Biomimetics in Energy Systems –
Addressing the global challenge of sustainable energy supply

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Abstract

A biomimetic approach is used to address the global challenge of satisfying the energy needs of the current and coming generations in a sustainable way. It is proposed to use large amounts of cheaply produced hydrogen, fix them to sustainable CO_2-carriers from biomass and thus produce artificial fuels and chemicals that can continue to power our current energy system, which is based on combustion technology. For the large-scale generation of cheap hydrogen, it is proposed to install an array of buoys in Antarctic seas to make use of wave energy with a high energy density. This hydrogen is to be transported to biomass-rich areas and then converted to artificial fuels and chemicals using the Fischer-Tropsch process. With this approach, a comparably soft transition towards a global sustainable energetic future could be reached.

Introduction

The problem

Mankind is confronted with one of the biggest challenges in their history. The worldwide energy consumption is predicted to rise from 15000 GW to 45000 GW by the end of this century, while our fossil resources, the basis of worldwide economy today, are nearing depletion. At the same time, CO_2-levels rise, changing the world climate, raising the sea level and increasing desert areas, thereby threatening millions of people with starvation and the loss of homes. Alternatives in regenerative energy show potential, but cannot fully replace our current method of energy production. Our means of storing electrical energy or transporting it over large distances are limited. Nuclear power plants promoted by some as a means of confining CO_2 emissions are extremely expensive in planning, constructing and maintaining, and pose a technology that can be highly dangerous and leave future generations with accumulating amounts of toxic waste.

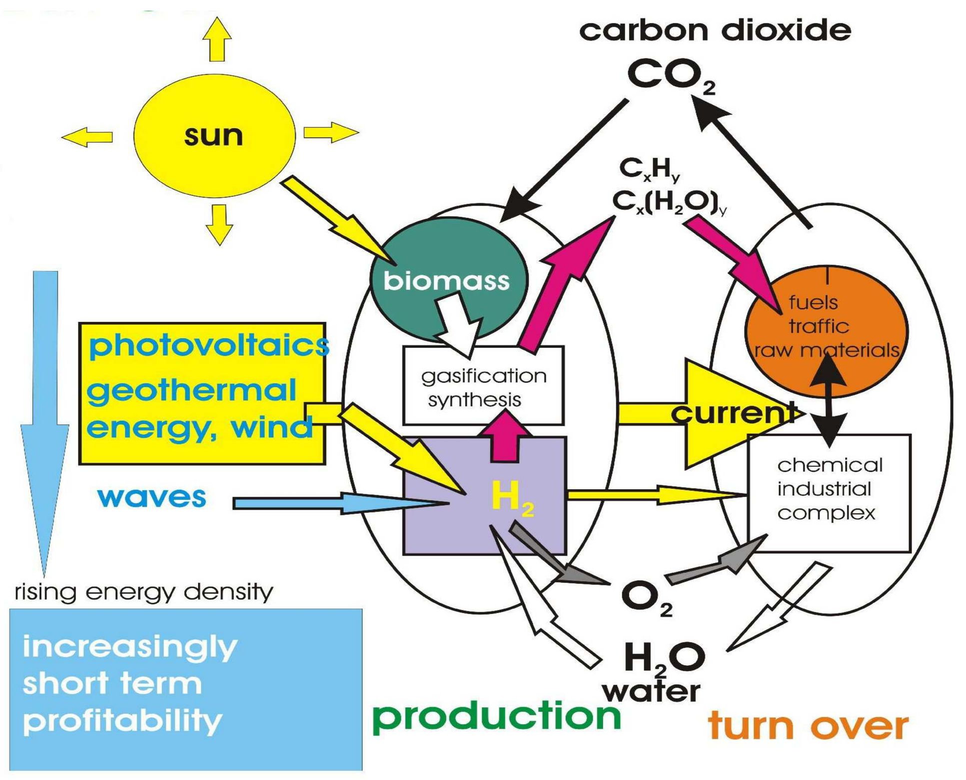

Figure 1: Bionic solar strategy: a sustainable energy-material cycle for the industrial society as continuation of biological evolution. (Tributsch, 2008)

Method

The inspiration

Nature on the other hand used evolution to develop a sustainable, fully regenerative cycle of energy turnover, driven by solar energy as the main power source. In this display, a biomimetical approach will be used to draw a sketch for a potential transition path towards a fully sustainable, solar-energy powered future.

