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NANO2ALL
SOCIETAL ENGAGEMENT ON RESPONSIBLE NANOTECHNOLOGY

# Current RRI in Nano Landscape Report

Deliverable 2.1.

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# Introduction

This report has been developed as part of the **Nano2All** (*Nanotechnology Mutual Learning Action Plan for Transparent and Responsible Understanding of Science and Technology*) project, which receives funding from the European Union Horizon 2020 programme, under Grant Agreement number 685931. This report represents Deliverable 2.1 of Work Package 2 – Developing a Common Understanding and has been elaborated by members of SPI, UNINOVA, EMRS, EUSJA, CERTH, ViLabs, and JRC under the directions of SYSTASI Consulting and Malsch TechnoValuation. The overall objective of WP2 has been to explore the current nanotechnologies and Responsible Research and Innovation (RRI) landscape at EU and international level, as well as ensure that the elaboration of the training modules will be based upon the latest information and methodologies available at European and International levels.

The current report aims to provide concise and up-to-date information on how the EU and its Member States deal with nanotechnologies from policy, research and societal engagement perspectives. Additionally, the report identifies and presents the national and international dialogue activities currently conducted with respect to RRI and Nanotechnologies, and provides an overall discussion about the activities that are currently promoted by the EU as well as international organisations on RRI and nanotechnologies.

In terms of structure:

The first chapter aims to set the scene by providing definitions and describing concepts relevant to nano-related RRI, such as the concept of nanotechnologies, RRI, societal engagement, the co-production of knowledge, research integrity, etc. as well as presenting the key stakeholders.

The second chapter discusses the current European and international landscape with respect to RRI in nanotechnologies. The aim has been to identify how the policy landscape on European level has evolved and integrated RRI; what RRI elements are to be found in current European and (selected) Member States nano-policies; how non-European countries and international organisations deal with RRI from a nanotechnologies perspective and the kind of international developments that should be taken into consideration.

The third chapter discusses stakeholders' approach towards RRI. In particular, the chapter explores how the stakeholders' perceptions on nano and RRI on European and international level, as reported by different projects/studies/articles/etc., have been identified to be formulated around nano-RRI issues.

The four chapter aims to explore the future of nanotechnologies, as well as initiate a "discussion" on the potential impacts that could be anticipated from these developments, particularly from a public trust and perception point of view.

The final chapter of the report summarizes the key findings and concludes on the issues that have been sufficiently discussed in the literature, identities the issues that need further research in the future, what the latest additions are

in the RRI-nano-agenda on EU and on EU and international level and what remains to be done with respect to RRI in the nanotechnologies area. This particular chapter is anticipated to serve as input to the next phases of the **Nano2All** project and in particular in the development of the training materials and the Dialogues.

# Chapter 1: Setting the Scene

# 1. Setting the Scene

## 1.1. Key concepts and definitions

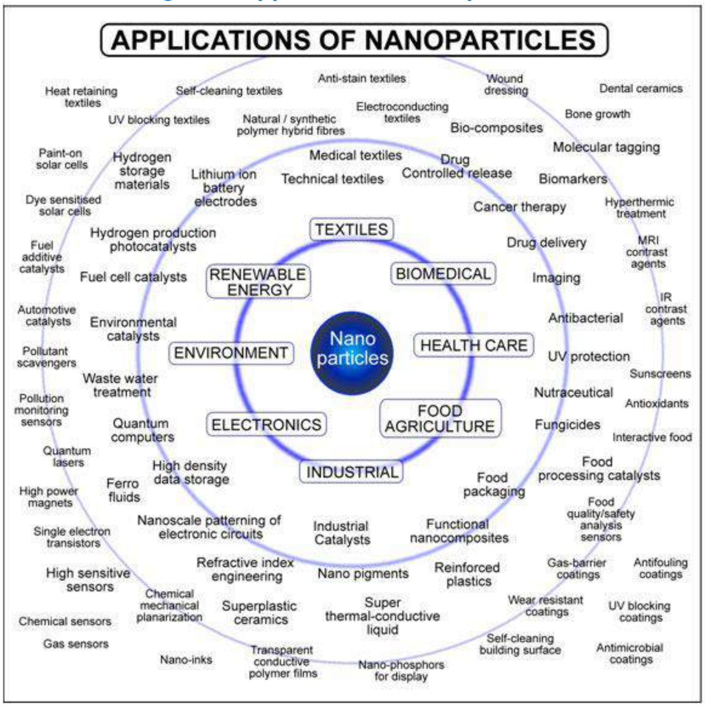
### 1. NANOTECHNOLOGIES

Most formal definitions of nanotechnology or nanotechnologies[1] revolve around the ***study and control of phenomena and materials at length scales below 100 nm, whereas informal definitions almost always make a comparison with a human hair, which is about 80,000 nm wide*** (Nature Nanotechnology, 2006)***.***

***At policy level,*** Nanotechnology is considered one of the Key Enabling Technologies identified by the European Commission as "***an umbrella term that covers the design, characterisation, production and application of structures, devices and systems by controlling shape and size at nanometre scale*"** (EC, 2013a).

Potential **applications** of Nanotechnology involve a wide range of sectors, such as Healthcare, Food, Agriculture, Environment, Energy and Industrial applications, as the image below depicts:

Figure 1 Application of Nanoparticles




*Source: Nanowerk: Nanotechnology Applications (*[http://www.nanowerk.com/nanotechnology-applications.php](http://www.nanowerk.com/nanotechnology-applications.php))

The Nanotechnologies, Advanced Materials and Production (NMP) area is delineated as follows (EC, 2012a):

- **Nanosciences and nanotechnologies** – studying phenomena and manipulation of matter at the nanoscale and developing nanotechnologies leading to the manufacturing of new products and services.

[1] In this report, the terms Nanotechnology and Nanotechnologies are used interchangeably.

- **(Advanced) Materials** – using the knowledge of nanotechnologies and biotechnologies for new products and processes.
- **New production** – creating conditions for continuous innovation and for developing generic production "assets" (technologies, organisation and production facilities as well as human resources), while meeting safety and environmental requirements.
- **Integration of (NMP) technologies for industrial applications** – focussing on new technologies, materials and applications to address the needs identified by the different European technology platforms.

## 2. RESPONSIBLE RESEARCH & INNOVATION (RRI)

As stated in a key European Commission report from 2012, ***"... RRI … is defined as: a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society)"*** (EC, 2012b). It means that societal actors work together during the whole research and innovation process in order to better align both the process and its outcomes with the values, needs and expectations of European society. Thus, it is an on-going process assuming equilibrium between values, needs and expectations (Karatzas, 2015). The notion of RRI is routed in the field of technology assessment (TA), which included some of the main ideas behind responsible innovation; and based on the TA tradition responsible innovation may be characterized as a broadened extension of technology assessment complemented by ethics and STS (Grunwald, 2011).

The RRI framework consists of six dimensions (EC, 2012c):

1. Public engagement: This dimension refers to the encouragement of participation of a wide range of stakeholders in shaping the future research landscape through collaboration and the development of new pathways of social interaction.

2. Gender equality: This dimension involves the integration of the gender element in stakeholders' strategies and policy decisions.

3. Science education: According to this dimension, scientific methods and tools – as well as the "language" for communicating scientific knowledge – need to become essential elements of the education system.

4. Open access: Good science is open science. Thus, an increase in the accessibility to scientific research methods, as well as scientific results, is anticipated to hold significant benefits for future research and innovation.

5. Ethics: This dimension refers to the need to integrate ethical standards in research and innovation design and methodology in a canonical manner, so as not to be considered a hindering factor.

6. Governance: Appropriate governance models for research and innovation must ensure that all other five dimensions are integrated in strategies, policies and research and innovation design.

## 2a. RRI INITIATIVES

### European Union

In terms of nanotechnologies and RRI, the most recent developments in the area go back to 2009 when the European Commission adopted the **Code of Conduct for Responsible Nanosciences and Nanotechnologies Research**. This Code of Conduct provides Member States, employers, research funders, researchers, and more generally all individuals and civil society organisations involved or interested in nanosciences and nanotechnologies (N&N) research ("all stakeholders") with guidelines favouring a responsible and open approach to N&N research in the Community (EC, 2009). Its key principles are:

1. Meaning
2. Sustainability
3. Precaution
4. Inclusiveness
5. Excellence
6. Innovation
7. Accountability

A year before that (2008), the **Responsible Nano Code for business** (Royal Society, 2008) was developed with the aim of exploring how RRI in nanotechnologies research can be supported by companies in Europe, the U.S. and Asia. Its purpose is to establish a consensus of good practices in the production, retail and disposal of products using nanotechnologies and to offer guidance on what organisations can do in order to provide responsible governance of this dynamic area of technology. Its key principles are:

1. Board Accountability
2. Stakeholder Involvement
3. Worker Health and Safety
4. Public Health, Safety and Environmental Risks
5. Wider Social, Environmental, Health and Ethical Implications and Impacts
6. Engaging with Business Partners
7. Transparency and Disclosure

### USA

A noteworthy nanotechnology initiative in the USA is the **National Nanotechnology Initiative (NNI)**, a government research and development enterprise involving departments and independent agencies working together toward the shared vision of *"…a future in which the ability to understand and control matter at the nanoscale leads to a revolution in technology and industry that benefits society"*[2]. One of the key goals of the NNI is **the responsible development of nanotechnology**. The NNI is committed to fostering the development of a community of experts on ethical, legal, and societal issues (ELSI) related to nanotechnology and to building collaborations among ELSI communities, such as consumers, engineers, ethicists, manufacturers, non-governmental organisations, regulators, and scientists. These stakeholder groups will consider potential benefits and risks of research breakthroughs and provide their perspectives on new research directions.

[2] http://www.nano.gov/about-nni

An additional USA RRI-focused initiative pertinent to nanotechnology is the **Project on Emerging Nanotechnologies**[3]. Initiated in 2005, the Project is dedicated to helping ensure that as nanotechnologies advance, possible risks are minimized; public and consumer engagement remains strong; and the potential benefits of these new technologies are realized. The Project on emerging nanotechnologies brings together researchers, government, industry, non-governmental organisations/civil society organisations[4], policymakers, and others, to look long-term, to identify gaps in knowledge and regulatory processes, and to develop strategies, respectively. Via the project, various reports and events regarding ethical and societal issues and the topic of responsible research have been created.

## 3. RRI & TRANSPARENCY

Transparency is a key subject across RRI literature and initiatives; and as stated in a recent report "*Openness and transparency is the underpinning principle of Responsible Research and Innovation*" (Sutcliffe, 2011). According to the RRI Tools project, *Transparency* can be paraphrased as 'meaningful openness', since insight into process structure, agenda-setting and outcomes also needs to make sense in the context of the content and the process at hand. Adaptive change describes how an RRI process must not only allow for learning on content and procedures, but must leave room for actors and organisations to adapt in accordance with such learning (RRI Tools).

The **Code of Conduct for Responsible Nanosciences and Nanotechnologies** focuses on transparency and openness of information. Principle 4, titled 'Inclusiveness', suggests that, "*Governance of N&N research activities should be guided by the principles of openness to all stakeholders, transparency and respect for the legitimate right of access to information*" (EC, 2009). Principle 7 – Transparency and Disclosure – of the **Responsible Nano Code** (Royal Society, 2008) suggests that, *"Each organisation shall be open and transparent about its involvement with and management of nanotechnologies and report regularly and clearly on how it implements the Responsible Nano Code."*

## 4. SOCIETAL ENGAGEMENT

One of the key dimensions of Responsible Research and Innovation is **Public Engagement,** which refers to **co-creating the future by bringing together the widest possible diversity of actors,** including researchers and innovators, industry and SMEs, policymakers, non-governmental organisations, civil society organisations and citizens, **that would not normally interact with each other on matters of science and technology** (European Commission, H2020).

According to the outcomes of a recent conference on Public Engagement and RRI in 2014 (Castellani, 2014), Public Engagement implies a two-way, iterative, inclusive and participatory process of multi-actor exchanges and dialogues. In research and innovation, public engagement fosters more societally relevant, desirable, and

[3] http://www.nanotechproject.org/about/mission/

[4] Civil society organisations are considered to be any legal entity that is non governmental, not-for-profit, not representing commercial interests, and pursuing a common purpose in the public interest

creative research and innovation actions and policy agenda, leading to wider acceptability of science and technology outcomes[5].

## 5. CO-PRODUCTION OF KNOWLEDGE

**In co-production of knowledge, scientific knowledge is produced in an integral process that involves both the scientific method and the social context**. The concept of co-production challenges the traditional scientific models, which do not take into consideration the social context, while constantly rejecting all *a priori* demarcations. Therefore, it places demands on both the research scientists as well as the stakeholders involved to rethink the *modus operandi* in traditional science research processes (Flood, 2014). And, most importantly it acknowledges that "*…lived "reality" is made up of complex linkages among the cognitive, the material, the normative and the social – and that understanding these links is indispensable to meaningful projects of social theory and prescriptive analysis*" (Jasanoff, 2004).

This concept has been embraced by the European Commission, as stated in the **Code of Conduct for Responsible Nanosciences and Nanotechnologies** (Royal Society, 2008) **fourth principle** (Inclusiveness), which suggests that governance of nanotechnologies research activities should allow the participation in decision-making processes of all stakeholders involved in or concerned by N&N research activities.

## 6. RESEARCH INTEGRITY

On a global level, there is no universally accepted definition of Research Integrity. Yet, the principles incorporated in relating documents, such as the *Singapore Statement on Research Integrity*[6], the *European Code of Conduct for Research Integrity* (ALLEA, 2011), the *Montreal Statement on Research Integrity*[7] and the *Global Research Council Statement of Principles on Research Integrity*[8], are similar in intent, but not identical in their content. **Overall, Research Integrity relates to the performance of research to the highest standards of professionalism and rigour, in an ethically robust manner and can be defined as the trustworthiness of research due to the soundness of its methods and the honesty and accuracy of its presentation**[9].

On European level, the *European Code of Conduct for Research Integrity* (ALLEA, 2011) states that Researchers, Research institutes, Universities, Academies and Funding organisations need to commit themselves to observing and to promoting the *principles* of **Research Integrity**, which are:

1. Honesty in reporting and communicating
2. Reliability in performing research
3. Objectivity
4. Impartiality and independence
5. Openness and accessibility

[5] https://ec.europa.eu/programmes/horizon2020/en/h2020-section/public-engagement-responsible-research-and-innovation
[6] http://www.singaporestatement.org
[7] http://www.researchintegrity.org/Statements/Montreal%20Statement%20English.pdf
[8] http://www.globalresearchcouncil.org/statement-principles-research-integrity
[9] The Singapore Statement on Research Integrity was developed as part of the 2nd World Conference on Research Integrity, 21-24 July 2010, in Singapore, as a global guide to the responsible conduct of research. It is not a regulatory document and does not represent the official policies of the countries and organisations that funded and/or participated in the Conference. For official policies, guidance, and regulations relating to research integrity, appropriate national bodies and organisations should be consulted. Available at: www.singaporestatement.org.

6. Duty of care
7. Fairness in providing references and giving credit
8. Responsibility for future science generations.

## 7. RESEARCH ETHICS

**The Conduct of Ethical Research implies the application of fundamental ethical principles to scientific research**. Despite its significance, ethics is often misunderstood by researchers as hindering scientific progress. While it is true that research **ethics intends to put boundaries to what is and is not possible** (under a certain perspective); yet **it does not intend to regulate research or go against research freedom** (EC, 2013b).

Ethical codes and guidelines are a means of establishing and articulating the values of a particular institution or society together with the obligations that it expects people engaged in certain practices to abide by (EC, 2010a). The relationship between codes, ethical practice and the law is complex; however, we should not assume that ethical evaluations can simply be a matter of 'applying' codes or laws. This is because:

1) codes and laws are general and thus often fail to provide clear guidance in complex specific cases. Often judgement is required, and what is legal may depend on the judgement of a research ethics committee;
2) codes and the law are silent about many research practices, aiming to rule out certain very unethical behaviours but not to give comprehensive ethical advice;
3) the contents of particular guidelines may be controversial and/or contradictory (internally or with other guidelines); and
4) even where the law or code is clear, it may not be ethically correct – for example research practices in Nazi Germany may have been legal but were clearly immoral.

The European Commission (EC, 2012c) introduces ethics as a Responsible Research and Innovation key in the following way:

***European society is based on shared values. In order to adequately respond to societal challenges, research and innovation must respect fundamental rights and the highest ethical standards. Beyond the mandatory legal aspects, this aims to ensure increased societal relevance and acceptability of research and innovation outcomes. Ethics should not be perceived as a constraint on research and innovation, but rather as a way of ensuring high-quality results.***

### 7A. ETHICS AND NANO

According to the report *Nanotechnology: Social and Ethical Issues (*Sandler, 2009), "...*the goal for any emerging technology is to contribute to human flourishing in socially just and environmentally sustainable ways.*" Given this, the role of ethics within responsible development of nanotechnology includes:

- elucidating what constitutes justice, human flourishing and sustainability;
- identifying opportunities for nanotechnology to accomplish the goal and anticipating impediments to its doing so;

- developing standards for assessing prospective nanotechnologies;
- providing ethical capacity (i.e., tools and resources that assist individuals and organisations to make ethically informed decisions) to enable society to adapt effectively to emerging nanotechnologies; and
- identifying limits on how the goal ought to be pursued.

### 7B. TYPES OF ETHICAL ISSUES RELATED TO NANOTECHNOLOGY RESEARCH

According to the aforementioned report *(*Sandler, 2009), the types of ethical issues which could emerge from research in nanotechnologies involve:

- **Social Context Issues**: Social context issues arise from the interaction of nanotechnologies with problematic features of the social or institutional contexts into which the nanotechnologies are emerging.
- **Contested Moral Issues**: Contested moral issues arise from nanotechnologies interaction with or instantiation of morally controversial practices or activities.
- **Technoculture Issues**: Technoculture issues arise from problematic aspects of the role of technology within the social systems and structures from which, and into which, nanotechnologies are emerging.
- **Form of Life Issues**: Form of life issues arise from nanotechnologies synergistic impacts on aspects of the human situation on which social standards, practices and institutions are predicated.
- **Transformational Issues:** Transformational issues arise from nanotechnologies potential (particularly in combination with other emerging technologies, such as biotechnology, information technology, computer science, cognitive science and robotics) to transform aspects of the human situation.

### 7C. GENERAL DEVELOPMENTS IN RESPONSIBLE RESEARCH AND INNOVATION

Beyond the realm of nanosciences and nanotechnologies, discussions have been held on science ethics and responsible research and innovation in general. This includes issues inherent in the scientific community, such as research integrity, biomedical ethics – for example using human embryonic stem cells, informed consent, the treatment of human subjects and animal testing, privacy, and impacts of research in developing countries. It also includes issues related to the impacts of research outcomes on society and the environment, including Environmental, Health and Safety aspects, dual use aspects, sustainability, etc. The recent report by the InterAcademy Partnership “Doing Global Science” (IAP, 2016) gives a clear overview of current issues for scientists working in public research centres and universities. The responsibilities of the individual and the institution are discussed. It does not explicitly discuss the responsibilities of researchers working in industry or freelance of Do-It-Yourself scientists. However, the current discussion on the revision of the UNESCO Recommendation on the Status of Scientific Researchers (1974) does explore this broader scope.[10]

## 8. CSR AND NANOTECHNOLOGY

Corporate Social Responsibility (CSR) and RRI are linked. CSR is related directly to the private sector and can be considered as an expression of corporate strategy, corporate identity and market power, driven by the values

[10] For further information please see http://www.unesco.org/new/en/social-and-human-sciences/themes/bioethics/call-for-advice-revision-of-unesco-recommendation-on-the-status-of-scientific-researchers/

of stakeholders. RRI on the other hand is (originally) aimed for the public sector and strives to establish procedures to better integrate societal needs in the process of research and innovation while acknowledging the equal roles and responsibility of societal actors and innovators. RRI often covers among others – especially on industrial context level –CSR.[11]

Currently there is a global shift towards CSR 2.0 model, which aims to bring business and society to co-exist in a mutually beneficial relationship. There are five principles that make up CSR 2.0 (Visser, 2012): Creativity, Scalability, Responsiveness, Glocality and Circularity. The CSR 2.0 model proposes that the acronym is kept, but that it is rebalanced so that CSR 2.0 will actually mean '*Corporate Sustainability and Responsibility'*. This change acknowledges that *'sustainability'* (with roots in the environmental movement) and *'responsibility'* (with roots in the social activist movement) are the two main future elements. Additionally, the concept around CSR 2.0 also proposes a new interpretation of the terms sustainability and responsibility: *like two intertwined strands of DNA, sustainability and responsibility can be thought of as different, yet complementary elements of CSR.* Hence, as illustrated in the Figure below, sustainability should be seen as a destination – the challenges, the vision, the strategy and the goals that we are aiming for – while responsibility is about the journey – solutions, responses, management and action that show how we get there (Visser, 2012).

**Figure 2**: Corporate Sustainability & Responsibility (CSR 2.0)


Source: W. Visser (2016), *CSR 2.0: Reinventing Corporate Social Responsibility for the 21st Century*

## 1.2. Stakeholders in RRI

The types of actors identified to be affected by Research, Technology, Development and Innovation (RTDI) developments that are also directly linked to RRI are:

1) The **research funders**, i.e. those who invest in R&D and innovation such as governments or businesses dealing with innovation. These types of actors increasingly recognize the need to promote research and innovation for developing solutions aimed at addressing the Grand Challenges[12] (ERAB, 2010). However,

[11] EESC conference, Responsible Research and Innovation in Europe and across the World, Brussels 14-15/01/2016

[12] The Grand Challenges are the following:
1. Create a single EU-wide patent and an Open Innovation Charter,
2. Agree on a fast-track timeline for a full and widespread implementation of pre-commercial procurement of research and development (R&D).
3. Concentrate research, development & innovation funding around a selection of themes relevant for 'Europe 2020: A strategy for smart, sustainable and inclusive growth'.
4. Create an annual 'City/Region of Innovation in Europe'.
5. Issue an EU framework directive on research & innovation focusing particularly on creating a single market for research, development and innovation.
6. Fully implement pre-commercial procurement of research, development and innovation around a few commonly agreed big projects.

there are currently no coherent criteria for the inclusion of RRI aspects in the process and outputs of research and innovation. Therefore, cases occur when the innovations that follow RTDI practices might not utilize their full potential to tackle these challenges because a comprehensive understanding of societal needs is missing (EC, 2013a).

2) The second category comprises **institutions that carry out research and develop innovation**, such as universities, laboratories, researchers or even enterprises (incl. Small and Medium-sized Enterprises - SMEs) that conduct R&D activities. These are facing a dynamic and global competition on technological as well as societal level. The consideration of ethical and societal aspects in the research and innovation process can lead to an increased quality of research, more successful products and therefore an increased competitiveness, as well as a higher degree of societal accountability and responsiveness. Nonetheless, sufficient incentives to integrate society into the research process are still missing (EC, 2013a).

3) The third category involves **European citizens**. They require and expect that science and innovation can address challenges like climate change, clean energy, an ageing population and social cohesion as well as create new jobs and contribute to higher standards of living. However, there are several factors that limit the participation of citizens, stakeholders and civil society groups in the R&D processes of research institutions or businesses, such as insufficient funding for stakeholders' participation or research processes not stipulating the inclusion of stakeholders (EC, 2013a).

4) **Legislators and regulators** are the actors responsible for articulating the societal standards and values for research and innovation, and integrating these in legal and regulatory frameworks. At the same time, coordination of policies (research, innovation, education, taxes, development, other sectoral policies) is essential to effectively translate into coherent governmental action all aspects pertaining to RRI. However, there is currently no coherent transnational approach to RRI among the actors included in this category, such as EU, national and regional policymakers, Ombudsmen and social rights watching organisations, regulatory bodies, standardization organisations, etc. (EC, 2013a).

5) **Civil Society Organisations** and **Non-Governmental Organisations**. Despite the latest developments in R&D&I governance (Quadruple Helix[13]), civil society organisations are, on the one hand, seldom involved in research projects and in the governance of research; yet, on the other hand, they have become important research users and knowledge producers as they have developed capacities to mobilise various forms of knowledge (empirical, local, professional, etc.) to support their expertise. These new actors in research can be large international NGOs (such as Greenpeace, Friends of the Earth and the World Wildlife Fund, etc.), or user and consumer organisations and associations (e.g. Via Campesina that is dedicated to food safety), or even small groups of citizens that act at local or regional level. These civil society organisations have become major players in domains such as environment, health, energy, etc., both locally and globally. They participate in international negotiations, advise governments and governmental bodies, work with the media, and with scientists – thus supporting the emergence of a new

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7. Concentrate and streamline all R&D funding in the Eighth Framework Programme (FP8) by minimising management obligations for all funding schemes and by earmarking 30 % of the Structural Funds and 10 % of the common agricultural policy (CAP) for RDI projects.
8. Foster an acceptable degree of risk-taking and excellence throughout all research, development and innovation (RDI) programmes.
9. Create a European venture capital fund capable of investing in early-stage 'proof of concept' and business development prior to commercial investment.
10. Make result and risk-oriented funding of research and innovation projects the dominant criterion for R&I funding of the EC.

[13] Quadraple Helix: Research – Business - Public Administration - Civil Society/Users. Further information available at https://www.surrey.ac.uk/sbs/sar/centres/bcned/BCNED%20Files/1%20Ruslan_Rakhmatullin.pdf

paradigm of knowledge creation based on cooperation instead of competition, on co-production by different actors and on the sharing of knowledge instead of its private appropriation (Sciences Citoyennes Foundation, 2014).

