

Nanotechnology: Green Innovation

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Abstract: *Now a days, nanotechnology is one of the fastest growing technology, which is used in every field of day to day's life. Nanotechnology as defined by size is naturally very broad, including fields of science as diverse as surface science, organic chemistry, molecular biology, semiconductor physics, micro fabrication, etc. Nanotechnology may be able to create many new materials and devices with a vast range of applications, such as in medicine, electronics, biomaterials and energy production. On the other hand, nanotechnology raises many of the same issues as any new technology, including concerns about the toxicity and environmental impact of nanomaterials, and their potential effects on global economics. Green nanotechnology refers to the use of nanotechnology to enhance the environmental sustainability of processes producing negative externalities. It also refers to the use of the products of nanotechnology to enhance sustainability. It includes making green nano-products and using nano-products in support of sustainability. Green nanotechnology brings significant potential gains at environmental, societal and economic levels, but there are also potential risks and costs.*

Keywords: Cost, Green, Nanotechnology

1. Introduction

As green innovation is not yet clearly defined, there can be no clear definition of what nanotechnology for green innovation – green nanotechnology – should encompass. From published papers on the issue, one could describe green nanotechnology as a foundation for products and processes that are safe and have a low net environmental impact, being energy efficient, reducing waste, lessening greenhouse gas emissions and using renewable materials. Green nanotechnology can be seen as supporting the development of sustainable solutions to address global issues such as energy shortages and scarcity of clean water, and many other areas of environmental concern, and being present in environmentally-sustainable manufacturing processes. Green nanotechnology is linked to other concepts such as green chemistry and sustainable and green engineering and manufacturing. Green nanotechnology can have multiple roles and impacts across the whole value chain of a product and can be of an enabling nature, being used as a tool to further support technology or product development. Nanotechnology is increasingly being used for green applications in conjunction with other technologies and disciplines such as biology and life sciences, materials and environmental sciences and electronics and computing, leading to products that encompass multiple technological innovations. While green nanotechnology applications may save energy and reduce carbon emissions in the final product, there are concerns about the amount of energy that might be involved in the upstream production of component nanomaterial's [1].

With on-going research in the field, energy and manufacturing costs for nanomaterial production are likely to reduce over time as process technologies are improved and new materials emerge. Nonetheless, the energy, waste and resource extraction costs associated with the production of the materials used in green nanotechnology applications remain an important part of the equation in assuring the responsible development of green nanotechnology. As the overall field of nanotechnology raises concern about potential EHS risks, as well as ethical and social issues, this is no different for the green nanotechnology area. Concerns

are, for example, linked to potential EHS risks through the use and disposal of nanostructures employed in green nanotechnology applications [2]. Many recent and current nanotechnology EHS studies contain calls for further research and monitoring, e.g. for research into more biocompatible alternatives. Many national and international initiatives are also being developed in order to better understand those risks and to reduce uncertainties in the field.

2. Strategies for Green Innovation through Nanotechnology

In many countries, supports for green nanotechnology have been mainstreamed within more general efforts to 'green' the trajectory of the economy. Green nanotechnology operates in a complex landscape of fiscal and legislative policies and allied measures for green growth and for science, technology and innovation more generally. Framing conditions - such as regulation and standards, and research, environmental and enterprise policy – strongly influence the development of green nanotechnology for use in processes or products. Policy to support green nanotechnology includes significant R&D efforts that are increasingly applications orientated and driven by grand challenges. Policy interventions to share and diminish the risks inherent in the development and commercialization of applications involving green nanotechnology are resulting in the creation of innovative public-private collaborations. Efforts to ensure that nanotechnology is developed in a responsible manner are being supported through investment and there is a growing number of initiatives (at the national and international level) looking at environmental health and safety (EHS) and ethical and social issues. There are also initiatives aiming to ensure the environmental and economic sustainability of manufacturing processes involving nanotechnology.

2.1 From basic research to technology applications

The potential to commercialize nanotechnology for green innovation has become a particular focus of interest in recent years as nanotechnology research is beginning to be used in multiple concrete applications. With the growing potential of the technology, and in the face of urgent environmental

challenges, strategies and investment in nanotechnology have moved from being science-driven to being more application- and challenge-driven, focusing on how technologies, and nanotechnology in particular, could help to address some major national and global challenges. This challenge-driven tendency is apparent in both OECD countries and emerging economies [3]. The evolving policy landscape of most countries reflects a shift in focus from a concentration on funding basic research towards initiatives focused on improving the links between research and development for nanotechnology, for example stimulating technology transfer and demonstration projects. There is a direct link made between nanotechnology and its applications in the strategies of many governments, and, where significant levels of investments are being maintained, there is a tendency to move funding to more applied nanotechnology research.

