Science System Assessment

Nanotechnology & TA in Japan

Nanotechnology in Japan and the possible contribution of technology assessment in handling its societal implications

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Preface

Nanotechnology is a prime example of a scientific and technological area which is developing as well being discussed in international networks. This report contributes to this process by mapping state of the art nanotechnology developments in Japan and analyzing how Technology Assessment (TA) can contribute to addressing the societal challenges which might come along. The research for this report has been conducted as a joint project (supervising a traineeship) of the Rathenau Instituut and the Netherlands Office of Science and Technology (NOST) at the Dutch embassy in Tokyo.

Japan as well as The Netherlands have invested substantially in nanotechnology and actively seek collaborations via the NanoNed Japan Office. Moreover, opportunities for institutionalizing TA in Japan have been studied in the context of nanotechnology. In The Netherlands TA activities on nanotechnology have been organized as part of the Dutch research consortium NanoNed, by the Dutch government and by the Rathenau Instituut itself. In close contact to the TA community in Japan it was therefore decided to focus at the question what TA could contribute to nanotechnology developments and their societal embedding in Japan.

The research however was not about just extrapolating Dutch experiences. TA as well as nanotechnology are dynamic fields, institutionalized in different political, cultural and local contexts. Hence the project took off with mapping nanotechnology developments and the discussion on TA in Japan and analyzing these with regard to three very basic functions of TA: information, participation and intervention. The findings presented in this report indicate several opportunities of TA contributing to the development of nanotechnology in Japan, which are relevant to the different modalities in which TA is going to be institutionalized in Japan.

The findings could have been elaborated further, if not the project had been disturbed by the earthquake and subsequent tsunami which stroke Japan halfway the project. As for the tragedy to our Japanese colleagues and the increasing risk of a nuclear incident at the Fukushima power plant, Violet Steeghs had to finish the project back in The Netherlands. As the impact of the earthquake put things in perspective, we wish Japan to recover strongly. Hopefully this report may contribute somewhere in that process.

Frans Brom, Head of the Technology Assessment department
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Abbreviations

AIST	Advanced Industrial Science and Technology
CMOS	Complementary Metal Oxide Semiconductor
CNBI	Centre of Nano Bio Integration
CRDS	Centre for Research and Development Strategy
DDS	Drug Delivery System
EUVL	Extreme Ultra Violet Lithography
FET	Field Effect Transistor
I2TA	Innovation and Institutionalization of Technology Assessment
JAEA	Japan Atomic Energy Agency
JSRM	Japan Society of Regenerative Medicine
LSI	Large Scale Integration
MHLW	Ministry of Health, Labor and Welfare
METI	Ministry of Economy, Trade and Industry
MEXT	Ministry of Education, Culture, Sports, Science and Technology
NEDO	New Energy and Industrial Technology Development Organization
NEMS	Nano Electro Mechanical Systems
NIES	National Institute Environmental Sciences
NIMS	National Institute for Materials Science
NML	Nano-Materials Laboratory
NOST	Netherlands Office of Science and Technology
OTA	Office of Technology Assessment
QoL	Quality of Life
RISTEX	Research Institute of Science and Technology for Society
RM	Regenerative Medicine
S&T	Science and Technology
STA	Planning Bureau of the Science and Technology Agency
STBP	Science and Technology Basic Plan
TA	Technology Assessment
TASC	Technology research Association for Single wall Carbon nano-tubes
TIA	Tsukuba Innovation Area

Summary

The project, described in this report, has been conducted by the Dutch Rathenau Instituut in collaboration with The Netherlands Office of Science and Technology, NOST, of The Netherlands Embassy in Tokyo, Japan. The aim of this project is to investigate the possible contribution TA could play in handling the recent (potential) societal implications accompanying nano S&T in Japan. These societal implications have been identified through studying the current state of the art, the opportunities and challenges of the Japanese nano-electronics, nano-materials and nano-life sciences areas. Difficulties in translating and adopting technologies and the shift from field- to issue-driven innovation have been found to challenge innovation in these areas. In addition, problems in ensuring the safety of nano-materials for the environment and public health create uncertainties for nano-technological developments. The recent nano-life sciences advancements are thought to have various potential implications for the health care sector. Furthermore, it has been acknowledged that privacy issues arise with the recent developments in nano-electronics. Japan has been conducting various activities, like the establishment of open innovation areas and the identification of risk issues in nano-food materials, to solve these implications. These activities are mainly focused on solving the more economically related issues for further stimulating innovation. Although risk issues are recognized, governance of these issues is recently absent due to a waiting attitude of stakeholders. Attention for other societal implications is recently limited.

The informing, interacting and mobilizing functions of TA, put forward in this study, could be helpful in further exploring and tackling of the identified societal implications. The usefulness of the informing function of TA in bringing relevant industrial and academic actors together, which is necessary for further improving the translation of research into applications, has been recognized. This function could, furthermore, be valuable for mapping expected societal outcomes of nano-medical innovations for the health care sector. The second function of TA, interaction, could be relevant for sharing views on the possible scenario´s and wishful outcomes of the recent nano-life sciences developments for the health care sector. Stimulating interaction among stakeholders could also be valuable for generating general visions on toxicity and the formulation of governing options. The last role of TA is communication. This role is found to be helpful for putting possibilities for the governance of the risks of nano-materials, on the agenda. This is necessary for breaking through the recent waiting attitude of stakeholders. The mobilizing role could also be relevant for increasing social and political attention for privacy issues by media, conferences or hearings.

In March 2011 the I2TA project, established as an incentive for the further innovation and possible institutionalization of TA in Japan, was finished. With the ending of this program the moment arises to discuss new starting points for TA and its institutionalization. The information, interaction and communication functions of TA, reviewed in this report, could be valuable input for this discussion.

Content

1 Introduction

1.1 Nano-technological developments

Nanotechnology has been seen as one of the key innovative technologies of the 21st century, delivering breakthroughs in a range of areas. By structuring materials on a nano-scale, between 1 and 100 nm, the strength, reactivity and electrical characteristics from existing macro-materials can be changed (Siegrist et al., 2008). Besides the construction of new materials, the integration of many scientific and technical disciplines, like biotechnology, information technology and cognitive science, has become reality on a nano-level. Although various scientific barriers still have to be overcome, these possibilities of nanotechnology promise to produce commercial gains in industry and delivering benefits for consumers (Besley et al., 2008). Due to these opportunities, nanotechnology has been highly prioritized on the global scientific agenda (Bowman & Fitzharris, 2007).

Japan is one of the countries that have been greatly investing in these nano-sciences. Last years total investment of Japan in this field has decreased and is currently below that of Europe and The United States. However, according the Japanese ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan's scientific strength on the nano-level exceeds those of Europe and the United States in many areas (Kishi, 2011). Despite great competition in the nano-materials and – electronics fields, Japan has a leading position in various research areas in these fields. Also Japan's specialization in developing nano bio-devices, based on the integration of the semiconductor technology and life-sciences on a nano-scale, has been apparent (CMSI, 2009). Because of its major role in the field, the nano scientific and technological (S&T) developments in Japan are of significant interest. This report specifically focuses on the current Japanese nano-technological developments.

Concerning the prospects of nanotechnology, global attention has been mainly focused on the probable economic benefits. There is, nevertheless, another more sceptical view on the potential of nanotechnology in the context of ethical and social domains (Patra et al., 2009). With the current transition of fundamental research into practical development, this view is becoming more important (Kishi, 2011). Nanotechnology is expected to have impact on various disciplines, like health care and energy supply by transforming respectively the medical system and power infrastructures. These outcomes can evoke significant social disruption. The indissoluble connection between nanotechnology research and its applications on the one hand and societal implications on the other hand, emphasizes the importance of recognizing and adapting to the expected impacts of nano-research (Roco, 2003).

1.2 Technology Assessment

Attention for technological change and its implications, is required for making full use of a technologies potential (I2TA, 2011). Technology Assessment (TA) aims to anticipate on the expected implications of new technologies and to improve interaction between technology and society. TA became institutionalized in the United States in 1972 and some countries in Europe during the 80's. Subsequent introduction in Asia, influenced by the Office of Technology Assessment (OTA) of the United States, led to TA activities in Japan. These studies, conducted by the Planning Bureau of the Science and Technology Agency (STA) and the Ministry of Economics, Trade and Industry (METI) were interesting as an analysis, but feedback to the decision making or the agenda setting was often lacking (Shiroyama, 2010). A lobby for parliamentary TA aimed at informing politics failed and resulted in the withdrawal of the TA studies within STA (Shiroyama, 2010). Even though the parliamentary interests in the implications of technologies continued, the idea of parliamentary TA has never been materialized (Shiroyama, 2010).

Since 2000 attempts have been made, influenced by European experience, to conduct participatory TA as an input for policymaking. Several participatory workshops, coordinated by the National Institute for Materials Science, NIMS, and the national institute of Advanced Industrial Science and Technology, AIST, were undertaken. The results, although relevant, were not taken up by the government (Matsuo, 2010).

The past ad hoc TA-activities performed in Japan, mainly conducted by STA and The Ministry of International Trade and Industry (MITI) were thought not to take social responsibility in the long term. Therefore, the project ´Innovation and Institutionalization of Technology Assessment´ (I2TA) was established to further stimulate the innovation and institutionalization of TA in Japan. This 3.5-year project, founded in 2007 by the Research Institute of Science and Technology for Society, RISTEX, specifically aimed to develop an innovative TA methodology, implement TA practices and give recommendations for new TA methodologies and institutionalization of TA in Japan (Matsuo, 2010). With the ending of the I2TA project in March 2011, the moment arises to look and evaluate new starting points of TA and its´ possible institutionalization.

1.3 Three possible functions of TA

Concerning the role TA can play in Japan in the future, three functions of TA can be brought forward. These functions originate from the following definition of TA: “Technology assessment is a scientific, interactive and communicative process which aims to contribute to the formation of public and political opinion on societal aspects of science and technology” (Butschi et al., 2004: 14). Based on this definition, TA could have an informing, interacting and mobilizing function in technological developments and their accompanying innovation and societal issues (van Est, 2011).

Informing function

Through the scientific activities of the informing function of TA, technical and social maps can be created. Technical maps inform about the recent technical developments and the possible issues that accompany these developments. The social maps give insight in which stakeholders are relevant for the specific issues and their possible responsibilities and tasks.

Interacting function

The second, interacting, function of TA aims to bring actors together. A continuous informing process can lead to a network of related stakeholders. Within this network, interaction between these different stakeholders can be stimulated. Relevant actors can integrate their knowledge by sharing views and jointly articulate certain societal implications of technologies or general visions.

Mobilizing function

TA can play a role, through its third mobilizing function, in influencing the recent technological and innovation processes by external communications. Networking activities of TA can initiate the agenda setting of identified issues in general by the media or put these issues on the political arena via by for instance pressure from expert meetings and conferences. The communication of identified governance options can potentially influence recent policies.

These three functions of TA are, to a certain extent, mutual related. Mapping the relevant stakeholders involved within a certain technological issue is, for instance, necessary for stimulating interaction among them. Another example is the necessity of mapping the mutual responsibilities and tasks for establishing good governance options. That agenda setting not only arises from activities of the mobilizing function, underlines this mutual relatedness as well. Activities of the informing and interactive functions already result, by looking at the implications of technologies, in this agenda setting.

1.4 Focus of the project

To add to the recent discussion on the future of TA in Japan the project described in this report aims to investigate the possible role TA can play in Japan in handling recent societal issues. Specifically, the relevance of the informing, interacting and mobilizing function of TA are assessed. The societal issues are identified by studying the current Japanese nano-technological progress in nano-materials, nano-life sciences and nano-electronics. These areas are of significant interest in both Japan as The Netherlands. Based on this goal, the study focuses on the following question:

What are the latest Japanese nano-technological developments and how could the informing, interacting and mobilizing functions of TA contribute to the handling of its societal implications?

In order to answer this question, the following sub-questions are studied:

- Chapter 2: What is the current state of the art and its' accompanying opportunities and challenges of the nano-materials, nano-life sciences and nano-electronics fields in Japan?
- Chapter 3: What possible societal implications arise from the recent developments in the nano-materials, -life-sciences and -electronics fields in Japan?
- Chapter 4: What past activities have been conducted in Japan to handle the identified issues and what are the recommendations and wishes of the I2TA project, based on these past activities, for the future of TA?

1.5 Set-up report

This report gives an overview of the main findings of the study. The second chapter describes the current and emerging trends, the opportunities and challenges of the R&D in the nano-electronics, -materials and -life sciences fields in Japan. These nano-technological developments take place in a certain economic and societal context, resulting in certain societal implications. The (possible) societal implications arising from the Japanese nano R&D in Japan are addressed in chapter 3. Subsequently, the past activities in Japan concerning the handling of recent innovation and societal issues are presented in chapter 4. This chapter also elaborates on the recommendations and wishes of the I2TA project for the future of TA in Japan, based on these past activities. The last, fifth, chapter of this report answers the main question of this research by discussing the possible contribution of the informing, interacting and mobilizing function of TA in handling the identified innovation challenges and societal implications. Moreover, this chapter indicates the relatedness of the past activities in Japan with regard to these three functions of TA.

About the project

The progress of TA in Japan is of interest for the Dutch Rathenau Instituut which assesses, amongst others, the societal implications of scientific developments by conducting various TA activities. With regard to these activities the Rathenau Instituut has put considerate attention to the developments and expected outcomes of nanotechnology, stimulating dialogue about nanotechnology in The Netherlands. In collaboration with the Netherlands Office of Science and Technology, NOST, of the Netherlands Embassy in Tokyo, The Rathenau Instituut repeatedly maps technological developments in Japan. Because of their common interest in the developments in nanotechnology, this project was set up to study the Japanese nano-technological developments and its accompanying innovative challenges and societal issues. Knowledge on the state of the art of Japanese nano S&T could be of interest for expanding and intensifying current collaborations between Japanese and Dutch nano-research institutes and companies, like the Dutch NanoNed Japan Office (NanoNed, 2010).

Information for this project was gathered through an iterative process. Via a qualitative survey, consisting of semi-structured interviews and desk research and meetings, conferences and company visits, information was obtained. An overview of these activities and gatherings can be found in appendix 1. In a working session, held on the 11th of March 2011, knowledge and experiences, with regard to nanotechnology and TA in Japan, were exchanged between scientists working in the field of nanotechnology and TA and governmental officials from Japan and The Netherlands. More information about this workshop, organized by the Rathenau Instituut in collaboration with NOST of the Netherlands Embassy of Tokyo, I2TA and Tokyo University, is shown in appendix 2.

