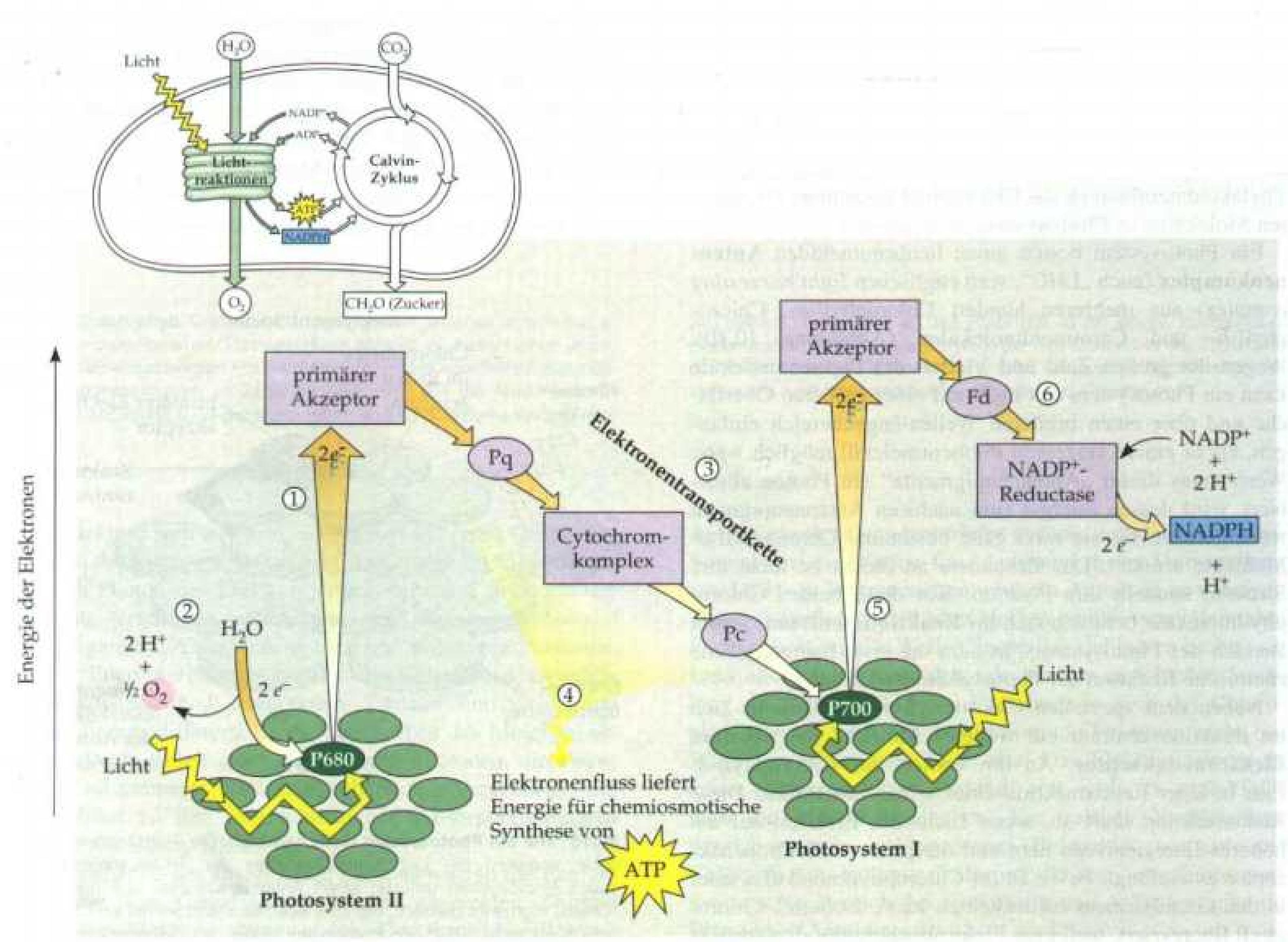
http://www.solar-fuel.net/

CO_2 Neutral Synthetic Fuels



Courtesy Dr. Pengg

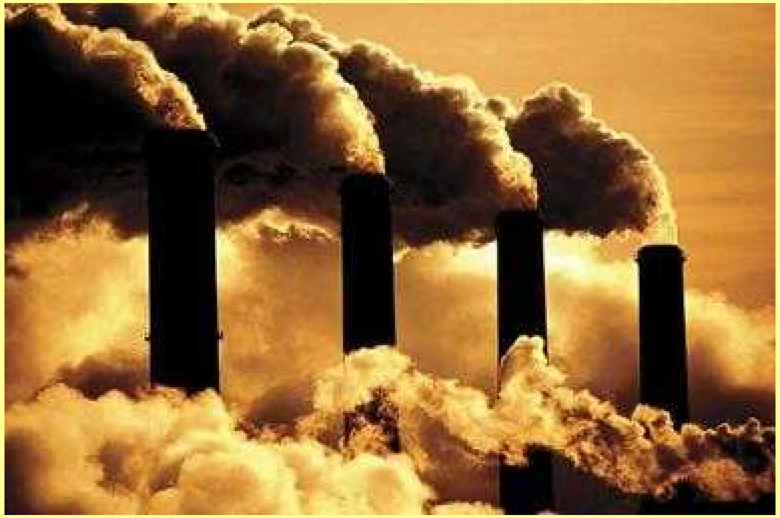
Natural Photosynthesis



Recycling of CO_2

Over 90 % of emitted CO_2 is generated by energy products.

To convert back CO_2 to fuels hydrogen or energy is required.