6) The **media,** and particularly the mass media, is a primary mean through which people obtain information on issues of their society and beyond. "*The media do not tell us what to think, but they do tell us what to think about*"[14]. Media can be distinguished into mainstream media (TV, radio, newspapers, magazines) and online social media. The latter have assumed significant importance and popularity since the growth of Internet in the 1980s, as people have been transformed from passive receivers of one-way mass communication to producers and transmitters of information (Creeber & Martin, 2009). With respect to RRI media's position is of importance, given the power they (can) exert over public opinion, the critical distance they take on the messages which are emitted by different actors, the correlation between public awareness and the amount of media coverage, etc. (Neubauer, 2013). Overall, their involvement in activities entailing risk (such as nano), has received both positive and negative views.: for example, in the 'Social Amplification of Risk' Theory (Kasperson, 1998) the sudden shift in the behaviour of people appears to be related to broad patterns of media coverage; in the 'Technocratic Media Criticism' (Heath & O'Hair, 2009) theory the view of the scientific elite assumes that the purpose of risk reporting should be the popularisation of experts' knowledge, as risks are known to experts. Whatever the discussions may be concerning the intentions of the media, the impacts of amount and context of coverage, the provision of an adequate amount of technical information, the appropriate questioning of their sources, etc., the media is a vital component in the communication of scientific information (Amanatidou & Psarra, 2004), especially when it involves risk elements and aspects, such as nanotechnologies.

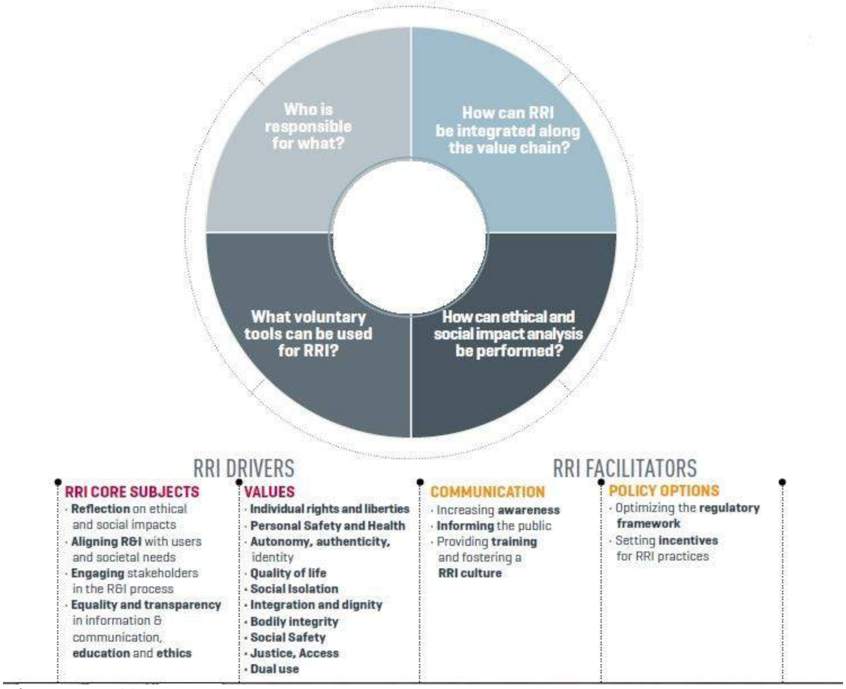
According to the AIRI-CNR "*Report on RRI"* (AIRI/CNR (2015), one fundamental aspect to take into count for the future of actors' involvement in RRI is *RRI in the result evaluation contexts*. As stated in the report, RRI aims to summarize three different areas:

i) social challenges and their impact;
ii) responsibility in the choices of research and innovation with respect to the uncertainty of the outcome and the activated processes;
iii) the need to make the organisation of activities, decisions and research results open, transparent and democratic.

In light of the above, research evaluation must therefore identify requirements, criteria and expectations. In particular, this must capture information on evaluation processes, both in quantitative and qualitative aspects by ensuring effective and efficient data processing (information deficits, plurality of hypothesis, opinions often divergent). The lack of appropriate and usable information amplifies the traditional gap that penalizes the evaluation. Thus, the *Governance* of research and innovation processes must focus on the policy-making process management and, in addition to the accepted evaluation activities linked to the "quality of research" should be added strategies, tools and actions to enable an assessment of initiatives compatible with RRI in a coherent and comparable framework.

[14] Crombs and Shaw as quoted in A. Mazur (1994), "Technical Risk in the Mass Media", in *Risk: Health, Safety & Environment,* Vol. 5, No. 3, 189 -192

**Figure 3: Implementing RRI Framework. Doing research and innovation responsibly benefits the company and contributes to making a better world**




Source: Responsible Industry, Dec. 2015

Overall, ethical acceptability requires more than scientific integrity; for instance, the application of the 3Rs principle (replace, reduce, refine). The challenges of risk management as well as achieving the right outcomes, benefits or impacts of science also need to be added. Likewise, broader challenges such as considerable funding, especially from public sources, must be considered. The following table summarizes the main challenges according to the three elements of RRI while adding global issues. The colours indicate relevant values from the EU *Charter* (2000) and the Lisbon Treaty (2007), as indicated in the graph below (Figure 4).

**Figure 4. Challenges to Responsible Research and Innovation**

*Table: Challenges to Responsible Research and Innovation*

| RRI Challenges | Ethical Acceptability | Risk Management | Benefits for Humanity | Global Issues |
|---|---|---|---|---|
| Unethical science | Loss of reputation and credibility | Rejection of new technologies | Less public and social engagement with science | New social and cultural values in science |
| Funding pressures, global financial crisis | Continued availability of well-trained scientists | "Cutting corners" and increasing risks | Agreement on benefits and assessment | Global competition for resources |
| Regulatory, compliance and bureaucratic burdens/costs | Compliance "fatigue" | Helicopter research in "ethics-free" zones | Best use of scarce public resources | Brain drains and research tourism |
| Need for global co-operation to further scientific goals | Disparate standards for scientific merit review | Privacy protection | Global agreement on benefits and assessment | Benefit sharing |

| | | | | | | |
|---|---|---|---|---|---|---|
| Justice | Solidarity | Equality | Citizens' Rights | Freedoms | Dignity | Sustainability |

Source: EC (2012), Ethical and Regulatory Challenges to Science and Research Policy at the Global Level", p.13

# Chapter 2: Responsible Research and Innovation in Nanotechnologies: a European and International perspective

# 2. Responsible Research and Innovation in Nanotechnologies: a European and International perspective

## 2.1. The European policy landscape

### 2.1.1. European Union

The current policy[15] in place – at the level of the European Union – that provides recommendations with regard to responsible research and innovation in nanotechnologies is the *Commission Recommendation of 07/02/2008 on a Code of Conduct for responsible nanosciences and nanotechnologies (N&N) research* (Code of Conduct). The Code of Conduct provides guidelines for all stakeholders involved or interested in nanosciences and nanotechnologies (N&N) to engender "*a responsible and open approach to N&N research in the Community*" *(For further information please see Chapter 1 Key Concepts and Definitions).*

The Code of Conduct foresees the review of its recommendations every two years and a monitoring by the Member States of the extent to which relevant stakeholders have adopted and applied it. Within this vision, the Commission organised a consultation process with representatives of the Members States in 2009 and a public consultation between 2009 and 2010. Suggestions were received on amending a number of points of the recommendation, while there was also a general view of the necessity for the code to extend beyond just research into nanotechnologies, covering also further steps of the cycle, like innovation, product development and marketing. Similar conclusions were also drawn by the Nanocode project (FP7) that aimed to facilitate a multi-stakeholder dialogue on the Code of Conduct at European level and in selected Associated Countries. No updates to the Code of Conduct have been implemented so far.

In another approach in the same year, a partnership between three UK-based organisations – the Royal Society, the Nanotechnologies Industry Association and Insight Investment – resulted in the publication of the *Responsible NanoCode*. The aim of this initiative was to establish a consensus of good practice in the research, production, retail and disposal of products using nanotechnologies and to provide guidance on measures that organisations can take to demonstrate responsible governance of this dynamic area of technology. [For further information, see *Chapter 2. RESPONSIBLE RESEARCH & INNOVATION (RRI)*].

On a different level, it is worthy of note the EU Nanosafety Cluster, an initiative of the Research and Innovation Directorate General which aims to maximise the synergies between nanosafety research projects funded under the FP6 and FP7 programmes. The Cluster implements various actions addressing nanosafety, including also a discussion forum and dialogue with stakeholders.

With respect to European level funding, the Horizon 2020 programme devotes significant attention to RRI and N&N, as RRI is now a cross-cutting action, and it is deeply embedded into its objectives and required in various dimensions of the programme[16]. Additionally, the Directorate-General for Research and Innovation of the European Commission is determined to bridge the gap between the scientific community and society at large. The 'Science with and for Society' programme (the lessons learned from its predecessor, 'Science and

[15] In Chapter 3, by "policy" we refer to legislation, action plans, research strategies and agendas, government visions, roadmaps, etc.
[16] https://ec.europa.eu/programmes/horizon2020/node/1306

Society'/FP7, gave birth to the concept of RRI that was tested and promoted during the last years of the Programme) is instrumental in addressing the European societal challenges tackled by Horizon 2020, building capacities and developing innovative ways of connecting science to society. Since 2010, a specific objective has been to build effective cooperation between science and society and to pair scientific excellence with social awareness and responsibility.

In terms of risk assessment, the existing regulatory schemes are being extensively reviewed for their capability in dealing with nanomaterials and nano-related products. The European Parliament requested tighter controls on nanotechnologies, in particular in the sectors of chemicals and materials, cosmetics, foods, occupational health and worker safety, and environmental safety and waste. Priority is given to the regulation of substances and chemicals with the objective of identifying and evaluating nanomaterials from the beginning of the life-cycle of a nano-related product (upstream regulation), and to the regulation of foods and cosmetics (close contact with people). In response to this, the European Commission is reviewing all relevant legislation with a view to proposing regulatory changes where necessary and to developing more nano-specific instruments for the implementation of regulation.

Finally, with respect to nanomaterials, these are regulated by REACH (Registration, Evaluation, Authorisation & restriction of Chemicals) and CLP (Classification, Labelling and Packaging), as they are covered by the definition of a chemical "substance" under both regulations. ECHA (European Chemicals Agency) is an EU agency which manages the technical, scientific and administrative aspects of the implementation of REACH and CLP. The agency is a driving force among regulatory authorities in implementing the EU's chemicals legislation, and facilitates companies' compliance with legislation and advances the safe use of chemicals.

### 2.1.2. EU Member States

As for the policy situation at Member State level, a group of EU Member States have been analysed for this purpose. Member States were selected based on a set of criteria, including countries with different levels of nanotechnology activities, countries that represent a considerable European geographic coverage, countries with different policy approaches to RRI and amount of data available through desk research.

From the short study conducted, it can be concluded that some countries tend to have more specific policies to nanotechnologies (such as Germany, France, the Netherlands, the United Kingdom, and Denmark), all of which include specific RRI aspects. These countries are principally those that are more active in this domain at EU level, considering the number of nanotechnology companies located in these states, and the amount of publications and patents produced (ObservatoryNANO 2011). Among these countries, some have implemented wide-ranging high level RRI measures in this domain, such as the Dutch *Nanotechnology Knowledge and Information Centre* and *Nanotechnology Social Dialogue Committee*, the German *Nano-Commission*, and the *Nanotechnology Strategy Forum* from the UK, among others. In other countries (Czech Republic, Spain, Portugal, Italy), although the field of nanotechnologies is of recognized importance, more general STI policies tend to cover these technologies, which generally include RRI references. It is to note, however, that nanotechnology related RRI measures in these Member States are less common than in the other group of countries.

The country descriptions followed a similar pattern, focusing first mainly on the policy context, providing then the institutional background and finally describing relevant R&D&I funding and important RRI initiatives, where such data were found. For this reason, although some states have more and others less extensive nanotechnology and nano related RRI policies and initiatives, the country descriptions are alike in length.

Short analyses of the selected countries' policies are presented below.

## Czech Republic

The Czech Republic does not currently have a dedicated strategy for nanotechnology research, development and innovation, although the possibility and a first draft were discussed in 2010. The current policy in place for science and technology is the *National Research, Development and Innovation Policy* (2009 – 2015), updated by the Czech government in 2013 with a vision for 2020. Additionally, the implementation plan of the *National priorities for oriented research, experimental development and innovation* (2012-2030) (including priorities for oriented R&D) was elaborated as part of the previously mentioned National Research, Development and Innovation Policy as a guide for preparing R&D programmes and defining the State budget for R&D. Nanotechnologies are part of this latter document and are included under the priority "*Sustainability of energetics and material resources*". With respect to RRI elements, there is little reference to this concept in this document.

On a more institutional level, it is the Section for Science, Research and Innovations of the Government that manages and coordinates the Czech system of science and research. This Section is advised by the Research and Development Council and its associated commissions. Among the research funders, the Academy of Sciences had a funding programme specifically dedicated to nanotechnology R&D called, '*Nanotechnologies for Society'* for the period of 2006 – 2012. The programme arose out of an acknowledgement of the importance of nanotechnologies for the development of the Czech Republic both in societal and economic terms. The programme focused efforts on bringing together academia and commercial enterprises and aimed to achieve progress in the practical use of nano R&D outputs for the benefit of society. In fact, project proposals were evaluated based on four equally weighted criteria, one of which was "the necessity of a project" [17]. This criterion was related to the importance of a project from a technological and societal point of view. Amongst those currently available, the most relevant national funders for nano R&D are the recently created *Technology Agency* of the Czech Republic (funds are mostly given to applied research, experimental development, and innovation), and the *Czech Science Foundation* (which funds basic scientific research).

## Denmark

The importance of strategic growth technologies, including nanotechnology, for increasing the global competiveness, growth and prosperity of the Danish society is recognized in the country's policy documents. Although not specifically addressing nanotechnologies, the Danish *Research 2020 Strategic Research Horizons* policy document, issued by the Ministry of Higher Education and Science and used as a basis for prioritising strategic funding of research, highlights nanotechnology as a priority area for the country. Regarding RRI, the

[17] Further information available at: http://www.cas.cz/veda_a_vyzkum/programy_vyzkumu_a_vyvoje/nanotechnologie_pro_spolecnost/podrobnejsi_informace_o_programu_nano.html

document states that "…*the development of new technologies may potentially lead to new risks. It is therefore essential that the technological development takes place in a sound and acceptable way which allows for possible human risks and ethical, social, environmental and safety-related aspects. The research topics must generally be driven by society's future need for knowledge and competences, and the results of the research must aim at benefiting businesses and society as such in the long-term*" (Danish Ministry of Science, Innovation and Higher Education, 2012).

Several other recent policy documents were also conceived (although not specific to nanotechnologies), inspired by the philosophy of RRI, such the *Open Access policy for public-sector research councils and foundations* (2012) and the Danish *Code of Conduct for Research Integrity* (2014).

With respect to N&N, in 2012 the Ministry of Environment and Food developed the action plan "*Better Control of Nanomaterial*", aiming to promote a better understanding of the "*possible exposure pathways and potential harmful effects of nanomaterials*[18]. As part of the initiative, a Nano-product Register was implemented, obliging producers and importers to report on nanomaterials used in products aimed for the general public.

The entity responsible for policy-making in the area of research and innovation (including the field of nanotechnology) is the Danish Ministry of Higher Education and Science, advised by the Danish Agency for Science, Technology and Innovation. Current funding for research and innovation in the area of N&N is channelled through the *Strategic Research in Strategic Growth Technologies* programme. This covers technologies, including nanotechnologies, which have potential to drive economic development and help overcome major societal challenges. According to the programme, participants need to comply with the *Open Access policy for public-sector research councils and foundations*, as well as with the Danish *Code of Conduct for Research Integrity*. The programme documentation also emphasises the importance IFD (Innovation Fund Denmark, the managing authority of the programme) attaches to RRI, abiding by the European Commission's definition and practices of RRI, as it requires all projects to "*involve all relevant parties and institutions in the research and innovation process*" and projects with a significant impact on society and citizens, from an ethical or technological point of view, will have to directly dialogue with the people.

## France

As a major player in this area, France has many organisations and networks committed to promoting and exploring nanosciences and nanotechnologies, while on educational level the country is home to a number of universities offering research and educational opportunities in nanotechnology. In 2009, the Nano-INNOV plan was launched by the French Research Ministry, aiming to boost nanotechnology innovation and provide the industry with means to turn nanotechnologies into successful products. Despite N&N importance in the French R&D&I system, there is no particular research strategy devoted to this domain; instead, N&N are covered in the more general national policy document, the *National Research and Innovation Strategy,* adopted in 2013.

With respect to the responsible conduct of nanotechnologies, there is a high awareness of the concept of RRI and it is widely applied in the national science and technology system. The *National Research and Innovation*

[18] For further information see: http://eng.mst.dk/topics/chemicals/nanomaterials/results-from-the-better-control-of-nano-materials-initiative/

*Strategy* specifically refers to such approaches, as it expresses the need of "*maintaining the link between researchers and citizens especially by ethics and ethical reflection on the expertise and the social responsibility of scientists*" (RESAgora, 2014). Additionally, it should be pointed that most funds for R&D into N&N in France require researchers to investigate ethical and societal implications of nanotechnology.

Concerning relevant regulations related to the responsible conduction of nanotechnologies, it is to highlight Articles L. 523-1 to L. 523-5 of the French Environmental Code. This is a Compulsory Registry of "Nanomaterials", according to which French entities that use (produce, import, distribute, or formulate) "*substances with nanoparticle status*"[19] are required to register this on an online platform. This regulation follows the precautionary principle and facilitates the traceability of nanomaterials on the market.

The Ministry of Higher Education and Research is responsible for developing the national research strategy and revising it every five years. Under the authority of the Ministry is the French National Research Agency (ANR), a major public investor in nanotechnology research, in addition to the different regional governments. Furthermore, the National Public Debate Commission (CNDP), an independent body, is responsible for organising public debates and citizens' participation in policy-making in diverse fields. CNDP has recently implemented several public debates in nanosciences and nanotechnologies among other subjects.

## Germany

The consideration of responsible research in nanotechnology dates back to 2003 when the Technology Assessment Bureau (TAB) of the Federal Parliament published a report on nanotechnology. The TAB study was followed by extensive discussions involving stakeholders and the general public. Since then, societal groups have taken part in debates on the benefits and risks of nanotechnologies. In 2006 a single national strategy for nanotechnology, the *Nano-Initiative–Action Plan 2010*, in which the responsible development of nanotechnology is a priority, was launched by the German Government in which the responsible development of nanotechnology is a priority.

Under the current policies of Germany, *Nano-2010* successor, the Federal Government's *Nanotechnology 2015 Action Plan should be emphasized*. The plan stresses the relevance of nanotechnology developments for the German industry and that such progress should be sustainable. The document serves as a common platform for handling all nanotechnology issues and discusses, among others, actions for identifying nanotechnology risks, including societal and ethical aspects. Another important reference in the document is made to the intensification of communication and conducting of dialogues. Recent initiatives of communication as well as dialogues are mentioned, which include also the work of the Nano-Commission (in two phases: 2006-2008 and 2009-2011). This was succeeded by expert dialogues in phases 3 and 4 (2011-2012 and 2013-2015). These dialogues involved science, business, policy-makers, churches, environmental and consumer associations. The fifth phase will start in summer 2016. The Federal Ministry for Education and Research BMBF hosts a portal on Innovation Accompanying Measures New Materials and Nanotechnology including competence maps for nanotechnology

[19] http://www.cnbss.eu/index.php/editorial/item/84-compulsory-registry-of-%E2%80%9Cnanomaterial%E2%80%9D-in-france-part-1

research and industrial organisations. This portal also includes information on future and past dialogue events targeting industry, citizens and stakeholders.[20]

Although the implementing body of the Action Plan is the Federal Ministry of Education and Research (BMBF), due to its different application fields, nanotechnology is anchored in various departments of the Federal Government, with a cross-departmental committee guaranteeing a coordinated approach. The major portion of federal level funding for nanotechnologies is provided by BMBF for institutional and research initiatives and a smallest portion is attributed by other ministries. State-level ministries also provide funding but mostly to support enterprises and local knowledge transfer. It is worthy of note that Germany is one of the European countries that invested more in nanotechnologies in the last years (NanoCode, 2014) and Germany has the highest number of nanotechnology companies in the European Union. Germany also produces the highest number of patents in this domain within the EU, and is among the largest producers of nanotechnology publications as well (ObservatoryNANO 2011).

Multinational companies headquartered in Germany are also active in nanodialogue, including BASF with its Dialogforum Nano in several rounds since 2011. In addition, it is to highlight the Bayer led the Public Private Initiative inno.CNT, an initiative sponsored by BMBF. Inno.CNT aimed to explore the innovation potential of carbon nanotubes (CNT) and it also dealt with the safety aspects of CNT.

## Hungary

Several policies and strategies exist with the regard to research, development and innovation in Hungary; however, no specific policy is dedicated to nanotechnology. The most relevant policy document is the current *National Research and Development and Innovation Strategy* (2013-2020) issued by the Ministry of National Economy. In the strategy, the field of nanotechnology is expressly mentioned and recognised as a future technology playing a "*privileged role in developing knowledge bases*"[21]. Additionally, the document also states that larger research and technological development groups as well as growth-oriented small enterprises (gazelles) strengthening is desired in fields of converging technological research, including the field of cogno-nano. With respect to RRI elements, a horizontal priority aims to promote the familiarization of knowledge and technology in society and strengthening its recognition, thus RRI is considered in a more general context.

At an institutional level, the National Research, Development and Innovation Office (NRDI), founded in 2014, is the national strategic and funding agency for scientific research, development and innovation. The Office provides policy advice to the Government and is the primary source for R&D&I funding in Hungary, handling the National Research, Development and Innovation Fund. Another relevant S&T institution is the Hungarian Academy of Sciences (HAS), the major public research player in Hungary that developed its own Science Ethics Code which impacted all HAS research institutes and supported research groups; and established the Science Ethics Committee focusing on emerging issues..

[20] http://www.werkstofftechnologien.de/en/
[21] http://nkfih.gov.hu/policy-and-strategy/national-strategies

## Italy

The importance of nanotechnology for the development of products with application in various key fields and sectors is widely recognized in Italy. A significant amount of funding has been provided over the last years for nanotechnology research and, at the end of the 1990s, the Italian National Research Council also launched a national research programme expressly dedicated to nanotechnologies (1998 – 2000). Nevertheless, at a policy level, Italy currently lacks a specific research strategy targeting nanotechnologies. The main governmental instrument for R&D planning and funding in Italy is the National Research Programme (PNR) 2014-2020 managed by the Ministry of Education, University and Research (MIUR). The PNR is drawn up by the MIUR every three years and, together with its annual revisions, it is approved by the Interminsterial Committee for Economic Planning (CIPE). The PNR for 2014 - 2020 is strongly aligned with Horizon 2020, focusing on major societal challenges and covering various research areas. In the framework of the PNR 2014-2020, under the theme of Industrial leadership, there is a specific funding line for nanotechnology and nano-electronics R&D. In fact, the programme discusses the importance of pursuing a responsible, rigorous and diverse research; however it does not go into detail in this respect.

In line with international trends and European priorities, there are also some initiatives at sectorial/institutional levels with regard to responsible nanotechnologies. For instance, a certification standard for the business world, the System for the Responsible Management of Nanomaterials in Consumer Products, or other measures that are based on the precautionary principle, such as the National Federation for Chemical Industry (Federchimica), which established a Nano Product Stewardship working group. In addition, CNR-IFN is in charge of carrying out, promoting, spreading, transferring and improving research activities in the main sectors of knowledge growth and its applications on the scientific, technological, economic and social development of the Country. Finally, in 2011 the Italian Workers' Compensation Authority (INAIL) published a White Book on occupational health and safety effects of engineered nanomaterials.

At regional level, some best practices come from Piedmont Region and its initiative called '*Piemonte Nanotech' (involving* the institute of science and technology on ceramic material, "centro Nano-SiSTeMI", Center of Excellence - Nanostructured surfaces and interfaces) and Apulia Region with the Salento University's Campus Ecotekne, as well as *Tuscany Region* with the initiative 'NANOXM – Nano for the Market'.

With regard to RDI funding, MIUR is the main state level funding agency for research and development. In cases of cross-disciplinary investments (for example enabling technologies) MIUR works together with other central government departments.

## The Netherlands

Although not comparable to the leading nations in commercialization of nanotechnologies in terms of absolute numbers (Japan, USA, Germany), the Netherlands is at the forefront of nanotechnology developments and is the largest player among the medium-sized economies, thanks to the proactive activities in industry as well as in academic institutes and support from science foundations (Lux Research, 2010). The Dutch *Cabinet Vision on Nanotechnologies* dates back to 2006 and describes a number of actions, including those dealing with risks and ethics. In 2008, the Vision document was further developed into a concrete *Nanotechnology Action Plan*. The four main lines of the Action Plan concerned risks, ethical aspects, social dialogue and communication. With respect to the Dutch scientific strategy in the area of nanotechnologies, it is worth mentioning the *Strategic Research Agenda of the Netherlands Nano Initiative (NNI)* elaborated in 2008. The Strategic Research Agenda emphasizes the importance of risk analysis and calls for a large investment into investigating the social aspects and impacts of nanotechnologies. Additionally, it also stresses the need to stimulate public debate on nanotechnologies and provide more public information on the subject. The *NanoNextNL* programme (2010-2016) is the current Dutch national research and technology programme for micro and nano technology, two of the six "Key Enabling Technologies" (KET's) of the European Commission, which has its foundations in the Strategic Research Agenda. Additionally, a more recent roadmap, the 2014 "*Roadmap nanotechnology in the top sector"* (Netherlands Enterprise Agency, 2013), gives an overview of the challenges of nanotechnology in knowledge and innovation in the Netherlands, and the proposed innovation items have been determined in close consultation between the industry concerned, knowledge institutes, and government and social institutions for the period 2012-2020.

Driven by the initial *Cabinet Vision on Nanotechnologies* and the *Nanotechnology Action Plan,* a number of initiatives have been implemented at institutional level, such as the establishment of the Nanotechnology Knowledge and Information Centre (KIR nano), which is part of the National Institute for Public Health and the Environment (RIVM). Among its activities, KIR Nano set up expert panels to discuss matters important for the responsible development of nanotechnologies. In addition, the National Nanomedicine Platform, also hosted by RIVM, brings together researchers, policy-makers, industry and civil society actors interested in nanomedicine research and regulations. To enable transparency in nanotechnologies, RIVM is assigned to communicate nanotechnology issues to the public. Furthermore, the Sounding Board on Risks of Nanotechnology has also been created and provides advice on nanotechnology risks. The societal and ethical aspects of nanotechnologies were dealt with by the Nanotechnology Social Dialogue Committee in 2009-2011, an independent body with a mission to conduct social dialogue about nanotechnologies. Its work was complemented by the Rathenau Institute´s social dialogue activities, which had started prior to this in 2003.