2 Nanotechnology R&D in Japan

Due to years of great investment, Japan has gained a significant position in the nano-field. This chapter investigates the current state of the art in Japan. The support of nanotechnology by the Japanese government started in 2001 by mentioning the nano-field in the 2nd Science and Technology Basic Plan, STBP. In this plan nanotechnology and nano-materials were prioritized as one of eight national issues of interest (Bureau of Science and Technology Policy, 2001). At that time, the Japanese government expected that investing in this technology would lead to breakthroughs in all S&T fields, helping Japan to maintain its technological edge. Total governmental funding of this field grew in these years from 85 billion JPY in 2001 to 97 billion in 2005 (Bureau of Science and Technology Policy, 2001). In its subsequent STBP, operative from 2006 to 2010, Japan established nanotechnology as one of its four priority research fields (Bureau of Science and Technology Policy, 2006). Major investments were mainly targeted at clean energy and electronics (Bureau of Science and Technology Policy, 2006). Other main nanotechnology research topics, described in this plan, were the development of advanced nano-materials that can substitute rare or deficit materials and nano-materials and technologies which support healthy lives. The governments´ interest was mainly focused on the research areas of nano-electronics, nano-materials, and nano life-sciences (Nanotechnology Researchers Network Center of Japan, 2006). Besides a governmental investment, a huge private sector investment made Japan an attractive place for nanotechnology commercialization. In 2009, Japan's businesses like Showa Denko and Mitsui spent 37% more on R&D than their United States counterparts (Hwang, 2010). In the years, Japan gained, with a total nano-research spending of 99.7 billion JPY in 2009, a superhero status within the nanotechnology field (Kawashima, 2010).

Governmental support for nanotechnology will change coming financial year. In April 2011, the Cabinet Office of the Japanese Government will introduce its 4th STBP. The total national budget of science and technology in Japan will be cut and, as a result, be lower than that of the United States and Europe. Nevertheless, the investment per capita will still be higher. Even though the total budget will decrease, the investment on developing advanced technology will increase (JST, 2011). In this 4th STBP, the Cabinet Office indicates it wants to shift from field to issue-driven research. In order to solve national and international issues, this STBP focuses on the development of green and life innovations. Nanotechnology is not mentioned as an independent field in this plan, but as a way to strive for these green and life sciences innovations. The potential meaning of this focus for the future nano-technological developments in Japan will be discussed in the following chapter.

The biggest nanotechnology markets for Japan are nano-electronics, followed by nano-materials and nano-life sciences (Saito, 2011). Japan's current research and development level in the nano-electronics and the nano-materials field is seen, in general, as above that of the United States (Komatsu and Ogasawara, 2005). These three fields create various possibilities for green and life sciences innovations. With regard to this project, it is also of interest that The Netherlands is very active in these research areas. This study therefore focuses on these three main nano-research areas. In this chapter, an overview of the state of the art and the accompanying opportunities and challenges of these three areas in Japan will be given. The societal implications concerning the developments of these nano-fields will be described in the subsequent chapter.

2.1 Nano-electronics

Electronics is a significant field within the Japanese nanotechnology market. For example in the Tsukuba Innovation area (TIA) academic and governmental research institutes and industry collaborate extensively in the nano-electronics area (TIA, 2011). An important research focus of this area, which is one of the first innovation projects in Japan, is the advanced semiconductor industry. Semiconductors, devices of semiconductor materials designed to transmit electricity, form the basis of various electronic devices and applications. This paragraph discusses the state of the art, opportunities and challenges of the semiconductor R&D in Japan.

2.1.1 Semiconductors

In the 1980's Japan was honoured with a number one position in the semiconductor industry. Over time, Japan lost its position to Korea and Taiwan due to increasing production costs and limiting possibilities for up-scaling. A lot of Japanese companies in the semiconductor industry disappeared or merged. Some other small companies specialized in a certain area within the semiconductor field, like Okidenki. This company focuses on the manufacturing of Large Scale Integration (LSI) systems, referring to the placement of thousands of electronic components on a single integration circuit (Okidenki, 2011). It is recognized that Japan needs this specialized knowledge in order to keep up in this globalized field of industry. Nevertheless, almost one-fifth of the international semiconductor industry is still dominated by Japan (Tech-On, 2011).

State-of-the-art in Japan

Last decades the development of semiconductors has in line with the law of Moore, been focused on size reduction and increasing the number of transistors per chip. As the size reduction of semiconductors has almost reached the minimum, the use of new materials, instead of silica and aluminium, is currently investigated. Japanese research institutes and academic parties shifted their research from the use of silica to, for instance, graphene in semiconductors (Watanabe, 2008). The Centre for Research and Development Strategy, CRDS, shows great interest in applying graphene in semiconductor materials and will therefore send a proposal, for further investigating the application of this material for nano-electronic devices, to TIA (CRDS, 2010). In addition, the use of carbon nano-tubes in the semiconductor industry is increasingly studied by Japanese industry consortium TASC (Technology Research Association for single wall Carbon nano-tubes). Particular emphasis is placed on the application of carbon nano-tubes as on-chip wiring and active devices, the two main building blocks of current semiconductor circuits (TASC, 2011). Also the application of organic substances or organic materials in semiconductor devices, have begun to draw attention (Takashi et al., 2005). Research on organic semiconductors has rapidly become active. RIKEN and other institutions, like Sony, are recently developing organic semiconductors with a high capacity for flexible and printable electronics (ThinFilm Electronics, 2011).

These new materials can add new functionalities and can increase the current depth/length ratio, creating more space in the 3D dimension (Kawamura, 2008). As a result, 3D semiconductor-applications can be created. In these 3D constructions different materials and applications, like Nano Electro Mechanical Systems (NEMS) and Complementary Metal–Oxide Semiconductor (CMOS) can be integrated. Selete, a Japanese corporation working on semiconductor leading edge technologies, investigates the on-chip integration with LSI and nano-photonics and the fusion of biological information with photonics and Micro Electro Mechanic System, MEMS (Kawamura, 2008).

Opportunities

Current research in the semiconductor field has been focused in Japan on, amongst others, the use of alternate materials besides silica. Through these new materials, it has become possible to fabricate smaller and improved semiconductor applications. The application of graphene, for example, could be promising for creating high speed applications (Watanabe, 2008). The newly-discovered carbon nanostructures are also expected to increase the speed of applications by electrical conduction in all directions (Fujitsu Laboratories Ltd., 2008). The use of these carbon composite materials can make the development of ultra-light, super-strength and high performance materials for semiconductors possible (TASC, 2011). Through the alternative materials, such as graphene and carbon, it will also become easier to create more space in the 3D dimension. By three-dimensionally chips, development costs can be lowered (Tech-On, 2011). The costs of current semiconductors can also be decreased by the use of easily available organic materials. Organic semiconductors hold a great promise for future applications as they, compared to inorganic semiconductors, can be easily tailored to the applications (Yu and Cardona, 2010). Organic materials have furthermore the potential of further increasing miniaturization, resulting in lighter and even smaller semiconductor production (TASC, 2011). This recent developments in the semiconductor industry will drive the world further into a digital society, as it is the driving source of digitalization (Tech-On, 2011). The possible construction of new devices through alternative materials and 3D applications will address new markets.

Challenges
The use of carbon materials has found to be beneficial in semiconductor applications. Commercialization of new semiconductor applications, based on these carbon structures, is however hampered by technical difficulties in mass producing these materials. Also the construction of organic semiconductors is still in a starting phase. At present, organic semiconductors are not yet used in any electronic devices (Yu and Cardona, 2010). Also the construction of 3D semiconductors is recently still challenging (Takagi, 2011). In the future the fusion between for instance solar cells, NEMS, nano-CMOS and spin-off will become more important (Kawamura, 2011). Currently, this fusion between different disciplines within nano-electronics is still limited as there is minor collaboration between different disciplines within nano-electronic research areas in Japan.

2.2 Nano-materials

By controlling materials at the nano-level, it is possible to develop next-generation nano-materials. These nano-materials can be used for a great diversity of industrial applications. Conventional materials used in both the electronics as life sciences field, can be remarkably improved by nano-material research. Currently, Japan accounts for 70% of the world share of nano-materials R&D (Baba, 2011). The Japanese Nano-materials Laboratory, NML, of NIMS makes a major contribution to the development of new nano-materials for practical industrialization (NIMS, 2011). This laboratory systematically explores and creates new nano-scale materials, like nano-tubes, nano-wires, nano-sheets, nano-particles (MANA, 2011).

An important project conducted by NML, in collaboration with universities, industry and research public institutes, is project ‘Green’. This project aims to develop nano-materials for green energy, focusing on the photo-catalysis and fuel cells research areas. Besides the development of nano-materials for green energy, the construction of new nano-materials in Japan is currently focused on the replacement of the current used rare metals and toxic substances (Takemura, 2011). By dealing with energy issues and the substitution of rare or deficit metals, a secure and safe society could be built (Baba, 2011). This chapter gives an overview of the state of the art and the accompanying opportunities and challenges of these two nano-material research areas, respectively nano-materials for green-energy and nano-materials used for the replacement of rare metals.

2.2.1 Materials for green energy

Nano-materials can be used to deal with energy issues by, amongst others, fuel cell and photo-catalysis innovations. Together, these innovative green energy applications could contribute to CO_2 reduction and creating a sustainable society. At present, around 70% of the world green energy production is generated by Japanese companies (Baba, 2011). A Japanese institute that is, amongst others, contributing to green innovation is AIST. AIST aims to create materials and devices that play a core role in green innovation by R&D on a nano-scale. This institute creates, for instance, novel fuel batteries and pho-catalytic materials that can realize energy saving and environmental purification, resulting in low environmental impacts (AIST, 2011). In this paragraph these developments, its opportunities and challenges, are discussed in more detail.

Fuel cell technology

Fuel cell technology is, because of the long time operation and quick charge of fuel cells, acknowledged as a key nano-research field in the 21st century. The fuel cell materials center of NIMS, is an example of a Japanese institute aiming to improve fuel cell activity by nano-manufacturing (NIMS, 2011). The latest developments in this field, described in this paragraph, are mainly focused on the miniaturization of fuel cells and the construction of fuel cells for electric applications and bio fuel cells.

State-of-the-art in Japan

Within fuel cell R&D in Japan there is increased attention for applying fuel cells in electronic transport (Zhang and Cooke, 2009). Fuel cells might replace batteries that are currently applied in electric cars. The Japan Hydrogen Fuel Cell project, founded by METI, aims at improving the mass production of electronic transport by fuel cells. Major automakers such as Toyota, Nissan, and Honda have joined this project (Zhang and Cooke, 2009). This project tries to overcome two factors, size and efficiency, that are now inhibiting the use of fuel cells in hydrogen applications. Based on these obstacles, Japanese fuel cell research is focused on the development of miniature, lightweight and long life fuel cells (AIST, 2011). Nanotechnology innovations are expected to be the answer for these problems. The use of nano-structures, such as carbon nano-tubes and graphite carbon nano-fibers, is studied for their ability to reduce the fuel cell size. These small fuel cells, in which nano-tubes are applied as their electronics, can be used to replace batteries in devices such as laptop computers or electric cars (AIST, 2011).

These smaller fuel cells are also useful for developing home fuel cells. Through these home fuel cells, home owners can generate electricity on site. In order to improve the efficiency, research is done on the catalysts in fuel cells. At present, the water and gas removal is a problem when using the current applied carbon catalysts (Yagi & Kimijima, 2011). The research centre Fc Cubic, established in 2005 as a division of AIST, aims to improve this mass removal and durability by increasing the size of the meso-pore (Yagi & Kimijima, 2011). At present, Fc Cubic is also investigating the possibilities of graphitized carbon as catalysts support. Graphene makes the surface smoother resulting in an improved transport. The costs, on the other hand, are higher as graphene is not easily to deposit.

The Japanese fuel cell R&D is making significant efforts in the construction of bio fuel cells as well. These bio fuel cells create energy through the conversion of glucose or fructose, enzymes and O_2 into water and CO_2 (Maruyama and Ata, 2010). Researchers from Kyoto University in Japan have developed such an enzyme-based bio fuel cell and are studying the possible miniaturization of these cells by the use of proteins (Hillie et al., 2005).

Opportunities

The current developments of hydrogen fuel cells are expected to result in the further improvement of the mass production and use of pure electric cars (Kozawa, 2010). Through nano-manufacturing it has become possible to create smaller and more efficient fuel cells for hydrogen applications. These applications will be helpful for establishing a low-carbon society. The creation of home fuel cells will be helpful for addressing a recent fundamental problem with the electrical grid. The recent long-distance electricity transmission results in a steady loss of electricity over distance. Home fuel cells, allowing home owners to generate electricity on site, could solve this line-loss problem, creating a more efficient energy environment (van der Veen, 2011).

Bio fuel cells promise to break down biological waste while generating electricity directly from the same process. In the future, these bio fuel cells can become sources, by decreasing the size through nano-manufacturing, for implantable devices within humans, such as pacemakers, insulin pumps, sensors, and prosthetic units (Meridan Institute, 2011).

Challenges

Current fuel cell applications lead to electric transport systems with a low and limited mileage, which implies restricted use and low competitiveness. Research is therefore conducted to improve the power lasting of these electric cars (Meridan Institute, 2011). Improving the efficiency of hydrogen fuel cells by using graphitized carbon as catalyst support, is not yet possible due to the high costs of this material. It has been estimating that the widespread usage of hydrogen cars will not occur until approximately 2020.

Research and development of bio fuel cells and fuel cells used for in house applications, are also still in progress. At present, a full-scale mass production of bio fuel cells into electronic devices is not yet possible because of limited power production (Zhang and Cooke, 2009). Further miniaturization of these bio fuel cells is also needed in order for these fuel cells to be commercially viable (Meridan Institute, 2011).

Photo-catalysis

Through the use of photo-catalysts, energy can be produced by the conversion of hydrogen and oxygen through sun- or UV-light (Kudo, 2011). This reaction takes place on the surface of photo-catalyst particles. Miniaturization of the particles has found to increase the photo-catalyst activity. Because of an increased surface and a decreased distance between the surface and the inner core of small photo-catalyst particles, the reaction will take place more easily (Kudo, 2011). To further improve this efficiency, the use of co-catalyst nano-particles on the photo-catalyst surface has been studied.