2.2 Investment in environmental health and safety, ethical and social issues and sustainable manufacturing

Efforts to ensure the responsible development of nanotechnology are being made through a growing number of national and international initiatives looking at environmental health and safety (EHS) and ethical and social issues. While nanotechnology for green innovation is increasingly revealing its potential to enhance current technologies or create entirely new solutions, most of these innovations are still in the laboratory and very few products have reached the market to date. This is due to a number of factors, one being the economic costs which may be incurred in the use of nanotechnology for green innovation. For example, while the application of nanotechnology may save energy and reduce carbon emissions, significant amounts of energy may be involved in producing the component materials [4]. While energy and manufacturing costs are likely to reduce over time as process technologies using nanotechnology are improved and new materials emerge, it will be important to ensure that energy usage, gas emission and other environmental factors associated with the production of materials used in green nanotechnology applications are monitored. Some nanotechnology applications also raise EHS concerns related to the use and disposal of nanostructures which they employ. The environmental and safety costs of the technology are particularly important to look at when trying to develop and label commercial nanotechnology solutions as “green”. In response to these issues, governments are increasingly including the concept of responsible development in their nanotechnology policies and programmes. Such responsible development aims to stimulate the growth of nanotechnology applications in diverse sectors of the economy, while addressing the potential risks and the ethical and societal challenges the technology might raise. In 2012, the OECD Working Party on Nanotechnology launched a project to inventory activities in several OECD member and non-member countries relating to the responsible development of nanotechnology. Preliminary results of that work show that some countries (e.g. Germany, Korea) have dedicated policies for the responsible development of nanotechnology. Most of the countries responding to the questionnaire fund activities and programmes in the areas of Environmental, Health and Safety (EHS) and Ethical, Legal and Social Implications (ELSI). It was also largely recognized by the participating countries that advances in analyzing the

potential risks of using nanotechnology can help to reduce uncertainty, thereby encouraging the responsible application of nanotechnology-based innovation. Intergovernmental bodies, such as the OECD (in particular, the OECD Working Party on Manufactured Nanomaterials), the World Health Organization (WHO) and the Food and Agriculture Organization (FAO), are complementing these national and multi-national efforts with a number of programmes dedicated to the responsible development of nanotechnology. Organizations, such as the International Organization for Standardization (ISO), through its Technical Committee ISO TC229, are also contributing to the thinking around the development of frameworks for responsible development and to the development of standards in the area of nanotechnology.

There is also an increased focus on fostering greener manufacturing using nanomaterials, trying to strengthen the link between green nanotechnology, green chemistry and sustainable manufacturing. The United States EPA, for example, has a dedicated project looking at how energy consumption can be minimized and waste/pollution prevented in the manufacturing of nanomaterials and products. The OECD Working Party on Manufactured Nanomaterials also has a dedicated Steering Group on the Environmentally Sustainable Use of Manufactured Nanomaterials.

There are also networks of professionals and institutions engaged with issues such as green synthesis of nanomaterials and advanced manufacturing. The Sustainable Nanotechnology Organization (SNO) is a recently created non-profit, worldwide professional group of individuals and institutions. Its purpose is to provide a professional forum to advance knowledge of all aspects of sustainable nanotechnology, including both applications and implications. There are also numerous initiatives to address ethical, legal and social issues for nanotechnology development that base their work on the premise that societal buy-in and public awareness are key to the uptake of nanotechnology innovation. All these investments, programmes and initiatives aim to create a sufficient pool of knowledge to enable informed policy decisions on responsible and sustainable nanotechnology development, uptake and commercialization, balancing risks and societal, environmental and economic benefits.

2.3 Public – private collaborations: Fostering the transition of green nanotechnology from research to commercialization

For companies, investment in nanotechnology for green innovation can be costly and without guaranteed returns. Governments are seeking to mitigate these risks by fostering various types of public private collaborations to enhance the sharing of information, knowledge and resources to make the field advance more efficiently.

There is still a great hesitancy from the private sector to engage in green nanotechnology. This is due to a number of factors, such as the perception of the EHS and ELSI risks associated with the technology (also leading to issues of consumer acceptance), regulatory uncertainty, the lack of maturity of the technology, potential economic costs, market

uncertainty and strong competition with incumbent technologies. Nanotechnology often competes badly with existing technologies mainly for two reasons –cost competitiveness and familiarity. For example, Asian manufacturers produce large volumes of products at low cost and effectively out-price novel alternatives such as nano-based photovoltaic, the existing high-volume product being considered as “good enough”. All of these factors lead to an environment of uncertainty and a perception of high investment risk. The possibilities that nanotechnology can offer for green innovation to address some of the major environmental and social challenges have triggered a response from governments that involves trying to reduce risks and uncertainty for companies, thereby aiming to facilitate and accelerate the transfer of nanotechnology innovation to the marketplace. Policies are being put in place to help bridge the gap between research and the market. This market-driven approach includes direct investment in SMEs, for example, but also creating partnerships between governments and public entities and the private sector in order to bring together the resources needed.