**Portugal**

The *Strategy for Research and Innovation for a Smart Specialisation* (ENEI) is the main policy for research and innovation in Portugal for 2014 – 2020, part of the *Partnership Agreement* (Acordo de Parceria - Portugal 2020) agreed between Portugal and the European Commission. Among other topics, nanotechnology is identified as a strategic field to be funded in order to promote a smart, sustainable and inclusive growth, particularly in the fields of ICT, Medicine, Materials, Sea Resources, Agro-food, and Space and Transport. Through this strategy, Portugal aims to develop the entire system of research and innovation in a sustainable manner, with the purpose of reducing the weaknesses identified in the R&I system's diagnosis of 2013[22].

ENEI fosters several principles of RRI, including ethics (by promoting research integrity and good R&D&I practices, as well as the protection of the objects of research), and open access (by promoting shared access

[22] http://www.fct.pt/esp_inteligente/diagnostico.phtml.en

and the creation of public repositories containing the results and information generated by R&D projects).

There are two main entities responsible for implementing the research and innovation policy in Portugal: the National Innovation Agency (ANI) and the Foundation for Science and Technology (FCT). ANI is a state-owned agency funded by the Ministry of Education and Science and the Ministry of the Economy. It aims to promote the strengthening of national competitiveness through the valorisation of scientific and technological knowledge and its translation into economic growth by fostering collaboration between companies and the national scientific and technological system. FCT is the national funding agency that supports science, technology and innovation, in all scientific domains, under the responsibility of the Ministry for Science, Technology and Higher Education.. Both entities, ANI and FCT, foster several principles of RRI through pursuing the ENEI strategy.

As evidence of the high relevance of nanotechnology, the International Iberian Nanotechnology Laboratory (INL) was established in Portugal in 2005. It is the result of a joint decision of the Governments of Portugal and Spain, whereby the two Governments made clear their commitment to a strong cooperation in ambitious science and technology joint ventures for the future. INL is the first, and so far the only, fully international research organisation in Europe in the field of nanoscience and nanotechnology.

**Spain**

The main Spanish policies on research, development and innovation are: the *Science, Technology and Innovation Act* 14/2011 (Science Act), the *Spanish Science and Technology and Innovation Strategy 2013-2020* (Strategy) and the *National Plan for Scientific and Technical Research and Innovation 2013-2016* (National Plan) can be highlighted. The Science Act sets the general legal framework for science, technology and innovation (STI) at a national level, while the Strategy defines general objectives, around which the specific actions for STI are to be drawn up. The National Plan includes specific programmes and strategic actions to achieve the objectives of the Strategy. Despite the fact that none of them focuses specifically on nanotechnology R&D and innovation, the nanotechnology field is identified as a priority by the Spanish policies. It is important to mention that as referred to in a recent OECD document (OECD, 2013), the Spanish government agreed with the regions to design and implement research and development policies on nanotechnologies in a coordinated way that suggests the high relevance of this field in Spain and the need for such policies.

The above documents include several principles of RRI, such as ethics, open access and public participation in general terms. As for the latest aspect, the Science Act refers to the societal participation from the point of view of the promotion of science, its social acceptability and states that one of the roles of the Advisory Council for Science, Technology and Innovation is to introduce evaluation mechanisms to “measure the social effectiveness of public resources used” (RESAgora, 2013). Moreover, the National Plan emphasises that a new model of R&D&I policies is needed that will help anticipate future demands, enabling thus the adoption of policies based on such demands.

Concerning risk assessment procedures on nanotechnologies, there are few examples of public laboratories implementing it. Some centres also developed their own codes and guides for nanosafety. Additionally, there are some regional level initiatives in Spain, such as the creation of the Competence Centre for Environment, Health and Safety issues on nanotechnology by the Basque government.

Regarding the national governance of science and technology in Spain, the Secretary of State of Research, Development and Innovation, within the Ministry of Economy and Competitiveness has responsibility for fostering research and technology in general. The Secretary is supported by the Council of Scientific, Technological and Innovation Policy in charge of the general coordination of the scientific and technological research and innovation. These two entities are advised on policy level by the Advisory Council on Science, Technology and Innovation.

**The United Kingdom**

After Prince Charles initiated an the international discussion about nanosafety in 2003, the Royal Society and Royal Academy of Engineering opened a public and stakeholder consultation about nanotechnology, resulting in the 2004 report *Nanoscience and nanotechnologies: opportunities and uncertainties* (The Royal Society & The Royal Academy of Engineering, 2004). This was followed by several public engagement and stakeholder dialogue projects. Another important initiative was the inquiry into nanotechnology and food launched by the House of Lords Science and Technology Committee in 2009, followed by its report on the inquiry published in 2010. This report contains conclusions and recommendations on several aspects, such as potential risks, regulation, public communication and engagement, some of which (including a recommendation on public engagement) were taken forward by the Food Standard Agency.

With regard to nanotechnologies, a policy document was published by the UK government in 2010, which was conceived through a collaborative effort involving various elements of the society. The policy document is called *UK Nanotechnologies Strategy: Small Technologies, Great Opportunities* and forms action points with regard to the various dimensions/aspects of nanotechnologies, including business, industry and innovation; environmental, health and safety (EHS) research; regulation; etc. The strategy aims to contribute to a responsible conduct of nanotechnologies, issuing better informed policies and regulations in the view of potential environmental health and safety risks, as well as enabling businesses to conduct transparent and responsible nanotechnologies. It also aims to enhance the public and stakeholder level of information about nano-matters. The *Nanotechnology Strategy Forum*[23] was established under the Government as an ad-hoc expert advisory body with a membership drawn from industry, regulators, academia and NGOs, following the adoption of the strategy, with the aim of promoting discussion between government and key stakeholders to foster the development of nanotechnologies.

Currently, nanotechnology is part of a broader science and innovation strategy of the UK government, called *Our plan for growth: science and innovation.* The strategy was published in 2014 and identifies 8 “Great Technologies” for which the UK could have a world leading position in their development. Advanced materials and nano-technology are one of these technologies. This strategy also stresses the relevance of several RRI principles, including the open access to research publications and citizen engagement. In regard of this latter aspect, the document refers to the UK Charter for Science and Society developed in 2014 by the government in collaboration with the science community, business, educators, media and civil society groups that committed

[23] For further information please visit: https://www.gov.uk/government/groups/nanotechnology-strategy-forum

themselves to improving the relationship between science and society.

The Innovate UK (formerly named as Technology Strategy Board - TSB) and the Research Councils (RCUKs) are among the main institutions planning and funding R&D in the country. Innovate UK is the leading government agency (executive non-departmental public body, sponsored by the Department for Business, Innovation & Skills) devoted to promote technology innovation. The RCUKs are responsible for investing public money in research for advancing knowledge and generating new ideas that will lead to a productive economy, healthy society and contribute to a sustainable world.

## 2.2. How has the European policy landscape evolved and addressed RRI over the past five-to-ten years?

'Nanotechnology' is the new frontier of science and technology in Europe and around the world, and scientists as well as policymakers worldwide praise the benefits it would bring to the entire society and economy" (Bonazzi, 2011). This was understood quite early by the European Commission, when designing and launching the EU 6th Research Framework Programme (2002-2006) in which 1.3 billion Euro was allocated for the advancement of nanotechnology and new materials. However, early in 2004 it was recognised by the EC that the expected emergence of nanoscience applications within several technological sectors would simultaneously create a significant need to address the responsible development of those technologies, considering public health, safety, environmental and consumer protection issues[24]. In this respect, in 2004 the European Commission adopted the communication "Towards a **European Strategy** for Nanotechnology" (EC, 2004), a first attempt to bring the discussion on nanosciences and nanotechnologies to an institutional level, and proposed an integrated and responsible approach for Europe.

This document led the European Commission, in 2005, to issue the communication "Nanosciences and nanotechnologies: an **Action Plan** for Europe 2005-2009" (EC, 2005). This Action Plan defined a series of articulated and interconnected actions for the immediate implementation of a safe, integrated and responsible approach for nanosciences and nanotechnologies, based on the priority areas identified in the above mentioned European Strategy. The Action Plan was updated in 2007 and progress was made by adopting a detailed plan for its implementation, through the communication "Nanosciences and Nanotechnologies: an Action Plan for Europe 2005-2009 - **First Implementation Report** 2005-2007" (EC, 2007).

In 2008, the communication "Recommendations on a **Code of Conduct** for responsible nanosciences and nanotechnologies research" (EC, 2009a) was published. This is the main policy document, that has been used until now as a guide to responsible research and innovation for all stakeholders involved or interested in nanosciences and nanotechnologies and with specific actions needed to achieve good governance on EU and Member States levels. In the same year, the EC prepared a first regulatory review of EU legislation in Nanomaterials (EC, 2008). Through this review, the EC reached the conclusion that there is no immediate need for new legislation on nanotechnology, and that adequate responses can be developed – especially with regard to risk assessment – by adopting measures, guidelines, etc., under existing legislation (EC, 2010d)[25]. Meanwhile,

[24] http://cordis.europa.eu/news/rcn/22025_en.html

[25] However, the European Commission will give follow-up to the request of the European Parliament to review all relevant legislation within the next two years, to ensure safety over the whole life cycle of nanomaterials in products.

recommendations were provided that all applications and use cases of nanosciences and nanotechnologies must comply with high levels of public health, safety, consumers and workers and environmental protection, in consultation with the wider Community.

In 2009, the communication "Nanosciences and Nanotechnologies: an action plan for Europe 2005-2009. **Second Implementation Report 2007-2009**" (EC, 2009b) was adopted. It outlined the key developments during 2007-2009 in each policy area of the Action Plan, identified current challenges, and drew conclusions relevant to the future European nanotechnology policy, incorporating societal benefits and impacts.

A reflection workshop on Responsible Research and Innovation was held in May 2011 at DG Research in Brussels, attended by a number of experts drawn from academia and policy. A report (Sutcliffe, 2011) was subsequently produced that reflected on the issues around RRI discussed during the workshop as well as the type of actions on RRI that should be integrated by the different stakeholders, including EC and Member States. Finally, an attempt at a first definition of RRI was provided: "*the focus of research and innovation to achieve a social benefit and the involvement of all stakeholders in society; prioritising social, ethical and environmental impacts and opportunities; anticipating and managing risks to adapt quickly to changing circumstances; and openness and transparency becoming an integral component of the research and innovation process*".

In 2011, the activities of the Unit for Nano-and Converging Sciences and Technologies for 2011-2015 were outlined in three main trajectories (EC, 2011a):

1. the research- innovation-commercialization route,
2. the means ensuring the safety of consumers, workers and the environment, which must be of the highest standard; and
3. the **proactive governance**, which really aimed to review the points of view of all people, their respective roles and what kind of message they may want to bring.

From this point on, the EC signalled the need for a fresh approach to communicating nanotechnology and building mechanisms allowing all stakeholders to engage and give feedback. In order to increase confidence and trust in nanotechnology, the potential benefits and the potential risks or challenges should be properly addressed. Responding to the EC's requirement, a range of EU-funded communication projects were launched in the context of FP7 that focused on the setting up of dialogue mechanisms about nanotechnology within the whole of Europe's society. Examples of such projects are: "*Nanodiode*" that aimed to inspire dialogue on research policy; "*NanOpinion*", which focused on open dialogue on nanotechnologies and its predecessor "*NanoChannels*" that involved a public experiment with students and stakeholders (industry, NGOs, consumers, the general public) on democratic dialogue in action about the new industrial revolution that could change the face of medicine, energy production and water purification, electronics, materials and security; "*Nanototouch*", which offered visitors in science centres and museums the opportunity to learn about scientific discoveries; "*Time for Nano*" that aimed to engage the general public, with special attention to young people; "*Nanoyou*", which aspired to connect the young in dialogue about the ethical, legal and social aspects of nanotechnologies; the "*FoTRRIS"* project aiming to foster a transition of the existing Research & Innovation (R&I) system to a Responsible Research and Innovation system by offering methods for researchers, citizens, businesses and policy-makers to solve 'glocal' challenges in a co-RRI way; and the Go6 RRI Projects of FP7 (*ProGReSS*, *RRI-Tools*, Res-AGorA, RESPONSIBILITY, GREAT, Responsible Industry and RRI-ICT Forum) dealing with RRI governance and with the RRI-ICT Forum funded via H2020, which together make up a critical mass of researchers taking forward RRI governance in Europe and beyond.

Since then, there have been - and continue to be - various European Commission initiatives designed to promote innovation and key enabling technologies with a view to increasing competitiveness, while also considering ethical and societal challenges. Examples include the Commission' Communications on a Common Strategy for Key Enabling Technologies' (2009 and 2012) and the 2014 'Communication on Research and Innovation as sources of renewed growth' (EC, 2014a). Particular attention has been paid to nanotechnology in several opinions of the European Economic and Social Committee (EESC), with a focus on Textile Materials and Technologies, Micro- and Nanoelectronic Components and Systems and the Chemical Industry[26].

In 2016, the EC produced the Staff Working document "**Better regulations for innovation-driven investment at EU level** (SWD/2016)" (EC, 2016) as a continuation of the **Better Regulatory Framework** (EC, 2015a) developed in 2015, which aimed to determine what Better Regulation is and how it should be applied in day-to-day practices of Commission officials preparing new initiatives and proposals or managing existing policies and legislation. The SWD(2016) presents an in-depth analysis of how the regulatory environment at EU level can stimulate or hamper innovation; and thus the non-legislative approach "Innovation Deals" was also introduced that aims to enable innovators and regulators to reach a joint understanding of how new technologies and innovations can be progressed in existing regulatory frameworks. According to the document, the first Innovation Deals are anticipated to be launched in the context of the Circular Economy. With respect to N&N, nanomaterials was acknowledged as one of the key areas. In further detail, it is mentioned that while offering significant innovation opportunities, nanomaterials may also cause health and environmental risks, raising concerns among consumers and workers. In order to ensure the safety of the products using such nanomaterials and to gain acceptance for their use, consideration needs to be given to the regulatory framework for their use. Thus, the regulatory framework needs to be able to respond to new health and environmental hazards, including appropriate screening and information gathering on nanomaterials, making good use of nanosafety research. On the other hand, it must be lean and flexible enough to avoid any unnecessary administrative burden. "*Good governance of nanotechnologies, and of nanomaterials in particular, and appropriate balance of risks and benefits are essential to secure what is already achieved and for nanotechnologies to deliver their promises. Transparent information to citizens, in the most appropriate and understandable form, will facilitate confidence in nanotechnologies. Products containing nanomaterial that are developed by the industry safely and sustainably, and are adequately controlled by the regulators will have high levels of acceptance with citizens*" [SWD(2016)].

## 2.3. The International Landscape

### 2.3.1. Introduction

From the start of the millennium, international dialogue on responsible nanotechnology research has been promoted by the US National Nanotechnology Initiative and the European Commission DG Research. The EC-NSF Workshop on Nanotechnology: Revolutionary Opportunities and Societal Implications[27] brought together

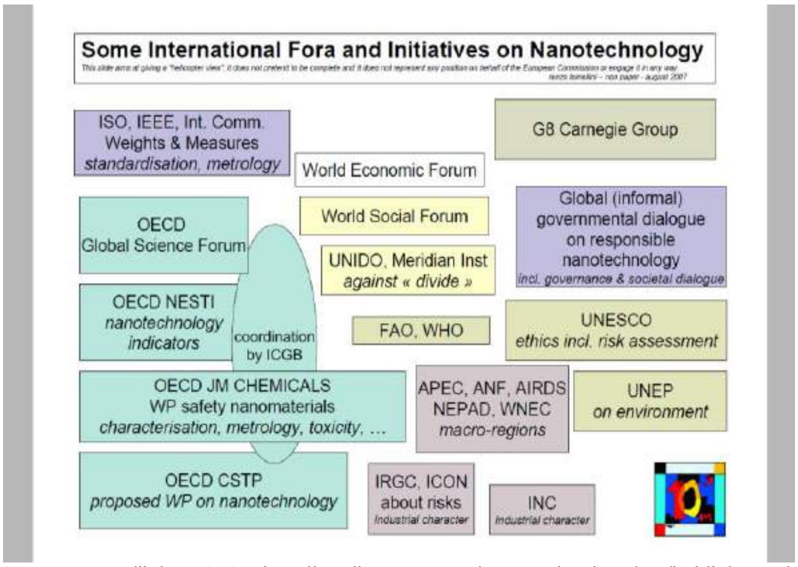
[26] EESC opinion on "Growth Driver Technical Textiles" (OJ C 198, 10.7.2013, p. 14); EESC opinion on "Strategy for Micro- and Nanoelectronic Components and Systems" (OJ C 67, 6.3.2014, p. 175); EESC opinion on "Nanotechnology for a Competitive Chemical Industry" https://webapi.eesc.europa.eu/documentsanonymous/eesc-2015-03991-00-01-ac-tra-en.docx
[27] https://cordis.europa.eu/pub/nanotechnology/docs/nano_lecce_proceedings_05062002.pdf

scientists, engineers, sociologists, philosophers, journalists and managers from Europe and the United States in 2002 (Roco & Tomellini, 2002). The subsequent European Commission Communication "*Towards a European strategy for nanotechnology*" (European Commission, 2004) and *Action Plan* (European Commission, 2005) included the intention to engage in international dialogue for *"…establishing a framework of shared principles for the safe, sustainable, responsible and socially acceptable development and use of nanotechnologies*".

This was implemented in a series of international dialogue events in Alexandria, USA (2004), Tokyo (2006) and Brussels (2008), with preparatory meetings in Brussels (2005) and Cape Town, South Africa (2007). In the third dialogue meeting, 97 participants represented 49 countries as well as international organisations, multinational bodies, industries and universities.[28] The discussions covered progress in nanotechnology governance, bridging the (North-South) gap, enabling means including standards and societal engagement (Tomellini and Giordani, 2008). One of the issues discussed was the then brand new European Commission's Code of Conduct for responsible nanotechnology research (European Commission, 2008), and its relevance in the context of non-European countries.

By then, a number of other platforms had been established for international dialogue on nanotechnology governance. Renzo Tomellini presented an informal helicopter view of some international forums and initiatives on nanotechnology as of August 2007, see Figure 5.

**Figure 5: Some international forums and initiatives on nanotechnology.**



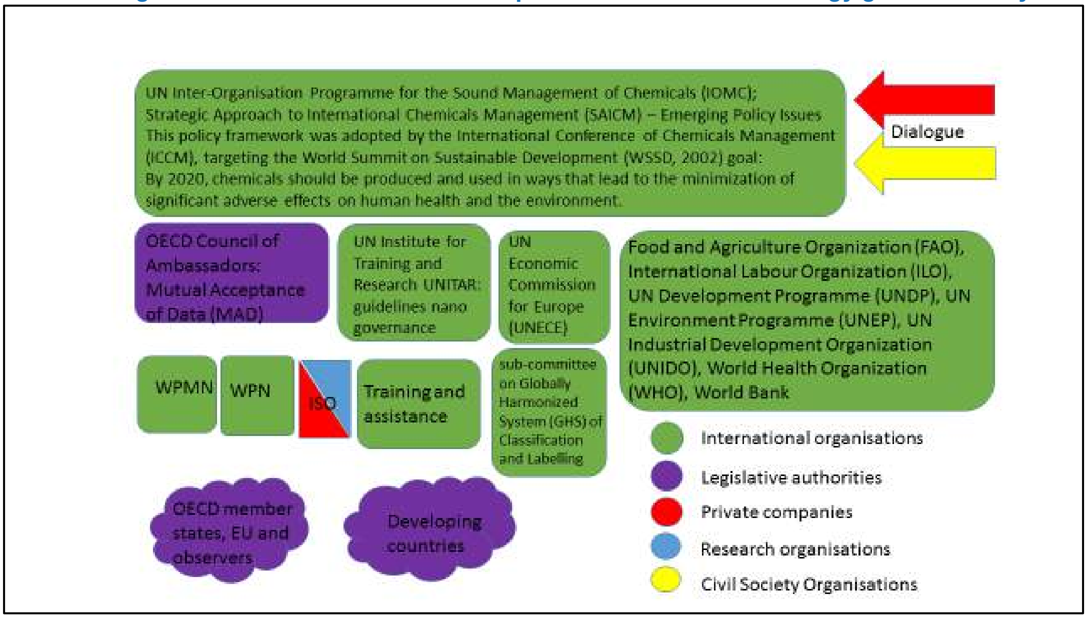

Source: Tomellini R., 2007, http://cordis.europa.eu/nanotechnology/src/intldialogue.htm

### 2.3.2. Current international dialogue platforms for responsible nanotechnology governance

This initial landscape presented by Tomellini has evolved into the ecosystem presented in Figure 6, which is coordinated in the Strategic Approach to International Chemicals Management (SAICM)[29]. The most active international organisations and platforms are presented here in the order in which they substantially started engaging with nanotechnology. Platforms which have ceased engagement with nanotechnology or shifted focus to other priorities are not included.

[28] http://cordis.europa.eu/nanotechnology/src/intldialogue.htm
[29] www.saicm.org

**Figure 6: Overview of international platforms for nanotechnology governance by 2015**




Source: Graph compiled by Ineke Malsch on the basis of SAICM, 2015.

### ISO – since 2005

The International Organisation for Standardisation ISO established a Technical Committee 229 (TC229) – Nanotechnology in 2005. This private body offers a platform for industry and governments to discuss and agree on international voluntary standards for industrial products, processes and management procedures. The ISO/TC 229 offers the key platform for industrial standardisation in nano. Topics include: terminology and nomenclature, measurement and characterisation, consumer and societal dimensions of nanotechnologies, nanotechnologies and sustainability, Health, Safety and Environmental Aspects of Nanotechnologies, and materials specifications. [30]

TC 229 collaborates closely with the OECD working parties covering nanotechnologies. The interesting thing about this Technical Committee is that it includes task groups on sustainability and on consumers and societal dimensions as well as more technical working groups. "*The Nanotechnologies and Sustainability Task Group [aims] to review the opportunities for nanotechnologies to address issues in the sustainability arena and to consider if and how standards might contribute to the successful implementation of these solutions for the benefit of mankind*" (ISO/TC, 2012).

"*The Consumer and Societal Dimensions Task Group [aims] to identify important issues in these fields and make recommendations to TC 229 on topics including: (a) Priorities for standards development in the area of consumer and societal dimensions of nanotechnologies; (b) Promotion of TC 229 standards and informational outputs to end users and other relevant organizations in collaboration with appropriate partners, e.g., ISO COPOLCO, European Commission, OECD, UNESCO; (c) Development of mechanisms for TC 229 to encourage and receive input from relevant consumer and other societal organizations; (d) Identification of topics in the area of consumer and societal dimensions of nanotechnologies for which it would be important for TC 229 to establish liaisons with other relevant standardization committees*" (ISO/TC, 2012). In 2011, TC 229 carried out a study on the

[30] http://www.iso.org/iso/iso_technical_committee?commid=381983

engagement of consumer and societal related organisations in the activities of the National Member Bodies (NMB) participating in their standardisation activities on nanotechnology. Thirteen out of 34 member countries and one out of ten observer countries responded. Several organisations participated in standardisation activities and discussions, but none proposed new topics. Lack of time, expertise and travel budgets were among the barriers for participation. (ISO, 2014). Kica (2013, 2015) analysed the legitimacy of ISO TC 229. One of the things she did was a survey of 76 participants from 20 of 35 participating countries, concluding that industry and developed countries played a more dominant role than NGOs and the least developed countries.

### OECD – 2006

The Organisation for Economic Cooperation and Development (OECD) has tabled discussion on nanotechnologies in two working parties since 2006: one on manufactured nanomaterials (WPMN)[31] and one on nanotechnology (WPN, succeeded by the Working Party on Bio-, Nano- and Converging Technologies, BNCT, since 2015)[32]. This international organisation offers a platform for industrialised countries to reach common international agreements that can be legally binding to the member states, including the OECD Council Decision on Mutual Acceptance of Data (MAD) for chemicals in general. Participants in the WPMN aim to clear the way for nanomaterials to become part of this international system of legally binding agreements on the exchange of safety data (Malsch et al. 2015). The WPN developed an OECD Planning Guide for Public Engagement and Outreach in Nanotechnology, published in 2012. Its procedural recommendations were tested on case studies in The Netherlands, South Africa, Ireland and South Korea. Current priorities in BNCT include Measurement and Impact, Emerging Technologies for Health, and Bio-Production. Current priorities at the WPMN include the development of OECD guidelines for testing strategies specific for nanomaterials and regular tour de tables of national activities regarding nanosafety.[33]

### UNITAR – 2009

The United Nations Institute for Training and Research (UNITAR) has taken over capacity building on nanodialogue and governance in cooperation with governments in emerging economies, transition countries and developing countries in Asia-Pacific, Latin America, Africa and Eastern Europe. It proposed “Guidance for Developing a National Nanotechnology Policy and Programme”. The focus is on risk governance and nano-regulation, emphasising the need for wide stakeholder engagement and training in all stages of the policy-making process (UNITAR, 2011).They have been organising regional workshops and national pilot projects in Africa, the Arab world, Asia-Pacific, Central and Eastern Europe, and Latin America and the Caribbean until today (c.f. Malsch et al., 2016).

