NanoEnergy- Technological and economical impact of nanotechnology on the energy sector

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ABSTRACT

According to a prognosis of the International Energy Agency the worldwide energy demand will reach more than 18.000 MTOE (Million Tons of Oil Equivalent) in the year 2030 which corresponds to a 50 % increase from today´s energy consumption. In respect of narrowing fossil energy resources and potential side effects of climate warming carbon dioxide emissions it becomes obvious that for a sustained longterm economical prosperity a fundamental renewal of the energy sector will be necessary. As a key and cross-sectional technology, nanotechnology has the potential to facilitate vital technological breakthroughs in the energy sector and, in this way, to make substantial contributions to a sustainable energy supply. The spectrum of possible applications for nanotechnologies ranges from continuous short and medium-term improvements in the use of conventional and regenerative energy sources to entirely new approaches to energy supply and utilisation in the long term. Nanotechnological innovations have an impact on the whole added value chain in the energy sector. Increases in efficiency and process innovations are possible in all subsectors, from primary energy production to energy transformation, transmission and storage and its utilisation by the end customer.

Keywords: nanomaterials, energy efficiency, CO_2-reduction, renewable energy sources, market potentials

1 PRIMARY ENERGY UTILISATION

Nanotechnologies offer substantial advantages in the utilisation both of conventional energy sources (fossil and nuclear fuels) and of renewable forms of energy such as geothermics, sun, wind, water, tides or biomass. Thanks to more wear-resistant nano-coated drilling tools, for example, the service life and efficiency of plants for the recovery of mineral oil and natural gas deposits or of geothermal heat can be optimised and, in this way, costs can be saved. Other examples are high-performance nanomaterials for lighter and more stable rotor blades in wind and tidal power plants, and wear and corrosion resistant coatings for mechanically stressed components (bearings, gears etc.). Nanotechnologies will play an essential role, in particular, in the increased use of solar energy through photovoltaics. Efficiency increases can be achieved in conventional crystalline silicon solar cells, for example, by using anti-reflective coatings for better light exploitation. First to profit from nanotechnology, however, is the further development of alternative cell types such as thin-film solar cells (of silicon or other material systems like copper/indium/selenium, for example), pigment-based solar cells or polymer solar cells. Because of their inexpensive materials and manufacturing process and their flexibility, the latter have a high potential, particularly for the supply of mobile electronic devices. Medium-term development targets here are an efficiency of approx. 10 % and a service life of several years, whereby the nanotechnologies can contribute, for example, to the optimisation of the coating design and the nanomorphology of the organic semiconductors in the component structures. In Germany a €360 million research initiative funded by the German Research Ministry as well as companies like BASF, Bosch, Merck and Schott has been launched to develop organic photovoltaic devices. The world market of thin film solar cells is expected to grow from $800 million in 2007 to $2 billion in 2010.

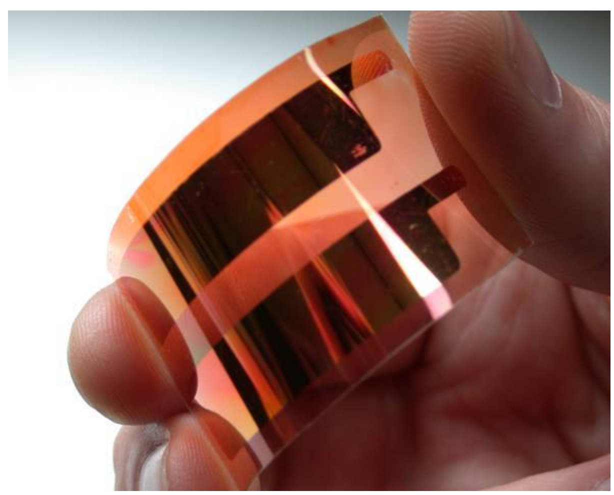

Fig. 1: Prototype of a flexible organic solar cell
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2 ENERGY TRANSFORMATION

Due to energy losses only a low percentage of primary energy sources is transformed into utilisable energy like electricity, heat and kinetic energy. Improvements in efficiency can be achieved, for example, by means of nano-scale protective heat and corrosion coatings for turbine blades of lightweight materials (e.g. titanium aluminides) for more efficient gas turbines in power plants or aircraft engines. The electrical power produced in the conversion of chemical energy by fuel cells can be increased by using nanostructured electrodes, catalysts and membranes, leading to economical applications in automobiles, in buildings or for the operation of mobile electronics in the future. The world market for fuel cells is expected to grow from around $1 billion in 2010 to over $20 billion in 2020. A promising future is also likely for thermo-electrical energy transformation. Using nanostructured semiconductors with optimised boundary surface design, gains in efficiency can be achieved which could open the way for their widespread application in the utilisation of waste heat, in automobiles for example, or even of human body heat for wearable electronics in textiles.