One promising field in this direction is the **photochemical**

Or electrochemical reduction of carbon dioxide using solar light

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

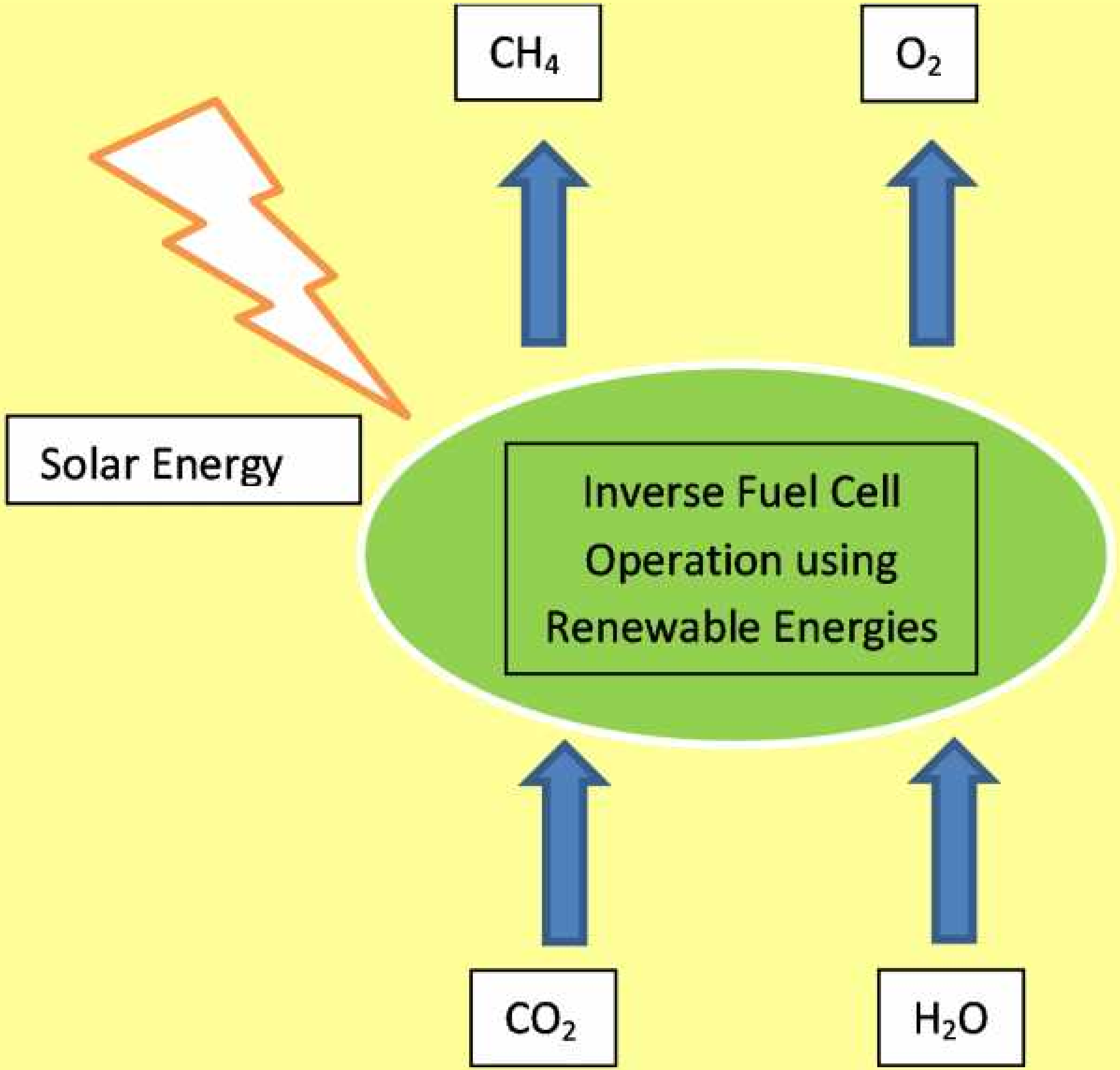
$$CH3OH + H2O \rightarrow CO2 + 6H+ + 6e-$$