### Other international organisations and platforms

Since around 2009, the World Health Organisation (WHO) has been developing Guidelines on "Protecting Workers from Potential Risks of Manufactured Nanomaterials" (WHO/NANOH)[34]. Since 2015, the WHO Chemical Risk Assessment Network has been drafting an Environmental Health Criteria Document on Principles

[31] www.oecd.org/sti/nano
[32] https://www.innovationpolicyplatform.org/oecd-working-party-bio-nano-and-converging-tech-bnct-0
[33] http://www.oecd.org/env/ehs/nanosafety/
[34] For further information please visit: http://www.who.int/occupational_health/topics/nanotechnologies/en/

and Methods for assessing the risk of immunotoxicity associated with exposure to nanomaterials.[35] The WHO and the Food and Agricultural Organisation (FAO) have been cooperating on discussions and technical papers on risk assessment and risk management in the food and agricultural sectors.[36] The Sub-committee on Globally Harmonized System (GHS) of Classification and Labelling of the UN Economic Commission for Europe (UNECE) has also put nanotechnology on its agenda. France took the first initiative in 2008. As more scientific evidence became available, this committee included a new work item “Review the applicability of GHS to nanomaterials” in the programme for 2013-2014, that was extended to 2015-2016 (source: Mireles Diaz). The SAICM brings together more international organisations interested in governance of nanotechnologies, that appear to be currently more observing than taking action by themselves (SAICM, 2015, see figure 2.4.2). The World Economic Forum hosts a Global Agenda Council on nanotechnology discussing potential benefits and risks of nanotechnologies. Topics include potential mainly beneficial impacts of nanotechnology on climate change, geopolitics, for reducing inequality, fighting superbugs, solving the energy crisis, jobs and entrepreneurship, etc.[37]

### Examples of International Engagement

At international level, researchers present their work at a wide range of large and small scientific nanotechnology conferences, and more disciplinary conferences. Some of these table discussions related to Responsible Research and Innovation. For example, in the area of nanomedicine, the European Foundation for Clinical Nanomedicine (CLINAM)[38] hosts the International Society for Nanomedicine, offering a platform for discussion about scientific as well as societal aspects. Online communities of nanoscientists include NanoPaprika where ethical, legal and social aspects and nanosafety are also covered.[39] Journals including Nature Nanotechnology[40] and Journal of Nanoparticle Research[41] offer platforms for publications of scientific results as well as discussion of policy, societal and ethical issues. Researchers also participate in ISO and OECD platforms as experts. Social and human scientists report on dialogue and engagement activities at several conferences including the S.NET[42] and in journals including NanoEthics[43], Science and Engineering Ethics[44] and Journal of Responsible Innovation.[45] Current issues include progress in nanosciences, translationary research and innovation, nanoeducation and training and communication to the public, responsible research and innovation and nanoethics, nanosafety, sustainable nanotechnology, etc. Nanotechnology is included in Future Earth’s Strategic Research Agenda 2014: Priorities for a global sustainability research strategy for the next 3-5 years. This is a new international platform for contributions of science and technology to sustainable development. Nanotechnology is part of priority C1: Understanding and evaluating transformations. *2. What opportunities and risks might arise from new technologies (e. g. nanotechnology, biotechnology, bioengineering and geoengineering)? What are the trade-offs and implications associated with new technologies, including their distributive social effects in the context of environmental change? How can the impacts of new technologies, products and services on global and local sustainability outcomes be assessed?* Future Earth is a platform for

[35] For further information please visit: http://www.who.int/ipcs/network/en/
[36] For further information please visit: http://www.fao.org/food/food-safety-quality/a-z-index/nano/en/
[37] http://www.weforum.org/communities/global-agenda-council-on-nanotechnology
[38] https://www.clinam.org/eur-int-society-for-nanomedicine.html
[39] http://www.nanopaprika.eu/
[40] http://www.nature.com/nnano/index.html
[41] http://link.springer.com/journal/11051
[42] http://www.thesnet.net/
[43] http://link.springer.com/journal/11569
[44] http://link.springer.com/journal/11948
[45] http://www.tandfonline.com/loi/tjri20

interdisciplinary research combining natural and social sciences for sustainability. It is the fruit of collaboration between several international scientific associations, UN bodies, etc.[46]

Several international NGOs have been fostering global dialogue on nanosafety. These include the ETC group,[47] the Centre for International Environmental Law (CIEL)[48] from the United States, IPEN[49] (international), Friends of the Earth Australia and Europe[50], the International Union of Food and Agricultural Workers (IUF) and its Latin American branch REL-IUTA, the American Federation of Labour and Congress of Industrial Organizations (AFL-CIO)[51], the European Trade Union Institute (ETUI)[52], etc. In 2007, over 70 social organizations and unions from six continents signed the Principles for the Supervision of Nanotechnology and Nanomaterials and established a global alliance of social groups interested in assessing and monitoring nanotechnology (Invernizzi and Foladori, 2013). This international NGO coalition participates in dialogue on risk governance of nanomaterials at the level of SAICM and its participating UN bodies. In addition, the World Social Forum has hosted workshops on nanotechnology since 2004, targeting nanosafety, employment, developing countries and capacity building of CSOs.[53] On a practical level, the NGO Practical Action has been working on local nanotechnology solutions for water since 2006, moving from dialogue in Zimbabwe via engagement in Peru to delivery of solutions to water pollution in mining regions in Peru.[54]

CSOs from the USA and Canada are campaigning for risk governance of nanomaterials and to a lesser extent other issues including implications for employment and the global south. They play a leading role in international CSO networks. Friends of the Earth Australia have been leading the international campaign on nanosafety especially targeting cosmetics and food. CSOs in other countries are less visible if at all active.

Several news and information sites cover mainly technological developments in nanotechnology, although nanosafety and ethical, legal and social aspects are also featured from time to time: Nanowerk[55], AZoNano[56], Nanotechweb (Institute of Physics, UK)[57] and Nanotechnology Now[58]. SciDev.Net covers science and technology for developing countries, including nanotechnologies.[59] Analyses of North American media reports on nanotechnology are covered in section 3.1.5. In Asia and the Pacific, media activity and focus depends very much on the country. Beumer (2015) analysed 273 articles on nanotechnology in the Times of India between 2000 and 2010, 205 of which were about positive effects and 15 about negative effects. The main issue identified is the concern of missing out on the benefits of nanotechnology, in particular for various social groups in India and for the country itself. Experts are concerned that media in Latin America hardly cover nanotechnology. Information on other countries is lacking.

46 http://www.futureearth.org/
47 www.etc.org
48 http://www.ciel.org/issue/nanotechnology/
49 http://ipen.org/
50 http://www.foe.org/
51 http://www.aflcio.org/
52 http://www.etui.org/
53 http://memoriafsm.org/?locale-attribute=en
54 http://practicalaction.org/aim4_nano_and_water
55 http://www.nanowerk.com/
56 http://www.azonano.com/
57 http://nanotechweb.org/
58 http://www.nanotech-now.com/
59 www.scidev.net

### 2.3.3. International initiatives fostering responsible nanotechnology development

#### USA – since 2000

The National Nanotechnology Initiative[60] was launched in 2000 and has since coordinated nanotechnology research funded by a wide range of federal agencies in the USA. The United States has well-established centres of excellence in all areas of nanoscience and technology, including EHS and ELSI.[61] Scientific societies also engage in discussion about nanotechnology, albeit more on technological and economic aspects than on Responsible Research and Innovation. A positive example is the American Chemical Society, which has issued guidance for nanosafety.[62] The NNI is coordinating efforts in nanotechnology development and regulation. In the USA, the 21st Century Nanotechnology R&D Act of 2003 governs federal policies for stimulating and regulating nanotechnology. Funding priorities include environment, health and safety. Since 2014, Nanotechnology-Inspired Grand Challenges are being developed. The first one, announced in 2015, targets future computing.[63] The USA participates actively in OECD and other international dialogue on risk governance of nanomaterials. The USA tends to favour a proactive approach in those negotiations. For further information on the USA national N&N activities, please see Section 1.

#### Canada – since 2005

Canada has had a nanotechnology research centre and network NINT-INNT in Alberta since 2001. It is a joint initiative of the National Research Council of Canada, the University of Alberta, the Government of Alberta and the Government of Canada. This centre is the flagship institute at the core of public-private cooperation fostering responsible research, innovation and human resource development in Canada. It aims to be a global leader in the field. The programmes focus on hybrid nanoelectronics, energy generation and storage, nano-enabled biomaterials, metabolomics sensor systems and innovation support.[64] In Canada, dialogue and research on RRI in nanotechnology is coordinated by the NE3LS network on ethical, environmental, economic, legal and social aspect of nanotechnology. The preparation for this network started in 2005 and the network is supported by the government of Quebec. In 2015, they organised the S.NET conference, themed: from Nanotechnologies to emerging technologies: toward a global responsibility.[65] Canada contributed to the OECD WPN Survey on Responsible Development of Nanotechnology (OECD, 2013). Currently, the National Research Council of Canada does not have a separate programme for nanotechnology. In 2016-2017, nanotechnology is mentioned predominantly under research targeting security and disruptive technologies, but also as an enabler of medical devices and as a priority area in measurement science and standards, which is relevant to nanosafety (NRC, 2016).

#### Asia-Pacific

The Asia Nanoforum, founded in 2004, brings together researchers, policy makers and industry interested in nanotechnology from Australia, China, Hong Kong, India, Indonesia, Iran, Japan, Malaysia, New Zealand,

[60] NNI, www.nano.gov
[61] www.nano.gov
[62] http://www.acs.org/content/acs/en/about/governance/committees/chemicalsafety/safetypractices/nanotechnology-safety-resources.html
[63] www.nano.gov
[64] http://www.nint-innt.ca/
[65] http://www.ne3ls.ca/?lang=en

Singapore, South Korea, Taiwan, Thailand, United Arab Emirates and Vietnam, plus Austria. Priorities in research target socio-economic needs including health, water and energy, as well as nanosafety. They organise annual Asia Nanotech Camps and a competition for young researchers, focusing on Lifestyle, Sustainable, Medical, Environment and water, Energy, and Smart city/nation (internet of things) technologies.[66]

### Peoples Republic of China – since 2000

The Chinese government has been stimulating nanotechnology development through consecutive Five Year Plans of National Key Scientific and Technological Research Program on Nanotechnology since the 1990s (Balzer and Askonas, 2016). The National Steering Committee for Nanoscience and Nanotechnology (NSCNN) has coordinated nanotechnology R&D since 2000. Standardisation has been incorporated as a key element from the beginning. China's concerns with nanosafety are similar to those in the EU, but China puts more emphasis on the responsibility of the scientist than of the government. By 2012, China was working on a Code of Conduct for responsible nanotechnology, but it is unclear what its current status is (Dalton-Brown, 2012). Progress and affluence are reportedly the main drivers in the public discourse on nanotechnology in China. While risk assessment and environmental, health and safety aspects of nanomaterials are a topic of research and international collaboration, this is predominantly seen as a contribution to the goal of achieving affluence. There is a scientific discussion exploring nanoethics issues, but this is not reflected in the public debate (Fautz et al. 2015).

### India – since 2001

The Indian government has been advancing nanotechnology through the National Science and Technology Programme (2001-2006) and the National Science and Technology Mission (from 2007) of the Department of Science and Technology.[67] They promote risk management of nanomaterials. Research on nanotoxicology (ongoing) and risk governance initiatives (until 2011) have been included. The Energy and Resources Institute (TERI) is a leading research centre in these topics.[68] The public discourse on nanotechnology in India emphasises its expected contributions to grand development challenges. Few projects target nanotoxicology and risk governance of nanomaterials is not a government priority (Fautz et al. 2015).

### Japan – since 2001

Japan has been a global leader in nanotechnology research and innovation from the beginning. The focus of subsequent national plans since 2001 has been on fostering industrial applications of nanotechnology. Research on nanosafety is included and carried out by several public research organisations (Zagar, 2014). Japan participates in international dialogue on responsible nanotechnology development, e.g. in the OECD. There have been projects involving European countries and Japan in attempting to set up technology assessment initiatives, including the I2TA (Innovation and Institutionalization of Technology Assessment) project in Japan. The Research Institute of Science and Technology for Society, RISTEX carried out this project between 2007 and 2011. It aimed to develop an innovative TA methodology, implement TA practices and give recommendations for new TA methodologies and institutionalization of TA in Japan (c.f. Steeghs, 2011).

[66] The homepage was hacked, but other pages are still working: http://www.asia-anf.org/ANFNetwork.php
[67] http://nanomission.gov.in/
[68] http://www.teriin.org/

### Australia – since 2008

The Australian government also formulated an approach to responsible nanotechnology governance including safety, standards and regulation.[69] The Australian Nanotechnology Network brings together all groups working in nanotechnology including one on philosophy and ethics (Centre for Applied Philosophy and Public Ethics, Australian National University, Canberra) and one on social and ethical aspects (Centre for Strategic Economic Studies, Victoria University, Melbourne).[70] Australia contributed to the OECD WPN Survey on Responsible Development of Nanotechnology (OECD, 2013).

### Israel

In Israel, former President Shimon Peres put nanotechnology on the political agenda in 2003, and raised funding for Israel's National Nanotechnology Initiative (INNI).[71] This platform stimulates the development of nanotechnology in Israel in international cooperation. From the beginning, ethical and societal issues have been addressed including potential contributions to water purification and food preservation as well as military applications (c.f. Malsch, 2011).

Israel has been an Associated Country to the EU Framework Programmes for RTD and Horizon 2020 for many years. Partners from Israel have participated actively in EU funded projects on nanotechnology in general and on responsible nanotechnology development in particular. A frequent player is the Israeli School Net ORT,[72] which participated in NanoYou, NanoChannels[73] and NanoEIS.[74] Tel Aviv University has participated in EU projects discussing ethical, legal and societal aspects of nanomedicine.

### Other countries in Asia-Pacific

The Nanotec Centre in Thailand has been the core institute for Thailand's nanotechnology research since 2003. Responsible research and nanosafety are a priority[75] (c.f. Dalton-Brown, 2012). The National Science and Technology Development Agency (NSTDA) of Thailand has expressed interest to become a member of the European NANoREG consortium aiming to establish a common approach to nanosafety and regulation.

India has been investing in Nanoscience and Nanotechnology since 2001 under the Nanoscience and Technology Initiative until 2005 and under the Nano Mission since 2007.[76] They also engage in international cooperation with Taiwan, the EU, Italy, Germany and the USA. The research is carried out in 13 main facilities and 56 key centres. Policy-makers from New Zealand, Japan, China, India and other active Asian-Pacific countries actively participate in international dialogue on nano at the OECD and other forums. South Korea has already signed a cooperation agreement with NANoREG. Information on other countries can be found on the ANF website.

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[69] http://www.industry.gov.au/industry/IndustrySectors/nanotechnology/Pages/default.aspx
[70] http://ausnano.net/index.php?page=home
[71] http://www.nanoisrael.org/
[72] http://en.ort.org.il/
[73] http://www.nanochannelsfp7.eu/
[74] www.nanoeis.eu
[75] http://www.nanotec.or.th/en/
[76] http://nanomission.gov.in/

### Latin America – since ~ 2005

Brazil is the most active Latin American country in nanoscience, followed at some distance by Mexico, Argentina, Chile and Colombia. Academic research is also carried out in other countries. In Brazil and Argentina, the government is stimulating nano-innovation and cooperation with industry. There is a big gap between industry and academia in innovation in general and nanotechnology in particular. Basic nanoscience is dominant all over Latin America. Priorities in research include health and energy applications, information and communication technologies, environmental applications, agrifood applications etc. Nanoeducation engaging professors from several Latin American countries is coordinated by NanoAndes. The aim is to improve the quality of the curriculum and to share resources.[77] Communication and public awareness raising activities on nanotechnology in Latin America, Spain and Portugal is coordinated by NanoDYF.[78] Social scientists interested in nanotechnology collaborate across Latin America in ReLANS. Research on responsible nanotechnology in Latin America is coordinated by the Latin American Network for Nanotechnology and Society ReLANS. Key priorities of this network include nanosafety, regulation, impacts on trade in commodities and employment, engagement with civil society organisations and other societal concerns.[79]. It is coordinated by Noela Invernizzi of the University of Parana in Brazil and Guillermo Foladori of the University of Zacatecas in Mexico.[80] A recent review of nanotechnology in Latin America has been developed in the EU funded project NMP-DeLA (Invernizzi et al, 2015).

So far, Responsible Research and Innovation (RRI) per se has seldom been discussed in broader Latin American forums beyond social and human scientists. The Argentinean National Committee on Ethics in Science and Technology (CECTE) has published “Propositions for a socially responsible science and technology” (CECTE, 2013). It has also been discussing a Code of Conduct for nanotechnology inspired by the European Commission Code of Conduct since 2008, without reaching a conclusion. In Brazil, the federal government funds research in nanotoxicology and in ethical, legal and social aspects. The Brazilian government has also signed a cooperation agreement with the European NANoREG project aiming to prepare the ground for the regulation of nanomaterials. Other countries, including Uruguay and Colombia, have cooperated with UNITAR in developing national strategies for nanotechnology including nanosafety aspects (Malsch et al., 2016). Policy-makers of several Latin American countries have been active in international dialogue on nanotechnology and on nanosafety. Brazil has signed a cooperation agreement with NANoREG.

### Russia – since 2006

The Russian government has been promoting nanotechnology through a “Program on Coordination of Nanotechnology and Nanomaterials Development” announced in 2006, the National Nanotechnology Network of universities and institutes and the Russian Corporation of Nanotechnologies (RusNano), for public-private partnerships and spin-off commercialization since 2007. Responsible Innovation is not clearly addressed (Balzer and Askonas, 2016).

[77] www.nanoandes.org
[78] www.nanodyf.org
[79] http://www.relans.org/inicio.html
[80] http://www.relans.org/inicio.html

# Chapter 3: Levels of awareness and engagement of Stakeholders in the EU

# 3. Levels of awareness and engagement of Stakeholders in the EU

## 3.1. Researchers

The widely spoken RRI is the European Union's approach to good governance on research and innovation. Taking this point into consideration, a few FP7 and H2020 projects have been aiming to develop tools to encourage and support the different stakeholders involved in RRI in taking up the respective concepts and practices (EC, 2013c, RRI-Tools project[81]). In the context of the present chapter, the academia/researchers group has been examined with respect to the opportunities, objectives, and needs it faces with respect to RRI (Table 1).

**Table 1 Identified opportunities, obstacles, and needs of the researchers**

| Researchers/Scientists | | | |
|---|---|---|---|
| **Opportunities** | **Obstacles** | **Needs** | **Recommendations** |
| New opportunities for individual researchers<br><br>Coordinating existing RRI practices across research and innovation structures<br><br>New networks and partnerships | Scientific culture rewards publications, not RRI<br><br>Science is unpredictable and academic freedom important<br><br>RRI shouldn't generate more bureaucracy<br><br>Need for the right relationships | Change current research culture to be more in line with RRI<br><br>Include RRI in training and education<br><br>Review research funding and commissioning through an RRI framework | Rewarding individual scientists who engage with RRI<br><br>More collaborations, new research questions, better science<br><br>Improving stakeholder collaboration |

**Source**: Based on information available through RRI Tools project - D2.2 Report on the analysis of needs and constraints of the stakeholder groups in RRI practices in Europe (http://www.rri-tools.eu/)

**Opportunities**: Currently, we are facing a dynamic process where development is stimulated by a need of commodities that provide comfort and a better life to citizens, and ambition is essential for "climbing the ladder" of progress. In this context, researchers are facing strong complexities in understanding how to adjust themselves to this "moving body" as the values of conduct and behaviour become mandatory, concerning the use of materials (recycling, re-use, and substitution – RRS) and connected safety issues.

The involvement of researchers in discussions with the public about issues of science and technology at its earliest stages is seen to enable science to more closely reflect the wishes of society, thus helping build trust in science and science governance (Wynne, 2006). Opportunities are also seen to come from open science, which could provide better access to collaborative tools and platforms, and help make knowledge production more productive, by encouraging researchers to work together (Fecher & Frieske, 2014). Addressing a 'largely unconscious bias' in scientific research, which involves making judgments or decisions on the basis of prior experience, own personal deep thought patterns, unconscious assumptions or interpretations, also offers the opportunity to improve scientific research and innovation (The Royal Society, 2015).

[81] http://www.rri-tools.eu/

This means that we have to reconsider the research funding and commissioning through RRI framework action that need to be taken, in order to encourage researchers to consider the outputs, consequences and impacts of their research.

**Obstacles and needs**: Outreach activities, such as public engagement and open dialogues, are time-intensive from the perspective of the individual scientists, particularly when formal scientific career development structures do not reward such activities (Smallman et.al., 2015). The researchers' perception that public engagement lies "*beyond the scope of normal scientific activity*" (Jørgensen et al., 2004) echoes the related perception that engagement does not contribute to 'better' research tied with a broader uncertainty about the objectives of outreach activities. This perception is in part due to a general lack of supporting infrastructure for outreach activities (training, integration in university curricula); researchers' limited awareness about existing opportunities to engage with society (EC, 2014b) and a general lack of clarity about whether individual scientists 'should' be responsible for engagement activities (Davies, 2008). This 'duty' to communicate is particularly relevant when researchers who do engage with the public face the pressure of being appropriate science representatives, and the risk of becoming a target once they become 'too' visible in the public eye (Smallman et.al., 2015).

**Recommendations**. The workshops conducted as part of the RRI-TOOLS project noted the opportunity of widening our understanding of responsibility in the context of R&I, specifically by looking beyond the roles and responsibilities of individual researchers and scientists. The participants of the workshops acknowledged that systems and incentive-structures offer powerful places for change. Further RRI was perceived as providing the opportunity for responsibility to be shared across stakeholders via open and iterative engagement processes from the early stages of the R&I process.

Researchers in particular viewed RRI as an opportunity to expand the way we understand the role of researchers in society. This means not only enabling scientists to engage more directly with RRI processes and outcomes (such as with public engagement activities), but also recognising that scientists work as part of a wider system of institutions, rules, and incentives which can all be transformed through RRI; in particular, helping scientists *feel they are making a difference*. According to the analysis conducted, scientists seems to value the feeling of making a difference through their work, and by providing an opportunity to directly engage with research users, as well as generate problem-oriented research, RRI creates this opportunity for more scientists. Researchers in particular noted that this was important for young and future scientists, and provided an opportunity to retain trained scientists in the R&I system. Additionally, new training opportunities at different stages of the scientific career as central to RRI, including developing more interdisciplinary curricula at universities or training researchers on public engagement and communication tools were considered as appropriate. New structural opportunities such as supporting cross-sector research (particularly researcher-CSO collaborations) and wider institutional recognition for RRI-related activities (changing the way scientific career advancement is assessed for example) were also discussed. By generating new incentives for scientists to engage in RRI process activities – such as developing an RRI seal or integrating public engagement into the way research is funded –RRI makes it easier to recognise and reward RRI practices within scientific careers. Overall, identifying new questions and helping scientists look at the big picture could enable the development of new research questions and target areas currently not even being addressed. In particular, engaging with the public would enable scientists to put people at the heart of research, to consider bigger picture questions and to trigger reflection and action about the end goals of specific research. Especially when there could be dual use of technology, engaging early would facilitate discussions about benefits and risks.

Overall, researchers focused on the important potential of RRI to transform the way science is done and viewed RRI as an opportunity to rethink the product(s) of science. They also emphasised the key role of RRI for better recognising and rewarding individual scientists who engage with RRI process requirements and outcomes, but were keen to emphasise that RRI also provides the opportunity to reshape the incentive structures that influence the culture of science in Europe (Smallman et.al., 2015).

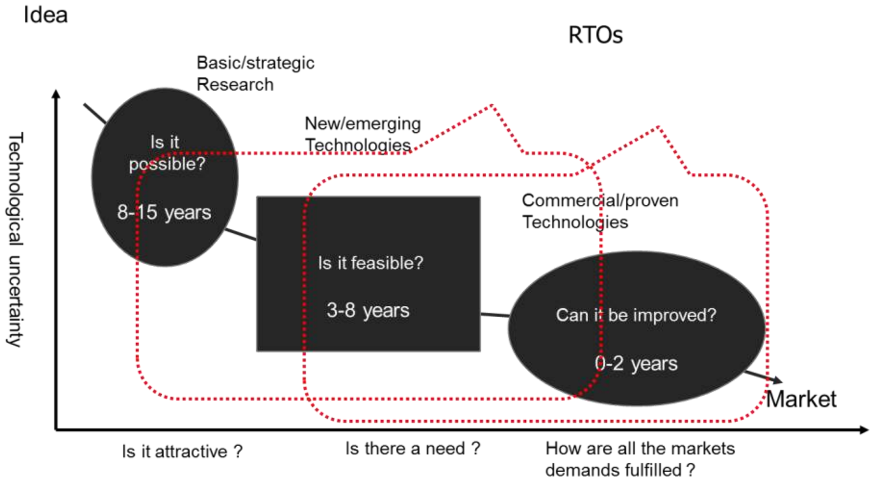
### The Role of RTOs in EU Innovation Ecosystems

Research and Technology Organizations (RTOs) are important institutions in Europe's research and innovation landscape, and they are usually established as "not for profit" organisations. There are many excellent and different models across Europe that have been successfully operating over many decades. The European Association of RTOs (Technopolis, 2011) lists a membership of >350 organizations with a combined workforce of ~150,000 staff. It reports a combined annual turnover estimated at €23 billion, with direct annual economic impact of ~ €40 billion which rises to €100 billion if economic spillovers are included.

RTOs are key technology translation vectors within innovation eco-systems, working with industry, universities and government across the whole innovation chain, from fundamental to technological research, from product and process development to prototyping and demonstration, and on to full-scale implementation in the public and private sectors. Their business models are based on income from 3 sources: a) public core funding; b) income from competitive contract research and consultancy for private and public clients including government and the EC; and c) commercial customer revenues.

A significant number of RTOs specialize in different Nanotechnologies, Advanced Materials, Biotechnology, and Advanced Manufacturing and Processing (NMBP) technologies, and this project has noted dominant players, both leading and participating in Nanosciences, Nanotechnologies, Materials and new Production Technologies' (NMP) projects (50% in FP7 up from 40% in FP6) (LEIT/NMPB, 2014), which are involved in proposals addressing different key areas within NMBP, aiming to exploit materials functionalities or in other DG research, such as CONNECT (ICT), exploiting their use to building blocks of products or systems. Individually, and through their umbrella organization EARTO, they have developed research and innovation principles based on Technology Readiness Levels (TRLs) to produce well-researched and ethically-balanced technology innovation portfolios for their respective organizations' business plans. An illustrative example is given in Figure 7.

