

### Learning from Nature - Artificial Photosynthesis

### Solar fuels replacing fossil fuels

- An alternative *Energiewende* route?

#### **Biological solar-energy conversion - Photosynthesis**



 $H_2O + Light + CO_2 \rightarrow O_2 + C_nH_{2n}O_n$ 





# Photosynthesis during the year











### Intergovernmental Panel on Climate Change (UNO) 4<sup>th</sup> IPCC Report 2007

2500 scientific reviewers (unpaid and independent) from 130 Countries; 6 years of work

Without any reasonable doubts

**Burning fossil fuels** 

- => Rise of atmospheric CO<sub>2</sub>
  - => Global Warming

=> disastrous consequences likely, especially if temperature rise exceeds 2°C

### 4th IPCC Report 2007



#### **Nobel Peace Price 2007**





# 2014 5th IPCC Report in 2013/14

Climate change is perceived as a global threat that is unprecedented in the history of mankind.

Not only by scientists and environmentalist, but also by most governments.



### Pariser Agreement signed on December 12, 2015

Signed by 195 UNFCCC\* members/ ratified by 160. Only Syria and Nicaragua did not sign. \*United Nation Framework Convention on Climate Change involving essentially every state on the world.

Holding the increase in the global average temperature to well below 2 °C above pre-industrial levels and to pursue efforts to limit the temperature increase to 1.5 °C...,

Parties aim ... a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century."

- Goal of zero net emissions in the 2<sup>nd</sup> half of this century



### **IPCC** Report 2014, Intergovernmental Panel on Climate Change (UNO)



### Primary Energy dominated by fossil fuels

#### Primary energy supply in Germany (1990-2016)

(according to data from Bundesministeriums für Wirtschaft und Energie / AG Energiebilanzen



### Net electricity production in Germany in 2017



#### Could renewable (solar) energy provide the energy needed in Germany?

## "Die Energieversorgung muss spätestens bis 2050 nahezu vollständig dekarbonisiert erfolgen." (Klimaschutzplan 2050 der Bundesregierung, November 2016)

"The energy supply needs to be nearly completely decarbonized until 2050, at the latest."



Covering the current primary energy demand of Germany by photovoltaics would require **ca 10% of its land area**, <u>provided the electrical energy can be stored and put to use as required</u>.

.. 10% is a lot, but **much less is needed for more efficient energy systems**; and there also is (off-shore) wind energy **and plenty of sun in EU countries like Spain** 

### Why non-fossil fuels are needed – Storing wind & solar energy

(1) Pronounced fluctuation of solar and wind energy can be compensated only partially by smart grid technologies



Large-scale midterm (day-night, weeks) and long-term (summer-winter) storage of renewable electricity needed for reliable electricity supply

(2) Electromobility is  $CO_2$ -neutral only if renewable electricity (solar, wind) is available when needed for loading the batteries.

### Why non-fossil fuels are needed – Replacing fossil fuels directly

(3) Electromobility (with batteries) too problematic in aviation and oversea ship transportation





### .. learning from Nature ?



Berlin 1889

Bird Flight as a Basis of Aviation Art, 1989

-ing 2 Suphider Berl

### .. learning from Nature



### .. learning from Nature

### **Artificial Photosynthesis**



or other valuable compounds

### .. learning from Nature





**Concepts and Materials** 



### Synchroton - our "atomic microscope"



ESRF, European Synchrotron Radiation Facility, Grenoble





# <u>Catalysts for</u> Water oxidation

Mn₄Ca(µ-O)5 oxide core of biological catalyst

Background photo by Ivelina Zaharieva Molecular graphics by Mathias Wiechen Catalysis by 'biomimetic oxides' that are based on manganese and other earthabundant elements (Ca, K, Ni, Fe, Co, ...)

Avoidance of rare elements (irdium, ruthenium, platinum, ..) will be - on the long run essential, but represents a scientific challenge.

### Photovoltaic + biomimetic water elektrolysis => $H_2$





Reece et al, Science, 2011 (Nocera-Gruppe am MIT)

### Photovoltaic + biomimetic water elektrolysis => $H_2$





Reece et

#### Hydrogen as a fuel – without basic technological problems



~1970, First fuel-cell cars



2003, Fuel-cell busses in various European cities



#### Electricity—heat cogeneration (250 kW)



Design study: European hydrogen plane

### Hydrogen $(H_2)$ – as a fuel and as a raw materials



toxic; danger of explosion comparable to natural gas or petrol fuels.

Favorable in the case of leakage: The light H<sub>2</sub>-gas moves rapid upwards and it is not a greenhouse

### **Power-to-X** $X = gases (H_2, CH_4, ..)$ or liquids



integrated device/facility, no "grid detour"



#### Alternative routes toward sustainable, non-fossil fuels





Sun + Photosynthesis => Energy supply of life on Earth

> Our society has deep black roots. Fossil fuels => Climate desaster





Learning from Nature ... like Lilienthal

The energy transition needs non-fossil fuels.

.. it can be done, but it will cost.





Don't wait for a miracle technology Now societal / political / economical transition needed.

> "Wer zu spät kommt, den bestraft das Leben."



"Those who are late will be punished by life itself."

Michail Gorbatschow to Erich Honecker on lack of political-economical change in socialist East Germany

#### For more information ..



DEUTSCHE AKADEMIE DER TECHNIKWISSENSCHAFTEN



#### Abschlussveranstaltung des Akademienprojekts Künstliche Photosynthese Ort: Berlin Termin: 15. Mai , 14:00 - 18:00 Uhr

Die durch Künstliche Photosynthese produzierten Brenn- und Wertstoffe können helfen, fossile Rohstoffe künftig zu ersetzen. Damit kann Künstliche Photosynthese einen wichtigen Beitrag zur Umsetzung der Energiewende leisten. Was dafür jetzt zu tun ist, beschreiben die deutschen Wissenschaftsakademien in ihren Empfehlungen an Politik, Wissenschaft, Wirtschaft und Gesellschaft.

Eine Anmeldung ist bis zum 3. Mai 2018 möglich.

Veranstaltungsort: Berlin-Brandenburgische Akademie der Wissenschaften Jägerstraße 22/23, 10117 Berlin acatech/Leopoldina/Akademienunion (Schriftenreihe zur wissenschaftsbasierten Politikberatung) 2017.

November 2017 Stellungnahme

> »Sektorkopplung« – Optionen für die nächste Phase der Energiewende

Recommended – inter alia because of honest cost estimates [60 billion EUR per year for 85% CO<sub>2</sub>-reduction in 2050]

Artificial Photosynthesis with sex and crime

Recommended, because it is fun to read



# This is the end ...

.. of my talk



Echnaton singing to the sun Alabaster, 1350 v. Christus



# This is the end ...

.. of my talk

### **Pariser Agreement** Signed in on December 12, 2015

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"In order to achieve the long-term temperature goal set out in Article 2, Parties aim to reach global peaking of greenhouse gas emissions as soon as possible, recognizing that peaking **will take longer for developing country parties**, and to undertake rapid reductions thereafter **in accordance with best available science**, so as to achieve a balance between anthropogenic emissions by sources and removals by sinks of greenhouse gases in the second half of this century, **on the basis of equity**, **and in the context of sustainable development and efforts to eradicate poverty**."

