



**NANO2ALL**

SOCIETAL ENGAGEMENT ON RESPONSIBLE NANOTECHNOLOGY

## D3.2

### Future nano-RRR applications and techno-moral scenarios



THE NANO2ALL PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME, UNDER THE GRANT AGREEMENT NUMBER 685931. THIS PUBLICATION REFLECTS ONLY THE AUTHOR'S VIEW AND THE COMMISSION IS NOT RESPONSIBLE FOR ANY USE THAT MAY BE MADE OF THE INFORMATION IT CONTAINS.

**Future nano-RRI application and techno-moral scenarios**

D3.2

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**Date:**

15-09-2017

Publicly available after finalisation

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# 1. Identification of future nano-RRI applications

# 1. Identification of future nano-RRI applications

The current deliverable *D3.2 Future nano-RRI application and techno-moral -scenarios* portrays the range of drivers expected to affect research and innovation with nanotechnologies and nanomaterials in the next 5, 10 and 20 years, as well as the respective scenarios around these that include the technological as well as moral aspects of them.

For the selection of the nano-application “scenarios”, the outcomes of the literature review previously implemented in the project were deployed in conjunction with the outcomes of a short Delphi-type survey conducted among nano and RRI specialists in Europe. These application scenarios are not real stories (as in elaborate narratives), but introduce a new application related to the topic into the general scenario story-line in each 5-year time step.

The scenarios created in this deliverable will be used in the context of the Scenario Exploration System (SES), which is a game that aims to assist stakeholders appreciate the dynamics of their interaction in the formulation of future strategies and roadmaps (for more information please refer to Deliverable D3.1 of the NANO2ALL project). SES was previously developed by the JRC Brussels and adapted to the objectives and prerequisites of NANO2ALL through the involvement of partners: JRC Brussels, SPI, Systasi and VU. The scenarios developed describe the overall political, economic, environmental, technological, and social aspects of societies envisaged in 2032, given certain trends, megatrends and drivers identified in the literature review conducted in earlier phases of the project (for more information, please refer to deliverable D2.1 of the NANO2ALL project), and within these societies how certain (envisaged) nano-applications will appear, be up-taken and cause desirable and undesirable effects. The scenarios, as part of the SES game developed, will guide the stakeholders’ interactions as if they were present in that particular scenario story in 3 different time-slots (2022, 2027, 2032) and will ultimately assist stakeholders to comprehend how their own organizational strategies affect and are affected by others’ strategies and actions, including the public which raises concerns and moral inquiries.

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

According to the research conducted as part of D2.1 Review of current RRI in nano-landscape, nano (i.e. nanotechnologies, nanosciences, nanomaterials and new production technologies) has 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<sup>1</sup>. These trends will be affected by a set of megatrends, as well as Social, Technological, Economic, Environmental, and Political (STEEP) Trends and Drivers that are anticipated to occur on global level.