Biocatalysis

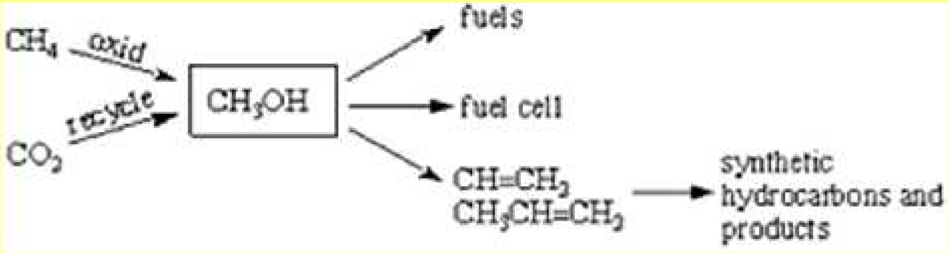
Photocatalysis

Electrocatalysis

Inverse Fuel Cells



RECYCLING CO2



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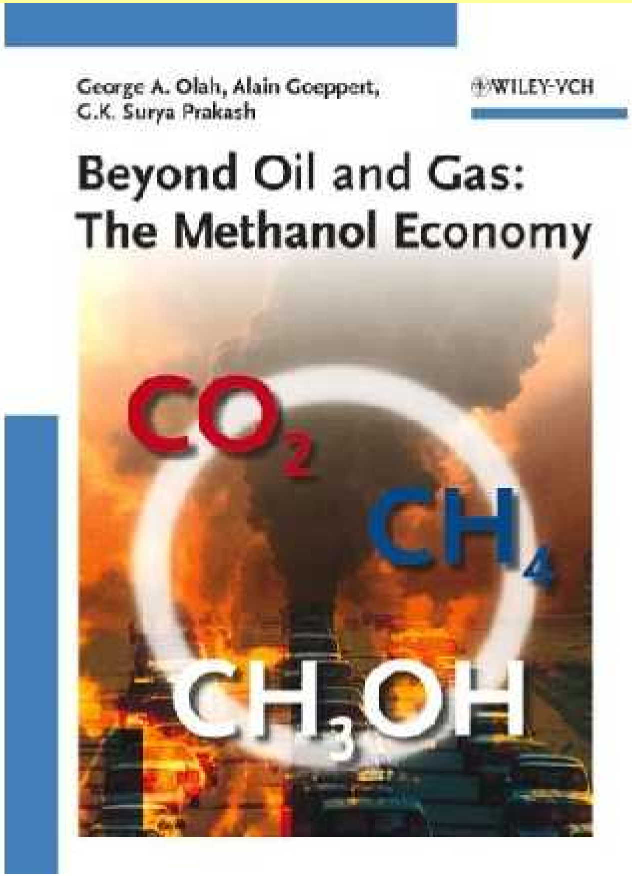
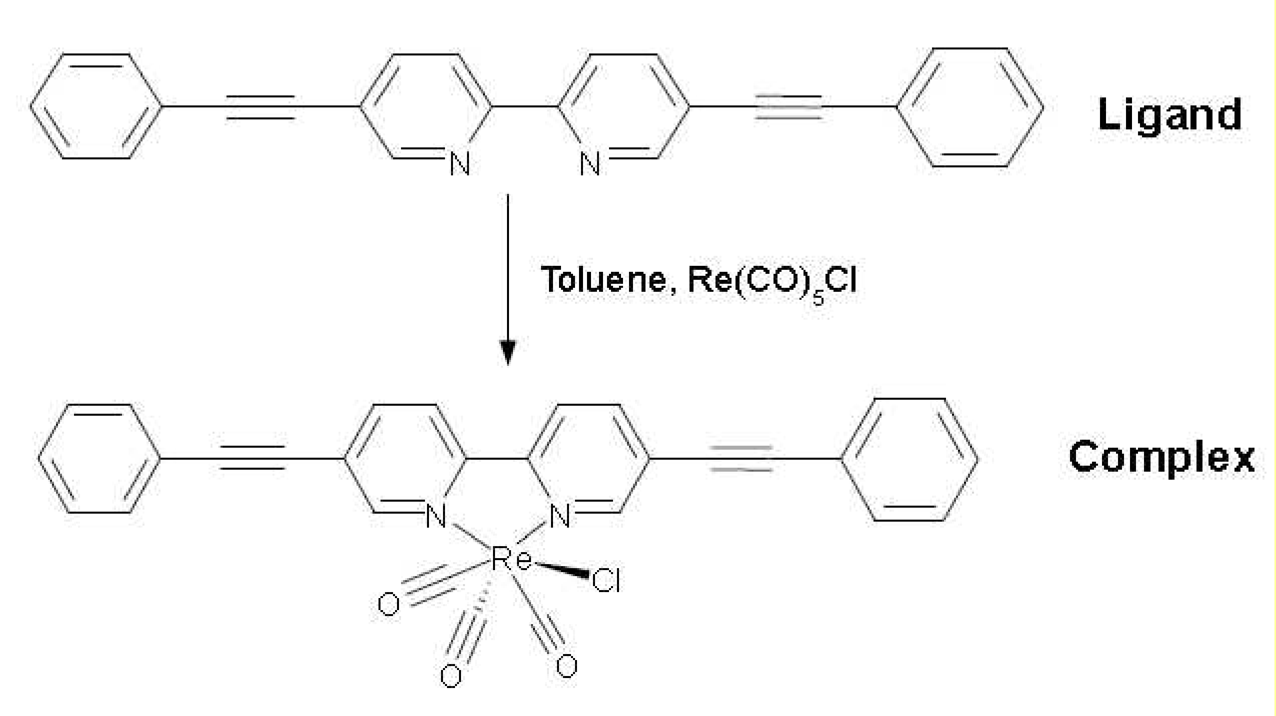
Univ. of Southern California, USA



Photochemical Reduction of CO2

Homogeneous photocatalysts as well as electrocatalyst,
Oppelt, Portenkirchner 2011



K. Oppelt, D. Egbe, U. Monkowius, M. List, M. Zabel, N.S. Sariciftci, G. Knör
Journal of Organometallic Chemistry 696 (2011), 2252

Electrochemical reduction of CO_2

- Excess electric energy can be conveniently used for the catalysed reduction of CO_2 in water to afford alcohols and/or C_n-hydrocarbons :

  storage of electricity!

- Such use of excess electric energy can play a key role in the short term for the conversion of CO_2 into fuels implementing a significant recycling of carbon.
- The use of **solar energy** for CO_2 reduction in water is a key issue for the medium term: a substantial recycling of carbon could be performed.