**Figure 7: Role of RTOs on Innovation Timescales**




Source: LEIT-NMBP Advisory Group (2014), Consolidated Report

*RTOs have also strong national and regional roles in developing smart specialization*[82]. In terms of revenues, employees and global footprints, the best could be described as large or mid-CAP companies. This enables strong engagement with multinationals, SMEs, higher education establishment and policy-makers.

## 3.2. Industry

Nano-enabled products generated $254 billion in 2009 (*WTEC Panel Report, 2010*) from new products as well as the improvement of existing products in medicine, chemistry, electronics, IT, optical industry, automotive industry, textiles, environment, energy and construction technologies. As anticipated, the revenues from nano-enabled products have continued to grow, from $339 billion in 2010 to $731 billion in 2012. An expanded forecast for nano-enabled products anticipates the global value of nano-enabled products, nano-intermediates, and nanomaterials to be reaching $4.4 trillion by 2018 (LuxResearch, 2014).

Overall, there are two ways of understanding the role of business in RRI, (RRI-Tools project):

1. The objective of businesses is to generate profits, according to the classical neoliberal school of thought, and thus social goods are not the immediate concern of businesses. However, a product that raises public concerns cannot generate profits. Thus, RRI can help businesses come closer to their clients, understand and address their concerns and thus produce products that will be appreciated and purchased by customers. Also, more innovative products and solutions can be developed through businesses engagement with people/entities that are/can be affected by the businesses' decisions. Finally, companies operate in regulated environments, and engaging in RRI activities can assist them to early identify upcoming regulatory regimes in terms of social, environmental and research responsibility.

[82] The Smart specialisation' approach, developed by JRC/IPTS in 2011, is an innovative policy concept which emphasizes the principle of prioritisation in a vertical logic (to favour some technologies, fields, population of firms) and defines a method to identify such desirable areas for innovation policy intervention. It combines industrial, educational and innovation policies to suggest that countries or regions identify and select a limited number of priority areas for knowledge-based investments, focusing on their strengths and comparative advantages. For further information please see: Foray D., Goenega X., (2013) The goals of smart specialisation and the S3P Platform: www.s3platform.jrc.ec.europa.eu/

2. The importance of companies' good image and respective CSR-attitude. Companies do wish to appear as socially and environmentally friendly to the general public, thus do employ themselves in CSR and socially-driven activities. In accordance, RRI activities are considered a step in this direction, as from a sociological perspective "good firms" that behave well are to be praised for their efforts, even if results are not as good as should; while "cowboy" (or "rogue" firms) are condemned because they endanger the credibility of the "good firms". (Rip, 2014)

Overall, in this large market, businesses have a significant role to play not only from the innovation and production side but also from the side of safekeeping customers and citizens while taking into consideration the dynamics and outcomes of all other involved interacting players. Thus, businesses in the area of nano have been in need of strategies for dealing with these uncertainties. In this context, a number of Codes have been developed that aim at "regulating" such issues.

### Industrial initiatives towards RRI

The Responsible NanoCode

On 7 November 2006, the 'Royal Society Insight Investment and the Nanotechnology Industries Association' organized a workshop where they brought together 17 European companies with a commercial interest in nanotechnology, from food and chemicals manufacturers to retailers of healthcare and fashion. One of the main outcomes of the workshop was a unanimous agreement on the requirements for a voluntary Code of Conduct for businesses engaged in nanotechnology. (For further information on the code, please see Chapter 1). Despite its promising nature, the initiative faced resistance from Industry, as corporate attorneys suggested that "*the structure of the code could create legal liabilities for members*" (Howard & Wetter, 2011).

Industry Messages on Nanotechnologies and Nanomaterials

*Nanotechnologies involve manufacturing and using materials at the smallest scale. The views of 15 European industry associations with an interest in nanotechnologies and nanomaterials (Cefic, ESIA, EURATEX, ELC, ACEA, European Crop Protection, FECC, PlasticsEurope, IMA Europe, European Photocatalysis Federation, EuPC, ETRma, CEPE, NIA, FEICA) have been recorded in the 2013 position paper "Industry messages on nanotechnologies and nanomaterials"* (CEFIC, 2013).

In 2013, the European industry associations gathered to declare their support to the Commission Communication on the 2nd Regulatory Review on Nanomaterials and its conclusion that the current European regulatory framework adequately covers nanomaterials is science-based and proportionate. Together, they called for a balanced policy on nanomaterials, ensuring the protection of human health and the environment, while providing the necessary framework for enhancing innovation, growth and jobs in Europe.

The following 7 key points were highlighted:

*Nanotechnologies provide solutions*: Nanotechnologies contribute to solving the important challenges that our society is facing. They provide solutions to food sanitation, hygiene, health, water, and climate protection for a growing global population in a world where the optimal use of natural resources is a must.

*Europe needs nanotechnologies to achieve the goals of the EU 2020 strategy*: European industry believes in innovation as a driver for social, technical and economic progress. Key enabling technologies, such as nanotechnologies are likely to affect innovation in most industrial sectors and are likely to contribute considerably to future smart, sustainable and inclusive growth.

*Safety is paramount*: European industries initiate and sponsor research into the safety of nano-enabled products. Significant progress has been made in test methods, data collection and assessments to evaluate any potential risks of nanomaterials in common applications.

*Openness and transparency are vital*: Industry supports the European Commission impact assessment on possible measures to increase transparency on nanomaterials on the market. This will ensure a pragmatic approach, taking account of the proportionality principle and the need to protect confidential business information.

*The comprehensive European regulatory framework in place has the capacity to govern the production and use of nanomaterials*: This framework sets the highest safety standards and covers all industry sectors.

*A common workable definition system for defining nanomaterials is welcome*: The current European Commission recommendation is a basis for assessing nanomaterials within the regulatory framework. However, its effective implementation still represents a challenge for industry.

*Europe cannot afford to miss out on the opportunities provided by nanotechnologies and the benefits they bring*: Without a positive investment climate for the deployment of nanotechnology in Europe, EU industries will become less competitive. This in turn would also risk giving rise to social, economic and environmental disadvantages for our region from a global perspective. European industries must be competitive in global markets.

Cefic's Responsible Care® and the Responsible Care Global Charter

*Responsible Care* is a global environmental, health, safety and security (EHSS) initiative to drive continuous improvement in performance across all of the European Chemical Industry Council's (Cefic) activities. It achieves this objective by meeting and exceeding legislative and regulatory compliance, and by adopting cooperative and voluntary initiatives with government and other stakeholders.

The Responsible Care Global Charter aims to commit companies and national associations to working together to implement the principles of Responsible Care and turn them into a living and working reality in chemical companies throughout the world. The Charter focuses on new and important challenges facing the chemical industry and global society, including the growing public dialogue on sustainable development, public health issues related to the use of chemical products, the need for greater industry transparency, and the opportunity to achieve greater harmonisation and consistency among national Responsible Care programmes. One of the key pillars for the implementation of Responsible Care is Product Stewardship.

Companies and chemical associations actively participate in the debate around the safety of nanomaterials and the need to implement risk analysis and risk management according to the precautionary principle as developed by the European Commission (EC, 2000).

BIAC – The Voice of Business at the OECD

BIAC[83] is the Business and Industry Advisory Committee to the OECD (Organisation for Economic Co-operation and Development). BIAC is an independent international business association devoted to advising government policymakers at the OECD and other related forums on the many diversified issues of globalisation and the world economy. BIAC mission is to promote the interests of business by engaging, understanding and advising OECD policy-makers on a board range of issues.

BIAC includes the following members:

- Member Organizations: the leading business and employers organizations in the corresponding OECD member countries
- Observer Organizations: granted an observer status in non-OECD member countries seeking to engage in BIAC's activities
- Associate Expert Groups: sectoral supra-national business organizations that engage regularly in BIAC's policy work

BIAC provides expertise on biotechnology and nanotechnology to the OECD and governments. Nanotech and Biotech Discussions on applied biotechnology and nanotechnology stimulate strong BIAC member participation in different working parties of biotechnology and nanotechnology at the OECD. They provide expert input into different projects carried under the OECD's Environment Directorate on the applications of these technologies, including the safety of novel foods and feeds, and different sponsorship programs under the working party of manufactured nanomaterials.

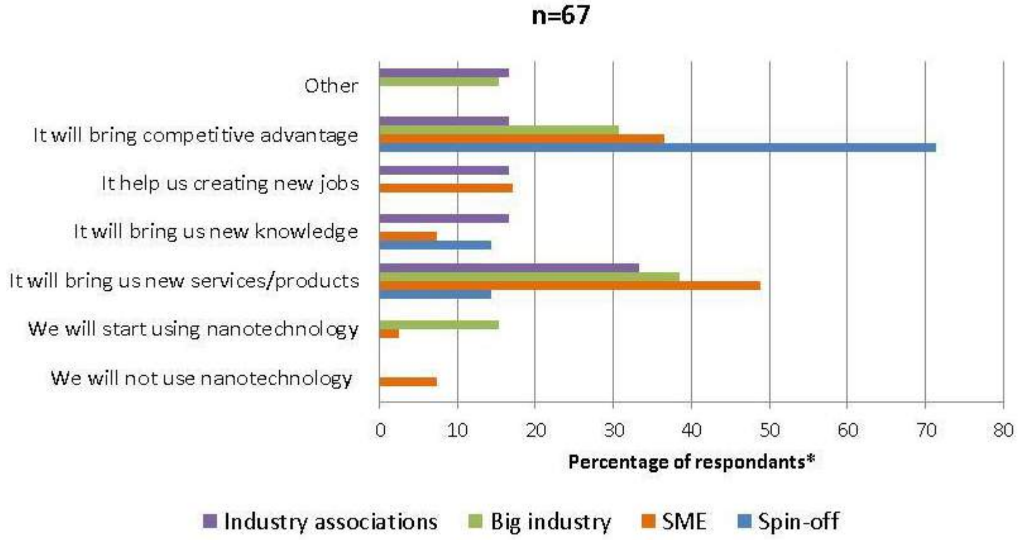
### Evaluation of European Industry Needs for nano, RRI Skills and Expertise

A report has been prepared by NANOfutures (NfA) and the Nanotechnology Industries Association (NIA) in the framework of the FP7 project NanoEIS aiming to analyse the needs for nanotechnology skills and expertise in employees, both at the time of recruitment and afterwards (i.e. lifelong learning). In gathering this information, an electronic questionnaire was prepared and distributed among industrial members of NfA, NIA and other European clusters and networks. A total of 67 filled surveys were received and analysed.

The bar chart below shows companies' different expectations in 5 years' time with respect to nanotechnology. The majority of spin-off respondents (71%) reported that they expect nanotechnology to bring them a competitive advantage. Almost half of the SMEs, around 40% of Big Industries and one third of Industry Associations expect them to allow them to develop new services and products

[83] http://biac.org

**Figure 8: Companies expectations in 5 years' time with respect to nanotechnology**

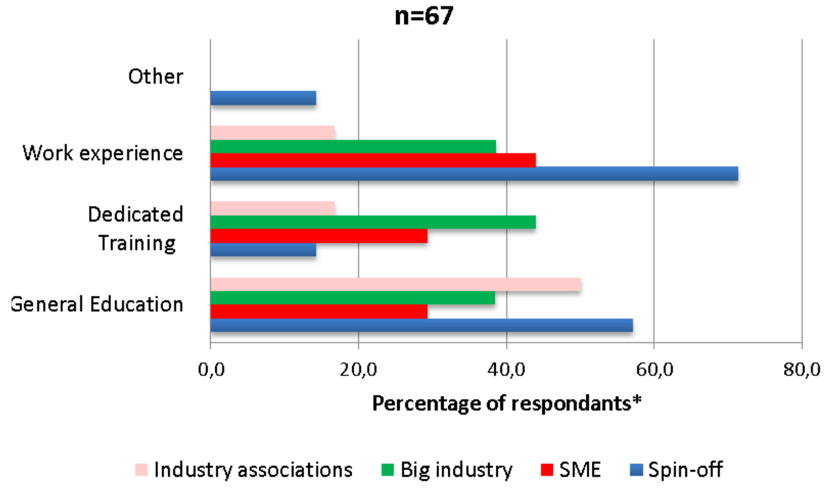



Source: NanoEIS (www.nanoeis.eu)

*Note: Percentages do not always total 100% because respondents could check all that apply*

The majority of the respondents (76%) declared that they have workers with nanotechnology related skills. Interestingly, in the case of spin-offs with less than 10 employees, the number of skilled employees varied from all to at least 1 worker, with an educational level of PhD or master andtThe same level can be found within big industry and associations. The bar chart below (Figure 9) shows companies' different *ways of nanotechnology skills acquisition.* Spin-offs and SMEs tend to rely more on work experience while Big Industries rely more on dedicated training in relation to work experience and general education. Industry Associations on the other hand rely more on general education.

**Figure 9 Nanotechnology's skills ways of acquisition**

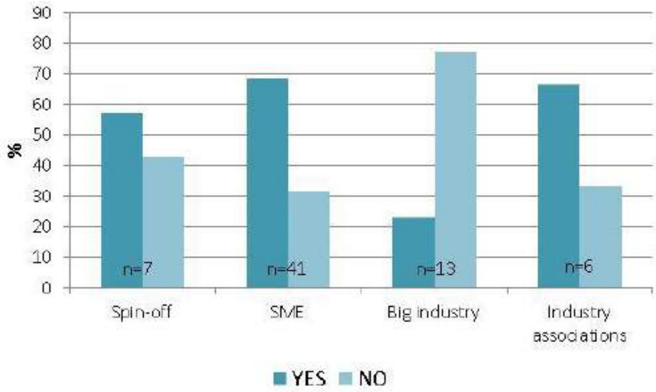



Source: NanoEIS (www.nanoeis.eu)

*Note: Percentages do not always total 100% because respondents could check all that apply*

In five years' time, "health and safety issues" are projected to be the main nanotechnology related skills/knowledge required by Industry Associations, followed by SMEs and Big Industry, together with "regulation/standardization". To acquire these skills, more than half of the respondents (58%) declared that they are willing to **invest in nanotechnology specialized training**. This is particularly relevant to SMEs and industry associations, where percentages increase to 68% and 67% respectively. On the other hand, **77% of big industry players replied that they are not considering investing in training**.

**Figure 10 Percentage of companies willing to invest in specialized training**




Source: NanoEIS (www.nanoeis.eu)

Overall, as identified in the recent RRI related Conference "*RRI in Europe and across the World*" (14-15/01/2016)[84] private companies know little about RRI as a comprehensive concept and only those participating in European research programmes, such as FPs or Horizon 2020, know about it. Nevertheless, companies do address topics that are covered by RRI through other concepts such as CSR, diversity management, sustainability, etc.

## 3.3. Policymakers

The mandate for the assessment of new technologies, due to societal and political concerns, has been in evolution over the last four decades (Lucivero, 2016). According to Grunwald (Grunwald, 2011), policymakers across Europe are concerned with the systematic inclusion of normative discussions at the research and innovation level as an aspect of RRI. On EU level, the European Commission is engaged to promote an integrated, safe, responsible and socially acceptable approach for the development and use of nanotechnology. In the context of the present chapter, the policymakers' group has been researched against the opportunities, objectives, and needs they face with respect to RRI (Table 2).

**Table 2 Identified opportunities, obstacles, and needs of the policymakers**

| Researchers/Scientists | | | |
|---|---|---|---|
| **Opportunities** | **Obstacles** | **Needs** | **Recommendations** |

[84] http://www.eesc.europa.eu/resources/docs/summary-from-the-conference-for-the-website-apres-relecture.pdf

| | | | |
|---|---|---|---|
| Involving the public can make more acceptable and accountable policy, research and innovation<br><br>New partnerships<br><br>Enhance competitiveness and creativity | Policymaking is inflexible and doesn't necessarily involve the public<br><br>Difficult to reach representative publics<br><br>Too much focus on the short term | Enable collaboration between different stakeholders<br><br>Review science practice and funding<br><br>Develop training for research funders and managers on RRI | Bringing science and society closer by avoiding controversy<br><br>Improving stakeholder collaboration<br><br>Competitiveness and creativity |

**Source**: Based on information available through RRI Tools project - D2.2 Report on the analysis of needs and constraints of the stakeholder groups in RRI practices in Europe (http://www.rri-tools.eu/)

**Opportunities**: According to the relevant literature, a number of opportunities appear to be offered through public engagement, open government, adaptive management and anticipatory approaches. With respect to policymaking, the early involvement of stakeholders can enable failures in governance and regulation of a technology to be addressed at the early stages of the development (Kearnes et. al., 2006). Widening the evidence base also has the potential to put some alternative issues on the table (Loeber et.al., 2011).

**Obstacles and needs**. For policymakers, the key issues appear to be: public engagement, resource issues, institutional structures, and perceptions of expertise (Emery et.al., 2014). Activities such as public engagement use valuable resources (Kleinman et.al., 2007), extend the timeline of often-pressing decisions and need to be slotted into well-established and often-inflexible processes within institutions (Kurath & Gisler, 2009). There is also a concern that there might be negative consequences – involving the public in decision-making might reduce the political legitimacy of the decision making process (Morrell, 1999), while openness can leave evidence open to challenge (Bresnen & Burrell, 2012), for example.

**Recommendations**. The workshops conducted during the elaboration of the RRI-TOOLS project emphasised the opportunity for greater European collaboration in RRI. Policymakers specified that RRI could foster greater competitiveness and creativity within the R&I ecosystem and also emphasised the potential for RRI to improve policy decisions around R&I, as well as highlighting the value of dialogue and communication in increasing trust in society.

### 3.3.1. NGOs/CSOs

Civil Society Organisations (CSOs) are crucial stakeholders in the development of RRI, representing a truly participatory approach to discussing S&T developments. This type of actors includes non-governmental organisations, consumer or human rights advocates, and any organisation with a focus on the public good operating on local, regional, national or even international level. On RRI, they can promote safe, secure, ethical and sustainable products and processes and can facilitate early stakeholder involvement or public engagement as well as lobbying for wider societal concerns. Within RRI systems they cooperate with industry, science and policy actors in order to contribute to the development of responsible practices in research and innovation activities and policies.

In this context, the RRI tools project set out to develop tools for five key stakeholder groups to encourage and support them in taking up the concepts and practices associated with RRI. A series of interactive one-day meetings across Europe, in form of workshops, were organized in order to understand better the stakeholders' dynamics. According to the outcomes of these workshops, the main needs, opportunities and obstacles were identified for CSOs:

**Table 3 Identified opportunities, obstacles, and needs of the CSOs/NGOs**

| Researchers/Scientists | | | |
|---|---|---|---|
| **Opportunities** | **Obstacles** | **Needs** | **Recommendations** |
| Involve new, more diverse, publics resulting in more informed and engaged citizens<br><br>Enable more open communication between science and society<br><br>Generate new networks and partnerships | CSOs/NGOs lack the relationships to do things on their own<br><br>Information and communication about RRI and science needs improvement<br><br>Limited resources in small organisations | Further and formalise public involvement<br><br>Improve science communication<br><br>Include RRI in organisational structures and strategies | Better support for CSOs in R&I<br><br>More collaboration with researchers and better science<br><br>Improving stakeholder collaboration |

**Source**: Based on information available through RRI Tools project - D2.2 Report on the analysis of needs and constraints of the stakeholder groups in RRI practices in Europe (http://www.rri-tools.eu/)

**Opportunities**. According to the analyses performed on the workshops conducted during the RRI Tools project, public participation was considered among CSOs as a way of avoiding conflict and sidestepping the political deadlock that has led to partisan positions on significant issues in some countries (Carpini D., Cook L., Jacobs R., 2004). Open science is seen by many as a potential way to involve the public more in 'making' science. For instance, opening science could 'extend membership of the research community to new public audiences' (Grand A. et.al., 2012). Democratic reasons are also put forward for open science – making knowledge accessible and freely available to everyone (Fecher & Frieske, 2014). Wajcman (2009) acknowledges that equal employment opportunities may be worthy in itself, but notes that drawing more women into science and innovation is also fundamentally about shaping the world we live in. By placing end users at the heart of R&I processes, gender concerns of RRI create the opportunity of putting the individual at the heart of R&I systems.

**Obstacles and needs**. According to the outcomes of the workshops, several obstacles were pointed out: limited resources and a lack of own performance in research. Thus, they felt the onus had to be on academia to initiate collaboration with them. Additionally, CSOs were perceived by other stakeholders as problematic legitimate and credible partners, which pose several obstacles to collaboration. Finally, the risk of tokenistic engagement was specifically mentioned in relation to collaborating with CSOs (Smallman et.al., 2015). According to the relevant literature, CSO involvement in the R&I system is currently limited (Gall, Millot & Neubauer, 2009) and tends to be even less likely throughout the agenda-setting and commissioning phases. According to the aforementioned report, limited resources are a central obstacle for CSO participation, despite the fact that CSOs differ widely in size and capacity, which affects the type of knowledge they have access to (academic journal subscriptions tend to be prohibitively high for small CSOs or unaffiliated independent researchers) as well as the type of knowledge products they are able to generate. Public trust and CSO reputation are central to their success (Hagendijk R. & Irwin A., 2006, Stirling A., 2007), and the possibility for the public to view CSOs as somewhat 'co-opted' by large institutional interests affects the ability of some CSOs to collaborate with other institutional actors. Indeed, "*CSOs need to be cautious that close relationships with major donors, whether government or business, do not lead to an undermining of public trust in them*" (Hutter & O'Mahony, 2004). The way other R&I stakeholders perceive the knowledge generated by CSOs as less rigorous/scientific than peer-reviewed research affects both the possibilities for their engagement with other actors (particularly business and researchers) and the credibility granted to CSOs operating within the R&I governance system (Epstein, 1995). There remain concerns around who CSOs represent and how to integrate them within PE exercises designed for 'pure' publics (Jørgensen S., et al., 2004, Stirling, 2007).

**Recommendations**. The participants of the RRI-Tools workshops argued that RRI process requirements like diversity and inclusion could give typically under-represented groups, such as small CSOs, access to more resources guaranteed at the European level. These resources would go beyond financial resources, and include – most importantly – appropriate institutional and training support. CSOs, themselves viewed new funding opportunities and tools from RRI as an opportunity to strengthen their position within the R&I system, and particularly their influence on agenda setting, as well as opening up the process to more constructive science-society dialogues via more user involvement in research. They also mentioned the importance of empowering their networking to other stakeholders, as a leverage of their construction of cross-European alliances. Interestingly, both CSOs and Researcher representatives saw value in RRI facilitating collaborations amongst them, emphasising how these may generate both better innovations and better science. CSOs in particular noted that collaboration may help scientists become more aware of the bigger picture. Finally, they emphasized the need to remove stereotypes that inhibit effective, efficient and fruitful collaboration. (Smallman et.al., 2015).

The EU-funded project **NanoDiode** initiated a range of public engagement activities across six European countries (Austria, France, Italy, Germany, the Netherlands and Poland in 2014-2015) with the aim of involving stakeholders and citizens in constructive dialogue on the ways that nanotechnologies could benefit society. By involving a broader range of stakeholders in technological decision making, the project has aimed to support the effective governance of nanotechnologies in Europe and to encourage responsible nanotechnology research and innovation, in an 'upstream' public engagement rationale: to enhance the responsiveness of policy-making processes by enabling the public and CSOs to participate in policy decisions on the direction of research. At the level of research policy-making, this implies fostering a culture of dialogue that allows researchers, industrialists, citizens, CSOs and policymakers to engage in constructive discussions on the desired directions of research. Enabling such a culture of dialogue requires:

- insight in public views and concerns on nanotechnology: what are the main points of contention?
- platforms and methods to productively engage in dialogue, to deepen the discussion on public preferences by means of two sequential instruments: an internet survey and a series of in-depth interviews.

According to the outcomes of the project, an interesting question was raised: To what extent do citizens really feel that RRI should be expert-driven? According to the survey conducted, the respondents (over 1.500 Europeans) considered the involvement of CSOs more important than the involvement of citizens themselves.

This point was further supported by the fact that around half of the respondents stated that CSOs are a valuable source of information on nanotechnologies.

Overall, it is clear in several policy and action reports that communication on nanotechnology research is critical for Europe and particularly European institutions[85]. Public engagement and deliberation over nanotechnologies has produced a consistent set of findings over the last decade through a series of EU-funded projects. The public, while enthusiastic about some applications, tend to view technology as a double-edged sword. They are concerned about the social context in which technologies develop, and are keen to see processes of technological governance opened up (EC, 2010d). In recognition, that CSOs have become key actors in the development of the field of nanotechnology, strategies for further outreach and public engagement in nanotechnology have been identified as crucial elements of national government policies regarding nanotechnology. The need to clarify how to communicate, with whom and how to engage a wide audience in the debate on nanotechnology, and in the development of policies related to it, has been a major point of discussion amongst policy-makers (OECD, 2012).

## 3.4. Media

Most media coverage of nanotechnology is framed within technological and industrial development. People seem to have expectations of greater benefit and less risk with 'nanotechnology' than with 'chemicals' although of course in the end nanomaterials are one kind of chemical.

Media analyses considering print, TV/broadcasting and online media coverage of nanotechnology deal with a variety of different parameters:

- Intensity of reporting on nano over the course of the years
- Intensity of reporting on nano in comparison between different countries
- Article size in print media
- Journalistic format in print media (e.g. opinion or reportage)
- Placement (e.g., science section)
- Evaluation of Nanotech
- Topics of reporting
- Mention of benefits of nano
- Mention of risks associated with nano
- Actors cited

The following points focus on those parameters which have been in the focus in a significant number of studies. This makes it possible to cross-check and validates results (especially if one is interested in findings not limited to a particular country):

- **Intensity of reporting on nanotechnology over the course of the years**: The number of articles on nanotechnology in the press has been consistently declining in the recent past. Even in cases

[85] https://ec.europa.eu/research/industrial_technologies/pdf/ec-nanotechnology-research-mapping_en.pdf

where there was a clear opportunity for reporting (public debates and discussions on Nano), these opportunities were often not seized by the media. (Epp et al. 2013)

- **Journalistic format in print media**: Media-coverage on Nano is clearly science-centred and focused on technological facts. Opinion pieces and investigative journalism are almost not present.