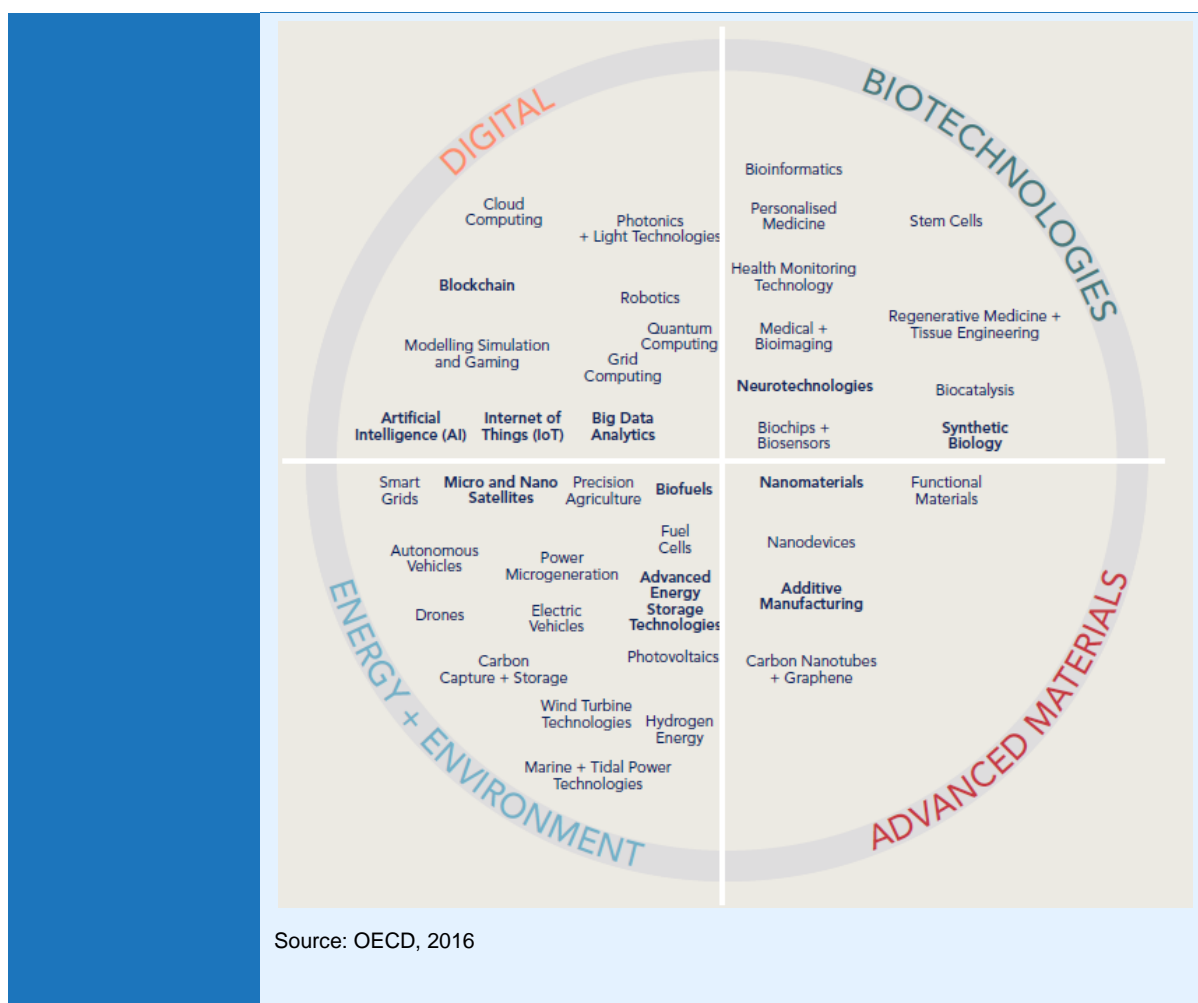
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<sup>1</sup> European Commission (2012), *Economic foresight study on industrial trends and the research needed to support the competitiveness of European industry around 2025*

**Table 1: Megatrends and global Social, Technological, Economic, Environmental, and Political (STEEP) Trends and Drivers**

Global Megatrends	<p><b>Growing, migrating, and ageing:</b> the 21st century human population covering demographics, international migration, and urbanization.</p>
	<p><b>Global marketplace:</b> 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</p>
	<p><b>The changing geo-economic and geopolitical landscape</b> relating to the changing roles of states as well as global power shifts due to changes in political, economic and energy markets</p>
	<p><b>Resourceful planet:</b> time for joined-up thinking covering water, energy, food security, and climate change. The application of new technologies will support natural resources to be more effectively and efficiently managed</p>
	<p><b>Technological advancements and breakthroughs:</b> digitalisation will impact economies and reconstruct the ways we work</p>
	<p><b>Countries divide:</b> wealth and inequality, health and well-being, access to knowledge, and societal change.</p>
Social Trends and Drivers	<p><b>Ageing population:</b> from 2030 onwards, life expectancy could reach 106. Food demand to increase. <b>Urbanization:</b> by 2050 two thirds of the world's population will be living in cities</p>
Economic Trends and Drivers	<p>The <b>world economy</b> is projected to <b>double in size by 2032 and double again by 2050</b>. <b>China</b> is projected to <b>overtake the US</b> as the largest economy by 2027<sup>2</sup> and India could become the 3<sup>rd</sup> 'global economic giant' by 2050. Today's '<b>F7</b>' frontier markets – Bangladesh, Colombia, Morocco, Nigeria, Peru, Philippines and Vietnam – can be anticipated to <b>become tomorrow's growth markets</b>.</p>
Environmental Trends and Drivers	<p><b>Global energy demand</b> is set to grow by 37% by 2040. 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 <b>engines of global energy demand growth</b>.</p>
Technological Trends and Drivers	<p><b>Advanced Manufacturing</b> will rely more on sophisticated information-technology-intensive processes. <b>Social, mobile, cloud, big data</b> and growing demand for anytime anywhere <b>access to information</b>. Around 40 technologies, clustered into: <b>Biotechnologies, Digital Technologies, Energy and Environment Technologies</b> and <b>Advanced Materials</b> are those most commonly identified as promising emerging technologies. Amongst them, nanotechnologies seem to be having a significant contribution.</p>

