Small-scale technologies for energy innovations: role and implication directions

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1. Introduction

Energy innovations[2] with sustainable fundaments are needed to fulfill energy demands for the coming decades. This leads to a seeking process for new knowledge and technologies in order to create incremental and breakthrough energy innovations. The question is what the role is of small-scale technologies (nanotechnologies) for these innovations? This paper examines in a brief and non-exhaustive manor the role and implication directions of small-scale technologies for energy innovations. First, the paper describes the necessity for energy innovations and small-scale technologies. Next, based on examples role and implication directions are discussed. The conclusion focuses on the outline presented.

2. Energy innovations and small-scale technologies

Several authors describe the essence of substantial transformations in a variety of areas like artifact production, energy usage, and recycling to facilitate wealth development on the basis of energy and material efficiency and to prevent future crisis in energy supply and irreversible environmental damage (e.g. Hawken et al., 1999, Rifkin, 2002; WBCSD, 2004). These transformations can be initiated via awareness and behavior change on energy consumption, regulations to limit the emission of greenhouse gases, or the introduction of new technologies to boost the generation of sustainable energy. This paper focuses on the technology approach.

Small-scale technologies represent a domain in the field of physics, chemistry and engineering that offers specific functionalities due the miniature scale of involved matter or

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[2] Rogers (1995: 11) defines innovation as 'an idea, practice, or object that is perceived as new by an individual or other unit of adoption'.

processes. Nanotechnology is seen as the small-scale technology cluster for the coming decades and is by Roco (1999: 1) defined as ‘development and utilization of structures and devices with organizational features at the intermediate scale between individual molecules and about 100 nanometers[3] where novel properties occur as compared to bulk materials’. These nanoscale structures and devices may have unique chemical, mechanical, electrical, magnetic, optical or biological properties, based on for example higher surface to volume ratio (usage: enhanced reactivity for catalysis or batteries), higher resistivity with decreasing grain size (usage: electronics), or increased hardness with degreasing grain size (usage: hard coatings and thin protection layers) (Köhler et al., 2003). For an overview of nanotechnology-based applications see European Commission (2004). A substantial part of these technologies are still in a phase of fundamental and applied research and it is hard to oversee the impact of these technologies.

Small-scale technologies offer new functionalities or properties for energy innovations for the coming years or decades (e.g. Arnall, 2003; Royal Society, 2004; Wood et al., 2004). Carbon nanotubes have the ability to make parts of cars or aircrafts lighter, influencing the fuel consumption per kilometer per kilo positively. Developments in catalytic nanoparticles improved the catalytic performance of fuel cells or batteries. Nanoscale-devices in semiconductor components can reduce the power consumption per bit processing or bit storage. Polymers are becoming a research fundament for new types of solar cells. Increased charge and discharge currents of batteries will be introduced via nanoparticles of specific materials. Research takes place in what way carbon nanotubes could store methane or hydrogen for fuel cells of mobile phones or laptops. Life cycle assessments is recommended to give complete insight concerning resources usage to develop, to produce, to use, and to dismantle the mentioned high-tech innovations (Royal Society, 2004).

3. Role and implication directions seen from a multidisciplinairy perspective

Technological development processes do interact with a variety of stakeholders or elements in a variety of segments. Related theoretical discussions can be found in Dosi (1982), Parayil (1993) or Callon et al. (1992). A multidisciplinary perspective on technological developments gives insight in the dynamics related to and role and implication directions of these technologies. In order to stimulate awareness on the role and implication directions of small-scale technologies on certain (future) energy innovations, this paragraph discusses some examples from a specific perspective. First, via the case of polymer-based solar cells the creation of a new scientific and technology regime is shown. Next, the geopolitical dimension is shown via a nanocatalysis case in the coal industry. Third, the impact of intellectual properties is related to the fuel cell industry. In the last example, the implications of the public opinion on ethical, legal and societal aspects of nanotechnologies are introduced.

[3] Hundred nanometers is 1/10.000 millimeter.