Photocatalytic reduction of CO_2

1. $Ru(bpy)_3^{2+}$ (bpy = 2,2’-bipyridine) as both photosensitizer and catalyst

2. $Ru(bpy)_3^{2+}$ as the photosensitizer and another metal complex as the catalyst

3. $ReX(CO)_3(bpy)$ (X = halide or phosphine-type ligand) or a similar complex as both photosensitizer and catalyst

4. $Ru(bpy)_3^{2+}$ or $Ru(bpy)_3^{2+}$-type complex as the photosensitizer in micro-heterogeneous systems

5. A metalloporphyrin as both the photosensitizer and the catalyst

6. Organic photosensitizers with transition-metal complexes as catalysts

---

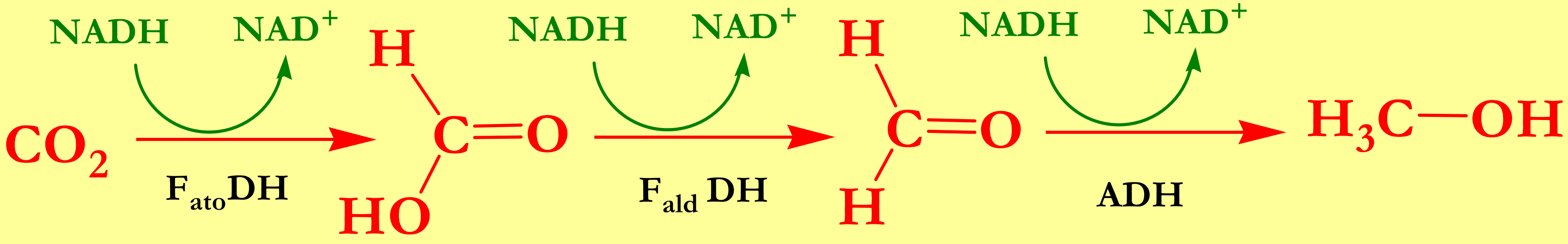
1.“*Photochemical carbon dioxide reduction with metal complexes*” E. Fujita, *Coord. Chem. Rev.* 1999

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**

Scheme of the enzymatic reduction of CO_2



Reaction conditions

Solution buffered at pH 7

T = 37 °C

P = 1 atm

4 mL of solution of
Sodium Alginate 2% (m/v)
In deionized water

1.6 mL TEOS

1 mL solution

$F_{ato}DH$ (10.0 mg)
$F_{ide}DH$ (10.0 mg)
ADH (10.0 mg)

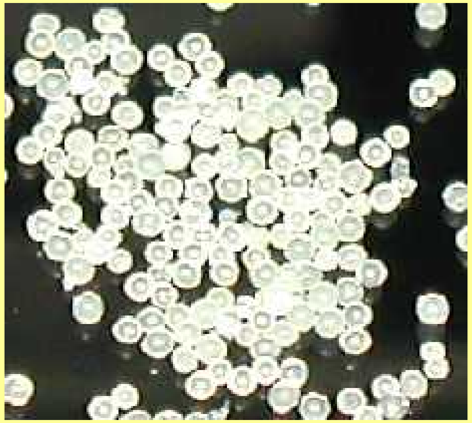
In buffer TRIS-HCl 0.1 M (pH 7)