<sup>2</sup> by 2017 in purchasing power parity (PPP) terms and by 2027 in market exchange rate (MER) terms.



In the context of the above big picture, nanotechnology applications are anticipated to deliver in both expected and unexpected ways to affect 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<sup>3</sup>. As Eric Drexler, the “father of nanotechnology”, mentioned in a recent post of his in the 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?*”<sup>4</sup>. 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:

<sup>3</sup> <http://www.nano.gov/you/nanotechnology-benefits>

<sup>4</sup> <https://www.theguardian.com/science/small-world/2013/oct/28/big-nanotech-unexpected-future-apm>, [last accessed May 2017]

**Table 2. Future nano-related trends, drivers and factors**

Category	Factors	Future trends and drivers
<b>Resources</b>	Natural Resources	Nanosciences, nanotechnologies, materials and new production technologies (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.
<b>Technological progress and innovation</b>	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.
<b>Commercialisation</b>	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
<b>Demand</b>	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
<b>Framework conditions and regulations</b>	Regulatory setting	Environmental, health and safety (EHS) concerns (in particular in the 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).

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 the European Commission's (EC) relevant research, nanotechnologies future developments in the NMBP (Nanotechnologies, Advanced Materials, Advanced Manufacturing and Processing, and Biotechnology) area are presented hereunder:

- **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.<sup>5</sup>
- **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.<sup>6</sup> 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<sup>7</sup> 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.<sup>8</sup>

<sup>5</sup> [http://ec.europa.eu/research/industrial\\_technologies/nanoscience-and-technologies\\_en.html](http://ec.europa.eu/research/industrial_technologies/nanoscience-and-technologies_en.html)

<sup>6</sup> [http://ec.europa.eu/research/industrial\\_technologies/materials\\_en.html](http://ec.europa.eu/research/industrial_technologies/materials_en.html)

<sup>7</sup> 2013 data, according to European Commission's Press Release of 22/1/2014 "Commission calls for immediate action for a European Industrial Renaissance"

<sup>8</sup> [http://ec.europa.eu/research/industrial\\_technologies/production\\_en.html](http://ec.europa.eu/research/industrial_technologies/production_en.html)

## 1.2. Delphi-type survey

In the last semester of 2016 a short Delphi-type survey was organised and conducted among 37 selected nano and RRI experts proposed by all partners. The objective was to identify how nanotechnology and nanosciences could evolve in the next 15 years from a likelihood of occurrence and their potential impact perspective, and what these impacts could involve, e.g. changes in Europe's ethical or hierarchical (power) or environmental or social, etc. status quo. The outcomes of the survey contributed to the triangulation of the themes on which the scenarios for the SES games were drawn. By this, Milestone *MS5 Experts Delphi survey*, which foresaw the consultation with nanoexperts to collect information for developing a representative number of viable application scenarios and associated techno-moral scenario, was achieved.

According to the outcomes obtained, the drivers with the highest impacts are considered to be:

- Nanotechnology is expected to become a general-purpose enabling technology (75% of all experts anticipate this trend to have a high impact on socioeconomic level in Europe).
- 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 (58% of all experts anticipate this trend to have a high impact on socioeconomic level in Europe); and

Interestingly though,

- The increased use of complex nanosystems and bottom-up nanotechnology-based components will be used in much larger scale (is considered as low likelihood trend, as around 42% of all experts consider it of low likelihood, yet it is considered a high impact trend).