State-of-the-art in Japan

The photo-catalytic materials center of NIMS is conducting fundamental research aiming at the further development and practical application photo-catalytic materials. It has been acknowledged that the properties of photo-catalysts can be advanced by nano-architectonics. Through a unique nano-structure, reached by applying co-catalyst nano–particles to the surface, longer light penetration and therefore distinguished photo-catalytic properties could be reached (NIMS, 2011). Ag and TiO_2 co-catalyst nano-particles have been found to improve the operation of Au photo-catalysts (Kudo, 2011). Japan is seen as the pioneer of this TiO_2 photo-catalytic nano-materials R&D (Nanotech, 2011).

Opportunities

The underlying system of energy generation by photo-catalysts, in which electricity is produced by converting water and sun- or UV-light into hydrogen and oxygen, is quite simple (Kudo, 2011). Photo-catalytic applications have low running costs and can be useful for lowering the recent consumption of fossil fuels (Kho et al., 2010). As photo-catalytic devices have a low environmental impact, they form an alternative for clean and renewable energy production (I2TA, 2011). The use of photo-catalytic devices can therefore contribute to the creation of a sustainable society (NIMS, 2011).

Challenges

For the production of energy by photo-catalyses, two processes, producing hydrogen and oxygen initiated by a H_2 and O_2 photo-catalyst, take place in an aqueous solution. To improve the efficiency of these catalysts, these processes should be separated. Nowadays, it is however still difficult to separate these two conversion processes. This makes the reverse reaction possible, which subsequently hampers efficient energy production (Kudo, 2011). An integrated system has to be developed for overcoming this problem in the future (Kho et al., 2010). Another current challenge in the field is to get sun-light based photo-catalyst applications working on a large scale (Kudo, 2011). Studied should be conducted for investigating ways in which the efficiency of recent applications could be further increased.

2.2.2 Materials replacing rare metals

The term rare metal is used for metals that are only found in rare amount and are used in small quantities in industry to improve the properties of materials (Kawamoto, 2008). At present Japan uses around 30 rare metals, such as palladium, platinum, indium and lithium, for industrial products. These metals are applied in a broad range of Japan's manufacturing industries that include materials for automotives, information technologies, electronics production and batteries. In recent years, the demand for rare metals has exploded. This significant demand growth and the scarce amount of existence, has led to a growing concern about the long-term supply of these materials. As a result, the price of rare metals has increased and the supply of the export policies more tightly regulated. Worldwide production of rare metals is limited to a few countries. As a bulk of the global manufacturing is controlled by China, Japan is highly dependent on China for their industrial production (Kawamoto, 2008). Because of the limited supply and problems with product recycling, the possibilities of elements that can replace of these metals were found to be necessary (Physorg, 2010). Structuring and manipulating materials on a nano-level is thought to be useful for developing substitutes for currently used rare metals. In this paragraph the latest developments of this research area in Japan and its' opportunities and challenges are described.

State-of-the-art in Japan

At present, Japan is a big user of minor rare metals and responsible for half of its' world use. It is the leading consumer of, for instance, the rare metals terbium and europium (NEDO, 2011). In order for Japan's broad range of industries to grow, it is thought to be necessary to carry out R&D to lower the demand of rare metals. Decreasing the minor metal use has become one of the priorities of the Japanese government. The Japanese government created two large rare metal substitute materials development research programs. The Ministry of Education, Culture, Sports, Science and Technology (MEXT) is responsible for the program consisting of all the basic research projects. The Ministry of Economy, Trade and Industry (METI) on the other hand, is accountable for the program focusing on the applied research projects. Both programs, which are conducted in the period of 2008-2013, were mentioned in the 3rd STBP under the field of nanotechnology and nano-materials (Kawamoto, 2008).

An example of a project conducted under the program of MEXT is the collaboration project of Hitachi metals Ltd., NIMS, Ehime University and Kitakyushu University. Together they investigate the possibilities of developing magnets with low dysprosium content for motors of hybrid cars. By reducing the particle size the amount rare metal dysprosium could be reduced significantly (Nozawa et al., 2011). It has also been made possible to create comparable magnet materials without dysprosium through Fe nano-coating processes. A research group of Kyoto University used nano-technology for producing a new composite consisting of the combination of rhodium and silver at an atomic level. This composite can, by having similar properties, replace the rare metal palladium. Palladium is used in computers, as well as mobile phones, flat screen TVs and applied in the production of fuel cells (Physorg, 2010). Another project under the program of MEXT is the research project of the Japan Atomic Energy Agency, JAEA, Daihatsu Motor Co. and Osaka University on the development of nano-particles that can be used in self-generating catalysts. These particles could in the future be used for substituting catalysts, which contain precious metals as rhodium, and platinum (Kawamoto, 2008).

The program of METI also initiated a great variety of projects performed by different research institutes and companies. This program led, for example, to a reduced national use of iridium of 50% (NEDO, 2011). Applied in the constitution of iridium tin oxide, this rare metal, is used in transparent electrodes of liquid crystal televisions. Iridium tin oxide nano-particles have been constructed to achieve more efficient use and subsequently lowering iridium usage. Another project of The New Energy and Industrial Technology Development Organization (NEDO) and Tohoku University succeeded in the production of a powder of iron nitride by manipulating on a nano-scale (Hono, 2011). This powder can replace the currently used rare metal dysprosium used in certain magnets (Kozawa, 2010). In 2009, a project was established in order to reduce the use of the rare metal platinum with 50%. Platinum is applied in a variety of catalysts, mainly automobile exhaust gas catalysts and in fuel cells and electronic equipment (NEDO, 2011). By using nano-sized platinum particles or using nano-particles of other materials, companies are able to reduce the amount of platinum needed. There is also strived for an 80% reduction of rare metals terbium and europium, applied in fluorescent materials in fluorescent lamps and as backlights for liquid crystal TVs (NEDO, 2011). These studies are still ongoing.

Japanese research initiatives have furthermore led to the reduction of the use of indium. Indium is a rare metal with unique electrical and optical properties with a myriad of uses. Today's primary use of indium is in the form of indium tin oxide in flat panel displays. Indium is a component of LCD screens of lap top computers, flat panel monitors, flat panel televisions, cell phones, digital cameras and touch screen devices. While two layers are incorporated in LCD panels to control liquid crystals and with that the brightness of the monitor, only one single layer is fitted in OLED monitors as alone the electrode facing the viewer needs to be transparent. As a result, less indium is used in OLED compared to LCD panels (Nakamura & Sato, 2011). In order to diminish the use of indium the further development of OLED screens has been stimulated in Japan.

Opportunities
Creating alternative nano-composites that can replace currently used rare metals, such as palladium and dysprosium, decreases the necessity of using these metals and therefore secures the present levels of these scarce resources. Besides the protection of limited resources, the development of substitute materials could decrease Japan's industrial dependency on countries exporting rare metals, like China (AIST, 2008). By this development Japan hopes to strengthen its relation with these exporting countries. In addition to the replacement of currently used rare metal containing materials, the new and enhanced characteristics of new substitute nano-materials can lead to new innovation possibilities. It is acknowledged that these possibilities can create big chances for the Japanese industry. The search for substitutes of indium, for example, has led to a shift from LCD screens to a next generation flat screens, like OLED, in Japan (Nakamura and Sato, 2011). As being an important supplier of flat screens, this is an important issue for Japan.

Challenges
Rare metals can be effectively substituted by other rare metals in the future. This will, however, not solve the problems facing these resources on the long term. The basic physical properties of rare metals have to be studied, enabling the bottom-up development of nano-composite substitutes (Kawamoto, 2008). The development of rare metal substitutes by nano-manufacturing is, however, still in its infancy. Various challenges have to be overcome, like the creation of a substitute for indium with a similar resistance and stability properties (Kawamoto, 2008). At present, no nano-materials have been discovered that can replace the magnet materials containing neodymium (AIST, 2008). Substituting catalysts, which can replace currently used catalysts containing rhodium and platinum, have also not yet been developed. With regard to iron nitride powder, which can replace currently used magnets containing dysprosium, mass-production is still a challenge (Kozawa, 2010). Studies of NEDO, that wants to start commercializing this powder around 2023, are still on-going (Hono, 2011).

2.3 Nano-life sciences

Although the United States dominate in the life sciences area and Japan accounts for only a fraction of the life-sciences applications, Japan has become very advanced in nano-technological research in this field (Kanama, 2006). According the national research institute RIKEN, Japan is ahead of most countries with regard to the integration of nano and bio manufacturing (Okada, 2009). The Centre of Nano Bio Integration, CNBI, of Tokyo University, founded in 2005, used the knowledge on the structure and functions of the biological systems at a nano-scale for developing bio-inspired nano-materials and devices (CNBI, 2011). The successor of this initiative, the Nano Bio First Project, has been successful in expanding these possibilities by integrating various functions of medical devices and drugs on a nano-scale (Website Nano Bio First, 2011). Key technologies investigated by this project are, amongst others, regenerative medicine, nano-drug delivery systems, DDS, and nano bio-devices (Nanotechnology Network Japan, 2009). Together these nano-life science technologies aim for an accurate, non-invasive diagnosis and targeting therapy of various diseases (Nano Bio First, 2011). Other research activities in this field are, for instance, focused on imaging applications using nano-particles. The developments in the nano-life sciences field in Japan, described in this paragraph, focuses on these three main research areas.

2.3.1 Regenerative Medicine

A new area of medicine known as Regenerative Medicine (RM) combines tissue engineering and stem cell research on a nano-level (van den Besselaar & Gurney, 2009). Through the use artificial stimulation of cell proliferation by various RM techniques, it is possible to grow cell sheets from cultured cells (Bhowmik et al., 2009). Three-dimensional tissue constructions can be achieved by actively controlling nano-structures, such as cell adhesion structures, observed in cells and reconstructed tissue. Since the beginning of the 21st century the interest in this field in Japan has been increasing due to the potential of RM in improving current cancer and wound healing treatments (CMSI, 2009).

State-of-the-art in Japan
Regenerating medical projects have started in Japan with the establishment of the Japan Society of Regenerative Medicine, JSRM, by the Ministry of Health, Labour and Welfare, WHLW, in 2001 (Kuroyanagi, 2004). This Society, which is part of the TWIns' Institute of Advanced Biomedical Engineering and Science, promotes research and clinical advancements in the field of RM (Website JSRM, 2011). By making use of nano-manufacturing, JSRM has been able to develop four or even ten layers of mucosa or stem cells (CNBI, 2011*).* These cultured cells, harvested as contiguous cell sheets from temperature-responsive culture surfaces, can be directly transplanted onto damaged tissues (CNBI, 2011). Regenerating tissues of a thickness over 100 micro-meters is known to be difficult, because it requires the introduction of blood-vessels for supplying oxygen and nutrients. Therefore, JSRM creates a vascular system in vivo by repeatedly attaching 3 layers on the organ (FIRST, 2011). The Society has also been able to connect beating cells, such as hart cells. Rat cells were, for example, used for self-renewing a damaged heart until a new donor heart was found. The use of these cell sheets for regenerative treatments of various diseases are currently studied in clinical trials.

Until now, these clinical trials have confirmed the effectiveness and safety of RM (FIRST, 2011). Besides JSRM, Prof. Yamanaka of Kyoto University has conducted significant research in the RM field. His research group successfully generated pluripotent stem cells on a nano-level. These stem cells can replace human embryonic stem cells of patients with intractable diseases by cell transplantation therapies, because they have similar gene expression patterns and proliferative capacity as human embryonic stem cells (JST, 2010).

Within industry, the company Biosenz is an active player of the RM field. Biosenz develops somatic stem cells which can be used in cosmetic surgery areas, such as treatments on wrinkles, spots and burn damage (Bioscenz, 2011).

Opportunities
The possibility of regenerating 3D tissues on a nano-level by RM, can lead to improved transplantation therapies (JST, 2010). These therapies, free of host rejection issues, can replace today's conventional treatments like artificial or organ transplants (Bhowmik et al., 2009). Replacing removed cancer tissue by regenerated tissue can enhance post-treatment reconstruction of the tissue in the lesion and as a result realize shorter hospital stays, helping patients return to work earlier (CNBI, 2011). Besides cancer

patients, many patients with heart diseases can possibly be helped by RM applications. Regenerated sheets from the leg can be used to prevent hart cell death. It is expected that it will even be possible to engineer whole organs through RM in the future. As it is difficult in Japan to find organ donors, especially for the heart, these techniques are very promising (Okano, 2011).

Challenges
A recent challenge in the field of RM is to fabricate functionally vascularised tissues not only in vivo, but also in vitro (Okano, 2011). To imitate an in vivo environment, JSRM, is trying to make micro-vascular beds in vitro and transplants layered rat cardiac cell sheets over the beds. These vascular beds can be prepared in two ways. One approach is to use living tissues, with a connectable artery and vein, of rats. The other way is to create collagen-based micro-channels by gelling collagen around parallel stainless wires and extracting them. Capillaries are regenerated between the cardiac cell sheets and the vascular beds. First results indicate the possibility of in vitro functional blood vessel formation and further development of bioengineered thick myocardial tissues with sufficient vascular network. Nevertheless, more research on the in vitro generation of tissues is still ongoing (CNBI, 2011).

2.3.2 Drug Delivery System

Nanotechnology has opened up new opportunities in recently used drug delivery systems, DDS. By manipulating materials applied in DDS on a nano-scale, these systems can become more efficient (Bhowmik et al., 2009). By using, for instance, nano-materials as coatings in drug encapsulation, the drug delivery of proteins and peptides can be improved. With regard to this scientific development, Japan is thought to be ahead of other countries (Nishiyama, 2011). Some of the main research developments in this field in Japan and the opportunities and challenges of these developments are described in this sub-paragraph.