Drop by drop addition in
20 mL $CaCl_2$ 0.2 M+TESO

Sol-gel-formation time 30 min

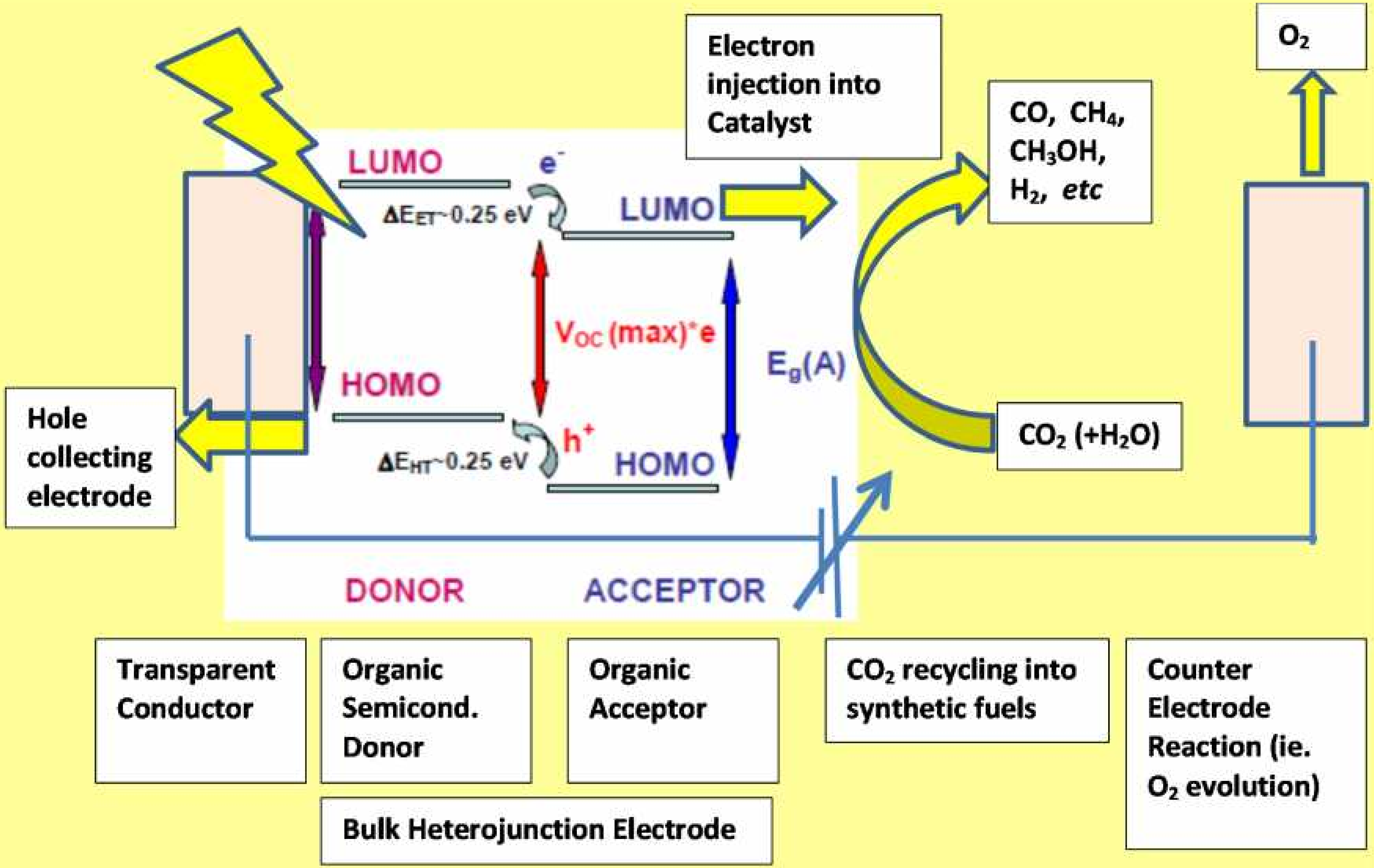
Filtration

Washing with water

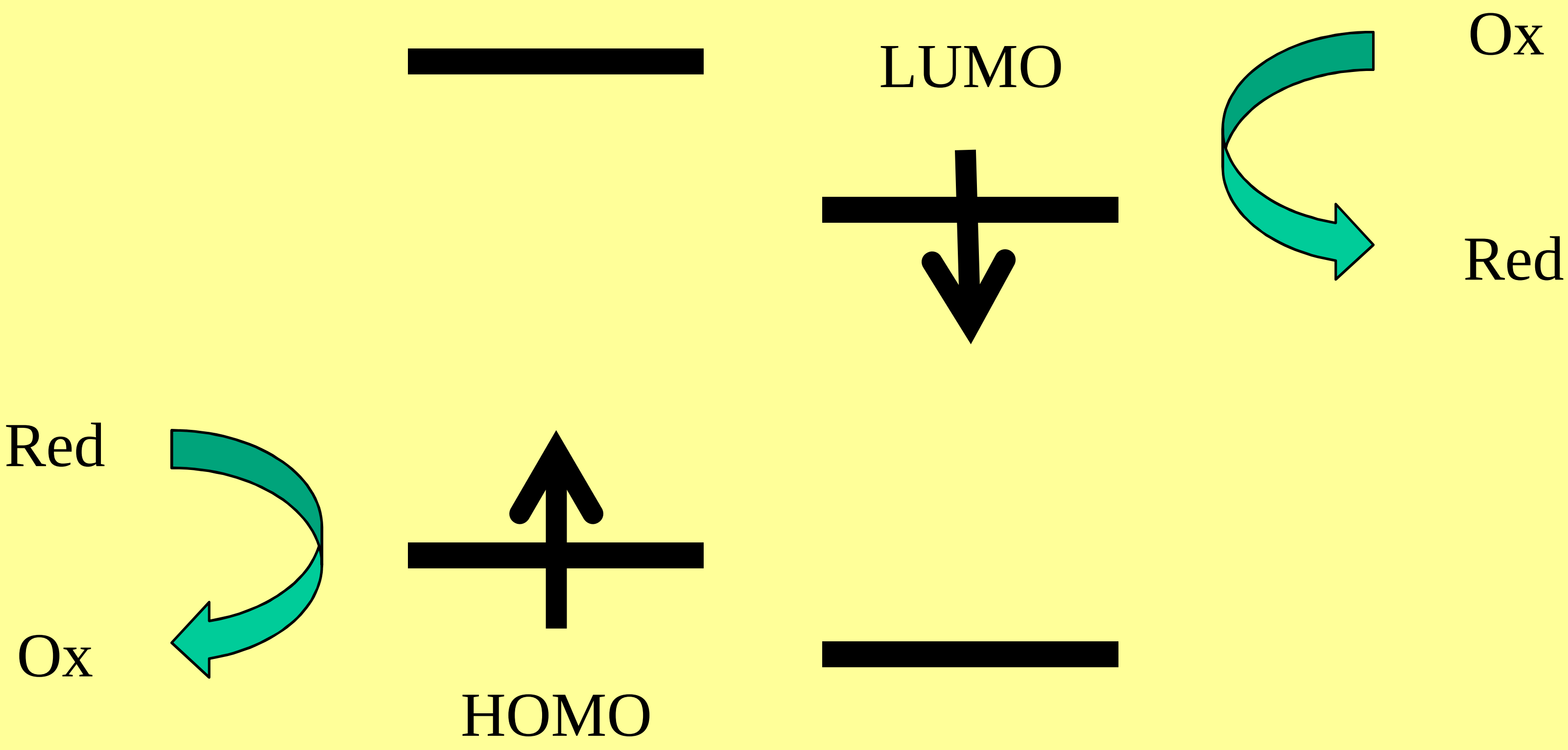


Michele Aresta, Bari, Italy

Bulk Heterojunction Electrodes in Photoelectrochemical CO2 Recycling

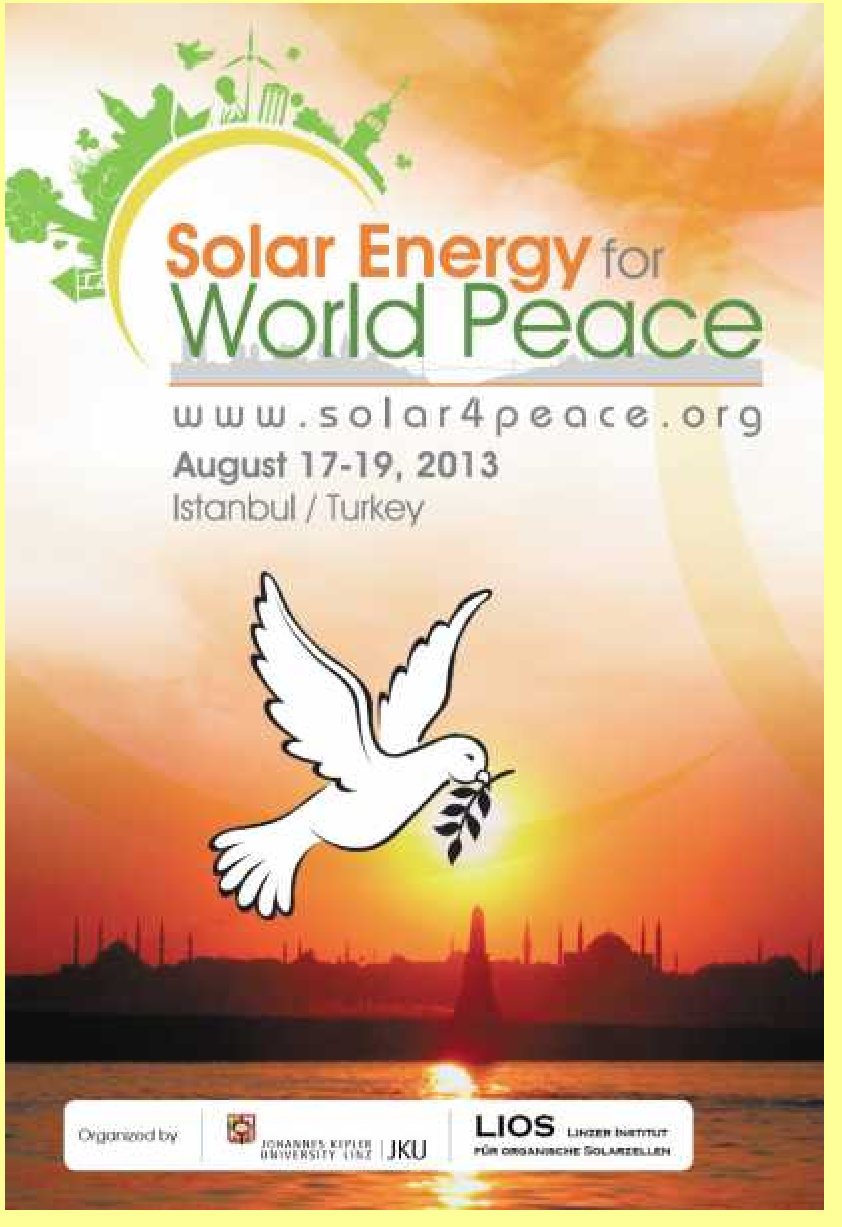


Photoinduced Charge Generation



Photoinduced Redox Chemistry

sign our petition



sign our petition

Solar Energy for World Peace

August 17-19, 2013
Istanbul / Turkey

www.solar4peace.org

Petition for using the solar energy for a peaceful, democtratic future for the world

We, the undersigned to this letter, wish to emphasize the potential contribution of solar energy to a peaceful and democratic future for our planet.

Energy is essential for the development of human society. It is the right of every human to have access to energy sources for sustaining a dignified standard of living. With fossil fuels as the dominant source of energy in modern societies, being depleted at an alarming pace, energy becomes a commodity for those who can afford it. Hundreds of millions of people in the developing world have no access to affordable energy for a sustainable life. Even the developed countries have to spend a major part of their national income for importing fossil fuels. This dependency imposes a heavy economic burden and associated volatility. Today human society looks like a "fossil fuel addict" throwing away its future.