In accordance to the above, the applications that we should integrate in the scenarios should relate to the enhancement of human health as well as the protection of environment, as well as components of larger systems not necessarily related to nanotechnologies.

## 1.3. Selected nano-application for the scenarios

Based on the outcomes of the Literature Review and the Delphi-type survey, a brainstorming session was performed among involved project partners and the following nano-applications were selected to be further elaborated into the (preliminary) application scenarios described below. The introduced applications represent technological applications that are supposedly frequently used at particular points in time (5, 10 and 15 years from now). This way, it provides with an indication of what is going on in the particular nano-application field at that particular stage of the scenario exploration. Participants are free to choose what they would like to do with this information about applications, and how they would like to adapt their actions towards it.

### 1.3.1 Nanomedicine

- 5 years: Molecular diagnostics in lab, in which humans are still the expert in interpreting the results (human expert system)
- 10 years: Molecular diagnosis + treatment within the body. One can also monitor the body on a molecular level
- 15 years: Interventions in genetic make-up

The changes in this application scenario occur on three levels/axes:

- Level of delegation (delegate responsibilities from humans/individuals to technology)
- Level of intimacy (proximity of technology to the body)
- Function creep (using the technologies for other purposes)

### 1.3.2 Nanotextiles

- 5 years: Textiles with enhanced properties
- 10 years: Textiles that can monitor (not only bodily functions, but also environmental conditions).
- 15 years: Textiles that can actively intervene (textiles can react to what they monitor)  
Note: another possibility would be to add an extra step: use it for different purposes (e.g. a plaster that speeds up wound healing, but is eventually also used at home as a cosmetic product → = function creep).

The changes in this application scenario occur on two levels/axes:

- Level of delegation (delegate responsibilities from humans/individuals to technology)
- Level of intimacy (proximity of technology to the body)

### 1.3.3 Brain-Computer Interface

- 5 years: Monitoring neuro-activity
- 10 years: Neuro-stimulation (therapeutic, mood control)
- 15 years: Human-machine integration

The changes in this application scenario occur on three levels/axes:

- Level of delegation/intervention
- Possibly: function creep

The following paragraphs describe the overall scenarios within which the application scenarios will be integrated and together will constitute the basis for the Scenario Exploration System, to be utilized during the NANO2ALL National Stakeholder Dialogue events. Thus, the scenarios presented hereunder will be used as the surrounding context within which the specific application scenario elements will be integrated. For more information on the methodological aspects of the Scenarios Development as well as the Scenarios Exploration System developed by JRC and accustomed to this project, please refer to D3.1 Multi-stakeholder methodology report.

## 2.Scenarios and scenario exploration for the stakeholder dialogue events

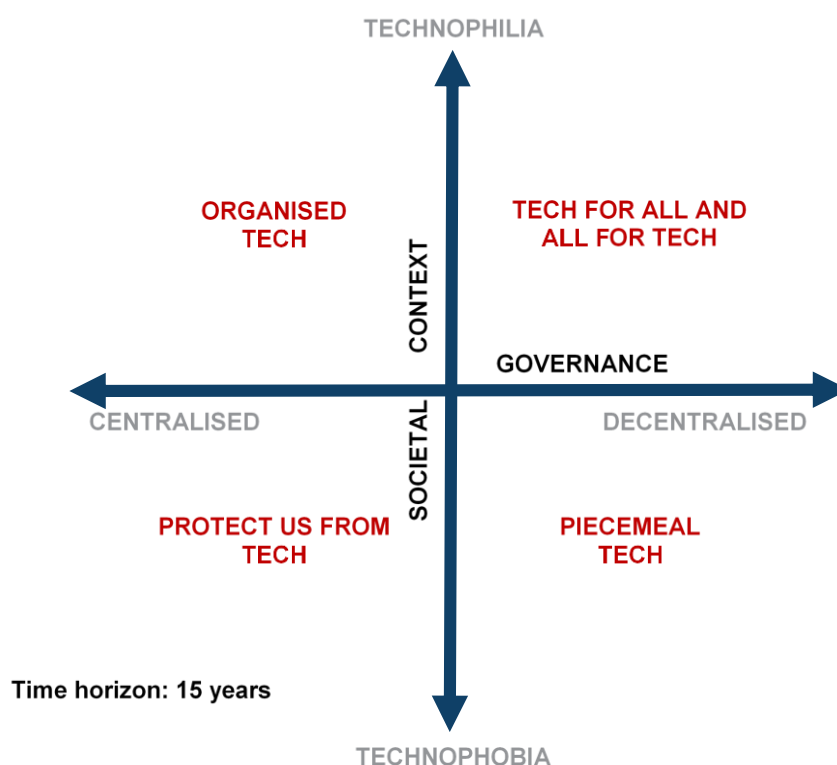
## 2. Scenarios and scenario exploration for the stakeholder dialogue events