3 ENERGY STORAGE

The use of nanotechnologies for the improvement of electrical energy storage devices like batteries and supercapacitors is proving extremely successful. Because of a high cell voltage and the outstanding energy and output density, the lithium ion technology is regarded as one of the most promising variants for power storage. Nanotechnology can significantly increase the performance and safety of lithium ion accumulators. This applies in particular for the new ceramic, but still flexible, separators and high-performance electrode materials. In Germany an innovation alliance for the development of high performance Li-ion batteries for applications in hybrid and electrical vehicles and for stationary energy storage has been launched funded with €360 million from the German Research Ministry and industrial players. In the long term, hydrogen also appears to be a promising energy store for an environmentally friendly power supply. Apart from the necessary infrastructural adjustments, the efficient storage of hydrogen is seen as one of the critical factors for success in the progress towards a possible hydrogen economy. Present materials do not meet the requirements of the automobile industry, for example, with its demands for an H_2 storage capacity of up to ten per cent by weight. Here, various nanomaterials, some based on nanoporous organometallic compounds, offer development potentials which appear to be economically realisable, at least for the operation of fuel cells in mobile electronic devices.

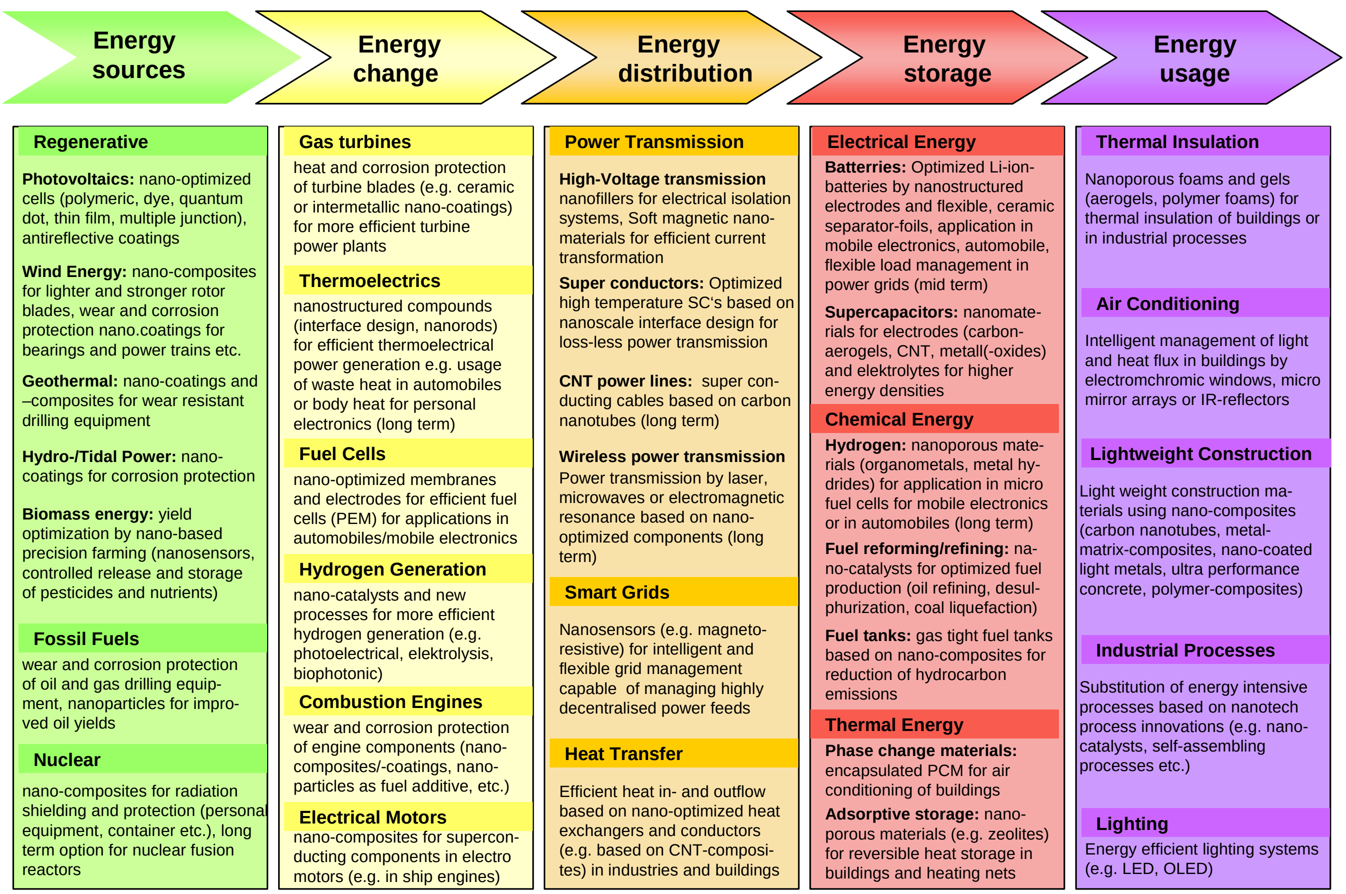

Fig 2: Overview on potential nanotechnology applications in the energy sector along the whole supply chain. (© VDI TZ)

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With a view to reducing the energy losses in power transmission, it is hoped that the unusually high electrical conductivity of nanomaterials like carbon nanotubes can be used for power cables. There are also nanotechnological approaches to the optimisation of superconducting materials for loss-free transmission. In the long term, options also exist for power transport without cables, using lasers, microwaves or electromagnetic resonance, for example. For power distribution in the future, power networks will be needed which offer dynamic load and fault management, a demand led power supply with flexible price mechanisms and the possibility of power input from a large number of decentralised, renewable power sources. Nanotechnologies could make significant contributions to the realisation of this vision, for example through nano-sensoric and power electronics components capable of handling the extremely complex control and monitoring of such power networks.

Fig. 3: Nanoporous polymer foams for thermal insulation of buildings have a big potential for energy savings. (© BASF)

5 ENERGY SAVING