  "There is hardly any opinion-focused reporting, with classical news reports and reports relating to current research activities or events predominating. (…) Investigative journalism and reports that result from a journalist's own research are rare. "(Haslinger et al., 2012)

  "The reporting on nanotechnology in the media in the three German-speaking countries is largely science-centred." (Haslinger et al. 2012)

  "Reporting was to the greater part fact-orientated and descriptive." (Epp et al. 2013; transl. RG)

  Similar results were found in analyses of Twitter-news on Nanotech, indicating moreover a clear focus on commercial reporting:

  - Most Tweets related to nanoscience are descriptions of nano-products […]
  - Tweets that do attempt to explain, tend to focus on nano-based products
  - Explanations of nano-based Products are more likely to appear after Descriptions of nano-based products, suggesting that when there is a specific product to sell, there is more motivation to explain nanoscience in language suited to a general audience. (Appelbaum et al. n.d.; cf. also Runge et al. 2013)

- **Placement (e.g., science section)**: Most media deal with Nano-topics only in sections reserved for science.

  "In all three countries [i.e. Germany, Austria and Switzerland], the newspapers' science departments play a dominant role, Evaluation of Nanotech." (Haslinger et al, 2012)

  "Most commonly, articles were related to the media's science department." (Epp et al. 2013; transl. RG)

- **Topics of reporting**: Most topics were related to those technologies with which consumers normally do not come into direct contact, such as arms, aerospace, energy industry or construction engineering. Also, basic research is reported upon by the media. To a lesser extent, but with rising frequency, applications in the area of healthcare (such as cancer treatment) were subject of media coverage (Epp et al. 2013). Public discussion on Nanotech and activities of NGOs are rarely to be found in the media (Tyshenko 2013).
- **Mention of benefits of Nano & connotations in reporting**: Most media analyses reviewed in this occasion unanimously confirm the positive connotation of reporting on Nanotech in the media. This applies to the language used (adjectives and general tone: Kjaergaard et al., 2008; Tyshenko, 2014), to the framing of reporting ("nano-opimistic"), Tyshenko, 2014) as well to the choice of overall beneficial aspects of nanotech.

More particular, Nanotech is being represented as an innovation important for the future. Chances and benefits play a significantly greater role than possible harms. Risks are not thematised or depicted as under control (Donk 2012; Epp et al. 2013; Kjølberg et al. 2009).

In numbers:
“[T]he benefits and opportunities of nanotechnology, on the other hand, are mentioned in 80 % of all articles. (Haslinger et al. 2012).”

“Only in 11,5 percent of the media analysed a negative evaluation could be found. (Epp et al. 2013; transl. RG)”

The single exception to the general finding is Twitter: one study found that pessimistic opinions outweigh optimistic ones (32 % of all tweets expressing opinion were neutral, 27 % were optimistic, and 41 % were pessimistic). Interestingly, the researchers who have conducted the study assume that their observations are “a glimpse into a community of like-minded nanotechnology innovators who are using Twitter for the purpose of communicating with each other” (Runge et al. 2013:7). This would mean that high percentage of rather pessimistic Tweets cannot be attributed to the same actors (i.e. journalists) as evaluations in traditional news media). This last finding is also confirmed by Appelbaum et al. (n.d.).

- **Mention of risks associated with Nano & negative connotations in reporting**: As mentioned above, risks and controversial reporting are almost absent in media coverage on Nanotech. Also concerns raised regularly in expert circles are seldom taken up by the press.

  Risks thematised most frequently were those in the area of healthcare, followed by “vague” risks, ethical and moral concerns, possible harms to society and ecological risks (Hasling et al. 2012).

  Reasons for the press’ clear focus on the benefits of Nanotech have not been investigated systematically. Hasling et al. (2012) propose that

  “One would have to examine the extent to which the absence of controversies can be attributed to the hitherto lack of evidence of possible dangers and risks or to well-functioning strategic scientific PR work.”

  Face-to-face interviews with science journalists reveal that

  “professional role conception, personal interest, news factors and organisational processes mainly influence the selection of science journalists. Overall, journalists have increasingly positive attitudes towards nanoscale science and technology.” (Guenther and Rohrmann 2013)

- **Actors cited**: Scientists play a central role as actors in media reporting on nano (Haslinger et al. 2012). Experts cited in the media often are in a leading position, representing dominant institutions or companies in the field (Epp et al. 2013).

### 3.4.1. Discussion: Possible Implications for RRI in Nanotech

What must be stated clearly is that "the media" should not be confused with the general public.[86] Factors shaping journalistic treatment of nanotech differ significantly from those influencing public opinion. In fact, the impact of media reporting on public opinion formation seems not even to be clearly discernible, as Scheufele (2006) summarizes:

"[M]most research on public attitudes toward nanotechnology does not show an impact of media coverage on lay audiences' understanding of the technology. […] Instead, most recent research has found that the driving factors behind public attitudes are various forms of heuristics or cognitive shortcuts that audiences use to make sense of the technology, even in the absence of information."

Thus, findings from media analyses should not be used to make assumptions about knowledge and preferences within the general public.

From an RRI-perspective, still some conclusions can be drawn from the findings of media analyses.

(1) One key issue is the almost complete absence of reporting on risks and controversies. In order to make co-production and public participation (e.g. in the development of norms and principles of risk-management) possible, it would be useful if information also about the risky side of Nanotech would be more prevalent in publicly accessible media. Putting more emphasis on risks cannot be prescribed, though. Still, one could try to find out why journalists tend to disregard risks and critical discussion. One proposal here is to

[…] examine the extent to which the absence of controversies can be attributed to the hitherto lack of evidence of possible dangers and risks or to well-functioning strategic scientific PR work. (Hasling et al. 2012)

If indeed the disregard of reporting on risks and controversies is an effect of clever-PR, one could think about measures for counter-action.

(2) Another concern might be that reporting deals predominantly with topics which, from a consumer perspective, are rather outside the realm of everyday concerns. From a public participation and –engagement perspective (especially when it comes to co-creation of products), this is not very helpful. Here one might think about measures to increase publicly accessible information which goes beyond the current narrow framing of scientific innovation and to focus instead more on applications of practical relevance for consumers (Tyshenko 2013).

(3) A third approach could be to frame (within societal engagement projects) information on nanotech and dialogues about nanotech to a vision of sustainable development. This would enable the discussion especially of societal implications of nanotech among lay audiences (cf. Stoeber 2006).

### 3.4.2. What has been the role of media in societal engagement?

Digital engagement tools such as chatrooms, virtual discussion rooms and wiki platforms (real-time or not) have proven to enhance both breadth and depth of understanding of technological and societal issues in the context of

[86] For public opinion on nanotech, the impact of news media on public opinion and other factors shaping public opinion on nanotech see Besley, J. (2010); Binder, A. R. (2013); CBC News (2006); Cobb, M. D. (2005); Leinonen, A., Kivisaari (2010); Nanowerk (2011); Nature.com (2016); Priest (2011); Turney, J. (2013).

nanotechnology. From the side of user experience and popularity, though, online-environments have emerged as second-best choice only, in comparison to face-to-face meetings.

Online media (in particular social media and digital engagement tools) offer a variety of benefits, especially in comparison to face-to-face events, which are usually employed in public-engagements projects in the context of science communications/RRI. Online media make possible:

- Large scale communication: due to the nature of digital communication, a large number of people can be reached and can interact simultaneously using online-/social media
- Efficiency: communication based on online-/social media is much more cost effective than face-to-face events such as e.g. citizen juries or consensus conferences
- Accessibility: From the point of view of participants, taking part in an online-event is more convenient than travelling to and participating in a live consensus-conference
- Rich options for evaluation: Many forms of online-communication allow for the employment of sophisticated tools of data collections and analysis (which are not available as easily in face-to-face communication formats)
- Asynchronous communication: Many forms of online-communication function in an asynchronous mode. Compared to face-to-face situations, this has the advantage that information fed into the process can be considered more carefully. Also, the number of contributions for a certain point is not limited by a given timeframe
- Popularity: Online-communication (especially social/Web 2.0-media) enjoys a high level of popularity among the general public. Therefore, science communication in general an RRI in particular should not miss the chance of engaging in this field.[87]

### 3.4.3. Digital engagement around nanotech

So far, surprisingly few digital engagement tools have been used in the context of societal engagements for nanotech.[88] In the following, we describe two instances where new media were both used and scientifically evaluated in the context of nanotech.

**Online Consensus Conferences**

One of the few examples of mainstream digital-engagement tools used for communication is a case study dealing with the use of an online-collaboration software for conduction sessions of the US National Citizens' Technology Forum (NCTF), which is a form of consensus conference (or citizen panel/citizen jury) (Delborne et.al., 2011). Consensus conferences have been used since the 1980s in order to include the lay public's opinion into the

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[87] Cf. Brossard, D., & Scheufele, D. a. (2013). „Science, New Media, and the Public". *Science*, 339(40). [https://cspo.org/legacy/library/1301221228F94045121DU_lib_BrossardScience.pdf, link accessed 31/03/2016]
For a media analysis specifically on nanotech-themes in Twitter, see Runge, K. K., & et al. (2013). "Tweeting nano: How public discourses about nanotechnology develop in social media environments". In *J Nanoprt Res*, (15), 1381 and Appelbaum, R., & et al., "Twitter as a tool for public engagement with emergent technologies?" (Poster) [http://www.cns.ucsb.edu/sites/www.cns.ucsb.edu/files/demtech/Hasell%20Stocking%20poster%20Nano%20Talk%20Poster.pdf, link last accessed 31/03/2016]

[88] We checked, among other things, the list of recent projects on http://www.nanotechia.org/activity-objective-areas/public-engagement-communication and the UK's Nanotechnology Engagement Group's report Democratic Technologies (2007) for digital engagement projects.

process of political decision-making. The purpose of a consensus conference is not only to obtain the opinion of an (informed) public, but also that of educating the conference participants in order to arrive at an informed and qualified opinion, decision or consensus concerning a giving topic. Members of a consensus conference are chosen to be demographically representative of the public[89].

Usually, members of a consensus conference meet several times over a couple of days in order to discuss with invited experts and to arrive at a final document. Concerning the triade 'co-creation of products, co-production of norms and participatory risk management', the deliberative format of a consensus conference seems to be well-suited particularly for participatory risk management. (Co-production of norms might already be too complicated as to be conducted on the basis of a discussion among lay persons which is not supported by problem structuring methods. Co-creation needs formats which do not rely on words only.)

In the case of the National Citizens' Technology Forum, face-to-face meeting were supplemented by 'virtual' keyboard-to-keyboard sessions for discussion. For this purpose, a virtual discussion room (chatroom + whiteboard area) was used. The process was evaluated on the basis of surveys, interviews with the participants and field notes taken by the researchers during the sessions.

Results of the process look, at first sight, very promising: By many measures, the NCTF was highly successful. Final reports from each locale demonstrated both breadth and depth of understanding, and significant overlap in their recommendations increases the potential for the reports to have impacts beyond the NCTF process. […] [S]urvey data […]show significant increases in knowledge by participants […] [and] increases in their sense of internal political efficacy" (Delborne et.al., 2011).

The picture changes, though, when subjective experience of participants is taken into consideration. Most participants assumed ex ante that they would prefer online-communication over face-to-face meetings. Ex post, preferences had reversed: nearly half of participants changed their preference for discussing controversial issues away from online and toward face-to-face. Among the reasons for this change of preferences were both technical problems and difficulties inherently tied to the format of online chatroom. One participant described her experience as follows: "*It seemed kind of frantic to keep up, even just reading*." Another commented, "*I was quite frustrated with the online sessions … There was no dialogue or interchange of thoughts. There was really no discussion to maintain*." In summary, participants' lack of active participation and their tendency to multitask during the online-session was identified as the two main reasons for unsatisfactory results by the researchers conducting the evaluation. They conclude:

Finally and most fundamentally, we question the capacity of the online environment to serve as a good place for the facilitation of meaningful deliberation among a large group of participants. Brainstorming, voting, and interacting with experts all seem promising online pursuits; but the careful and thoughtful discussion required for the frank speech of deliberation may simply overwhelm any online (synchronous) environment. "[…] [O]ur data and experience suggest that rich deliberative democratic practice may always require face-to-face communication" (Delborne et.al., 2011).

**Scenario-building to debate nanotech-enabled products**

[89] https://en.wikipedia.org/wiki/Consensus_conferences

At the Center for Nanotechnology in Society at Arizona State University, the US National Science Foundation sponsored a research programme where a new media platform was used for open-scenario planning to assess and critique prospective nanotechnology-enabled products (Selin & Hudson, 2010). The platform (NanoFutures) hosted a wiki platform and discussion forum which presented future technological products for critique by a broad range of stakeholders. By choosing examples for prospective nanotech-products, plausibility was examined ("Is this product technically feasible to invent and build?") and workshops, laboratory meetings, and bibliometric analysis were used to validate the scenes. These were the scenes finally chosen for further discussion:

**Figure 11: NanoFutures Scenes**

**Engineered Tissues**
Using tissue printing technology, this system builds tissues with a vascular structure that enables the building of new organs.
**Living with a Brain Chip**
A cranial chip that features a data feed, which puts information into the brain while the user is resting.
**Automated Sewer Surveillance**
Ultra-fast sequencing technology is used to analyze the DNA in harvested waste water, thus screening large populations.
**Disease Detector**
A device that tracks an individual's protein levels to monitor changes that may imply early-stage illness or disease even before symptoms emerge.
**Barless Prison**
A caged drug that is injected into prisoners, then becomes activated by radio control if prisoners cross designated boundaries.
**Bionic Eyes**
An optical implant that looks and functions like a normal eye yet has enhancements enabling magnification, visualizing infra-red, and night vision.

Source: Selin, C., & Hudson, R. (2010). "Envisioning nanotechnology: New media and future-oriented stakeholder dialogue". *Technology in Society*, (32), 173–182

For the purpose of evaluation, a variety of techniques for textual analysis was employed. According to the researchers, results of these analyses indicate that

"[C]omments were comparable to those that occur in live conversations but they lacked a situatedness, interactivity, and stickiness that occur when people engage face-to-face. That is, while we might venture that learning occurred, satisfied by the astute comments made, there is no way to ensure that users "listened" to each other, weighed alternative perspectives, or left the engagement having learned something useful.

# Chapter 4: New Exciting Evolutions in Nanotechnologies

# 4. New Exciting Evolutions in Nanotechnologies

## 4.1. Trends, drivers, megatrends and wildcards anticipated to impact the course of nanotechnology in the next 10-20 years

Nanotechnologies, together with nanosciences, nanomaterials and new production technologies have the potential to contribute significantly to Europe's shift from a resource-intensive economy to a knowledge-intensive economy, through the ease of development of new applications, new business models, new products, new production patterns, new services, new processes and other outcomes (European Commission 2012a ).

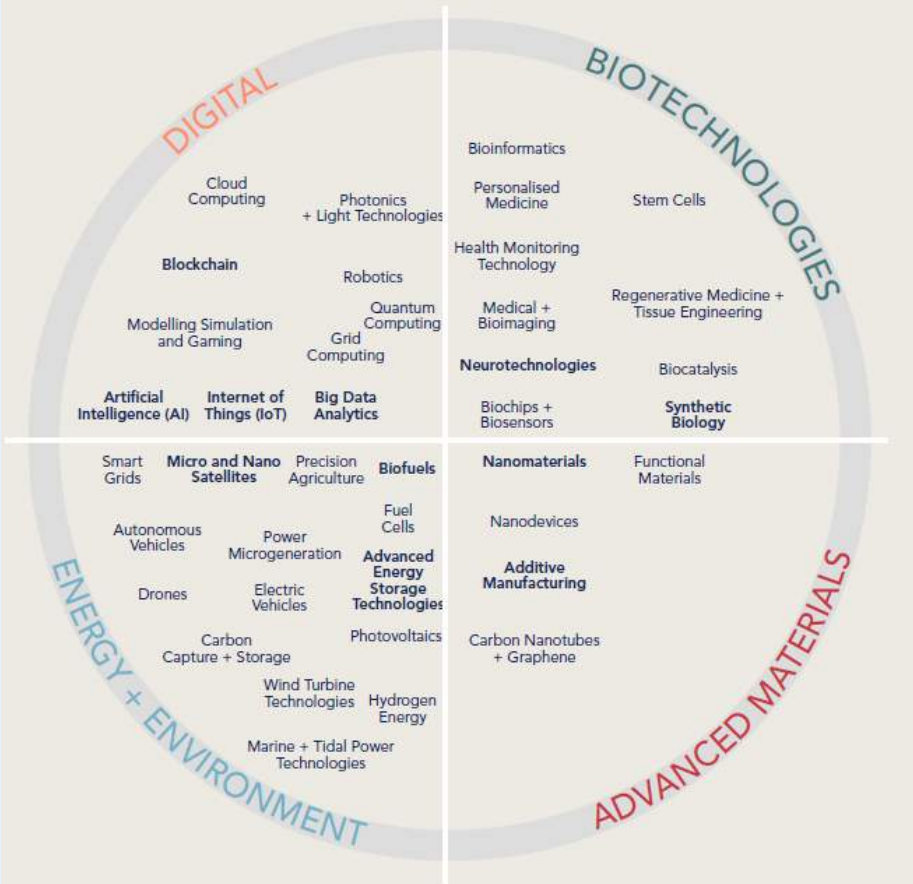
Before discussing the specific nanotechnological trends identified in relevant studies and reports, a general overview of the megatrends as well as the Social, Technological, Economic, Environmental, and Political (STEEP) Trends and Drivers has been developed (for more information please see Annex 3), which set the overall context within nanotechnologies as well as any other technological or not development will occur, the forces shaping them and the areas to be shaped by future advancements.

**Table 4. Overview of Trends**

| | |
|---|---|
| **Global Megatrends** | **Growing, migrating, and ageing**: the 21st century human population covering demographics, international migration, and urbanization (OECD, 2016) |
| | **Global marketplace:** Faster growth rates, favourable demographics in key rapid-growth markets, the economies of the world will remain highly interdependent driving the need for stronger global policy coordination among nations |
| | **The changing geo-economic and geopolitical landscape** relating to the changing roles of states as well as global power shifts due to changes in political, economic and energy markets |
| | **Resourceful planet**: time for joined-up thinking covering water, energy, and food security, and climate change. The application of new technologies will support natural resources to be more effectively and efficiently managed |
| | **Technological advancements and breakthroughs**: digitalisation will impact economies and reconstruct the ways we work |
| | **Countries divide:** wealth and inequality, health and well-being, access to knowledge, and societal change (OECD, 2016) |
| **Social Trends and Drivers** | **Ageing population**: from 2030 onwards life expectancy could reach 106. Food demand to increase. **Urbanization**: by 2050 two thirds of the world's population will be living in cities |
| **Economic Trends and Drivers** | The **world economy** is projected to double in size by 2032 and double again by 2050 (UN, 2014). China is projected to overtake the US as the largest economy by 2027[90] and India could become the 3rd 'global economic giant' by 2050. Today's **'F7' frontier markets** – Bangladesh, Colombia, Morocco, Nigeria, Peru, Philippines and Vietnam – can be anticipated to become tomorrow's growth markets. |
| **Environmental Trends and Drivers** | **Global energy demand** is set to grow by 37% by 2040 (IEA, 2014). In the early 2030s China will become the largest oil-consuming country, crossing paths with the United States, but, by this time, it will be India, Southeast Asia, the Middle East and sub-Saharan Africa that will take over as the **engines of global energy demand growth** (Birol, 2006). |
| **Technological Trends** | **Advanced Manufacturing** will rely more on sophisticated information-technology-intensive |

[90] by 2017 in purchasing power parity (PPP) terms and by 2027 in market exchange rate (MER) terms.

<table>
<tr>
<td>and Drivers</td>
<td>processes. Social, mobile, cloud, big data and growing demand for anytime anywhere access to information. Around 40 technologies, clustered into: Biotechnologies, Digital Technologies, Energy and Environment Technologies and Advanced Materials are those most commonly identified as promising emerging technologies (OECD, 2016). Amongst them, nanotechnologies seem to be having a significant contribution.




Source: OECD, 2016</td>
</tr>
</table>

In the context of the above big picture, nanotechnology applications are anticipated to deliver in both expected and unexpected ways to benefit society and will help to considerably improve, even revolutionize, many technology and industry sectors, such as ICT, energy and environment, medicine, security, food, and transportation, among many others. [91] As Eric Drexler, the "father of nanotechnology", mentioned in a recent post of his in Guardian: *"What if nanotechnology could deliver on its original promise, not only new, useful, nanoscale products, but a new, transformative production technology able to displace industrial production technologies and bring radical improvements in production cost, scope, and resource efficiency?"*[92]. In the context of the above, it is apparent that nanotechnologies cannot be seen as an isolated industrial or R&D area, but as a counterpart of other areas, including materials, processes, ICT, biology, etc. Thus, their trends and drivers need to be seen accordingly, depicted in the table below:

[91] http://www.nano.gov/you/nanotechnology-benefits
[92] https://www.theguardian.com/science/small-world/2013/oct/28/big-nanotech-unexpected-future-apm

**Table 5. Future NMBP trends, drivers and factors**

| Category | Factors | Future trends and drivers |
|---|---|---|
| **Resources** | Natural Resources | NMP has the potential to reduce the use of critical resources (e.g. by nano), substitute critical (e.g. limited, toxic) materials and re-use strategic relevant resources by means of closed-loop production (life cycle, recycling) |
| | Human resources (skilled labour force) | Human capital could be a restricting factor to NMP development. Interdisciplinary researchers/workers being specialised and generalists are needed for NMP. Both skill shortages and skill gaps will increase. |
| **Technological progress and innovation** | R&D funding | NMP is unique to the EU in this constellation. The funding should be maintained whereas private investment should be further increased so as to compete with other regions like the US or Japan; new players are arising (e.g. China) |
| | Key technologies & innovation paradigms | "Newcomer" countries such BRIC and the South-East Asian countries are serious competitors in NMP in the future. In particular, China is developing extraordinary rapidly. NMP have to be understood as a part of further KETs (photonics, biotech, etc.) within a multi-KETs innovation development and should not be regarded independently. |
| **Commercialisation** | Modern capital formation | The gap between R&D and production as well as deployment has to be filled in the future. |
| | Global Networks | Co-operations have to be continued and even further strengthened as a means of covering the whole value chains in the future |
| | Industry structure | There is a need for clear market drivers, for example, industrial problems, global challenges that can be solved by the application of NMP, to exploit commercialisation |
| **Demand** | Market adoption of innovations | Expected annual growth rates are particularly high for nano-technology (16 to 46%) and rather moderate for advanced materials and advanced manufacturing technologies (5 to 6%) |
| | Customers as sources of innovation | There is a growing future demand towards environmentally friendly, further technologically improved, etc. products |
| **Framework conditions and regulations** | Regulatory setting | Environmental, health and safety (EHS) concerns (in particular in context of nanotechnology, nanoparticles) are particular for NMP and will have to be addressed seriously (risk assessment, dialogue with public, etc.) |

Source: EC, 2012, Economic Foresight study on R&D for the European Industry Directorate-General for Research and Innovation Industrial technologies (NMP).

Apart from the above, eminent technological advancements in other sectors are also expected to have an impact upon the course of nanotechnologies – in the form of wildcards[93] – in the next 5-10 years. Several studies and projects (Ricci A., et.al. 2013, EC 2012a, EC 2012f) have identified a series of these advancements, with the most dominant being the following:

- The technology progress in **genomics and proteomics** will lead to a much improved knowledge of molecular processes linked to diseases and this will lead to a redefinition of many diseases. Advances in nanotechnology will allow manufacturing and manipulating materials on nanoscale. That means the scale of proteins and DNA that make the body work. Using nanomaterials allows targeting cancerous tissue, transporting drugs and imaging agents into cells or stimulating cell responses that support the healing process. For these applications, nanomaterials are unique as their scale corresponds to the scale of biomolecules and it is intuitively understandable that nanomaterials could potentially be of great value for medical applications (Ferrari, 2005).
- The shift towards **personalised medicine** is driven by the need to develop therapies that have fewer side effects and that are more cost-effective than traditional therapies, in particular for cancer (Wagner et al., 2008). Much of the improvement for the patients' healthcare, to be brought by nanodrugs and contrast agents, will be related to their ability to provide patient-specific treatments and specific diagnostic information. Future medical nanotechnology could involve molecular manufacturing for targeted drug delivery (Abeer, 2012). A growing area for research is the brain-computer interface, such as methods for the handicapped to control artificial limbs, vehicles and computers. Genetic research is looking to re-grow organs and even improve those (Rajan & Subramanian, 2011).
- The developments in the **Energy and Environment** together with the global warming requirements for $CO_2$-free or a low carbon economy, will lead to the demand for energy-efficient nano applications, and the need for advanced (nano)- materials for renewable energies, e.g. batteries, light-weight composites, etc. (Serrano, Rus & Martinez, 2009). In particular with respect to the **Automotive industry**, graphene and carbon nanotube based super capacitor batteries could dramatically decrease battery charging time and increase storage capacity, as well as increase the speed and power of electronic devices. Further improvements are expected in the coming decade, making electric and hybrid vehicles more competitive.
- **Electronics** is an ongoing potential of technologies for new products and markets. The toolbox of applications beyond Moore's law is expanding and many more possibilities exist to replace analogue with digital applications. Another key driver is the demand for environmental friendly products. While the potential for NMP to contribute to environmental friendly products is relevant for all sectors, it may be especially likely that it is further increased here by corresponding regulations in the electronics sector.