State-of-the-art in Japan
A research group at the University of Tokyo, under the lead of Prof. Kataoka, is conducting research on nano-DDS. This group has successfully developed nano-carriers, which incorporate various kinds of low molecule medicine (Kataoka, 2008). The function of these particles is governed by their hydrophobic / hydrophilic interface. The hydrophilic outer shell is composed for the biocompatibility and the hydrophilic core segregates the drug reservoir from the outer environment (CREST, 2011). These nano-carriers enhance the antitumor activity of drugs by carrying the drugs specifically into tumour cells. By harnessing the cell´s internal transport system, utilizing enhanced vascular permeability, the particles are able to release their cargo close to the cell´s DNA (Schultz, 2011). Releasing the drug close to a cancer cell's nucleus appears to protect it from the cell's self-defence mechanism. As prof. Kataoka describes it: “Nano-carriers work as nano-scaled Trojan horses to efficiently deliver a drug into the nucleus of cancer cells” (Schultz, 2011). The nano-carriers can release the drugs in different ways, by light irradiation or by the reaction to ultrasound signals. The particles are also pH-sensitive. As conditions become more acidic, the molecules of the micelles which have self-assembled around the drug molecules lose their ability to stick together and release the drug molecules (CREST, 2011).
Nano-DDS has been tested for the colorectal cancer drug ´oxaliplatin´ in mice with human colon cancer. These drug-loaded nano-carriers clearly exhibited higher antitumor activity than did oxaliplatin alone. Slowed tumour growth was shown, even in tumours that were completely resistant to the drug when it was administered normally (Schultz, 2011). Clinical trials show the possible benefits of nano-carriers for patients with colorectal cancer. Also other nano-carriers have been tested in phase I en II clinical trials in Europe, Asia, USA en Japan (CREST, 2011). Some of the drug delivery systems have already been approved. Also Fujifilm Corporation and the company Nanocarrier started to develop nano-DDS on a nano-level for controlling the sustained release of anti-cancer drugs (FujiFilm, 2009).

Opportunities
Resistance to the medicine oxaliplatin is a major drawback of the conventional treatment of colorectal cancer (Murakami et al., 2011). Through nano-DDS, it has become possible to treat patients with drug-resistant tumours, who benefit little from existing drug treatments. Through this new DDS, nano-carriers can specifically accumulate the drug in the target site. This decreased volume of distribution of the drugs results in a reduced incidence of the drug-related side effects, which are apparent in current cancer therapies (CNBI, 2011). The nano-cariers stay longer in the blood. Therefore, fewer doses are needed. This increased efficiency of nano-DDS can result in lower treatment costs (Nanocarrier, 2008).

Challenges
Currently DDS by nano-carriers are still under investigation in phase I and II clinical trials. The results of these on-going investigations should shed light on the real possibilities of this new technology. Although studies try to reveal the possible risks or effects of nano-carriers on the body, the effects on the long term are not yet studied (NanoBio Frist, 2011).

2.3.3 Nano Bio-devices

Miniaturization in both the electronics as life sciences field, made the integration of these fields possible. The fusion between these research areas is increasingly explored in Japan. By applying the semiconductor technology in the life sciences area, the creation of nano bio devices has become reality. Efforts in designing these devices, integrating bio-molecules and living cells into engineering materials, started in Japan around 2003. This sub-paragraph further elaborates on the Japanese developments in this field.

State-of-the-art in Japan
The integration of electronic and bio sciences is pursued in Japan by, amongst others, the Research Institute for nano-devices and bio systems of Hiroshima University. This Institute integrates these sciences with the aim to create measures for preventive medicine and diagnoses on early stages of illness (Hiroshima University, 2008). An example of an application in this research area is the nano biochemical transistor. The trend of these diagnostic transistors is currently shifting from ion, enzyme, immunological and gas to DNA, carbohydrate, lipid, peptide and cell transistors (Miyahara, 2011). A research group of the University of Tokyo, under the lead of Prof. Miyahara, has recently developed a transistor device for genetic analysis. The operation of this device is based on the potential to consider the binding of DNA molecules to a normal or mutant probe on a silica surface by DNA recognition events (Goda and Miyahara, 2010). A patient’s DNA within a blood sample will bind to the normal or mutant probe, depending on the patient’s DNA type. The extension of the target DNA with the patient’s DNA will increase the negative charge. Since DNA molecules are negative charged in an aqueous solution, these events will lead to a charge density change in the transistor, which can directly be transduced into an electrical signal. Single-base mismatch of the target DNA as well as DNA sequencing could be successfully demonstrated with the use of this nano-bio device (CNBI, 2011). The lab gave permission to the American company ‘Ion Torrent’ to commercial this device (Miyahara, 2011).

The expression of certain glycan structures on the cell surface can also be detected by nano bio devices. The over-expression of the glycan structure sialic acid has been found in tumours and metastasis. This technology, currently still in research phase, can result in the development a simple device for cancer diagnostics. Furthermore, NIMS has developed a clinical chip as an automatic testing device which enables testing of total-cholesterol levels (NIMS, 2011). Moreover, the presence of allergens can be detected in the future by nano-molecular diagnostic bio-sensors. These devices, created by Hiroshima University, could be helpful for the treatment of allergic disorders (Hiroshima University, 2008).

Opportunities

Because nano bio devices are seen as sensitive, simple and inexpensive methods, these devices have been attracting broad interest in Japan (Miyahara, 2011). Nano bio devices for genetic analysis have the potential to quickly analyse a patient's DNA. As a result, these devices make diagnosis in an earlier stage, without the need for labelling target DNA molecules, possible (Miyahara, 2011). Through nano-bio devices the easy non-invasive detection of small pathological changes, has become possible as well. It will therefore become simpler to detect diseases such as cancer. In the future, diagnostic activities will be increasingly conducted at the physician office, making these activities less invasive for the patient (Miyahara, 2011). This will improve health promotion and the Quality of Life, QoL, of the patients (CMSI, 2009). Innovations in nano bio devices may lead, in the future to an advanced medical-care society beyond the present information society.

Challenges

For the development of nano bio devices it is crucial that the targeted bio-molecules, like proteins, can bind to a specific site within the device, while preserving its function. This is, however, not an easy task. Further studies are needed for making commercial use of these devices achievable. Another major challenge of the development of nano bio-devices is to miniaturize the current measurement systems of these devices into a large-scale integrated circuit chip. Through this miniaturization, the generation of chips that can be implanted into the human body will become possible in the future. The further innovation and commercialization of nano-bio devices is still challenging. Industrial interest in this field is often mentioned to be lacking. Efforts have to be put into translating the technology into useful and viable applications.

3 Societal implications

The scientific developments in the Japanese nano-electronics, -materials and -life sciences fields, described in the previous chapter, take place in a certain economic and social context. Societal implications, which arise in these contexts, need to be considered. Before 2004, attention for possible societal implications of nanotechnology was completely absent in R&D policy in Japan (Ishizu et al., 2008). Research and experience however, showed that basic R&D on nanotechnology and research regarding its implications must be done in tandem in order to promote responsible R&D of nanotechnology in Japan (Ishizu et al., 2008).

In this study six types of societal implications, accompanying the recent nano-electronics, -materials, and -life sciences fields in Japan have been identified. The first issue, indicated by Japanese scientists contacted for this project, is the difficulty to translate nano-research into industrial applications. Even when translation of the technology has been reached, it is still questionable whether the application will actually be adopted by society. These implications hamper the commercialization of nano-products. Including socio-economic value within research can be valuable for improving this adoption of technologies. In order to increase the societal value of research, the Cabinet Office proposed, in its' 4th CSTP basic plan, to shift from field-based to issue-driven research. Implementing this shift in the recent research system in Japan will nevertheless be challenging.

Besides these issues related to the economic context within nano-innovation, risk and safety issues arise. Concerns about the possible risks of nano-materials on the environment and human health resulted in budget allocation and the establishment of this term in the 3rd STBP. Attention for other societal outcomes of nano-technological developments is still very limited in Japan. Still, privacy issues are expected to arise within nano-electronic research and the developments in the nano-life sciences field is thought to lead to possible implications for the health care sector. The modest recognition of these implications of technologies could be explained by the fear that paying attention to potential negative outcomes could hamper innovation and adoption of these technologies as well. Such a fear constitutes an extra challenge for Technology Assessment, as will be discussed in the next chapter. This chapter further illustrates the societal issues indicated above.

3.1 Translation difficulties

Although nano-applications increasingly appear on the Japanese market, difficulties are found in leading nanotechnology research into innovation. This difficulty in commercializing technologies is not only recognized in nanotechnology, but in other S&T fields as well. This issue is especially apparent in the nano-life sciences field, where collaboration between the academic field and industry is limited (Nano Bio First, 2011). Research institutes perceive a lack of interest of the Japanese industry in their research, in particular in the areas of photo-catalysis, drug delivery systems and regenerative medicine. Life sciences companies' persistence of investing in these areas could, on the one hand, be explained by the fear of risk amplification by the media (CRDS, 2010). At present, the potential risks of DDS and RM are still greatly unknown. Studies that have to shed light on the potential side-effects of applications in these research areas have not yet been completed. On the other hand, a persistent attitude towards industries that have not yet shown to be truly successful is underlying this waiting attitude (Miyahara, 2011). Japanese companies are increasingly no match for other Asian industries which produce products in higher quantities for less money. According to several professors from Tokyo University contacted for this study, this situation results in a lack of investment capital for taking up risky businesses by Japanese companies. The Japanese industry pays, little attention, for example, to photo-catalysis research, which large scale use has not yet been proven to be of commercial interest. Due to this limited investment, research institutes in the photo-catalysis field struggle with up-scaling their current practices (Kudo, 2011). In order to commercialize their findings, Japanese academic and national research institutes increasingly collaborate with foreign companies in, for instance, The United States and Europe. The Institute of Biomaterials & Bioengineering, for instance, sold its' patent on a device for genetic analysis to the American company Ion Torrent, which will commercialize this device (Miyahara, 2011).

Besides a lack of collaboration between academic institutes and companies in Japan, the difficulty of approving clinical trials amplifies the translation issue in the nano-life sciences field. Clinical trials are necessary to regulate the commercialization of medical applications in order to protect patients from potential unwanted side-effects. As clinical trials are rather time-consuming, performing these trials has been found to decelerate the translation and commercialization process of technologies. Governments' reluctance in approving clinical trials could be explained by its fear of getting blamed for possible future accidents. Some decades ago, the Japanese government was highly criticized by the media for approving blood donation practices which led to the subsequent spread of aids. Recently, the Japanese government acknowledged the recent translation gap and is now trying to increase their cooperation with academia (Okano, 2011). The government is, furthermore, starting to stimulate the collaboration of academia and industry by open innovation programs.

The linkage between R&D and manufacturing is found to be a problem not only in Japan, but in European countries as well. The Netherlands is, for example, coping with a similar translation issue in which new techniques based on nano-particles have progressed, but are hardly commercialized (Walhout et al., 2010) Sharing views on this translation difficulties and the possible ways for handling the issue, could be valuable for mutual learning of these countries.

3.2 Limited adoption

Next to translating research into applications, innovation requires adoption of new technologies. For professional users, the high complexity of nanotechnologies hampers the adoption, resulting in a minor uptake of nano-applications by society. Slow adoption is also an issue in other S&T fields, but is specifically identifiable in the research area of nano-bio devices. The commercialization of nano-bio devices has begun, but adoption of these devices is limited as the market for these devices has not yet been developed. For example, diagnostic activities are increasingly shifting from the hospital to the general practitioner's office. This requires changes in the current health care infrastructure as well. Moreover, as nano bio devices can affect systems that are decisive for life, like in health care, adoption will be slower than for ordinary consumer products. Because of the existing ignorance with the potential future outcomes of nano bio devices, people tend to have a more careful, waiting, attitude towards these technologies. Adoption speed is often higher in more entertainment ways of living, like cosmetics and sporting goods, because less regulation is needed in these industries. There is, in general, also more interest for these areas within society. This interest can stimulate the further spread of a technology into society. Adaptation of the health care system and linking devices to internet systems, where gaming and medical devices might interact, could accelerate the development of these kinds of technologies (NOST, 2011).

Japanese scientists, contacted for this study, indicated a lack of public knowledge as another explanation for the limited adoption of nanotechnologies. These scientists regularly feel that society tends to underestimate the value of nanotechnologies (Okano, 2001). In interviews for this project this feeling was also expressed by researchers of Fc Cubic.

Patients and general practitioners, for instance, are generally unaware of certain new treatment options arising from nano-medical developments. At present, general practitioners usually prefer using conventional methods and are hesitant in adopting this new treatment due to unfamiliarity about the underlying technology. Japanese research institutes therefore recognize the need of communicating the benefits of their technologies. These institutes think that increasing awareness of the opportunities of certain technologies by the public can stimulate application development of this technology.

3.3 Shift to issue-driven research

In order to better connect technological developments to societal needs, the Cabinet Office proposes in its 4th STBP to promote science and technology that addresses national or global issues, instead of field-driven support. As a result, S&T in Japan is increasingly seen as issue-driven, instead of discipline-oriented. Examples of grand national challenges in Japan are climate change, limitation of resources, aging, health and emerging infection diseases (NISTEP, 2011). The Cabinet Office puts special attention to green and life science innovations as measures to overcome these challenges (Baba, 2011). A sustainable low carbon society should be maintained by promoting green innovations. Future applications of this field are focused on energy and resources and include, amongst others, renewable energy, low power electronics, materials replacing rare metals and high-efficient transportation (Kishi, 2011). Following the 4th STBP, life innovations should lead, despite an aging population, to the realization of a society with a high living standard and a medical system that enables the secure provision of high quality and cost effective medicines for anyone, anytime. An improved monitoring system for diseases is an example of a life sciences application that will be stimulated in this new STBP (NISTEP, 2011). Nanotechnology is not specifically mentioned in this last STBP, but is seen as a way to strive for green and life innovation (NISTEP, 2011). Therefore the nano-field will not be funded directly, but indirectly via green and life sciences projects. Current nano-research projects that contribute to green innovations are investigating the construction of efficient energy conversion processes and the generation of green energy by photo-catalysis or biological fuel cells (MANA, 2011). Nano-research developments contributing to life innovations are the improvement of current medical treatments by efficient nano-DDS and the regeneration of pathological tissue through RM. The current developments in nano-material and nano-life sciences research, like the creation of nano-materials for green energy and an efficient nano-DDS, therefore contribute to this objective of green and life science innovation.

Recently, most research activities are conducted within a single discipline. Because issue-driven research typically requires interdisciplinary activities, a shift from discipline-oriented to issue-driven research is not straightforward. In order to develop nano-bio devices, which simplify and improve diagnostic activities of diseases, require both medical knowledge as knowledge on nano-electronics. Collaboration between physicists and engineers is therefore a necessity. Intensifying collaboration amongst different research areas could be improved by focusing S&T infrastructure on more flexible cooperation practices. The establishment of interdisciplinary programs and open innovation projects can, furthermore, push towards this field transcending research.