With the aim of a sustainable energy supply, in parallel with the opening of new energy sources, the efficiency of energy utilisation must naturally also be improved and unnecessary energy consumption avoided. This affects all branches of industry and also private households. Nanotechnologies offer a large number of approaches to energy saving. Examples are the reduction of fuel consumption in automobiles through the use of light construction methods based on nanocomposites, optimisation of fuel combustion by means of lighter, more wear-resistant engine components and nanoparticular fuel additives or even nanoparticles for optimised tyres with lower rolling resistance. There are also great energy saving potentials in building technology, for example, through the use of nanoporous thermal insulation, which could be applied with advantage particularly in the energy saving remediation of old buildings. In general, the control of the flow of light and heat through nanotechnological components such as switchable glass, for example, is a promising field for reducing the energy requirement in buildings.

6 CONCLUSIONS

Nanotechnology has the potential to be a key technology on the path to a sustainable CO_2-neutral power supply in the future. Their potential applications are extremely varied. For numerous firms in Germany, a location with pronounced strengths in the nanotechnologies and regenerative energy technologies, attractive market opportunities will open up. However, the success of nano-based innovations will strongly depend on public funding programmes, subsidies for regenerative energies and other framework conditions like regulation, the development of energy and raw material costs as well as evolving social demands resulting from consequences of the climate change. Germany has initiated several research initiatives to press ahead with nanotechnological developments in the energy sector to address the ambitious climate protection goals adopted by the European Commission. In addition to increased support for research and innovation, their realisation also demands coordinated action by all those involved in the added value chain. As an important step to utilise the potential of nanotechnologies in the energy sector it is necessary to establish a dialogue between all the actors with a role to play, transcending sectors and specialist scenes. To further this intersectoral dialogue the Hessian Ministry of Economics, Transport, Urban and Regional Development has launched several initiatives like the NanoEnergy conference which will take place the second time in September 2008 as well as an information brochure pointing out the innovation potentials in detail.

REFERENCES

[1] Luther, W.: Nanotechnology applications in the energy sector", Hessen Agentur, 2008 in press
[2] Cientifica: „Nanotechnologies and Energy“, white-paper, Cientifica, London, 2/2007
[3] Nanoforum: "Nanotechnology helps solve the world's energy problems" April 2004, www.nanoforum.org

Internetlinks:
www.bmbf.de/de/nanotechnologie.php
www.hessen-nanotech.de
www.zukuenftigetechnologien.de/ENG/index.php