The applications of nanotechnologies and their scenarios described above will be used by the project to engage with stakeholders as well as the public. However, on their own, they are insufficient to provide the richness of narrative necessary to hold meaningful conversations. Therefore, it was decided to develop broader societal and techno-moral scenarios within which the technology applications will be embedded to hold conversations with stakeholders. The following paragraphs describe these scenarios. Two of these scenarios are being incorporated to the Scenario Exploration System, the participatory foresight tool that will be utilized during the National Stakeholder Dialogue events.

### 2.1. Scenario development

The broad societal and techno-moral scenarios that will be used were developed using a classic scenario building methodology. When considering the future of nanotechnologies, two drivers of change that were considered both the most important and the most uncertain were selected to create a logical frame: how technology friendly society will be and what type of governance will dominate. On that basis, two axes were constructed. The extremes of the vertical axis were technophilic and technophobic society. The extremes of the horizontal axis were centralised governance and decentralised governance. This creates a 2x2 logic matrix that serves as a basis to develop the scenarios (see Figure 1 below).

Figure 1: The logical framework of the scenarios



To apply the Scenario Exploration System, only two contrasting scenarios are needed. On the logic matrix, scenarios that are at the two extremes of a diagonal contrast most. Therefore, and to ensure consistency across national dialogue events, it was decided to work with the diagonal running from top right to bottom left. As a result, only the scenarios "*Technology for all and all for technology*" and "*Protect us from Technology*" were developed and adapted to the Scenario Exploration System. They are presented in the following sections.

## 2.2. Scenario 1: Technology for All – And all for Technology (Technophilia - decentralized government)

### Social context and Societal Values

Due to a number of issues associated with the high number of refugees fleeing to Europe, the exit of Britain from the EU as well as the shifting of economic powers on global level, Europe has been moving towards becoming a collection of independent states, in which states decide for themselves on their future.

The slow and uncoordinated integration of the refugees causes several problems on political and social level, such as ghettos and social uneasiness. Furthermore, the phenomenon of urbanisation is further intensified and the high gathering of people in cities – not only in best conditions – deteriorates the quality of life, urban amenities and civic services, resulting in serious social discrepancies.

On the other hand, over the last 30 years (we are now in 2037), the high rise of technological advancements, e.g. ICT, artificial intelligence, new energy sources, etc., has resulted in an alienated society in which technology is considered as a panacea for everything.

The lack of big funding programmes from the EU and the high correlation between technology and social welfare, has pushed regions to form alliances among them, so as to be able to compete on global scale. Thus, more and more innovation hubs tend to appear around Europe, which manage to attract people from different geographic areas and disciplines as well as funding sources and leading research and innovation institutes. These areas resemble a lot the Silicon Valley in the US.

### Technology

Technology supply and consumer demand drive phenomenal growth in the number of Internet connections and Internet-enabled devices. By 2037 smartphone traffic will exceed PC traffic, and on average there will be 6 networked devices per person (e.g. PC, tablet, smartphones, smartwatches, etc.). Despite progress though, still a large number of people in the developing world are still offline.