3.4 Difficulty of ensuring safety

The importance of protecting the environment as well as the health of employees and consumers, with regard to potential risks of nano-materials, has been acknowledged. At present, there are however concerns to whether this safety can really be sufficiently ensured (I2TA, 2011). Preliminary evidence for example, suggests that some engineered nano-particles may cause undesirable toxicological properties, presenting potential risks to human health (Bowman & Fitzharris, 2007). Another study shows that some nano-materials have the potential to damage skin, brain, liver and lung tissue, to be persistent in the environment, or to destroy ecologically essential micro-organisms (Matsuda & Hunt, 2009). Ensuring this safety is, of course, not a new issue and legislation to protect the environment and human health from the risks of materials, already exists. Due to the great variations in nano-materials and its diversified applicability, current legislation and guidelines are, nevertheless, seen as insufficient for regulating the possible risks of nano-materials. As long as there is no social consensus on the product reliability, scaling up will be difficult. Evaluation of the safety of nano-materials, by accepted methods, is therefore needed (METI, 2009). Institutes like the research institutes AIST and TASC have put efforts in conducting risk assessments and standard-setting for nanotechnologies (AIST, 2011). Also the National Institute Environmental Sciences, NIES, is moving ahead with assessments on the environmental impacts of nano-particles (Ishizu et al., 2008). Despite these activities the tackling of risk and safety issues has been found to be difficult (NOST, 2011).

3.4.1 Risk measurement issues

At present there is considerable debate regarding to whether or not nano-structures exhibit toxicity (Ishizu et al., 2008). Although extensive research on the possible environmental and health effects of nano-materials is undertaken worldwide, the data needed to assess these risks remains fragmentary and insufficient. In Japan this lack of scientific risk data is also due to a limited budget and a low number of toxicologists (NOST, 2011). Another explanation is the recent ‘rely on us’ attitude of the Ministries, resulting in an overall waiting attitude in industry concerning the performance of risk studies (NOST, 2011). More scientific data is needed in order to be able to estimate and minimize potential risks (Ishizu et al., 2008). Besides lack of data, different views on toxicity hamper the development of safety assessment methods. Concerning safety limits, a medical and industrial perception can be distinguished. The industry recognizes toxicity per definition as undesirable. The medical therapeutic field, on the other hand, indicates that it is not really possible to separate safety and risk matters from the overall therapeutic effect. The medical community views toxicity as inevitable and is of the opinion that even risky materials could be used as therapeutics when there is an overweighing beneficial effect for the patient (NOST, 2011). Following the president of JSRM, professor Okano, a new science is needed to investigate the efficacy and safety of new technologies (Okano, 2011).

3.4.2 Risk governance issues

As risk assessment is difficult, risk management is a challenge as well (I2TA, 2011). The lack of data makes it difficult to create effective ways for ensuring the safety of nano-materials. Industry is held responsible to invest in safety research. Nevertheless, Japanese industry is hesitant with enclosing information and requests the establishment of legal and regulatory mechanisms to support industrial initiatives (I2TA, 2011). The government however, doesn’t want to go ahead with regulations (NOST, 2011). Distinct activities in collecting data also hamper the translation of existing toxicological results into regulations. Little collaboration between Ministries and ambiguity about responsibilities and roles, with regard to the governance of the risks, are reinforcing this situation (NOST, 2011). A document of METI indicates that until 2009 no action has started towards the establishment of laws adequate to handle the majority of risks posed by nano-materials, but that existing laws could be adequate for handling the majority of risks posed by nano-materials (METI, 2009). This might be a solution, given the current absence of scientific findings that could be a basis for the immediate introduction of laws targeting nano-materials. Nevertheless, there are concerns about whether appropriate and sufficient administration through existing laws is indeed possible (I2TA, 2011). The fear exists that consumer nano-products will go through an existing regulatory scheme without being handled carefully.

3.4.3 Risk communication issues

The difficulty of measuring and governing the risks of nano-materials makes it hard to communicate about these potential risks. Nevertheless, it has been acknowledged that consumers have the right to know about certain safety limits of nano-applications (NOST, 2011). In order to be able to protect it against potential risks, it is important that consumers are knowledgeable about these risks. The probable existence of limited safety of nano-materials indicates the necessity for communicating risk information through, for instance, product labeling (Ishizu et al., 2008). Labelling of the possible risks of nano-materials on nano-applications is currently limited in Japan. Consumers are also not informed in other ways of risk communication. The danger of not clearly communicating the potential severe effects of nano-materials can lead to lawsuits and subsequently in a reserved attitude of the government of approving new drugs in the future (NOST, 2011).

3.5 Health care issues

The priority of the state of the art of nano-medical R&D, described in paragraph 2.3, is to develop more targeted therapies for, amongst others, cancer. The research developments in this field could decrease possible side effects, by less affecting healthy tissues, and increase the efficiency of current cancer therapies (Nishiyama, 2011). This recent advancements promise to enable secure provision of high-quality and cost-effective medicines (Nano Bio First, 2011). But the present nano-medical developments could also lead to more negative outcomes. Attention on the possible implications of these developments is currently mainly focused on the risks of the nano-materials used in nano-life sciences applications. A more broad view, regarding the potential implications on the health care system, would be valuable. The recent developments in the nano-life sciences field could influence the health care sector in various ways. Recent visions about these potential scenarios, concerning the health care sector in Japan, are lacking. Vision development is important for anticipating on the technological developments and their potential outcomes. Two medical developments that will possibly accompany the current nano-life sciences innovations, the shift to non-chronic treatments and increased self-diagnosis have been identified in this study. This paragraph discusses these developments and their possible implications for the health care sector.

3.5.1 Shift to non-chronic treatments

Current medical treatments could be improved by the regeneration of pathological tissues at the nano-scale. By replacing diseased tissue in an early stage, the realization of early non-chronic treatment of diabetes and heart diseases has become reality (AIST, 2011). As a result, the recent chronic treatment of diabetes at home could be replaced by a temporal treatment in the hospital (Okano, 2011). The possibilities of early, non-invasive diagnostic activities by nano bio devices, further stimulates this shift to non-chronic treatments. Through these temporal treatments the diseased period of patients and therefore the time patients spend on taking medicines or laying in bed, is decreased (Nishiyama, 2011). This shift to more temporal treatments of certain diseases could influence the current medical infrastructure in various ways.

At present, the Japanese medical care infrastructure is heavily centered on hospitals, which are viewed as recuperative centers rather than merely therapeutic institutions (Harden, 2009). Compared to other developed countries, Japan has the longest average length of stay for inpatient hospital services (five times that of the United States). Until now, the government has largely been unable to reduce the length of hospital stays (Harden, 2009). The replacement of chronic by temporal treatments has the potential to replace monitoring practices at home in short hospital services. This shift will further increase the long inpatient hospital services and the accompanying waiting lists. It is yet unclear how these changes could influence the whole medical system. Changes in work strain in the hospital and changed activities of general practitioners could be possible outcomes. With the possibility of treating diabetes by RM, the role of the hospital concerning the treatment of diabetes, will become more important. Furthermore, the preventive and temporal treatment of chronic diseases could result in longer life spends in a country with an already high population age. This could lead to extra costs. Changes in health insurance and the use of robots for medical handlings might be required to born these additional costs (Garcés and Cornell, 2001). Uncertainty about how the shift to non-chronic treatments will actually influence the current health care sector still exists.

3.5.2 Self-diagnosis

Diagnostic devices used for monitoring patients' health status are currently handled by the physician. In the future, nano bio-devices can create possibilities for individual patients to diagnose themselves and as a result better control their personal, individual health. It is expected that it will become possible to determine one's own health status by nano-bio devices. With respect to this individualization, the potential changes and challenges for the whole medical sector should be reviewed. Self-diagnosis and monitoring by nano bio-devices increases the need of patients' understanding about the underlying technology and the proper handling of these devices. Incorrect usage could lead to certain safety issues (NOST, 2011). Incorrect diagnosis or monitoring of their own health status by these devices could result in improper treatment of the patient. The innovations in nano-bio devices could furthermore moderate certain treatment activities outside the hospital and the general practitioners' office (Harden, 2009). This self-diagnosis could lead to reduced involvement of the physician in a patients' treatment plan, possibly changing current doctor-patient relationships. The ability to self manage personal health could, for example, higher the threshold of patients tendency to visit their general practitioner and therefore make it more difficult for these general practitioners to get a good view of a patients' health. At present, Japanese doctors, having the highest number of contacts per capita, work long hours and under a high amount of stress (Harden, 2009). The job activities of the physician could be influenced by applying nano bio-devices in diagnostics and treatment practices. Even though the possibility of self-diagnosis seems to reduce current job activities, control and informing activities will be needed to properly guide these self-diagnostic handlings. This technological advancement is expected to change the tasks and roles of both patients and physicians, changing the medical sector as a whole.

3.6 Protecting Privacy

The recent R&D in the field of nano-electronics, described in paragraph 2.1, pushes towards the further development of digital information and communication systems (Nanoquine, 2009). Nanotechnology allows the incorporation of information storage, processing, and communication in daily used devices. Eventually, every manufactured object might keep a digital record and will thus be networked. As a result, data can be aggregated from our transactions with various web servers (Garcés and Cornell, 2001). The assembling of digitalized data can result in new vulnerabilities and therefore the possible misuse of this data is feared. A variety of consumer electronic devices, consisting of nano-electronic materials, can contribute to privacy or digitalization issues (Takagi, 2011). Different home applications can be digitally integrated through nano-electronic technologies. As a result, new opportunities are created to jointly generate and share data, which in turn create new risks for obtaining data by others. With the introduction of nano-bio devices privacy issues have also entered the medical field. By the use of nano-biodevices monitoring of someone's health, will become easier. This can lead to an unnecessary interference of employers and health insurance companies with someone's personal health and the pressure to take more preventive health measures. In Japan, privacy is seen as an idea that has already come into its own, which is more than an individual civil right enforced only on an ad hoc basis in the courts (Lawson, 2006). Although privacy resonates deeply in Japanese society, there is currently little attention in Japan with regard to these potential privacy issues.

4 Technology Assessment in Japan

The previous chapter listed societal implications surrounding Japanese nano-technological developments, like the shift to issue-driven research, the difficulties in the translation and adoption of technologies and potential risk, health care and privacy issues. In order to identify how functions of Technology Assessment (TA) could contribute to the handling of these issues, various activities that have already been performed in Japan to address the societal implications are investigated in this chapter. In particular the project ‘Innovation and Institutionalization of TA in Japan’ (I2TA) acknowledged the need for assessing the developments and implications of nanotechnologies. This project organized various TA-activities, such as open symposia and workshops, to evaluate certain nano-research areas (Matsuo, 2010). Based on these past activities I2TA indicated in its final conference several wishes for the further progress of TA. This chapter discusses the past TA activities with regard to the identified issues described in the previous chapter and the recommendations of I2TA that are relevant for future TA activities in Japan.

4.1 Stimulate open innovation

The Japanese government acknowledged the difficulty of turning fundamental knowledge into industrial applications and has been trying to connect basic research stages of some nano fields with industrial development (Yamaguchi & Komiyama, 2001). An example of these initiatives is the Tsukuba Innovation Area (TIA) an open innovation area for nano-electronics, in which industries, national and academic research centers are collaborating under one roof to create innovation for global markets. The Japanese government also funded the Nano Bio First program established in 2010, to improve the translation of nano-bio research into a medical industry by creating industry-university platforms and stimulating the nano-DDS industry (Nano Bio First, 2011). The Regenerative Medicine Innovation Forum was launched in March 2011 as a pathway to commercialization of RM. In this forum government, pharmaceutical companies, medical devices manufacturers, research institutions and a patient organization are working together towards the embedding of RM in the health care sector.

In the I2TA project the need for bringing different stakeholders, such as industrial and academic actors, together in a network has been addressed as a task for TA. Bringing industrial actors and research centers together into a network could be valuable for exchanging ideas on translating nano-research into products and thereby stimulating the commercialization of nanotechnologies. Following I2TA this networking function is indispensable to facilitate cooperation (I2TA, 2011).

4.2 Communicating the benefits

Despite the difficulty in translating nano-technological research into applications, a great range of nano-products can be found on the Japanese market. Yet, some of these products are minimally taken up by society. As Japanese scientists have put forward that the limited adoption of nanotechnologies can be explained by societies´ limited knowledge with respect to this technology and its benefits, research groups have been trying to communicate the benefits of their technologies via the media. In the years nanotechnology as a research area was just recognized, there was a lot of attention for nanotechnology. Media communicated promises and positive future prospects. These promises were not fulfilled as quickly as expected and the attention for nanotechnology disappeared. The 4th STBP of the Japanese Cabinet Office now emphasizes the importance of promoting efforts for attaining wide-ranging citizen consensus (I2TA, 2011). Following this plan, citizen consensus can be pursued by conducting various consensus conferences. I2TA indicated the possibility of informing the general public through TA activities. Only communicating the benefits of technologies will however be at daggers drawn with the critical role of TA in addressing societal issues.

4.3 Determining societal needs

Due to the focus of the Japanese Cabinet Office on issue-driven innovations, Japanese R&D has started to shift from field-based research to research driven by certain national and global issues. In order to enable issue-driven innovation societal challenges have to be determined. I2TA indicated the importance of TA in determining such needs. In a workshop of I2TA on nano-green, eco-life, safety and security were identified as important requirements for society (I2TA, 2011). Based on this workshop I2TA recommends to use a bottom up approach, involving the general public, when identifying societal wishes.

4.4 Identifying risk issues

Through TA activities of I2TA on nano-food, the difficulty of ensuring the safety of the nano-materials used in food applications was articulated (I2TA, 2011). The problems in handling the risks of these materials were found to be based on several factors. I2TA acknowledged unclearness about the tasks and mutual responsibilities of relevant stakeholders with regard to the measurement of the risks. Furthermore, I2TA showed that the establishment of criteria for the safety of materials is hindered by the different views on toxicity between academic and industrial parties (I2TA, 2011). The TA activities on nano food showed that besides limited data, a waiting attitude of different stakeholders is underlying the current lack of risk governance.

The risk and safety issues that have been identified by I2TA were specifically focused on nano-food materials and not on nano-materials in general. Based on these issues I2TA has formulated various recommendations for future TA activities in handling risk and safety issues: TA could play a role in engaging various types of stakeholders into a network. Within this network, stakeholders can create a common view on, for example, the concept toxicity. I2TA also acknowledged a possible role of TA in putting the identified risk issues on the political agenda. Following I2TA, TA could be relevant in the future for contributing to formulation of risk government policies (I2TA, 2011).