Photosynthesis

Nature uses photosynthesis to split water into hydrogen and oxygen by means of sunlight. Hydrogen is then fixed onto carbon compounds, thus creating chemical energy storages that were during earth's history converted to the fossil energy carriers powering our current technology. The technology of water splitting with sunlight is not available to scientists yet; instead, we have to fall back on electrolysis for the generation of hydrogen.

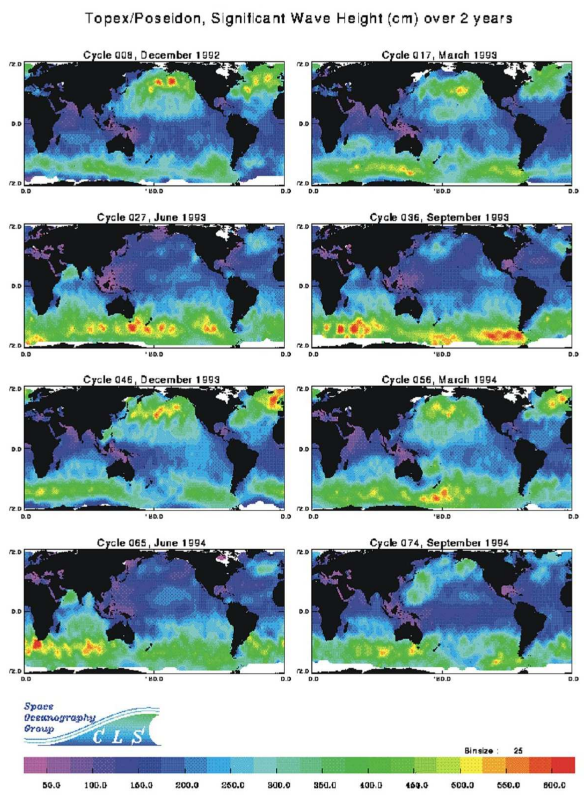

Figure 2: Global wave heights over the course of two years. Areas in green, yellow and red indicate wave heights of more than 4 m. (Tributsch 2008)

Cheap hydrogen

For the purpose of cheap generation of large amounts of hydrogen, it is advisable to make use of a medium with high energy density: water. Since wave energy rises with the square of wave height, the highest energy density would be reached in a surrounding with heavy storms and high waves. Such conditions can be found in the Antarctic seas. A further advantage is that these areas are less frequented by ship routes.

For the generation of electrical energy used for the electrolysis it is proposed to install a modular array of buoys. These buoys should be constructed in a way that only the buoyancy chamber floats on the surface while the rest of the construct stays below, thus protecting the structure from heavy weather impact. Given a capacity of 1 MW per buoy, it is calculated that an array surface of 100 times 1000 kilometres would be sufficient to generate enough hydrogen to satisfy the worldwide needs for energy.

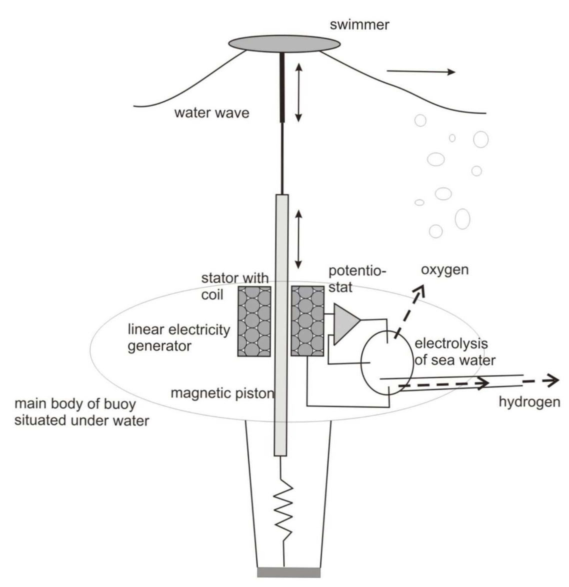

Figure 3: Schematic of a possible buoy design. To allow for a cheap modular installation and easy maintenance, the design should be kept as simple as possible. (Tributsch 2012)