In 2037, transportation will be different: trains will be equally used to airplanes, as new technologies have been developed that allow trains to travel faster than airplanes. More and more people prefer buying electric autonomous (self-driving) cars, while the majority of vehicles contain vehicle-to-vehicle (V2V) communications transmitting information about speed, heading, brake status. This has resulted in significant reductions to traffic accidents as well as environmental pollution, although the needs for electric energy have pushed for more innovations in the area of energy production and energy storage.

Technological advancements have also been recorded in health, as DNA editing has proceeded into understanding how to omit parts of DNA that cause illnesses, such as certain forms of cancer, etc.; yet, applications have not been made.

Artificial Intelligence will be integrated in a high number of devices, resulting in a high number of middle or menial jobs to be made redundant by computers holding AI. Finally, 3D printing is changing the way we conceive construction, from printing houses to printing organs.

### Environment

The lack of a uniform European voice in relation to environmental issues is counterbalanced by concerned citizens who are acting on personal level, promoting the use of renewable energies (RES). Overall, climate change is affecting a great part of Europe, with severe winters and hot summers.

Electric power is slowly taking the place of gas and diesel power; however, higher costs are associated with the electric line maintenance of the old infrastructure. The rising demand for electric power is also driven by the rising use of electric cars, which has made an impact on the confrontation of air pollution.

### Economy

On global level, BRICS – and most importantly China – is becoming a dominant world player in the economic arena, together with the US and Russia, which latter is competing with Germany on the largest economy in Europe.

On European level, due to the design and implementation of national level programmes and initiatives with restricted budget, the competitive advantage of Europe in certain industries has shrunk and it is up to specific countries, across regions, and their companies to flourish and perform innovations. Certain innovation hubs have flourished around Europe: France is competitive in nanotechnologies, ICT and biotechnologies; Germany in renewable energy, advanced manufacturing and waste management; etc. This situation has intensified the big divide observed between the northern and the southern parts of Europe: the northern countries tend to rely more on technological developments and manufacturing, while the southern parts rely more on services (incl. tourism) and agricultural production.

The high push towards technological advancements, has led people to get more qualified in such skills. Also, this push has led to the disappearance of many middle-class and manufacturing jobs. Jobs are either for the highly-skilled creative people, or are menial and thus low-paid.

There is high tension between global corporations and start-ups as innovation and independence are highly valued.

Due to the increase of the greying population, a high pressure on healthcare systems has been posed and governments strive to find alternative ways to confront this.

### Policy and Governance context in 2037

The role of national governments has become stronger at the expense of EU level governance. The Schengen Agreement is no longer respected by countries, and a number of them have built walls (metaphorically and literally) to protect their countries.

The EU citizens have turned to their national governments and demand decisions to be taken closer to home, which in turn has created issues between Super-Regions, which act as countries, and national governments. The focus of policies is on the promotion of technological developments, often at the expense of human-centric or other social issues, or human-centric or social issues tend to be dealt in relation to technology (for example the focus is on the improvement of

the infrastructure of schools or the acquisition of new tech skills by teachers but not on the reinvigoration of the schools' curricula). This technological focus has pushed regions to collaborate with neighbouring ones, so as to reinforce their technological as well as market areas.

## THE PATH TO THE SCENARIO

- **5 years:**
  1. Nationalists gain across the EU
  2. Citizens want decisions taken closer to them
  3. Immigration and climate change loom large
  4. Technology perceived as source of solutions
  5. Public is aware of new techno developments
  6. Context spurs creativity and enterprise
  
- **10 years:**
  1. Regions push innovation hubs
  2. Governments promote local product
  3. Diverse funding sources for innovation
  4. IT, robotics enabling work to change
  5. Tech books diverse successes
  6. Technology object of fashion, can be fast discarded
  
- **15 years:**
  1. Governments must adapt taxes
  2. Flexible life-long learning is new norm
  3. High individual responsibility and experimentation
  4. Insurance companies push tech against risk
  5. People turn to technology in taking responsibility
  6. Technologies fulfill specific needs