2.4 Beyond green nanotechnology: Convergence of green technologies

An increasing trend in science, technology and innovation strategies is to consider nanotechnology not only on its own but in convergence with other technologies. At the recent OECD/NNI Symposium on Assessing the Economic Impact of Nanotechnology, it was noted that it is from the integration of different key enabling technologies that it is most likely that their anticipated potential will be achieved [5]. One example of policies for the integration of nanotechnology with other technologies can be found in the third phase (2011-2020) of the Korean nanotechnology strategy. It highlights strategies for nanotechnology convergence in energy and environmental areas in Korea, especially the convergence of nanotechnology with information technology, energy technology and biotechnology.

3. The Impact of Green Nanotechnology

There are significant potential markets for green nanotechnologies but very few products have been commercialized to date. It is expected that the contribution of nanotechnology will be significant but that one or two more decades might be needed to fully realize the market potential of green nanotechnology. In the process of producing and using green nanotechnology products, in addition to direct impacts, there are likely to be a series of indirect effects, including spillovers to third parties and other impacts on supply chains, impacts on the environment and energy usage. The costs associated with the application of green nanotechnologies need to be offset against their beneficial impacts, taking into account such factors as the timing and distribution of various benefits and costs, interest rates, opportunity costs, and the relative advantages of green nanotechnologies compared with conventional applications.

Not all of the benefits and costs will be easily measurable. As the technology is being developed, greater efforts are being made to find ways of assessing or tracking the impact of nanotechnology on specific policy objectives such as green growth. This is a very challenging task. Methodologies

being considered for use in assessing the impact of green nanotechnology need to value the full range of potential impacts - economic, environmental and societal implications - which the technology might provide. The risks of using new green nanotechnologies need to be considered relative to the risks in using current technologies (which may be highly energy intensive, use toxic materials or have negative environmental impacts) and valued against the human and environmental costs of not effectively addressing key global challenges.

3.1 General Challenges in Assessing the Impact of Nanotechnology

Some of the numerous issues which make assessing the impact of nanotechnology difficult include the following:

1. There are no conventional definitions or classifications for nanotechnology, nor definitions of a nanotechnology product, a nanotechnology process or a nanotechnology company. It is in general not clear to what extent organizations, such as companies, universities and research institutions, are involved in exploiting and developing nanotechnology. Definitions are central to understanding the nature of the contribution of nanotechnology and to enable in data collection;
2. Measuring the impact of nanotechnology is made more complex by its multipurpose nature.
3. Nanotechnology can be fundamental to a product and give it its key functionality, or it can be ancillary to the value chain and constitute a small percentage of a final product; or it may not even be present in the final product, only affecting the process leading to its production. For a complete impact assessment it is necessary to look not only at the final product containing nanotechnology but also the potential impact of nanotechnology all along the value chain;
4. The sheer number of applications of nanotechnologies across all technology sectors, and their enabling nature, creates a complex and fractured landscape for analysis;
5. Gathering information from industry can be difficult because of sensitivity surrounding nanotechnology products.

3.2 Factors to be Considered in Valuing Green Nanotechnology

Simple analyses of the economic contribution of green nanotechnologies would consider the net costs of technological development and market entry relative to the value of the outputs and outcomes achieved, taking into account considerations of time and perspective. The net costs include such inputs as public R&D investment, knowledge development costs and the costs of facilities, private industry R&D costs and the cost of prototyping, testing, commercialization, production and marketing. The outputs from such expenditures can include contributions to scientific and other knowledge, development of generic or specific technologies, creation and use of intellectual property (including patents and licenses), the development of standards and the spin-off and start-up of new companies. These outputs can have intermediate economic value but the clearest economic impacts are through outcomes such as profitable sales from new products, increased productivity

and other process improvements, cost savings, employment and wage generation, taxation and benefits to consumers and users [6]. These outcomes can lead to developmental and public benefits including contributions to national and regional gross domestic product, improved competitiveness and balance of trade and environmental and other societal benefits.

There can also be strategic benefits in the use of nanomaterials, for example to reduce reliance on rare metals and materials sourced from overseas locations. However, the relative weight of benefits and costs of a new technology may vary according to whether the perspective is that of a producer, competitor, customer, worker, industry, region, or country.

4. Future Scope

An increasing trend in science, technology and innovation strategies is to consider nanotechnology not only on its own but in convergence with other technologies wastewater treatment. At the recent, it was noted that it is from the integration of different key enabling technologies that it is most likely that their anticipated potential will be achieved.

5. Conclusion

In this way we can conclude that, green innovation is innovation which reduces environmental impacts: by increasing energy efficiency, by reducing waste or greenhouse gas emissions and/or by minimizing the consumption of non-renewable raw materials. The potential of nanotechnology to support green growth, focusing on two particular aspects: *i)* the potential for nanotechnology to contribute to green innovation; and *ii)* the potential and perceived risks and environmental costs of using the technology. The second of these may reduce the ability of nanotechnology to achieve its green goals, i.e. to meet its "green vocation"

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