The underwater structures in the fertile waters of the Antarctic seas could furthermore serve as artificial reefs and might be used as fish breeding grounds, taking pressure off the overfished marine ecosystems. The generated hydrogen could then be transported using pipelines, submarines or current tankers with slight modifications.

CO_2 fixation

The hydrogen should be transported to areas with high biomass production in tropical regions. Here, a fixation of hydrogen to CO_2 should take place using the Fischer-Tropsch-process, in which the biomass is gasified and then enriched with hydrogen at temperatures around 150 to 300 degrees Celsius. The resulting Biomass-to-Liquid fuels and chemicals could be used to replace current fossil fuels as well as the chemicals needed by today's industry, with just slight modifications needed to continue to pursue our current combustion technology. At the same time, the existing infrastructure for fuel distribution could stay in use. The product would be sustainable since the CO_2 in the biomass origins from the atmosphere.

Conclusion and Outlook

The proposed technology path has the potential of supplying future generations with sufficient amounts of sustainable energy. While the required technologies are already available and manageable, substantial investments would have to be made in a globally common effort to introduce this technology on a large scale. However, these are investments that will be necessary in any case to overcome the global challenges concerning energy supply that we are faced with today. Contrary to equally expensive investments in nuclear power, these investments would lead a path towards a fully sustainable, solar-driven energy future without vast amounts of toxic waste as by-products. The construction of large numbers of buoys would generate work for shipyards around the world. Additionally, a method of balancing natural fluctuations of CO_2-content in the atmosphere could be installed by storing large amounts of artificial fuel.
Special attention would have to be paid to avoid the competition between surface areas used for biomass and for nutrition. As research progresses, the fixation of hydrogen to biomass generated by the combination of solar radiation and bacterial chemosynthesis of black smoker Archaea becomes imaginable, which could take place in deserts or on other infertile grounds and is expected to reach a productivity ten times higher than photosynthesis.

Furthermore, scientists may learn to mimic nature's photosynthesis to a point where direct splitting of water by sunlight becomes possible.
Further research would have to focus on the process of energy catalysis and kinetic nano-solar cells. The expected results in these areas would lead to a further reduction of prices and ensure the worldwide availability of cheap, sustainable energy.

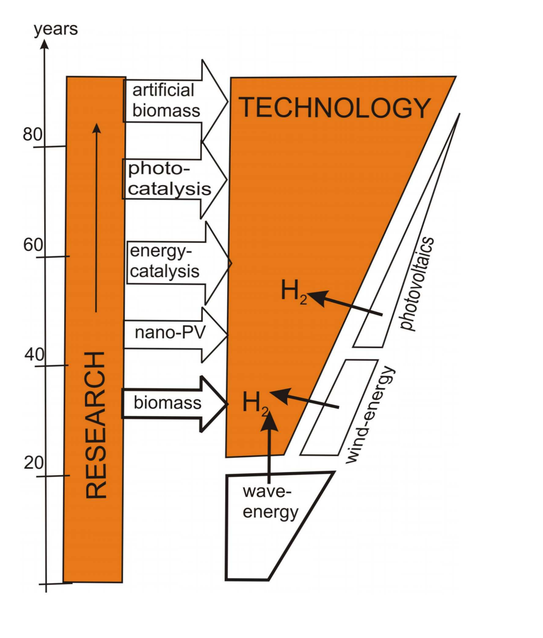

Figure 5: estimated timeline for research progress (Tributsch 2008)

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