sign our petition

The control of fossil fuel supplies by a few corporations at both the international and national levels permits an oligarchy to undermine any true democracy in future.

In contrast to nuclear and fossil energies, which are associated with catastrophes, wars, inequality and power politics, solar energy is correlated with a peaceful, clean, democratic, green and sustainable future for mankind. Solar energy can never be monopolized. Human society needs decentralized solar energy for realization of global democratization. With energy independence and automony through solar energy, the world will have a better prospect to realize global democratization and prosperity and to ensure harmony among regions, nations and people. Solar light is widely distributed on our planet and has the capacity of providing many orders of magnitude more energy than we consume as a human society today.

With this motivation in mind the delegates of the conference "Solar Energy for World Peace" (www.solar4peace.org) came together in Istanbul to exchange scientific information on new solar energy technologies. A particular aim of this meeting has been the transfer of know how to the developing countries in Africa and the Middle East, with emphasis on the need for mutual cooperation at the scientific and technical levels in order to make this technology available to every human being on earth with equal rights to this free source of energy.

sign our petition

The undersigned participants request responsible persons at all national and international political levels to support the research, development and dissemination of solar energy. As scientists and engineers, we will strive to create the sciences and technologies needed to harvest and utilize solar energy economically for all people on our planet. The future of human society and of our planet will depend upon the widespread use of solar energy as an abundant, free and clean source of energy.

Future is…

Convergence of multiple crisis conditions:

1.) Energy crisis (oil running out)
2.) Climate crisis (CO2 and global warming)
3.) Demographic crisis (10 Billion population)
4.) Economic crisis (see your daily newspapers)

Will converge to a difficult future around 2050

Future is, what we make of it.

Investing in clean energy future
will solve and ease all four crisis conditions simultaneously

THANK YOU FOR YOUR ATTENTION