Scientific and technology regimes and polymer-based solar cells

Scientific research is a process of exploration (looking for and investigating new and unknown phenomena) and exploitation (producing scientific knowledge and - if possible - creating fundaments for new technologies). Specialization in research areas leads to development of scientific and technology regimes with a certain degree of intellectual and economic lock-in. But in some cases, fundamental scientific or technological breakthroughs are based on the creation of unknown relations, not necessarily within the actual regime. With respect to energy innovations, a strong basis for the current research in the field of organic photovoltaic systems (polymer solar cells) was created by the discovery of light-emitting polymers to create next generation flat panel displays - a huge market for players like Philips, Samsung and Cambridge Display Technologies. Due to the fact that researchers did see the opportunities to use the scientific fundaments of polymers for solar cells, a new scientific and technology regime was created in the domain of photovoltaic systems (e.g. Nunzi, 2002; Spanggaard & Krebs, 2004). These systems will reach an energy conversion efficiency of 10% in the long run, together with interesting parameters like relatively low production costs and high mechanic flexibility (e.g. Brabec et al., 2001). This example shows the implication direction of new scientific and technology regimes: on the basis of creativity, knowledge from other regimes, and (scientific) entrepreneurship, new energy solutions based on small-scale technology-based materials are developed.

Geopolitical aspects of nanocatalysis for the Chinese coal industry

New technologies can facilitate leapfrog movements of organizations and countries. Knowledge generated and build-up for years can be bought and embedded in local innovation systems without hurdles related to pioneering technology development processes. In the energy sector, countries like China are able to use modern technologies to upgrade and expand their energy infrastructure. In 2002, the Chinese coal company Shenhua Group together with a subsidiary of the US company Headwaters Inc. started a project to build a nanocatalysis-based coal liquefaction plant to produce relatively clean diesel fuel / oil at an economically rate. For the coming years more plants are planned in China. Nanocatalysis creates possibilities for China to reduce dependence of oil imports and to produce coal-based fuel for its rapid growing transport sector (Nolan et al, 2004). The example shows that from geopolitical point of view coal liquefaction based on latest developments in nanocatalysis puts less economical and political pressure on oil-rich countries and places China - as a coal-rich country - in a new energy position.

Intellectual properties based on high-throughput synthesis and analysis

High-throughput screening is an efficient method to discover new material properties or reaction parameters by the usage of a constellation of parallel (precision) reactors, including advanced material characterization possibilities and computing power, to test automatically a wide range of reactions based on slightly different materials (e.g. Murphy et al., 2003). Companies like Intematix, Nuvant, Symyx or Avantium use this high-throughput concept to synthesize and analyze breakthrough properties of for instance catalytic materials. Related to the energy sector, this kind of high-throughput screening offers substantial possibilities to find new, highly functional catalytic materials (efficient, durable, cheaper) for fuel cells, leading to new - economically interesting - intellectual properties (IP) (see also Veen et al., 2003). These mentioned companies - and their customers - have the technological and IP / legal means to influence the economic power balance in existing and developing fuel cell industries, due to their opportunity for speeding-up technological development processes and their potential to possess key patent positions for next generation fuel cell catalysis materials and catalysis constructions.

Public opinion (ethical, legal and societal) on nanotechnologies

The ethical, legal and societal aspects (ELSA) of new technologies needs to be analyzed and discussed, in order to seek and to define boundaries for technology diffusion and adoption. In the field of nanotechnology research projects, debates and surveys are initiated (e.g. Arnall, 2003; Bainbridge, 2003; ETC Group, 2004; Roco, 2003; Royal Society, 2004). Important topics are health, environmental and safety impacts of nanoparticles, fibres and carbon nanotubes. Academic research is necessary to map these impacts. Developments on energy innovations based on nanotechnologies do have a chance to be influenced by the attitude of the general public. The future path of nanotechnology-based energy innovations will be linked to open communication to stakeholders and boundaries given by concepts like responsible innovation.

The four examples show that small-scale technologies have a role for specific energy innovations and that implication directions can be found in specific domains; in these examples respectively scientifically and technological, geopolitical, intellectual property, and public opinion domains.

4. Conclusion

Energy innovations are fundamental for future societies and small-scale technologies have a role in the development and implementation of a variety of energy innovations. The given examples show that role and implication directions need to be seen from a multidisciplinary perspective: e.g. scientifically and technological, market, geopolitical, intellectual property, legal, and public opinion. It is recommended to create awareness on the multiple roles and implication directions of small-scale technologies for energy innovations. Instruments like scenarios and roadmaps (e.g. Millet, 1988, Knol, 2004, Walsh, 2004) trigger the mental models of involved actors and stimulate a broader sense of awareness. Let an multidisciplinary approach and involved actors with critical and creative mental models create the pathways to intelligent, clean and secure energy innovations.

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