4.5 Recognizing societal implications

Until now, little activities have been conducted to identify potential societal implications of nano-medical developments. Studies which investigate the possible outcomes of nano-medical and nano-electric advancements have been limited to the risks of the materials used. Clinical trials, for determining potential risks of nano-life sciences applications, have been little activities for studying the possible implications of the recent developments in this field. In order to discuss the developments in nano-DDS, I2TA has conducted various round table meetings with stakeholders. Outcomes were mainly focused on the risks and translation difficulties and did not define broader challenges for the health care sector. I2TA suggests creating a network of relevant stakeholders within nano-life sciences technologies to identify societal issues and formulate common views on the future development of the national health care sector (I2TA, 2011).

4.6 Institutionalization of TA

At present, the secure, continuing and consistent collaborations that I2TA requests for TA in Japan are limited. With respect to the institutionalization of TA, I2TA addressed the importance of appropriate distance between strategy building and interaction with society. Moreover, the consistent funding of TA must secure institutionalization of TA-activities. Various options for institutionalization have been suggested by I2TA. TA could be institutionalized as a new parliamentary organization under the lower house, as an independent governmental unit under the Science, Technology and Innovation Strategy Headquarters of the Cabinet Office, a governmental funding frame, a R&D organization, voluntary TA activities or as an international institutionalization through the establishment of an Asian TA organization or by collaborating with Korea or The European Union (I2TA, 2011). These options of institutionalization could be valuable for the future progress of TA.

5 Conclusions

How could TA contribute to the handling of the societal issues surrounding nanotechnology developments in Japan? In this final chapter we return to the informing, interacting and mobilising functions of TA, which have been described in the introduction. The previous chapter showed that the various attempts which have been conducted by the Japanese government only partially covered the identified issues. Recommendations for improvement have recently been done by the I2TA project. The first section will discuss how the several functions of TA correspond to the issues listed in chapter 3 and the recommendations of I2TA. In the last section conclusions are drawn about contributions of TA in the further handling of societal issues accompanying developments in nanotechnology.

5.1 Applying the three functions of TA

5.1.1 Informing function

Through the information function of TA, it is possible to create more insights in S&T innovation by technical and social maps. Technical maps can provide information on the recent scientific and technological developments, and the accompanying societal implications, in a certain field. The potential implications of nano-medical evolvements on the health care sector could, for instance, be visualized by these technical maps. Attention for these possible implications on the health care sector is currently limited in Japan. I2TA acknowledges the importance of conducting TA practices for examining the possible societal implications of the nano-medical field in the future. TA could be used for instance, to map how the use of nano bio-devices will affect the current health care system, such as the work descriptions of general practitioners.

Social maps can be used to identify actors involved in a certain innovation area. This can be helpful for determining which research institutes and industrial actors are relevant for the nano-life sciences field. As minor industrial involvement is underlying the recent translation problem of nano-life science technologies, visualizing and bringing stakeholders together could possibly improve this translation and in the long term the commercialization of nano-medical applications.

Mapping societal needs can also be part of the information function. The wish of the Cabinet Office to shift to more issue-driven research, addresses the importance for doing so. I2TA showed that TA activities can be used for this goal en recommends further initiatives.

5.1.2 Interacting Function

The second function proposed in this study, is the interacting role of TA. The goal of this function is to bring actors together. Within a network different stakeholders can interact, share their views and articulate visions. This function could be helpful in stimulating the exchange of views among relevant stakeholders. At present, engagement of final users in the technological process is limited. TA-activities could stimulate the interaction of research institutes and industry with patient organizations and general practitioners, which are the future users of nano bio-devices. Companies can create interaction with end-users and include their views before manufacturing a prototype-design (NOST, 2011). As end-users determine how the technology is actually adopted, the engagement of end-users during scientific developments could be useful.

The interacting function of TA could be important for exchanging and integrating the different views on toxicity and the interpretation of toxicological data. Chapter 3 mentioned the difficulty of ensuring safety because of the contrasting perspectives of industry and the medical community on toxicity. Collaboration between stakeholders could be useful for developing a more common approach and dividing tasks with regard to the risk governance of nano-materials. Constructive interaction and exchange of views could also lead to the development of visions on possible future scenario´s with regard to technological advancements. Such a vision development, which could be seen as an example of constructive TA, can broaden and deepen the understanding of socio-technical dynamics (Rip, 2004). In the same way, generating visions by interaction of different stakeholders can be applied to identify future impacts of nanotechnology developments in the health care sector or with regard to privacy issues.

5.1.3 Mobilizing function

Information and interaction are necessary functions of TA, but to realise sufficient impact on policy processes, political debate or the behaviour of stakeholders, TA activities also have to pursue agenda setting by dedicated positioning and communication. Recently it has been found unclear, for example, who should take the lead in developing risk measurement methods and regulations for nano-materials. Risk assessment is seen as an industrial task, but industrial initiatives are waiting for governmental guidelines. Just offering governance options (mapping) and discussing them by stakeholders (interaction) might not be enough as this the current situation is characterized by a waiting attitude among stakeholders. In order to break through TA also has to provide recommendations which make sense (mobilizing) to actual policy frameworks and political agendas. . As I2TA also acknowledged a possible role of TA in setting the identified risk issues on the political agenda, this would require carefully positioning of TA activities and dedicated communication of the results.

For other issues, like the minor attention for privacy issues, communication serves raising awareness rather than direct agenda setting. Communication via the media, hearings or conferences, can help in stimulating interest in this issue. I2TA considered the possibility of informing the general public on potential implications of nanotechnologies via, for instance, the media.

Besides societal implications, the benefits of technological developments and the possible accompanying value for society can be communicated as well, possibly resulting in increased public support. Limited adoption of nano-technological applications, such as nano-bio devices, is often viewed as a result of a lack of societal knowledge on nanotechnologies and their benefits. This kind of persuasive public communication can however be in conflict with the critical role of TA.

5.2 Current activities and functions of TA

The most important aspects of how TA can contribute to the further handling of societal implication accompanying developments in nanotechnology can now be identified by getting back to the current activities listed in the previous chapter. Attention in Japan with regard to the issues identified in chapter 3, turns out to be mainly focused on stimulating innovation. The Japanese government has put a lot of effort in generating open innovation systems. By bringing companies, research and academic institutes together in these systems, the transfer of knowledge into applications should become easier. Yet, as scientists explain the still limited adoption of technologies societies’ limited knowledge on nanotechnology and its benefits, research groups have been trying to communicate the benefits of nanotechnologies via the media (I2TA, 2011). In this context scientists and policymakers might interpret the informing function of TA in a similar way. However, communicating only the chances and not the potential pitfalls of technologies, can be at daggers drawn with the critical function of TA, especially as there is a role for TA in raising awareness about more negative societal implications as well. This has been showed by the TA activities of I2TA on nano-food, which articulated the difficulty of ensuring the safety of the nano-materials used in food applications (I2TA, 2011).

The I2TA activities on nanofood also showed that the informing function of TA is not limited to mapping issues, but also tasks and mutual responsibilities in the risk governance process. By mapping these roles I2TA identified a waiting attitude among relevant stakeholders. Such a mapping is useful to stimulate interaction – the second function of TA – in order to formulate governance options. At the moment this interaction is currently limited. In this case the mobilizing function of TA will be needed as well in order to break through the identified waiting attitude, for example by putting the governance options on the political agenda.

Finally TA can contribute to the handling of societal implications by widening the scope of debate. At present the studies which investigate the possible outcomes of nano-medical and nano-electric advancements have been limited to the risks of the materials used. In the various round table meetings of I2TA on DDS both risks and translation difficulties have been discussed, but broader challenges for the health care sector as listed in chapter 3 have not been identified. Attention for these implications can start by creating technical maps, visualizing the potential societal implications of the recent nano-life sciences developments or the impact on protecting privacy with regard to novel nano-electronic applications. Next the interacting and mobilizing functions of TA will be needed to define governance options with regard to these issues.

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References

AIST, national institute of Advanced Industrial Science and Technology (2008). Rare Metals. 5th issue of AIST Today. Printed in September 2008.

AIST, national institute of Advanced Industrial Science and Technology (2011). [online: web]. (Accessed: 13-04-2011).

Baba, T. (2011). Presentation: Japan's R&D strategy of Nanotechnology. *Cabinet Office, Government of Japan.* February 2011.

Besley, J.C., Kramer, V.L. and Priest, S.H. (2008). Expert opinion on nanotechnology: risks, benefits and regulation. *Journal Nanoparticle Research, 10,* 549-558.

Van den Besselaar, P. and Gurney, T. (2009). Regenerative Medicine: an Emerging Research Field. *Rathenau Instituut*. Science System Assessment Report, June 2009.

Bhowmik, D., Margret, C.R. and Jayakar, C.B. (2009). Role of Nanotechnology in Novel Drug Delivery System. *Journal of Pharmaceutical Science and Technology, 1(1)*, 20-35.

Bioscenz (2011). [online: web]. http://www.bioscenz.com/ (Accessed: 19-04-2011).

Bowman, D.M. & Fitzharris, M. (2007). Too small for concern? Public health and nanotechnology. *Australian and New Zealand Journal of Public Health*, *34(4)*, 382-384.

Bureau of Science and Technology Policy, Cabinet Office, Government of Japan (2001). 2nd Science and Technology Basic Plan from 2001-2005. March 30th 2001.

Bureau of Science and Technology Policy, Cabinet Office, Government of Japan (2006). 3rd Science and Technology Basic Plan, 2006-2011. March 28th 2006.

Bütschi, D. Carius, R. Decker, M. Gram, S. Grunwald, A. Machleidt, P. Steyaert, S. and van Est, R. (2004). The Practice of TA. Science, Interaction, and Communication." In: M. Decker, M. Ladikas (Eds.): Bridges between Science, Society and Policy. Technology Assessment - Methods and Impacts. Springer Heidelberg, New York.

Cabinet Office, Japan government (2011). [online: web]. http://www.cao.go.jp/index-e.html (Accessed: 07-06-2011).

CDBIM, Centre for Disease Biology and Integrative Medicine, The University of Tokyo (2011). [online: web]. http://www.cdbim.m.u-tokyo.ac.jp/ (Accessed: 14-06-2011).

CMSI, Centre for Medical System Innovation (2009). Seminar: 'Medical Innovation'. June 28th 2009.

CNBI, Centre for Nano Bio Integration (2011). Medical Innovation.

CREST, Core Research for Evolutional Science and Technology (2011). Basic Research Programs CREST 2010 – 2011. *Japan Science and Technology Agency, JST.*

CRDS, Centre of Research and Development Strategy (2011). [online: web]. http://crds.jst.go.jp/en/ (Accessed: 14-06-2011).

CRDS, Centre of Research and Development Strategy (2010). Nanotechnology: Grand Design in Japan. Key technology for solving global issue. A proposal submitted to the Japanese Government. Original Japanese Version Published on March 31st 2010.

van Est, R. (2011). Keeping the dream alive: What ELSI-research might learn from parliamentary Technology Assessment. In: Cozzens, S. and Wetmore, J. (2011). The Yearbook of Nantotechnology in Society. Springer Science. *Nanotechnology and the Challenges of Equity, Equality and Development Part 5, 1(2),* 409-421*.*

Fc Cubic (2011). [online: web]. http://www.fc-cubic.or.jp/index.html (Accessed: 05-04-2011).

FIRST, Funding Program for World-Leading Innovative R&D on Science and Technology. Brochure FIRST International Conference January 24th-26th 2011.

FujiFilm (2011). [online: web]. http://www.fuji.nl/. (Accessed: 05-04-2011).

Garcés, J.M. and Cornell, M.C. Focus on Economic and Political Implications of Potential Technology: Impact of Nanotechnology on the Chemical and Automotive Industries. In: National Science Foundation. (2001). Societal Implications of Nanoscience and Nanotechnology. *Logistical, editing and management assistance by International Technology Research Institute, World Technology (WTEC) Division.*

Goda, T. and Miyahara, Y. (2010). Molecularly Engineered Charge-Conversion of Proteins for Sensitive Biosensing. *Analytical Chemistry*, *82* (21), 8946–8953.

Harden, B. (2009). Health care in japan: low cost, for now aging population could strain system. *Washington Post.* September 7th 2009.

Hiroshima University (2008). Research Institute for Nano-device and Bio Systems. May 2008.

Hiroshima University (2011). [online: web]. http://www.hiroshima-u.ac.jp/index.html (Accessed: 14-06-2011).

Hono, K. (2011). Presentation: ‘Research Trends on Rare Earth and Critical Elements in Japan’. National Institute for Materials Science.

Hwang, D. (2010). Ranking the Nations on Nanotech: Hidden Havens and False Threats. Lux Research Inc.

I2TA, Innovation and Institutionalization of Technology Assessment (2011). Workshop organized by I2TA on 6th of March 2011.

I2TA, Innovation and Institutionalization of Technology Assessment (2011). Conference organized by I2TA on 11th of March 2011.

IBB, Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental University (2011). [online: web]. http://www.tmd.ac.jp/english/ (Accessed: 14-06-2011).

Ishizu, S., Sekiya, M., Ishibashi K., Negami, Y. and Ata, M. (2008). Toward the responsible innovation with nanotechnology in Japan: our scope. *Journal Nanoparticle Research, 10*, 229-254.

JAMS, Japan Association Medical Sciences, (2011). [online: web]. http://www.med.or.jp/english/ (Accessed: 14-06-2011).

JST, Japan Science and Technology (2010). Presentation: 'Basic research programs: successful milestones.'

JSRM, The Japanese Society of Regenerative Medicine (2011). [online: web]. http://www.jsrm.jp/ (Accessed: 19-04-2011).

Kataoka, K. and Itchiki, T. (2008). Presentation: 'Overview of research of the Centre for Nano Bio Integration, CNBI'. CNBI.

Kawamoto, H. (2008). Japan's Policies to be adopted on Rare Metal Resources. *Science and Technology Trends. Quarterly Review, No. 27 April.*

Kawamura, S. (2008). Presentation: 'Nano-electronics', From More Moore to More than Moore. Semiconductor Leading Edge Technologies, Selete. *February 8th 2008.*

Kawashima, K. (2010). Presentation: 'Japan's R&D Strategy of Nanotechnology including Nano-Medicine.' OECD Workshop 'Challenges in the Innovation Environment of NanoMedicine'. *February 23rd of 2010.*

Kho, Y.K., Iwase, A., Teoh, W.Y., Mädler, L., Kudo, A. and Amal, R. (2010). Photocatalytic H2 Evolution over TiO2 Nanoparticles. The Synergistic Effect of Anatase and Rutile. *Journal Phys. Chem. C. 114,* 2821-2829.

