Pathways to SDG: Macro to Micro Perspectives

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Nanoscience and Nanotechnology: The role of these new sunrise industries for SDG attainment

Conference on Technology, Innovation and Governance for attainment of the SDGs

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Key questions

- RQ 1: Whether nanotechnology can help address the challenges of improving global sustainability and attainment of SDGs? If so, how?

- RQ 2: Can nanotechnology be developed in a sustainable and responsible manner?

- RQ 3: Are we on the right trajectory of nanotechnology development with respect to sustainability?

- RQ 4: How the emergence and orientation of the innovation ecosystem around nanotechnology could be guided towards attainment of SDGs?
RQ 1: Whether nanotechnology can help address the challenges of improving global sustainability and attainment of SDGs?

*Planetary boundaries* - estimating a safe operating space for humanity with respect to the functioning of the Earth System

Nanotechnology has the potential to address each of these areas of global sustainability, where metrics could be developed to quantify the impact of, for example, the ability of nanotechnology to ameliorate a critical value of one or more control variables for the planetary boundaries, such as carbon dioxide concentration (Diallo & Brinker, 2011)
RQ 1: How can nanotechnology help address the challenges of improving global sustainability and attainment of SDGs?

Nanotechnology

- SDG 1: No poverty
- SDG 2: Zero hunger (grow, process, store, and distribute food)
- SDG 3: Good health & well-being
- SDG 4: Quality education
- SDG 5: Gender equality
- SDG 6: Clean water & sanitation (water treatment, desalination, and reuse)
- SDG 7: Affordable & clean energy (Clean energy technologies)
- SDG 8: Decent work & economic growth
- SDG 9: Industry, innovation & infrastructure (green manufacturing and chemistry in the semiconductor, chemical, petrochemical, materials processing, pharmaceutical etc.)
- SDG 10: Reduced inequalities
- SDG 11: Sustainable cities & communities (sustainable habitats & transportation)
- SDG 12: Responsible consumption & production (Sustainable utilization and supply of critical materials)
- SDG 13: Climate action (NT based CO2 separation technologies)
- SDG 14: Life below water
- SDG 15: Life on land
- SDG 16: Peace, justice & strong institutions
- SDG 17: Partnerships for the goals
Sustainable water supply: NT-based solutions in the areas of water treatment, desalination, and reuse (Savage and Diallo 2005; Hilie et al. 2006; OECD 2008; Shannon et al. 2008; National Research Council 2008).

Food Security and Sustainability: NT developments resulting in improvements in the technologies used to grow, process, store, and distribute food (Traver 2006; Srinivas et al. 2009; FAO/WHO (2010); House of Lords 2010).

Sustainable Habitats: Producing key zero energy buildings components, including super-insulating aerogels, and more efficient solid-state lighting and heating systems.

Sustainable Transportation: Carbon nanotube polymer nanocomposites (PNCs) and clay PNCs provide clear opportunities for significantly improved new vehicle materials that are 10 times stronger than steel, but a fraction of the weight (NNI 2000; Coleman et al. 2006; Kotov et al. 2007).

Sustainable Mineral Extraction and Use: Nanoscale supramolecular hosts that can serve as high-capacity, selective, and recyclable ligands and sorbents for extracting valuable metal ions from solutions and mixtures (Gillett 2002; Tomalia et al. 2007; Diallo et al. 2008).

Sustainable Manufacturing: NT is emerging as an enabling platform for green manufacturing in the semiconductor, chemical, petrochemical, materials processing, pharmaceutical, and many other industries (Schmidt 2007).

Clean Environment: Advanced monitoring and detection concepts, devices, and systems for various environmental contaminants (Fan et al. 2004; Vaseashta and Dimova-Malinovska 2005; Rickerby and Morisson 2007; Wang et al. 2008; Aravinda et al. 2009); efficient and cost-effective waste treatment and environmental remediation technologies (Savage and Diallo 2005; Tratnyek and Johnson 2006).