Overall, nanotechnology is expected to become a general-purpose enabling technology, critical to commercial competitiveness in sectors such as advanced materials, electronics, as well as foundation for new activities in diverse industry sectors (Roco et.al., 2011). According to EC's relevant research, nanotechnologies future developments in the NMBP area are presented hereunder:

[93] Wildcards are surprising and unexpected events with low 'perceived probability' of occurence but with very high impact - http://wiwe.iknowfutures.eu/what-is-a-wild-card/

- **Nanotechnology and nanosciences** are expected to ***further develop into mass markets*** in the forthcoming years, with new products and services capable of enhancing human health, while also conserving resources and protecting the environment.[94]

- **New or advanced materials** will continue playing a crucial role in the advancement of a number of important industrial sectors, including the chemical industry, the automotive industry, the metals industry and others. Future new and advanced materials may introduce new functionalities and improved properties adding value to existing products and processes, thus representing an ***invisible revolution***; at the same time, the engineered production of materials by design may allow the development of products and processes under a sustainable systemic approach.[95] Current trends in materials research include ***smart materials*** that will be able to sense their environment and react actively to changes in specific environmental conditions, materials for applications in the health care sector and materials for the energy sector. **Nanotechnology and biotechnology** are expected to play important roles in the development and production of future materials: for example, new materials based on renewable resources may be made by biotechnological processes or using nanoscale production and analyses technologies for materials research. ***The expected trends in materials research will most likely call for new or modified skills of the workforce***. In particular, interdisciplinary skills could play an important role when it comes to the convergence of materials research, biotechnology, ICT and nanotechnology.

- **Production and manufacturing industries** are still of major importance for future welfare, added value and jobs in Europe. While the manufacturing sector itself has been slightly declining in recent years, new jobs and added value have been created by outsourcing activities of manufacturing companies to business services. Manufacturing represents approximately 15% of EU's GDP[96] and combined with the directly induced value added in the service sector, manufacturing industries are (still) responsible for one-third to one-half of the GDP in European countries. Today, European manufacturing is a dominant element in international trade, leading the world in areas such as automotive, machinery and agricultural engineering. Despite growing globalisation and challenges from low-wage economies, manufacturing has a bright future in Europe in a sustainable, knowledge-based society. There is a strong indication of the re-emergence of the EU manufacturing sector as part of the new sustainable economy – in technical, environmental and social terms. But it is clear that such sustainable development requires continuing innovation in the underpinning products and processes, with a need for consistent and effective research over the next decade based on a clear and long-term vision.[97]

### 4.1.1. Accelerating Innovation in Nanotechnologies & the Importance of Nanosafety

A greater emphasis is needed to bridge the gap between innovation and the discussion on safety. Uncertainty in regulatory decisions is hampering consumers' and investors' trust and ultimately investment in innovation. Given the urgency to address stakeholder concerns, the Nanosafety Cluster (Network) for supporting regulatory development is deeply involved and so we do expect this must be further addressed in the future for which specific target, for instance like pilot-lines should be created at EU programme levels.

[94] http://ec.europa.eu/research/industrial_technologies/nanoscience-and-technologies_en.html
[95] http://ec.europa.eu/research/industrial_technologies/materials_en.html
[96] 2013 data, according to European Commission's Press Release of 22/1/2014 "*Commission calls for immediate action for a European Industrial Renaissance*"
[97] http://ec.europa.eu/research/industrial_technologies/production_en.html

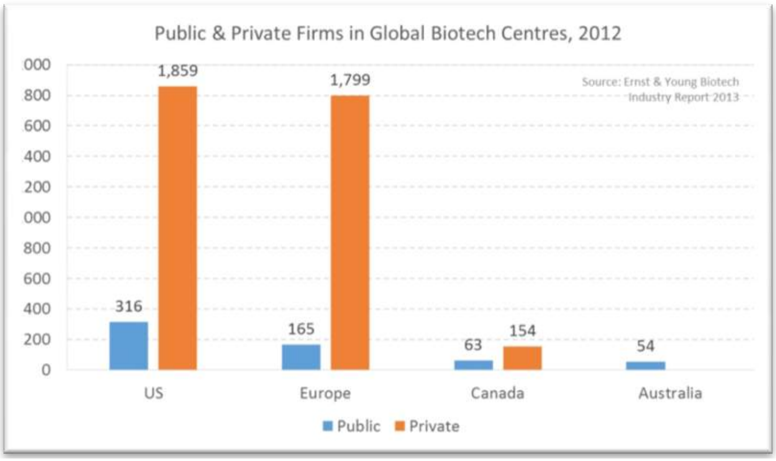
The use of high-functionality online analysers in "*process analytical technology*" (PAT) at the pilot plant stage could provide a tipping point for acceleration of REACH regulatory processes for ENPS. The US Food and Drug Administration (FDA) have successfully used this practice for nearly 10 years to accelerate registration of innovative new pharmaceuticals (US FDA, 2005)[98].

The NSC road map for H2020[99] published in June 2013 addresses the laboratory research and methods to migrate Nano EHS science to regulatory processes in some detail (Savolianen et. al., 2013). However, it needs to be updated with an engineering innovation component particularly to: a) exploit PAT and control technologies and b) multi-scale chemical and environmental engineering models for rapid and low-cost prediction of hazards and exposure.

### 4.1.2. Accelerating Innovation in Bioprocessing as an integrated part of NMBP

Bioprocessing is an area where Europe has a global leadership position and is competitive against the U.S. (Figure 12)[100]. There is evidence of considerable potential for growth in the healthcare, energy, industrial and agricultural sectors, which could be enhanced via generic policy measures and tools for acceleration of innovation processes. It also has important potential synergies with nano-, materials- and production-technologies. These synergies suggest a multi-KETs dimension to the NMBP strategic innovation agenda and work programmes for accelerating innovation might be rewarding.

**Figure 12. Public & Private Firms in Global Biotech Centers**




Source: Ernst & Young, Biotech Industry Report 2013

## 4.2. What social or environmental impacts could be anticipated from future nano-trends?

Like biotechnology before it, nanotechnology is seen as highly versatile, with numerous applications in various domains (Satterfield et.al., 2009) and one of the Key Enabling Technologies of the 21st century (EC, 2011b). By 2020 they are expected to reach mass applications in products and processes, significantly guided by societal needs-driven governance (Roco et.al., 2011) as well as by collaborations between the industry, universities and government that will bring about the next generation of nanotechnology based products and new markets (Khan,

[97] U.S. Department of Health and Human Services, Food and Drug Administration, Guidance for Industry: PAT — A Framework for , Innovative Pharmaceutical Development, Manufacturing, and Quality Assurance, September, 2005
[99] http://bnci-horizon-2020.eu/roadmap
[100] http://www.datafox.co/blog/biotechnology-industry-analysis-key-players-future-trends/

2014). Nevertheless, the public – particularly in the risk-averse societies of the industrialized world – is unlikely to embrace the technology unquestioningly. Thus, the governance of nanotechnology development for societal benefit is a challenge with many facets ranging from fostering research and innovation to addressing ethical concerns and long-term human development aspects (Roco et.al., 2011). And RRI and the general concept of responsible innovation have thus become part of the nano policy discourse (Rip, 2014).

"*RRI is an attempt at social innovation, ranging from discursive and cultural innovation to institutional and practices innovation*"[101] (Rip, 2014). In the context of nano, Arie Rip argues that in the future RRI will be changing the roles of the actors involved and their embedding in society, while public engagement exercises will be an input in development trajectories (Krabbenborg, 2013). The dominant focus could be the "*utilitarian ethics perspective"* maximizing technology's positive contribution while minimizing negative consequences, together with a neo-liberal perception, according to which it is enough if actors avoid causing harm, and a narrative of containment, i.e. if hazards are controlled then there is no problem with new technologies and developers can continue doing what they are doing (Rip, 2014). In the future, Rip anticipates that an emerging path in the development of RRI is expected that will relate to entanglements, how actors refer to RRI, take it up (or not) and how. Overall, he believes that the new discourse of RRI, and its related practices, will reflect, depend and contribute to the forthcoming changes in the science in/with/and/for Society "context".

This issue of changing RRI paradigm and its future "shape" has been surveyed over the years in the EU as well as the US and other countries. In 2009, a literature review counted 22 risk perception surveys about public perceptions of prospective nanotechnological developments' risks and benefits primarily in Europe, North America and Japan (Satterfield et al., 2009). In the context of this literature review, a meta-analysis of these surveys was performed so as to assess the extent to which the following four hypotheses could be valid:

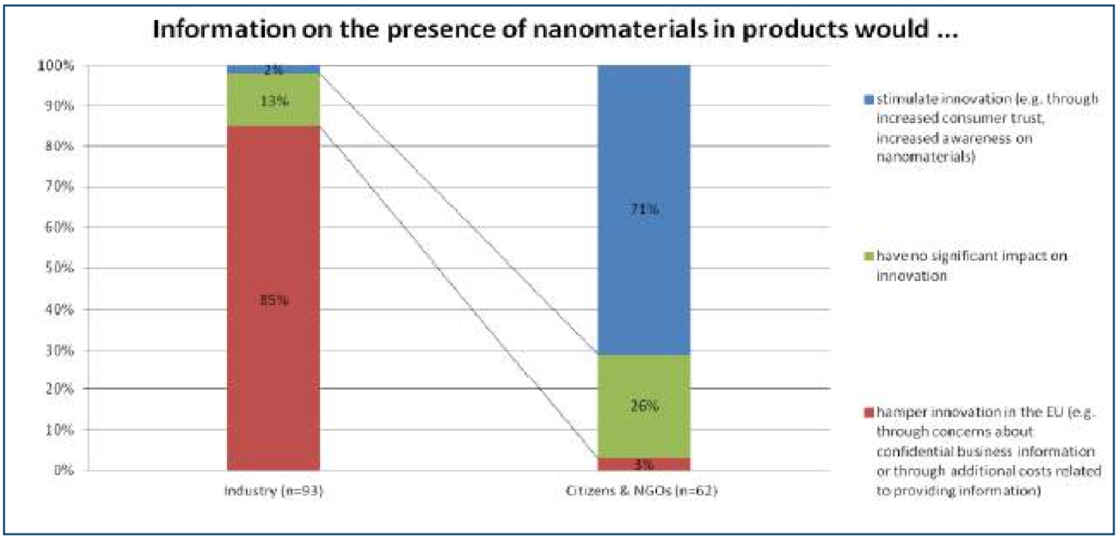
1) Can risk aversion prevail over benefit appreciation?
2) Does an increase in knowledge correlate with reduced aversion to risks?
3) Are judgements malleable and subject to persuasion given risk-centric information?
4) Can contextual, psychometric and attitudinal predictors of perceived risk (from prior studies) help anticipate future perceptions of nanotechnologies?

Overall, it was identified that a large minority (44%) stated that they are unsure about the benefits of nanotechnologies, suggesting that risk judgements are highly malleable. These results contradict the usual findings, i.e. the fact that when risk objects are 'new', 'unknown to science' or 'not observable', they are generally judged as highly risky. Additionally, unfamiliarity with nanotechnology was identified *not* to be strongly associated with risk aversion and reduced 'knowledge deficits', which are correlated with positive perceptions in the early and controversy-free period. The psychometric variables of *trust* and *affect* seem to *drive risk perceptions*, although the influence of both is mediated, or even reversed, by demographic and cultural variables. Finally, a significant outcome and suggestion of the study, was that given the potential malleability of perceptions, novel methods for understanding future public responses to nanotechnologies will need to be developed (Satterfield T., et.al., 2009).

[101] One innovative element is the shift in terminology, from responsibility (of individuals or organized actors) to responsible (of research, development and innovation). The terminology has implications: who (and where) lies the responsibility for RI being Responsible? This may lead to a shift from being responsible to "doing" responsible development (Rip, 2014)

According to a recent study elaborated by RPA & BiPRO (PRA & BiPRO, 2014), the information on the presence of nanomaterials in the products is considered by the industries as an additional burden – that eventually will hamper innovation – while citizens and NGOs consider that will increase innovation, as it will increase their trust towards such products.

**Figure 13: Likely impacts on extra-EU competitiveness of information on nanomaterials and products containing nanomaterials that could be gathered in a nanomaterial registry**




[About 200 Participants responded to the survey: 93 from Industries, from which 70% LE (>250 Employees) and 30% SMEs (<250 Employees); 10 MS Authorities; 63 Citizens and NGOs; Other: 11]

**Source**: RPA & BiPRO . Summary of the public consultation on transparency for nanomaterials on the market . November 2014

Overall, the increased use of complex nanosystems and bottom-up nanotechnology-based components is expected to increase not only societal benefits but also concerns. This will require better approaches to build accountable, anticipatory, and participatory governance with real-time technology assessment. New dimensions of societal implications will emerge as a result of the effects of new generations of nanotechnology products and the convergence of nano with biology and other areas and the balance between competitive benefits and safety concerns will have to be addressed in each economy while taking into consideration the international context. (Roco, 2011, Roco et. al., 2011).

Innovation – especially in the nanotechnology area – reflects a multifaceted weaving of 'knowledge strings', involving multiple actors, ranging from local to international level, in which innovations can be re-purposed and where their interactions and impacts are often unpredictable (EC, 2013a). Irresponsibility is usually an emergent consequence of the innovation ecosystem (what Beck described as '*organised irresponsibility'* in his 1986 book '*Risk Society*')  and interactions and implications may only become more visible when the context of the use of the innovations is comprehended effectively (EC, 2013a). Thus, "*a strong focus is needed on improving anticipatory and participatory governance for nanotechnology that integrates the four simultaneous characteristics of effective nanotechnology governance: transformative (including a results or projects-oriented focus on advancing multi - disciplinary and multisector innovation), responsible (including ethical, legal and social concerns and equitable access and benefits), inclusive (participation is open to agencies and stakeholders), and visionary (long -term planning and anticipatory, adaptive measures)*" (Roco et. al., 2011).

# Chapter 5: Concluding Remarks

# 5. Concluding Remarks

By 2020, the increasing integration of nanoscale science with engineering knowledge of nanosystems promises mass applications of nanotechnology in industry, medicine, and computing. *"Nanotechnology's rapid development worldwide is a testimony to the transformative power of identifying a concept or trend and laying out a vision at the synergistic confluence of diverse scientific research areas"* (Roco, 2011a). Thus, the proper exploration of its developments, implications and countermeasures are of immense importance on policy as well as operational levels.

In the context of the present report, we aimed to identify what constitutes RRI in the nanotechnologies area; what the most recent developments are in Europe (Member States as well as EU level) and internationally in RRI with respect to the nano area; what the perceptions are of stakeholders with respect to its notion and application; and, finally, what the future of nano could be and how it could impact – and be affected – by RRI developments. Hereunder, the main outcomes of these analyses are presented:

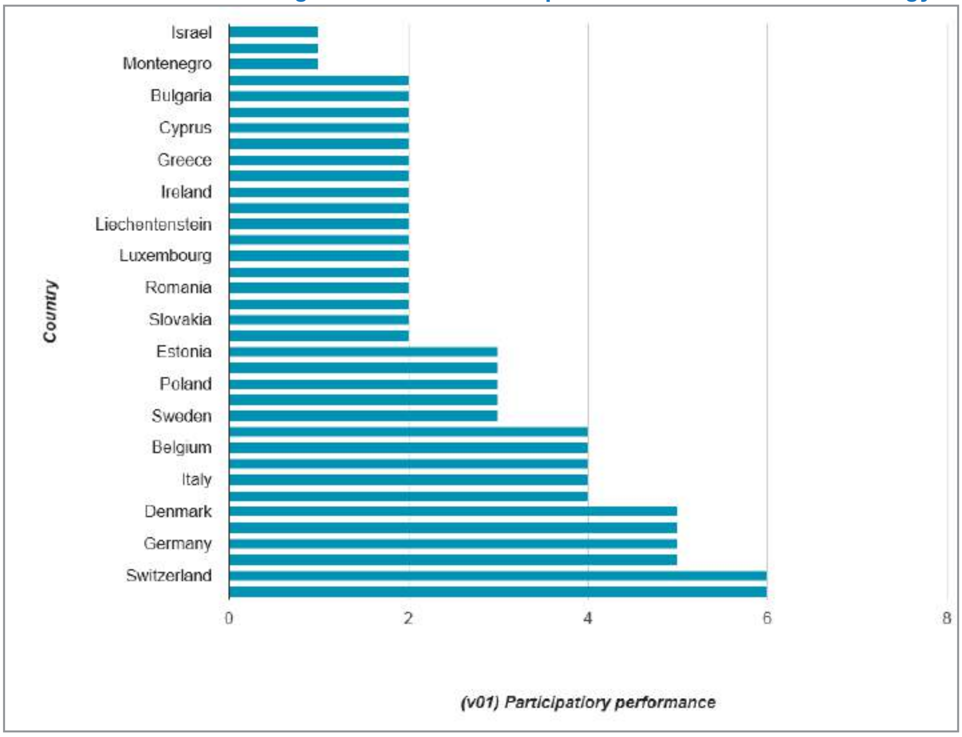
**Which issues have been sufficiently discussed?**

In countries with significant research activities in nanotechnology (cf. Chapter 3), broad scope explorations of nanotechnology and its potential implications can be considered to be sufficiently clarified. This includes several European countries with dedicated national funding programmes for nanotechnology, such as France, Germany, the UK, the Netherlands, etc. This point has also been identified in the research conducted by Rask et. al. (2012), which indicates public participatory performance in S&T and accordingly, the European countries are divided into 3 categories (

Figure 14):

1) Those inactive in developing their public engagement activities, such as Israel (0-2),
2) Those willing to develop and invest in public engagement activities, such as Sweden, Poland and Italy (3-4) and
3) Those active and innovative in developing public engagement activities, such as Denmark (5-6).

**Figure 14. Public Participation in Science and Technology**




Source: Rask M., Maciukaite-Zviniene S., Petreauskiene J. (2012): "Innovations in public engagement and participatory performance of the nations", Science and Public Policy, vol 39, issue 6, pp. 710-721. Graph available at: http://www.rritrends.res-agora.eu/database/indicators/

Also, within the report we identified that most stakeholders' views on RRI are positive and their opportunities, objectives, and the needs they face with respect to RRI have been identified, with the exception of industry and the media. Overall, the policymakers and the NGOs tended to have similar views across all categories, and a common denominator among all three stakeholders (researchers, policymakers, NGOs) was the need for improvement of stakeholder collaboration. The common areas of interest among reviewed stakeholders are presented in Table 5:

**Table 6 Identified opportunities, obstacles, and needs of researchers, policymakers and NGOs/CSOs**

| Opportunities | Obstacles | Needs | Recommendations |
|---|---|---|---|
| Coordinating existing RRI practices and involving the public can make more acceptable and accountable policy, research and innovation<br><br>Develop new networks and partnerships | Scientific culture rewards publications, not RRI<br><br>RRI shouldn't generate more bureaucracy<br><br>Policymaking is inflexible and doesn't necessarily involve the public<br><br>Lack of effective relationships engaging all the stakeholders | Review science practice and research funding through an RRI framework<br><br>Need for more RRI related training and science communication<br><br>Need for more collaboration | Improvement of effectiveness of stakeholders' collaboration |

**Source**: Psarra F. (2016) Adapted from RRI Tools project - D2.2 Report on the analysis of needs and constraints of the stakeholder groups in RRI practices in Europe (http://www.rri-tools.eu/)

**Which issues need further discussion?**

Young generations, workers handling nanomaterials, and the general public will still need to be informed about nanotechnology in general and what it means to them in particular. This is more an issue of education in order to raise awareness prior to engaging in dialogue than of the dialogue itself, especially if we take into consideration the latest results of a Eurobarometer survey stating that around half of Europeans are currently unaware of nanotechnologies overall (EC, 2010b). Such training should involve a general introduction to nanotechnology, its current and potential applications, nanosafety issues - including consumer and worker health, environmental impacts, and ethical, legal and societal aspects among others (c.f. Malsch, 2014).

The issue of national, European and international risk governance of nanomaterials is expected to remain on the policy agenda for the coming decade or so (c.f. European Nanosafety Cluster Strategic Research Agenda 2015-2025). Two aspects are still unresolved: agreement on definitions and terminology; and the compilation of sufficient good-quality nanosafety research results for regulatory purposes. The OECD WPMN, ISO and other international organisations coordinated in SAICM as well as multilateral and bilateral agreements between countries offer platforms where these discussions are taking place. In Europe, the European Commission takes the lead in coordination, engaging several Directorates General including DG Research and Innovation, DG Enterprise (GROW), DG Environment, DG Employment and DG Health and Consumer Protection (SANCO). European agencies including ECHA (Chemicals) and the Joint Research Centre also offer dialogue platforms. In the future, DG GROW will take the lead in EU activities and ECHA will host the newly established Nanomaterials Observatory.[102] In this respect, the EU 7th Environmental Action Plan 2013-2020 states: "…*there is therefore a need to ensure a broader, explicit societal debate about the environmental risks and possible trade-offs that we are willing to accept in the light of sometimes incomplete or uncertain information about emerging risks*[103] *and how they should be handled. A systematic approach to environmental risk management will improve the Union's capacity to identify and act upon technological developments in a timely manner, while providing reassurance to the public*" (EC, 2013d).

A second unresolved issue is nano-innovation in value chains. In the EU, Nanofutures is a main platform organising discussions in this area.[104] While increasing numbers of companies are engaged in manufacturing of nanotechnologies and nanomaterials and products with nano inside, their real market potential remains to be explored. A key issue for dialogue is perceived risks and benefits of nano-enabled products and what should be done to target the technology to the needs of end users. Past experience in nanodialogue suggests that this issue should not be addressed in general but by focusing on some key value chains including nanomedicine (with clinicians and patients, etc.), nanoelectronics (highlighting privacy and surveillance/security issues), nanofood (with consumer associations, food industry, farmers etc.), nanocosmetics (possibly combined with nanomedicine), etc.

A third unresolved issue is the targeting of nanotechnology in the UN Sustainable Development Goals (SDG) for 2030, adopted by the UN General Assembly in September 2015. Contrary to the previous, more policy-oriented Millennium Development Goals (2000-2015), the SDG envisage a more explicit contribution of science and technology. Nanotechnology as interdisciplinary area of research is well-placed for contributing to the SDG. This should include standardising a nanotechnology education curriculum, building local research and governance capacity for nanotechnology in less developed countries, and pooling resources from national and international

[102] This was announced during the DialogForum Nano BASF meeting on 14 March 2016 in Brussels. http://www.nanotechia.org/events/dialogforum-nano-basf
[103] Including nanomaterials and materials with similar properties
[104] www.nanofutures.eu

investors in a common strategy for nanotechnology. Suggestions for priorities are included in the roadmaps on nanotechnology applications for health, water and energy developed in the NMP-DeLA project[105]. These include nano-based solutions for cleaning mining water effluent, solar and other sustainable energy applications, and local capacity for translational nanotechnology for neglected tropical diseases and cancer. Building up research capacity in emerging economies and developing countries for nanosafety in liaison with the European Nanosafety Cluster is another priority. The aim is to avoid 'ethics dumping' that could be practiced by carrying out risky research in countries lacking the capacity to implement international standards for nanosafety in particular and chemicals safety in general.

A fourth unresolved issue concerns how RRI will be embedded into the operations of the industries and the media without halting the innovation process or causing censorship, appropriation or yellow journalism issues. To date, a number of voluntary codes of conduct for nanotechnology have been developed in Europe as well as internationally, but their uptake relies on companies' willingness and appreciation. Additionally, the evolution of nanotechnologies means that new products to be developed will not only be available for mass consumption but also will be developed for usage by other companies. Thus, the RRI responsibilities of companies are extended. From a media perspective, it is important to realize the limitations reporters face when covering a story and the need for appropriate science communication by and among all involved stakeholders. Suggestions on improving stakeholder collaboration, the development of new catholically approved risk governance frameworks and most importantly, designing and providing training on RRI from an early school age are considered moves in the right direction.

The evolving framework of governance of nanotechnologies with(in) the concept of RRI is an issue anticipated to be of significant importance in the forthcoming years. How is the RRI path shaping up and how will it be transformed in the coming years, given the upcoming changes in the nanotechnologies area as well as all other industrial and socioeconomic areas? How will RRI change in the context of evolving science and society? How could RRI assist towards anticipating future impacts of nano-developments? Future moral responsibility involves two dimensions: the dimension of 'care' (what do we care about? What kind of new innovations do we want?); and the dimension of responsiveness while being open to listening and discussing issues in an inclusive and participatory manner. "*Can RRI reframe innovation, and in doing so reframe our political economy?*" (Owen, 2016).

**Latest additions in the RRI-nano agenda**

The development of indicators for progress in RRI is a relatively new issue on the agenda. An EC expert group has made suggestions for indicators for promoting and monitoring RRI in six key areas: governance, public engagement, gender equality, science education, open access/open science, ethics, sustainability and social justice/inclusion (European Commission, 2015b). Some suggestions regarding indicators for nanotechnology for health, water and energy have been made in the NMP-DeLA roadmap published in 2015. These include indicators for measuring progress in nanoresearch; nanosafety and risk management; skill development; policy-making and funding; applications and industry; and ELSA, RRI and public engagement (Malsch et al, 2015). The Res-AGorA has identified quantitative and qualitative indicators, which help to put the project's RRI Trends

[105] www.nmpdela.eu

country reports in perspective. These indicators cover the following topics: Science in Society, Innovation Capacity, R&D intensity, Interaction of public and private research, Gender equality and Research excellence.[106]

Another proposal for stimulating Responsible Research and Innovation is the Responsibility Navigator developed in the EU-funded project Res-AGorA.[107] This presents ten governance principles and requirements for so-called 'responsibilization' that should be tested in practice in the coming years. This implies stimulating the stakeholders involved in the governance of new technologies to contribute to a common responsibility for the impacts on human beings, society and the environment.

The Engage2020 project has developed an online Action Catalogue tool helping researchers, policy-makers and others to identify (an) appropriate method(s) for engaging society in research and innovation in their project. This tool can also be tried out in the **Nano2All** project.[108] Furthermore, those recommendations of the RRI-Tools[109] project which are phrased in a testable form could be validated. These include:

- Rewarding individual scientists who engage with RRI,
- Bringing science and society closer by avoiding controversy
- Better support for CSOs in R&I (see also chapter 3).

**What remains to be done**

Ever since the start of the public and stakeholder discussion on nanotechnology around 2003, the conflicting interests between 'haves' and 'have nots' have been an issue on the table. It is reflected in the criterion inclusiveness in the EC Code of Conduct for nanotechnology, and activities of UNITAR and national governments investing in nanotechnology for development. So far, this has not resulted in bridging the gap between industrialised countries and developing countries. The dialogue in **Nano2All** will therefore have to include this issue, which was also recommended by the RRI Tools project. Related to this are different interpretations of what constitutes the sustainable development of nanotechnology.