Kishi, T. (2011). Seminar: Nanotechnology R&D Policy of Japan and Nanotechnology. *Nanotech Expo*. February 18th 2011.

Komatsu, H. and Ogasawara, A. (2005). Applying Nanotechnology to Electronics. *Science and Technology Trends, Quarterly Review No. 16 July 2005.*

Kozawa, S. (2010). Trends and Problems in Research of Permanent Magnets for Motors – Addressing Scarcity Problem of Rare Earth Elements. *Science & Technology Trends,* 40-54.

Kudo, H. (2011). Personal communication. Department of Applied Chemistry, University of Tokyo. *February 25th 2011.*

Kuroyanagi, Y. (2004). Guest Editorial: Studies on Regenerative Medicine in Japan. *Artificial Organs, 28(1)*, 11-12.

Lawson, C. (2006). Japan's New Privacy Act in Context. UNSW Law Journal, 29(2), 88-113.

MANA, International Centre for Materials Nanoarchitectonics, (2011). WPI Research Centre Program. January 2011.

Maruyama, R. and Ata, M. (2010). Presentation: Trend of Nanotechnology R&D in Japan. *Sony Corporation, JST and CSTP. Given on the 3rd of March 2010.*

Matsuda, M. & Hunt, G. (2009). Research on the societal impacts of nanotechnology: A preliminary comparison of USA, Europe and Japan. *Bio-Medical Materials and Engineering, 19,* 259-267.

Matsuo, M. (2010). Presentation: The Current Status and Discussion of TA in Japan. I2TA.

Hillie, T., Munasinghe, M., Hlope, M. And Deraniyagala, Y. (2005). Global Dialogue on Nanotechnology and the Poor: Opportunities and the Risks. Meridian Institute.

METI, Ministry of Economy, Trade and Industry (2009). Report METI. *Published in March 2009*.

MEXT, Ministry of Education, Culture, Sports, Science and Technology (2011). [online: web]. http://www.mext.go.jp/english/ (Accessed: 28-04-2011).

Ministry of Economical Affairs, Agriculture and Innovation (2011). [online: web]. http://www.agentschapnl.nl/ (Accessed: 30-11-2010).

Miyahara, Y. (2011). Presentation: Detection of bio-molecular recognition using bio-transistors. Japan – Singapore Joint Workshop. *August 11th and 12th 2011.*

Miyahara, Y. (2011). Personal communication. Institute of Biomaterials & Bioengineering, Tokyo Medical and Dental University. February 8th 2011.

Murakami, M., Cabral, H., Matsumoto, Y., Shourong, W., Kano, M.R., Yamori, T., Nishiyama, N. and Kataoka, K. (2011). Improving Drug Potency and Efficacy by Nanocarrier-Mediated Subcellular Targeting. *Drug Delivery3(64),* 1-10.

Nakamura, E. and Sato, K. (2011). Managing the scarcity of chemical elements. *Nature Materials, 10,* 158-161.

Nano Bio (2008). Newsletter Center for for NanoBio Integration, University of Tokyo. Vol.7 January 2008.

Nano Bio First (2011). [online: web]. http://park.itc.u-tokyo.ac.jp/nanobiof/en/. (Accessed: 19-04-2011).

Nanocarrier (2008). Presentation: Introduce Innovative Nano-biotechnology for Human Health and Quality of Life. December 16th 2008.

NanoNed (2010). [online: web]. http://www.nanoned.nl/ (Accessed: 01-12-2010).

NanoQuine (2009). Information Leaflet NanoQuine. *Published in March 2009*.

Nanotech (2011). [online: web]. http://www.nanotech.com/ (Accessed: 22-06-2010).

Nanotechnology Researchers Network Center of Japan (2006). Presentation: Nanotechnology research in Japan.

NBCI, Nanotechnology Business Creation Initiative (2011). [online: web]. http://www.nbci.jp/en/index.html (Accessed: 28-04-2011).

NEDO, New Energy and Industrial Technology Development Organization (2011). Development of Nanotechnology and Materials Technology. *February 2011.*

NIMS, National Institute for Materials Science (2011). ‘Mission NIMS’. October 2nd 2011.

NIMS, National Institute for Materials Science (2011). [online: web]. http://www.nims.go.jp/ (Accessed: 18-04-2011).

NISTEP, National Institute of Science and Technology Policy (2011). FIRST International Conference. 8th March 2011.

NISTEP, National Institute of Science and Technology Policy (2011). [online: web]. http://www.nistep.go.jp/index-e.html (Accessed: 07-06-2011).

Nishiyama, N. (2011). Personal Communication. Centre for Disease Biology and Integrative Medicine, The University of Tokyo. *February 3rd 2011.*

NOST, Netherlands Office Science and Technology (2011). ‘Working Session: Technology Assessment for Nanotechnology’. Netherlands Embassy Tokyo. *March 11th 2011.*

Okada, S. (2009). Big on nanotech: Japan is one of the world leaders in nanotechnology, but its position could be threatened by a lack of government. *Chemistry and Industry*, 1-3.

Okano, T. (2011). Personal Communication. Institute of Advanced Biomedical Engineering and Science, Tokyo Women’s Medical University. *January 25th 2011.*

Osaka University (2008). Research Programs Osaka University. *Published in May 2008.*

Panasonic corporation (2011). [online: web]. http://www.panasonic.com/ (Accessed: 18-04-2011).

Patra, D., Ejnavarzala, H. And Basu, P. (2009). Nano-science and nanotechnology: ethical, legal, social and environmental issues. *Current Science, 96(5), 651-657.*

Phenitec Semiconductor Corporation (2011). [online: web]. http://www.phenitec.co.jp/e/index.html (Accessed: 25-01-2011).

Physorg (2011). [online: web]. http://www.physorg.com/news/ (Accessed: 05-01-2011).

Rip, A. (2004). Constructive Technology Assessment of Nanotechnology. 15th of April 2004.

RISTEX, Research Institute of Science and Technology for Society (2011). [online: web]. http://www.ristex.jp/EN/aboutus/history.html (Accessed: 18-04-2011).

Roco, M.V. (2003). Broader societal issues of nanotechnology. *Journal of Nano-particle Research, 5,* 181-189.

Rorze co. ltd. (2011). [online: web]. http://www.rorze.com/english/ (Accessed: 14-06-2011).

Saito, M. (2011). Meeting. Research Institute of Science and Technology for Society (RISTEX). March 9th 2011.

Schultz, N. (2011). Tiny Trojan horses deliver a cancer drug to cell nuclei. *MIT Technology Review.*

Shiroyama, H. (2010). Limits of Past Practices and Possible Future Institutionalization of TA in Japan. *Technikfolgenabschätzung – Theorie und Praxis, 19(2),* 80-83.

Siegrist, M., Keller, C., Kastenholz, H., Frey, S. and Wiek, A. (2007). Laypeople's and Experts' Perception of Nanotechnology Hazards. *Risk Analysis, 27*(1), 59-70.

Takagi, S. (2011). Personal communication. Department of Electrical Engineering Graduate School of Engineering University of Tokyo. *February 2nd 2011.*

Takashi, A., Akira, U., Ken´ichi, K. (2005). New development of nano structure. Organic semiconductor material. *Science of Machine, 57(1),* 195-202.

Takemura, M. (2011). Presentation: NIMS. *February 17th 2011.*

TASC, Technical research Association for Single wall Carbon nano-tubes (2011). [online: web]. http://www.tasc-nt.or.jp/ (Accessed: 19-06-2011).

Tazmo co. ltd. (2011). [online: web]. http://www.tazmo.co.jp/E/index.html (Accessed: 14-06-2011).

Tech & Industry Analysis from Asia (2011). [online: web]. Tech-On: http://techon.nikkeibp.co.jp/english/ (Accessed: 19-05-2011).

Thin Film Electronics (2011). [online: web]. http://www.thinfilm.se/ (Accessed: 19-06-2011).

Tokyo University (2011). [online: web]. http://www.u-tokyo.ac.jp/index_e.html (Accessed: 14-06-2011).

TIA, Tsukuba Innovation Arena (2011). [online: web]. http://tia-nano.jp/en/about/ (Accessed: 18-04-2011).

TWMU, Tokyo Women's Medical University (2011). [online: web]. http://www.twmu.ac.jp/ (Accessed: 14-06-2011).

Van der Veen, C. (2011). Energy Ecosystem of the Future Hinges on Many Sources. *Government Technology. Published on the 11th of April 2011.*

Walhout, B., van Keulen, I., van Est, R. (Rathenau Instituut) and Malsch, I. (Malsch Techno Valuation). (2010). Nanomedicine in The Netherlands: social and economic challenges. *Rathenau Instituut, The Hague. Published on the 31st of May 2010.*

Walhout, B, van Keulen, I., van Est, R., Brom, F., Malsch, I. (2009). Nano in the Netherlands: Policy paper for the Nanotechnology Round Table Talks of the Permanent Committee for the Ministry of Economic Affairs. *Rathenau Instituut, The Hague*.

Watanabe, H. (2008). Presentation: 'Japanese government funding nano-electronics projects'. March 4th 2008.

Wilsdon, J., Kearnes, M., MacNaghten, P. (2006). The technical and social complexity of nanotechnologies demands a genuine dialogue between scientists and the public : Governing at the Nano-scale People, policies and emerging technologies. *Demos, London.*

Yagi, I. and Kimijima, K. (2011). Personal Communication. Technical Research Association Fc Cubic. February 23rd 2011.

Yamaguchi, Y. & Komiyama, H. (2001). Structuring knowledge project in nanotechnology materials program launched in Japan. *Journal Nanoparticle Research*, 3, 105-110.

Yu, P.Y. and Cardona, M. (2010). Fundamentals of Semiconductors: Physics and Materials Properties. *Springer Verlag Berlin Heidelberg, 4th Edition.*

Zhang, F. and Cooke, P. (2009). The Green Vehicle Trend: Electric, Plug-in hybrid or Hydrogen fuel cell? *Centre for Advanced Studies, Cardiff University, United Kingdom.*

Appendix 1: Meetings and Visits

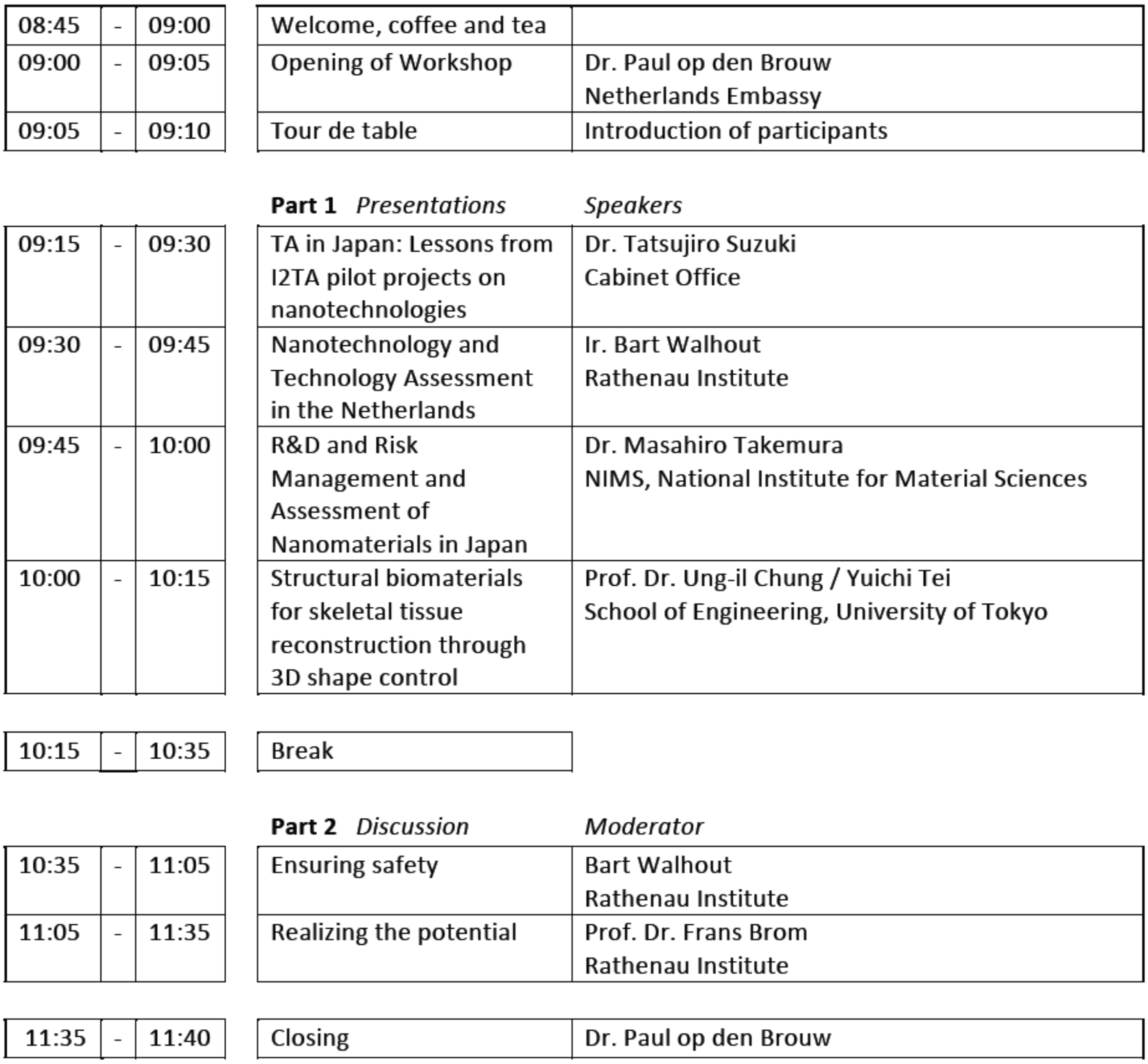
In the following table, the meetings and other gatherings had took place during the period of January 2011 until April 2011 in Japan, are shown.