Sustaining Biodiversity: Advanced sensors and devices for monitoring ecosystem health, monitoring and tracking animal migration in terrestrial and marine ecosystems; application of nanotechnology to biodiversity has received little attention (Global Biodiversity Sub-Committee, 2009).
RQ 2: Can nanotechnology be developed in a sustainable and responsible manner?

Effective governance of nanotechnology can be achieved through a “proactive and adaptive framework, with a high level of interaction between those who develop, manufacture, sell and regulate NT-based products, as well as representatives of civil society and which addresses trans boundary issues.” (Widmer et al. 2010)

Although there might be a focus by the government to promote research aimed at solving societal problems in their funding programmes, there is still a gap between the amount of funding needed and the amount being provided to conduct problem-oriented and trans-disciplinary research with stakeholder participation.

Also, markets are typically not suitable to take into account societal needs or ethical concerns as it is difficult to internalise such externalities and translate them immediately into prices due to complex causalities.

RRI: A transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (von Schomberg, 2011)

Source: Anand 2016
Korea and China display specialization in NT & IT, with Japan also showing specialization in the latter field. However, they are yet to prove superiority in biotechnology.

USA and India demonstrate specialization in BT, with the potential of gaining technological expertise in NT.

The primary focus in these three technology platforms is devising a solution to global issues relevant to sustainable growth and materializing productivity boosts in different sectors.
RQ 3: Are we on the right trajectory of nanotechnology development with respect to sustainability?

Distribution of nanotechnology projects supported by DST across basic and applied research/product development and other areas

The bulk of the projects in the area of synthesis, characterization, processing which help to develop an understanding of the unique properties of nanostructured materials
Initially the projects supported had no particular sectoral orientation, but increasingly they are focused on the health sector and environment (SDGs 3, 6, 7).

Sector-wise distribution of application oriented R&D projects in nanotechnology supported by DST

Source: Anand 2016
### Actors, Knowledge and Innovation Networks in Nanotechnology in India

<table>
<thead>
<tr>
<th>Sectors</th>
<th>Partner types/ Focal system builder</th>
<th>Nature of linkages</th>
<th>Location of linkages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Textile</td>
<td>Research institute, Industry</td>
<td>Scaling-up</td>
<td>Non-local domestic firm</td>
</tr>
<tr>
<td>Textile</td>
<td>Academia, industry, government</td>
<td>Research work, analytical services, commercialization</td>
<td>Local &amp; non-local domestic firm, MNCs located locally</td>
</tr>
<tr>
<td>Energy</td>
<td>Academia, government, industry</td>
<td>Research &amp; technology development</td>
<td>Non-local domestic firm</td>
</tr>
<tr>
<td>Energy</td>
<td>Industry</td>
<td>Component supplier, scaling-up</td>
<td>MNC outside the country, domestic firm</td>
</tr>
<tr>
<td>Water</td>
<td>Research institute, industry, NGO</td>
<td>Manufacturing, risk assessment</td>
<td>Local domestic firm</td>
</tr>
<tr>
<td>Health</td>
<td>Research institute, industry</td>
<td>Joint research centre, research &amp; technology development</td>
<td>Local domestic firm</td>
</tr>
<tr>
<td>Health</td>
<td>Research institute, industry, government</td>
<td>Product development, toxicology work, clinical trials</td>
<td>Local domestic firm</td>
</tr>
<tr>
<td>Health</td>
<td>Academia, industry</td>
<td>Technology development &amp; transfer</td>
<td>Local &amp; non-local domestic firm</td>
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<tr>
<td>Health</td>
<td>Academia, industry</td>
<td>Technology development &amp; transfer, prototype development, commercialization</td>
<td>Non-local MNC in the country</td>
</tr>
<tr>
<td>Health</td>
<td>Industry, knowledge partners (research institute etc.), commercial vendors</td>
<td>Contract research, targeted solutions, devices development, commercialization</td>
<td>Local &amp; non-local domestic firm, Firm outside the country</td>
</tr>
<tr>
<td>Health</td>
<td>Research institute, academia</td>
<td>Product development, efficiency improvement</td>
<td>Non-local research laboratory</td>
</tr>
<tr>
<td>Health</td>
<td>Industry</td>
<td>Manufacturing, marketing</td>
<td>MNC outside the country, domestic firm</td>
</tr>
<tr>
<td>Miscellaneous (Instrumentation)</td>
<td>Research institute, Industry</td>
<td>Provision of equipment, joint research laboratory</td>
<td>MNC outside the country</td>
</tr>
<tr>
<td>Miscellaneous (Instrumentation, research, water)</td>
<td>Academia, industry, government</td>
<td>Joint research work, analytical services, integrating specialized skills, human resource development, technology development &amp; transfer, prototype development, commercialization</td>
<td>Local &amp; non-local domestic firm</td>
</tr>
<tr>
<td>Miscellaneous (Automotive)</td>
<td>Academia, industry, government</td>
<td>Resources mobilization, integrating specialized skills, technology development</td>
<td>Non-local domestic firm</td>
</tr>
</tbody>
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*Source: Anand 2016*
RQ 4: How the emergence and orientation of the innovation ecosystem around nanotechnology could be guided towards attainment of SDGs?