On a more fundamental level, differences between the proactive approach in the USA and the precautionary approach in Europe have been addressed from the beginning of international dialogue on nanotechnology. At a global level, additional value conflicts between individual and collective cultures are visible that pose barriers to reaching agreement on responsible research and innovation, including in nanotechnology. A recent comparison between the EU, China and India was published in 2015 (Ladikas et al. 2015). Related to this are differences in perspectives between liberal and communitarian thinkers (Malsch, 2015). As researchers and industry work in international networks fostering nanotechnology and the EU aims for harmonised norms governing nanotechnology, tabling discussion on these underlying values in **Nano2All** seems appropriate and timely.

[106] http://www.rritrends.res-agora.eu/database/indicators/
[107] http://res-agora.eu/news/
[108] http://engage2020.eu/
[109] http://www.rri-tools.eu/

Overall, we need to move from risk to innovation governance and fundamentally reframe our concept of innovation; and in order to do so we need to adjust our education programmes, improve stakeholders' collaboration and promote dialogues with meaningful participation of all involved stakeholders. The work plan sets measurable targets for participation of citizens and stakeholders in the online and face to face activities organised in the project. In this context, **Nano2All** aspires to contribute by organising structured dialogues in various locations around Europe (France, Israel, Italy, Poland, Spain and Sweden) ensuring first that they are "educated" beforehand on nano and RRI, as well as organising "games" for two N&N societies and policymakers so as to assist them while developing their future nano-roadmaps to effectively and efficiently incorporate RRI aspects. .

**Nano2All** has the potential to make a difference, because it explicitly invites citizens and stakeholders to invest in mutual learning and offers tools for engaging in fruitful dialogue that goes beyond polite exchanges of predetermined positions. Underlying values are not only explored but actively challenged, improving the chances of reaching consensus rather than compromises. Before entering the actual dialogue, all stakeholders are invited to online or face to face training sessions, according to their needs as identified via a Self-Assessment questionnaire. Issues addressed include information on nanotechnology, the concept of Responsible Research and Innovation, constructive dialogue techniques, foresight methods and positions of other stakeholders on nanotechnology. This should ensure a level playing field in the actual dialogue, giving lay persons the same chances to contribute as top-level experts.

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11. 2020 Science website: http://2020science.org/2010/01/07/uk-house-of-lords-scrutinizes-nanotechnology-and-food/
12. Food Standard Agency website: https://www.food.gov.uk/science/novel/nano
13. Our plan for growth: science and innovation (HM Treasury, Department for Business, Innovation & Skills and The Rt Hon Greg Clark MP, 2014): https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/387780/PU1719_HMT_Science_.pdf
14. Great Britain: the best place in the world to do science (Department for Business, Innovation & Skills and The Rt Hon David Willetts, 2014): https://www.gov.uk/government/speeches/great-britain-the-best-place-in-the-world-to-do-science

# 7. Annexes

# Annex 1

**LEIT**

Horizon 2020 Work Programme 2016-2017 in the area of Information and Communication

Technologies

- ICT-01-2016: Smart Cyber-Physical Systems
- ICT-11-2017: Collective Awareness Platforms for Sustainability and Social Innovation
- ICT-18-2016: Big data PPP: privacy-preserving big data technologies
- ICT-19-2017: Media and content convergence
- ICT-22-2016: Technologies for Learning and Skill
- ICT-23-2017: Interfaces for accessibility
- ICT-24-2016: Gaming and gamification
- ICT-28-2017: Robotics Competition, coordination and support
- ICT-35-2016: Enabling responsible ICT-related research and innovation
- ICT-36-2016: Boost synergies between artists, creative people and technologists
- ICT-39-2016-2017: International partnership building in low and middle income Countries

**EXC**

Horizon 2020 Work Programme 2016-2017 in the area of Future and Emerging Technologies

(FET)

- FETOPEN-01-2016-2017 FET-Open research and innovation actions
- FETOPEN-02-2016 FET-Open Coordination and support actions

- FETOPEN-03-2017 FET-Open Coordination and support actions
- FETOPEN-04-2016-2017 FET Innovation Launchpad
- FETPROACT-01-2016: FET Proactive: emerging themes and communities

**SCs**

Horizon 2020 Work Programme 2016-2017 in the area of Health, demographic change and

well-being

- SC1-PM-12–2016: PCP - eHealth innovation in empowering the patient
- SC1-PM-14–2016: EU-Japan cooperation on Novel ICT Robotics based solutions for

active and healthy ageing at home or in care facilities

- SC1-PM-15-2017: Personalised coaching for well-being and care of people as they age
- SC1-PM-17–2017: Personalised computer models and in-silico systems for well-being
- SC1-HCO-12–2016: Digital health literacy
- SC1-HCO-13-2016: Healthcare Workforce IT skills

- Horizon 2020 Work Programme 2016-2017 in the area of Europe in a changing world –

inclusive, innovative and reflective Societies

- CO-CREATION-04-2017: Applied co-creation to deliver public services
- CO-CREATION-06-2017: Policy-development in the age of big data: data-driven policymaking, policy-modelling and policy-implementation
- REV-INEQUAL-09-2017: Boosting inclusiveness of ICT-enabled research and Innovation
- REV-INEQUAL-10-2016: Multi-stakeholder platform for enhancing youth digital opportunities

- CULT-COOP-08-2016: Virtual museums and social platform on European digital heritage, memory, identity and cultural interaction

- CULT-COOP-09-2017: European cultural heritage, access and analysis for a richer

interpretation of the past

- CULT-COOP-11-2016/2017: Understanding the transformation of European public

Administrations

Horizon 2020 Work Programme 2016-2017 in the area of Secure societies – Protecting

freedom and security of Europe and its citizens

- DS-01-2016: Assurance and Certification for Trustworthy and Secure ICT systems,

services and components

- DS-02-2016: Cyber Security for SMEs, local public administration and Individuals
- DS-03-2016: Increasing digital security of health related data on a systemic level
- DS-04-2016: Economics of Cybersecurity
- DS-05-2016: EU Cooperation and International Dialogues in Cybersecurity and Privacy

Research and Innovation

- DS-07-2017: Addressing Advanced Cyber Security Threats and Threat Actors
- DS-08-2017: Privacy, Data Protection, Digital Identities

**Cross-cutting**

Horizon 2020 Work Programme 2016 – 2017 in the area of Cross-cutting activities (Focus

Areas)

- IoT-01-2016: Large Scale Pilots
- IoT-02-2016: IoT Horizontal activities

**SWAFS**

Horizon 2020 Work Programme 2016-2017 in the area of Science with and for Society

- SwafS-22-2017: The ethical dimensions of IT technologies: a European perspective focusing

on security and human rights aspects

# Annex 2

### Regional open innovation ecosystem models

The present study aims to give an overview concerning the expected strategies of the future, linking team concepts to which industry innovation is deeply connected to creativity, whose main players are individuals/researchers. By doing so with link a short-medium term strategy to which SME & industry are more interested, to a long term strategy, targeting the vision and expectations of policy-makers and stakeholders concerning the future routes of Europe economy and jobs growth.

For this we have to define the steps to which the present approach could be linked, as described below.

### Models to be exploited

This part of the report aims to go beyond the present science and technology European programmes, targeting also the type of bridges that are central in Horizon 2020 programme, under the umbrella of Directorate-General for Research and Innovation targets concerning advanced materials, nanotechnologies, biotechnology, and manufacturing (http://cordis.europa.eu/nanotechnology/home.html and http://ec.europa.eu/programmes/horizon2020/en/area/key-enabling-technologies) that can make with the regional focused ones, funded by the national and regional funds

For this, it has been identified three regional open innovation ecosystem models:

a) ***Regional industry centred model.*** These are close to sites with a history of industrial revolutions or specializations and have arisen organically around large industries or from industry or government intervention in times of industrial restructuring. SME creation, support service companies, incubator shelters and venture capital companies are present. Often research and technology organizations (RTOs) are integral to the success and sustainability of this model. Examples include Chemalot Campus, NL.
b) ***Regional university centred model.*** These are close to academic centres of excellence with long track records of success. Again SME creation, support service companies, incubator shelters and venture capital companies are present. RTOs often also interact with this model.
c) ***Inter-regional centred model***. This is a new hierarchy model that aims to integrate into a common network/platform, common interests that go across of more than one region or country. It aims to aggregate the needs of regions with the creativity of research institutes. That is, besides a short-medium range strategy, it will supply the resources for long-term strategy that involves promoting to the industry arena the creativity or leading to the modernization of the regional industrial tissue.

Regional ecosystems types a) and b) are co-funded by member states and industry sources and from the engine rooms for delivering smart regional specialization in Added-Value Manufacturing (AVM) innovation. There is now a growing recognition by the Member States and European levels that such ecosystems should be the foci for efficient deployment of taxpayers' funds for re-industrialization to achieve sustainable economic growth and jobs.

The proposed c) model was not yet been tried in the past.

### Players of Innovation & Creativity

The interactions of all three types of innovation ecosystems essential for success and hence are of relevance to this study. However, European added-value is achieved through interactions between Horizon 2020 Directorates with regional innovation types a) and b). These innovation types have considerable interest with respect to growing and sustaining AVM innovation.

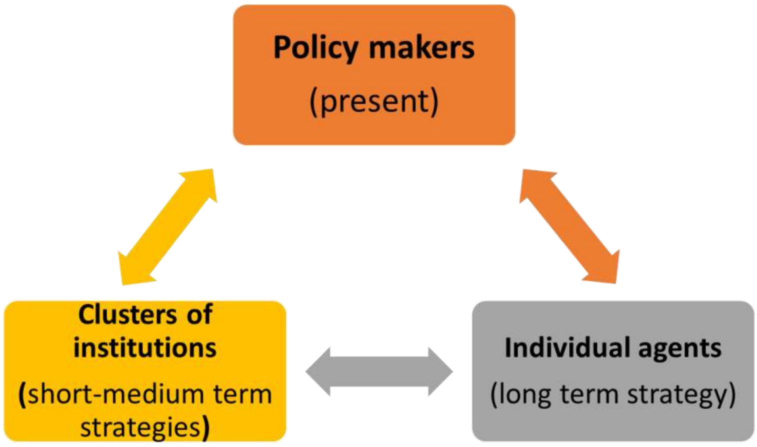
Finally, there are two other vitally important pan-European innovation ecosystems for supporting innovation listed below in Table 7. Both are connected to and supported by the NMBP Directorate's Bioprocessing and Production Technologies Unit.

**Table 7 Examples of Pan-European Enabling Innovation Ecosystems**[110]

| Enabling Innovation Ecosystem | This study | Role in accelerating innovation |
|---|---|---|
| EURAMET<br>Network of 37 European National Measurement Institutes (NMIs) | Yes | €600 million EMPIR strategic research programme in metrology, co-funded by the NMBP program and the Member States via an Article 185 joint funding instrument. Its purpose is to support industry and trade competitiveness |
| Nanosafety Cluster (NSC)<br>A voluntary network of leading European scientists, clinicians and engineers specializing in the human and environmental hazards of engineered nanoparticle | Yes | Its 10-year roadmap addresses public concerns and provides novel science and innovation to underpin regulatory development for *safer-by-design* nanotechnology. It also provides a strategic innovation agenda (SIA) for informing the NMBP H2020 work program *[NB €150 million program in H2020]* |

Moreover, we have to report the level to which the innovation and creative authors should interview. For this we established a triangular structure where we define the vertices of it as being the **policy-makers** to which the present study is addressed; **clusters of institutions** dealing with common or complementary matters, as the vertex for short-medium term strategies and **individual agents**, as promoter's of ideas and creativity, for a long term strategy and the pillar of excellency of our triangle.

**Figure 15 Stakeholders of innovation and creativity**




This triangle must be tuned with societal challenges and able to answer to their demands without forgetting the human dimension impacts that this will bring to our society.

[110] HORIZON 2020 Advisory Group For Nanotechnologies, Advanced Materials, Biotechnology And Advanced Manufacturing And Processing (Nmbp) Consolidated Report, July 2014 – available online http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=19372&no=1

### Future strategies and role of the Societal Challenges

As defined by the consolidated report of NMBP advisory group of Horizon 2020[111,112], societal Challenges are defined as very complex layers of interests of stakeholders from EU to local and individual levels. For instance, building new building blocks of a system, while creating sustainable jobs, requires bringing together financial, societal and technology areas both at individual end-users and systems levels. Europe must, therefore, balance this complexity of Societal Challenges with the need for reduction of complexity of requests to ensure the broad, affordable availability of innovative industrial solutions across Europe. Once this has been achieved with reasonable certainty it will encourage long-term engagement and investment in technologies by the related industries as well as the public sector. It is essential to strike a balance between complexity and diversity of societal requests with the structured coordinated approach needed by the business. Therefore, connectivity between research in enabling technologies (e.g. new materials), market applications (e.g. energy efficient buildings) and societal solutions (e.g. smart city) is important.

Decision-making structures and criteria for work development towards Societal Challenges (SCs) need to guarantee transparent framing and evaluation, and seamless collaboration with the other pillars of Horizon2020. This has to be promoted by defining dedicated areas for broad scale real environment demonstration of technologies in all European programs.

Thus, the purpose of the new integrated bridging approach can only be successful if the European Commission exerts high-level leadership to establish this approach at all levels of their organization for implementation. The current bottom-up approach is not sufficient to ensure timely delivery of sustainable solutions considering the need for action and the complexity and diversity of issues. Some main opportunities and programs for technologies deployment are European Innovation Partnerships, SET-IR, Smart Specialization of Regions, and Horizon 2020.

**Smart** demand side measures (such as consumer demand, smart regulation, standardization, procurement), combining technology push with challenge pull, are the most effective drivers of the transformation towards new sustainable business opportunities for the European economy. Technologies related industries engaging major parts of the value chains must be given an adequate role for scoping and implementation of work programs addressing societal challenges. The role of European manufactured technology building blocks in standardization; regulation and *public procurement should be strengthened.*

*An effective link between Horizon 2020 pillars will also create growth in Europe by using* the innovation pull from major Societal Challenges (SCs) to develop technology readiness levels towards industry and end-users requirements, significantly affecting market uptake in other areas such as textiles, paper, among others.

The progress on SCs programs must be measured towards Sustainability including the impact on jobs and growth in the industrial eco-system, as ultimate objectives, not only by specific important sectorial policy targets like energy reduction, healthy life years, environmental impact, and safety issues.

[111] Horizon 2020 Advisory Group For Nanotechnologies, Advanced Materials, Biotechnology And Advanced Manufacturing And Processing (Nmbp) Consolidated Report, July 2014 – Available Online http://ec.europa.eu/transparency/regexpert/index.cfm?do=groupDetail.groupDetailDoc&id=19372&no=1

[112] Nanotechnology: the invisible giant tackling Europe's future challenges - EC publication from Directorate-General for Research and Innovation Industrial technologies (2014)

Therefore, it is essential to ensure that all EU projects have the potential to be timely replicated at pan-European level. Societal challenges like health, resource efficiency, water, energy, and raw materials cannot be solved by just ignoring the multidisciplinary fields to which they are connected as well as the outcomes and potential of their chain integration, and human resources involved and use must of them for the conform of their life.

Now is the moment to have stakeholders fully involved and to encourage innovation and experimentation, e.g. better skills, quicker permits to build industrial installations. The goal should be to make Europe more visible to international investors. It is therefore important that knowledge on NMBP technologies solutions to Societal Challenges is effectively disseminated towards decision makers. For example, city administrations are currently not really enabled to make choices on far-reaching technological solutions.

In order to increase investments and improve public acceptance, the European stakeholders and Science Policy-makers should foster an integrated approach concerning benefits and uncertainties regarding the safety of new technologies in general, and in particularly about the exploitation of nanomaterials for a broad range of applications.

To accomplish this mission special attention should be paid to the knowledge working force *to promote at education level the appropriate skills of Youngers and technologists*, to master technology push and pull. Therefore, the dissemination and exploitation of innovation programs at higher Technology Readiness Levels (TRL) should include the development of initiatives to build up skills capacity to speed up the uptake of innovation in Europe.

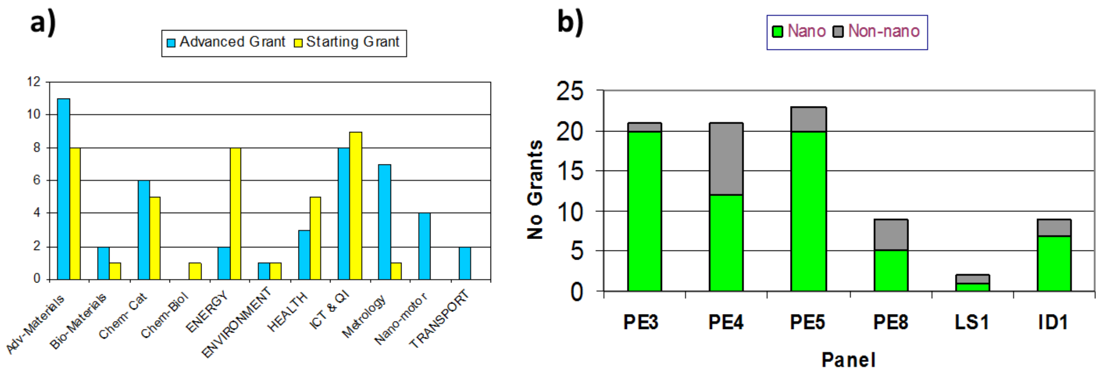
This is a key deliverable for SCs, since is fully linked with human impacts for which institutions (see sketch above) will deeply contribute.

**Meaning of Excellence in Science for Future NMBP Accelerated Innovation**

The FP7 EAG's feasibility study of data mining ERC Advanced and Starting Investigator research projects for potential theme for accelerated innovation is reproduced below[113]:

[113] Grounded theory textual analysis of abstracts, FP7 EAG Best Practice in Innovation H2020 Orientation Paper, 2012

**Figure 16 Analyses of all FP7 ERC Advanced & Starting Grants (2007-2010): a) Technology Cluster Analysis, and b) % Nanotechnology Grants**




The trends are clear-cut and demonstrate the long-term potential applications of nanotechnology (subject to positive outcomes of EU Nanosafety research and public acceptance.

# Annex 3

The STEEP structure is often used for scanning developments in the external (contextual) macro environment. The following megatrends, trends and drivers are anticipated to form the basis of future nano-related developments in the next 15-20 years:

**Global Megatrends**: Megatrends refer to global transformative forces that have overwhelming impacts. With respect to these, several public and private organisations, (EY 2015, EEA 2015, KPMG 2014, Frost & Sullivan 2014, the Flagship project, etc.) have published their anticipation of megatrends. Almost all agree that the following may be the main transformative global forces that will impact all future scientific developments, including NMP:

- **Digital**: Fuelled by the convergence of social, mobile, cloud, big data and growing demand for anytime anywhere access to information, technology is and will be disrupting all areas. Enormous opportunities exist for enterprises to take advantage of connected devices enabled by the “Internet of Things” to capture vast amounts of information, enter new markets, transform existing products, and introduce new business and delivery models.
- **Global marketplace:** Faster growth rates and favourable demographics in key rapid-growth markets will continue to be a feature of the next decade or so. Innovation will increasingly take place in rapid-growth markets, with Asia surfacing as a major hub. The economies of the world will remain highly interdependent through trade, investment and financial system linkages, driving the need for stronger global policy coordination among nations and resilient supply chains for companies operating but, at the same time, will continue to clash and compete with the forces of anti-globalization, nationalistic, religious and ethnic movements.
- **Urban world**: The number and scale of cities will continue to grow, driven by rapid urbanization in emerging markets and continued urbanization in mature markets. The UN reported in 2014[114] that by 2050 $^{2}/_{3}$ of the world’s population will be living in cities. In order to harness the economic benefits of urbanization, effective planning by the public and private sector will attract investment in railroads, highways, bridges, ports, airports, water, power, energy, telecommunications, and other types of infrastructure.
- **Resourceful planet:** The application of new technologies will support natural resources to be more effectively and efficiently managed. Growing concern over environmental degradation, securing strategic resources and the fate of food and water supplies are indicative of the fact that protecting and restoring the planet is a critical future imperative. Governments, societies and businesses should work to develop more sustainable approaches to the task of achieving economic growth while leveraging natural resource inputs.
- **Healthcare:** This already accounts for 10% of global GDP. Health systems are under increasing cost pressure, driving them to seek more sustainable approaches, including incentives that emphasize value. Changing demographics, rising incomes in rapid-growth markets and an imminent chronic-disease epidemic exacerbate these cost pressures. An explosion in big data and mobile health technologies is enabling a move beyond the delivery of health care (by traditional health care companies

[114] http://www.un.org/en/development/desa/news/population/world-urbanization-prospects-2014.html

in traditional ways) to the management of health (by diverse sets of players, with more focus on healthy behaviours, prevention and real-time care).

- **Social Trends and Drivers:** According to the UN (UN, 2014) and the OECD (cf. WWF, 2014), the world population is expected to reach around 9 billion people in 2050; however, the European population will shrink as the forecasts for the EU-27 population in 2030 are estimated to be 5% lower than that of 2010. Nevertheless, our children can expect to live on average 97 years, and from 2030 onwards it will not be surprising if life expectancy reaches 106 (EC, 2012e). This significant increase in the global population will impact food demand, e.g. by 2050 global farm animal production is expected to double from present levels. Improvements and efficiencies in agricultural production are likely to meet much of the increased demand, given likely scientific advances that develop high-yield, disease-resistant crop strains, combined with better land usage and improved irrigation.
- Another important driver at the European and global levels will be the issue of the "*greying*" population: more elderly citizens, longer healthy life expectancies, fewer numbers of working-age individuals. At the EU level, around 30% to 40% of healthcare expenses are already being spent on people aged 65+, and as they rise, social and healthcare systems will experiene intensifying pressure.
- **Economic Trends and Drivers:** The world economy is projected to double in size by 2032 and double again by 2050. China is projected to overtake the US as the largest economy by 2027[115] and India could become the 3rd 'global economic giant' by 2050. China, India, Brazil and other emerging markets will become not just low cost production locations, but also increasingly large consumer markets involved with the production of high-end consumer durables. Additionally, countries like Mexico and Indonesia could be larger than the UK and France by 2050, and Turkey could be larger than Italy. At European level, Russia could overtake Germany as the largest European economy before 2020[116]. Overall, the major trend that is anticipated to impact the economy of the future is the "reshuffling" of big players: today's 'F7' frontier markets – Bangladesh, Colombia, Morocco, Nigeria, Peru, Philippines and Vietnam – can be anticipated to become tomorrow's growth markets and an expanding pool of highly skilled talent will fuel this emergence, with people from emerging markets increasingly leading global multinationals.
- **Environmental Trends and Drivers:** According to the International Energy Agency's (IEA) World Energy Outlook 2014 report (IEA, 2014), global energy demand is set to grow by 37% by 2040. According to their scenarios, the global distribution of energy demand will change drastically, with energy use essentially flat in much of Europe, Japan, Korea and North America, and rising consumption concentrated in the rest of Asia (60% of the global total), Africa, the Middle East and Latin America. A landmark is anticipated to be reached in the early 2030s, when China will become the largest oil-consuming country, crossing paths with the United States, where oil use falls back to levels not seen for decades. But, by this time, it will be India, Southeast Asia, the Middle East and sub-Saharan Africa that will take over as the engines of global energy demand growth (Birol, 2006). Renewable sources of energy now stand poised to lead the world in new electricity supply. Supported by policies aimed at enhancing energy security and sustainability, renewable power expanded at its fastest rate to date in 2014 and now represents more than 45% of overall supply additions. (IEA, 2015).

[115] by 2017 in purchasing power parity (PPP) terms and by 2027 in market exchange rate (MER) terms.
[116] Before 2020 in PPP terms and by 2035 at MER terms

- Europe currently represents 20% of world energy consumption but this may decrease to less than 12% by 2050 (Braun, 2010). By 2030, the EU could cover one quarter of its road transport fuel needs with clean and $CO_2$-efficient biofuels, with a substantial part to be provided by EU industry. Hydrogen power can reduce demand for oil by more than 11 million barrels per day by the year 2040.[117]
- Eco-innovation and green technologies can constitute a third industrial revolution with a shift to new forms of 'blue technologies' considered. Overall, climate change and the shortage of resources will be catalysts for innovation, but there will be an increasing need of systemic governance of innovation to successfully tackle climate change and sustainability challenges.
- **Technological Trends and Drivers:** Advanced Manufacturing will rely more on sophisticated information-technology-intensive processes and will become increasingly *globally linked* as automation and digital supply-chain management become the norm across enterprise systems (Institute for Defence Analyses, 2012). The migration to *cloud sharing* will be the "computing commons" followed by a need for secure management of massive amounts of data generated within the supply chain and manufacturing facility, i.e. *cyber-security* of globally linked enterprise systems. The use of modelling and simulation will accelerate the development of new materials, products, and processes in diverse fields such as *integrated computational materials engineering* (ICME), *nanoelectronics* (which will affect every industry from aerospace and construction to energy, transport and medicine as it will create products that we cannot possibly imagine now with important impacts on peoples everyday lives) and *synthetic biology* (potential to engineer and use biology for manufacturing applications, e.g. biomimetics, or biologically-inspired design and materials, will yield unique properties and functionality and cut across technology areas, such as bio-electronics). *Intelligent sensor networks* will allow the creation of increasingly autonomous systems across sectors, such as transportation, energy management, and health. Technology adoption can be expected to increase in the future because of the need to produce even more cost efficiently and in an environment friendly way (ZEW & TNO, 2010). Finally, over the next several years, significant advances are expected in carbon nanotube manufacturing technology, specifically in controlling the purity and structure, and in reducing costs due to economies of scale[118].

[117] The EC HyWays Roadmap estimates that in 2030 there will be 16 million hydrogen cars and the total cumulative investment for infrastructure build-up will amount to €60 billion.
[118] https://www.asme.org/engineering-topics/articles/nanotechnology/top-5-trends-in-nanotechnology