Date	Type	Institution/ department	Person
25-01-2011	Meeting	Institute of Advanced Biomedical Engineering and Science, Tokyo Women's Medical University	Dr. Okano Mrs. Agami
27-01-2011	Meeting	Nano Bio FIRST Project, Japan Science and Technology And Tokyo University	Mr. Tawara Dr. Takanori Ichiki Mrs. Nagai
03-02-2011	Meeting	Centre for Disease Biology and Integrative Medicine, The University of Tokyo	Dr. Nishiyama
07-02-2011	Meeting	Air Liquide	Dr. Kemeling
08-02-2011	Meeting	Institute of Biomaterials & Bioengineering, Tokyo Medical and Dental University	Dr. Miyahara
09-02-2011	Meeting	Japan Association Medical Sciences (JAMS)	Mr. Takaku
10-02-2011	Meeting	Centre for Research and Development Strategy (CRDS)	Dr. Kawamura
10-02-2011	Meeting	Cabinet Office, Japan Government	Dr. Ing. Baba Ms. Inokuma
14-02-2011	Meeting	Research Institute nano-device and bio-systems, Hiroshima University	Prof. Kikkawa
14-02-2011	Tour	Phenitec Semiconductor Corporation	Various
14-02-2011	Tour	Tazmo Co. Ltd.	Various
15-02-2011	Tour	Rorze Co. Ltd.	Various
15-02-2011	Seminar	'Semiconductor Industry Japan – Netherlands'	Organized by Oost NV
16-02-2011	Tour	Panasonic Corporation	Various
17-02-2011	Meeting	Nanotechnology Business Creation Initiative (NBCI) and (National Institute Material Sciences) NIMS	Prof. dr. Takemura
17-02-2011	Meeting	Centre for Medical System Innovation (CMSI)	Various
18-02-2011	Conference	Nanotech Conference	Organized by nanotech executive committee
22-02-2011	Conference	CMSI Conference	Organized by CMSI
23-02-2011	Meeting	Technical Research Association FC Cubic	Mr. Yagi Mr. Kimijima
25-02-	Meeting	Department of Applied Chemistry, University of	Dr. Kudo

Date	Type	Institution/ department	Person
2011		Tokyo	
28-02-2011	Meeting	Department of Electrical Engineering Graduate School of Engineering University of Tokyo	Dr. Takagi
06-03-2011	Meeting	Final Meeting I2TA	Organized by I2TA
07-03-2011	Workshop	Special Workshop on Next Steps of TA activities in Japan: ´Knowledge exchange between I2TA Project and Rathenau Instituut´	Organized by I2TA
07-03-2011	Symposium	´How can Technology Assessment contribute to government policy and society in Japan?´	Organized by I2TA
08-03-2011	Conference	The 4th International Conference on Foresight – Foresight for future society: diversified development of activities –	Organized by NISTEP
09-03-2011	Meeting	Research Institute of Science and Technology for Society (RISTEX)	Mr. Saito
09-03-2011	Meeting	National Institute of Science and Technology Policy (NISTEP)	Mr. Terutaka Kuwahara Mr. Sotaro Ito Dr. Fumhiko Kakizaki Mr. Mitsuaki Hosono Ms. Asuka Hoshikoshi
10-03-2011	Meeting	Ministry of Education, Culture, Sports, Science and Technology (MEXT)	Mr. Toichi Sakata
11-03-2011	Conference	´Intelligence and Community Development for Evidence-based Science Technology and Innovation Policy Making in Japan and the Netherlands´	Organized by I2TA

Appendix 2: Working Session

The Working Session 'Technology Assessment for Nanotechnology was organized by The Netherlands Office of Science and Technology of the Netherlands Embassy in collaboration with The Rathenau Instituut, I2TA and Tokyo University. This working session took place on the 11th of March 2011 at The Netherlands Embassy in Tokyo. The program of the working session, existing of four presentations and two discussions, was as following:



08:45	-	09:00	Welcome, coffee and tea	
09:00	-	09:05	Opening of Workshop	Dr. Paul op den Brouw Netherlands Embassy
09:05	-	09:10	Tour de table	Introduction of participants
			Part 1 *Presentations*	*Speakers*
09:15	-	09:30	TA in Japan: Lessons from I2TA pilot projects on nanotechnologies	Dr. Tatsujiro Suzuki Cabinet Office
09:30	-	09:45	Nanotechnology and Technology Assessment in the Netherlands	Ir. Bart Walhout Rathenau Institute
09:45	-	10:00	R&D and Risk Management and Assessment of Nanomaterials in Japan	Dr. Masahiro Takemura NIMS, National Institute for Material Sciences
10:00	-	10:15	Structural biomaterials for skeletal tissue reconstruction through 3D shape control	Prof. Dr. Ung-il Chung / Yuichi Tei School of Engineering, University of Tokyo
10:15	-	10:35	Break	
			Part 2 *Discussion*	*Moderator*
10:35	-	11:05	Ensuring safety	Bart Walhout Rathenau Institute
11:05	-	11:35	Realizing the potential	Prof. Dr. Frans Brom Rathenau Institute
11:35	-	11:40	Closing	Dr. Paul op den Brouw

Appendix 3: List of Institutions

The table depicted below, shows a description of the institutions that have been visited during the project.

Name Institutes	Short Description
Cabinet Office, Japan Government	The Cabinet Office, government of Japan, assists the general strategic functions of the Cabinet by drafting plans. *Source: Cabinet Office, 2011.*
CDBIM, Centre for Disease Biology and Integrative Medicine, The University of Tokyo	The Centre for Disease Biology and Integrative Medicine, CDBIM, was established in April 2003. CDBIM covers a broad range of research topics in the mechanisms, prevention, and treatment of various disorders. CDBIM combines basic medical sciences, clinical medicine, and engineering, and aims to develop new integrated research fields in the 21st century. *Source: CDBIM, 2011*.
CMSI, Centre for Medical System Innovation	The Centre for Medical System Innovation, CMSI, of Tokyo University is a new education program aimed at nurturing and training leaders who promote innovation in the medical field from a global perspective. The program aims at integration of knowledge and experience at the individual level through practical curriculum including lectures on latest achievement in an interdisciplinary field involving medicine, engineering, and pharmaceutical sciences as well as lectures on social contribution studies, interdisciplinary hands-on training, long-term internship programs at companies and foreign universities, and case studies. *Source: CMSI, 2011.*
CRDS, Centre for Research and Development Strategy	Centre for Research and Development Strategy, CRDS, strives persistently to advance science and technology toward fulfilment of societal needs and realization of our vision of future society. The missions of CRDS are to promote dialogues between S&T policymakers and academia; survey S&T fields and draw their "bird's-eye view maps; select important R&D subjects to be funded by the Government, and investigate effective methods for performing R&D on the selected subjects; compare the technology levels of Japan with those of other counties, and propose R&D strategies that can contribute to realization of our vision of future society, enrichment of S&T base, and expansion of research frontier. *Source: CRDS, 2011.*
Fc Cubic, Technical Research Association	FC-Cubic was established in April 2005 as a research centre of AIST through strong demands

Name Institutes	Short Description
	from industries and a proposal by the ANRE of METI. FC-Cubic studies phenomena and mechanisms of electrochemical reaction, of material transportation in PEFC by using latest scientific methods. *Source: Fc Cubic, 2011.*
Hiroshima University, Research Institute nano-device and bio-systems	The Research Institute for Nano-device and Bio Systems was founded on May 1, 2008, aiming to develop the fundamental technologies necessary to achieve global excellence in electronic and bio integrated sciences for preventive medicine and ubiquitous diagnoses on early stages of illnesses in the future advanced medical-care society beyond the present information society. The research field includes Nano-integration, Integrated Systems, Molecular Bio-information and Nano-medicine. *Source: Hiroshima University, 2011.*
IBB, Institute of Biomaterials and Bioengineering, Tokyo Medical and Dental University	The Institute of Biomaterials and Bioengineering, IBB, was originally established in 1951 as the Research Institute of Dental Materials with the aim for development innovative dental devices and materials. Through the reorganization to the Institute for Medical and Dental Engineering in 1966, the Institute expanded into the present IBB in 1999. Since the establishment, IBB has been contributing to the development of biomaterials and medical devices as the international forerunner through harmonizing the engineering and technological science with medical and dental sciences. The IBB expands and deepens the basic science for biomaterials and bioengineering since April in 2004, leading to the development of applied science and technologies for the advanced medicine and dentistry. *Source: IBB, 2011.*
JAMS, Japan Association Medical Sciences	The Japanese Association of Medical Sciences, JAMS, began its activities in 1902 and was incorporated as an academic organ within the JMA in 1948. At present it comprises a total of 105 specialist Medical societies. The General Assembly of the Japan Medical Congress is held once every four years, constituting the largest medical congress of its kind in Japan, and brings together leading scientists in the fields of medicine and medical care. *Source: JAMS, 2011.*
MEXT, Ministry of Education, Culture, Sports, Science and Technology	The Science and Technology Policy Bureau of MEXT is responsible for the planning and drafting of basic science and technology policies. The Bureau is also responsible for the formulation of research programs and promotion of research

Name Institutes	Short Description
	evaluation, training of researchers and technicians, regional science and technology promotion, increasing the understanding of science and technology, the promotion of a comprehensive policy on international research exchange, and duties related to safety systems for experimental nuclear reactors and radioactive isotopes. *Source: MEXT, 2011.*
Nano Bio FIRST Project, Japan Science and Technology	The Nano Bio First project aims to establish a system for accurate diagnosis and treatment that realizes the provision of minimally invasive, seamless medical care from very early diagnosis to curative treatment of cancer and other intractable diseases. In order to reach this goal the project creates nano-bio devices that integrate the various functions of medical devices and drugs on a nano-scale, the project. This will eventually bring innovation to the medical system, enabling secure provision of high-quality, cost-effective medicines to anyone, anytime, and anywhere. In addition, Nano Bio First intends to be a global pioneer in establishing a new medical industry that leads the future of Japan and boosts Japan's international industrial competitiveness. *Source: Nano Bio First, 2011.*
NBCI, Nanotechnology Business Creation Initiative	Nanotechnology Business Creation Initiative, NBCI, is an industry-driven organization run on annual-membership-fees. Missions of NBCI are to create and advance business utilizing nanotechnology, to promote collaboration among different industry fields, among big enterprises and small-med companies, among industry, academia and government and to exchange up-to-date information of nano-business. *Source: NBCI, 2011.*
NISTEP, National Institute of Science and Technology Policy	NISTEP is a national research institution that was established under the direct jurisdiction of the Ministry of Education, Culture, Sports, Science and Technology, MEXT, to be engaged in the Japanese government's science and technology policy-planning process. It is expected to ascertain government needs, to collaborate and cooperate with government agencies, and to participate in the decision-making process. NISTEP has three missions. The first mission is to forecast future policy issues and investigate them through autonomous research. The other two missions are to carry out research in response to requests from government agencies and as a core institution in the science and technology policy research field

Name Institutes	Short Description
	and to provide data that forms the basis of research by other institutions and researchers in order to contribute to the accumulation and expansion of knowledge. *Source: NISTEP, 2011.*
Panasonic Corporation	Under the Panasonic brand and its slogan, "Panasonic ideas for life," Panasonic Corporation provides a wide range of products, from audio-visual and information/communication equipment to home appliances and components, as one of the largest electronic companies in the world today. The company aims to become the number one "Green Innovation Company" in the electronics industry. Source: Panasonic, 2011.
Phenitec Semiconductor Corporation	As a foundry company, Phenitec specializes in manufacturing semiconductor chips. PHENITEC is expanding its foundry business efficiently, through tie-ups with companies in and outside Japan, producing a wide range of products from discrete semiconductors to various ICs. Phenitec's chip manufacture facilities include 4", 5" and 6" lines, of which the 6" line started mass production in fiscal 2002. *Source: Phenitec, 2011.*
RISTEX, Research Institute of Science and Technology for Society	RISTEX is a part of Japan Science and Technology Agency, JST. While collaborating with a wide variety of stakeholders, RISTEX aims to bolster social systems and mechanisms which generate outcomes valuable to the public. In doing so, RISTEX's research and development, R&D, produce and utilize "know-how" such as evidence-based, scientifically-grounded data, methods, theories, models, policy proposals and tools-that contribute to solving social problems. *Source: RISTEX, 2011.*
Rorze Co. Ltd.	Rorze Co. Ltd. aims to manufacture products for serving the semiconductor and the flat panel display industry's needs. They have organized systems at Headquarters, FA centres and overseas affiliates in order to get the most out of each regions specific aspects. The company is positively collaborating with advanced global companies and affiliate groups in order to keep up with market trends in the semiconductor and flat panel industries. *Source: Rorze, 2011.*
Tazmo Co. Ltd.	Tazmo co. ltd. constantly strives for technological innovation to obtain the optimum combination of high technology and humanism. The company employs an unique technology to develop precision processing and fine mechatronics. This technology has been highly acclaimed both in Japan and overseas. They will continue our quest

Name Institutes	Short Description
	to create the ultimate in products as we maintain our commitment to technology for the good of people. Source: Tazmo, 2011.
TWMU, Tokyo Women's Medical University, Institute of Advanced Biomedical Engineering and Science	The Institute of Advanced Biomedical Engineering and Science was established in 2001 as a centre for biomedical engineering research aimed at improving medical care by advanced medical treatments that cross the boundaries of conventional fields. The Institute unites the concepts and technologies of science and engineering, including material science, electronics, mechanical engineering and its related disciplines with biological sciences such as cell biology, pharmacology, medicine and so on. *Source: TWMU, 2011.*
University of Tokyo, Department of Applied Chemistry	The mission of the Department of Applied Chemistry is to design substrates and to derive new functions that are useful for people and society. In our researches, we value originality and creativity. We always endeavour to create new concepts in various fields of chemistry, from pure to applied. *Source: University of Tokyo, 2011.*
University of Tokyo, Graduate School of Engineering	The School of Engineering is responsible for graduate level education in engineering. Faculty members also engage in research activities in their respective specialties while teaching graduate level courses. *Source: University of Tokyo, 2011.*

Who was Rathenau?

The Rathenau Instituut is named after Professor G.W. Rathenau (1911-1989), who was successively professor of experimental physics at the University of Amsterdam, director of the Philips Physics Laboratory in Eindhoven, and a member of the Scientific Advisory Council on Government Policy. He achieved national fame as chairman of the commission formed in 1978 to investigate the societal implications of micro-electronics. One of the commission's recommendations was that there should be ongoing and systematic monitoring of the societal significance of all technological advances. Rathenau's activities led to the foundation of the Netherlands Organization for Technology Assessment (NOTA) in 1986. On 2 June 1994, this organization was renamed 'the Rathenau Instituut'.