- Governance framework - Connecting global technologies to the local needs; anticipatory governance for emergent nanotechnology (Barben et al. 2007, Guston 2008)

- Performing interdisciplinary research – scientific cultural change, making suitable institutional arrangements…

- Assessment of the impacts to human health, environment, livelihoods, gender, traditional technologies

- Bringing different stakeholders together – creating ‘trading zones’ (Galison 1996)

- Capacity factor approach - Assessing community resource levels and technology management levels: institutional, human resources, technical, economic/financial, environmental/natural resources, energy, socio-cultural, services (Garrick Louis)
RQ 4: How the emergence and orientation of the innovation ecosystem around nanotechnology could be guided towards attainment of SDGs?

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- Ticking all the right boxes for an emerging technology to address one of the SDGs, but a complete failure in the local market
- Contradictory narratives emerge along two complexly related axes of the market and of technology
- Need for a trading zone as scientists/technologist, entrepreneur, users come from different cultures/frames
- Need to treat capacity factors as a boundary object rather than a rational, quantitative solution into which the local problem must be fit
- Understanding innovation-technology-obsolescence link and renegotiating the meanings and processes of innovation
Key findings

- Collective action of complementary actors and institutions of innovation system and their capabilities might be crucial in the build-up of new technological fields.

- Convergent action across floors (such as, laboratory, policy, production site, etc.), different stages of the research and innovation process, range of actors across spatial scales, and disciplines enabling effective translation of concepts and meanings from one floor to another, and from one discipline to another, will be crucial for nanotechnology to address SDGs.

- Innovation system is fraught with the challenge of a lack of long-term and transparent strategy or roadmap to effectively engage with this emergent technology.

- Pre-existing capabilities and research focus areas of S&T organizations is an important factor to engage in different application areas of nanotechnology and consequently in their ability to contribute towards SDGs.

- Development of institutional mechanism of knowledge transfer in S&T institutes should be preceded by efforts to strengthen the S&T capabilities of these institutes.

- The innovation system framework needs to incorporate a wider set of actors such as global, informal, user and social.

- Instead of focusing on the firm as a driving force, a focus on non-firm actors such as the community of practice, user, public sector, and the individual is important.

- National policies on science, technology, and innovation also need to be international in orientation.

- International linkages of nanotechnology innovation system indicate orientation towards global North with little attention to technologies that could address societal challenges of developing countries; need more of South-South linkages.

- Government spending is significantly important for nanotechnology development, however, a better re-alignment and functioning of existing capabilities and addressing knowledge, skills and institutional capability gaps, will help address SDGs.

- Appropriate focus on technological benefits as well as addressing issues of environmental, socio-economic, and ethical impacts as well as the accompanying regulatory and governance challenges is imperative.