**Table 3: Main elements of Scenario 1: “Tech for All – And All for Tech”**

Parameter	Scenario 1: All for Technology – And Technology for All
<b>Society and values</b>	Interest in technology, creativity, diversity, randomness Society is avid of novelty, fashions are a strong phenomenon Your data is everyone's, for a price Potentially limited concern for privacy as people understand the usefulness of data for tech development Thanks to technology, virtual lives develop Connected, platform society Collaboration and co-creation, potential for sharing Local initiatives, more community action, more local diversity
<b>Technology</b>	Fast and cheap, trial and error, co-creation in technology Lots of innovation: many people innovate in many different ways and different places Adaptable and diverse technologies Strong crowdfunding Cities and other local governmental bodies have their own innovation policies to stimulate technological development
<b>Environment</b>	In general, high awareness about the environment, but probably unequal Solutions for the environment are sought in technology itself (green tech) but not centrally organized → own/local initiatives, diversity of solutions
<b>Economy</b>	Market oriented, flexible, driven by a decentralised approach to technology development Very dynamic platform economy In this fairly liberal economy, industry strives to adapt to local markets and fast changing technology
<b>Policy</b>	Small and nimble government that focusses on the organization of some matters and delegates responsibilities related to other matters. Pragmatic opportunism (less attention for long-term issues, or large, complex and boundary-crossing societal problems) It is cities and local governments that create policies that are targeted at innovation.

## 2.3. Scenario 2: “Protect us from Technology” (Technophobia-decentralised government)

### Social context and Societal Values

Over the past 15 years, doubts about technology have been rising and risk-averse attitudes have become more pronounced throughout society. People are fearful of the consequences and risks that new technologies could bring about and are sceptical of their added value for society. Many understand technology as something promoted by capitalists and show little trust in industry or research experts. Instead, people turn to governments and higher decision-making bodies to ask for protection against untested technologies. Since individual actors feel that they have little scope for meaningful action, collectivist trends become visible and influence is sought through large and influential NGOs or national and EU level policy initiatives.

### Technology

Over the last 15 years, R&D has continued apace but the stream of investments has increasingly shifted towards the development and centralized implementation of more frugal technologies, which are considered preferable over high-tech solutions. Technological development is controlled through centrally organized inspection: everything needs to be certified. High-tech products and services are only used where absolutely needed, and are mainly promoted by large private interests. Public research and development is characterized by a strong focus on safety; centralized and systematic risk assessment programmes have been put in place and new technologies are only allowed on the market after having proved their worth. There is a battle of interests: industry wants to innovate and develop new technologies, but government and society want to regulate. Industries have to lobby the government, which is difficult, but now and then they reach an agreement to push some technological innovations through.

### Environment

The battle to solve environmental issues and the promotion of environmental awareness have remained at the forefront of EU policy. Education nurtures a strong societal focus on environmental protection, which is pursued through regulation and central inspection mechanisms. There are many rules and regulations on what one is allowed to do (and what not). National and European nature reserve systems are expanded and waste management systems are optimized. Risk management and risk assessment are separated. For companies and organisations, it is essential to obtain environmental certifications from external risk assessment bodies in order to attract customers. There is a preference to use existing tried and tested solutions to solve problems instead of new fancy technologies that could have their own problems.

### Economy

Technophobic tendencies in Europe have slowed down technological development, affecting the general dynamics of EU economies. Due to the many protective rules and regulations that have been put in place by governmental bodies, it has become harder for industries to bring new technological innovations on the market. A true battle of interests can thus be distinguished: industry wants to innovate, while government and society want to regulate. Although protective rules and regulations have put a break on quick economic growth, the commercial success of more frugal innovations prevents economic stagnation and fosters a stable economy that is characterized by high levels of government control.

### Policy and Governance context

National governments and EU-level decision making bodies have a strong influence and demonstrate high levels of control. Strict regulations are in place to protect society from potential risks and many moratoria have been declared on contested technologies. Industry is largely dependent on government/EU authorization to get their innovations on the market. This is a difficult process that requires intensive lobbying, sometimes resulting in success, but more frequently resulting in a failed operation. This pushes private R&D operations outside of the EU. For some actors in industry, this fuels the incentive to attempt bribing authorities.

### THE PATH TO THE SCENARIO

- **5 years:**
  1. Events create a negative view of technology
  2. Citizens want tech regulation
  3. Algorithms kill serendipity
  4. Low tech now fashionable
  5. Social innovation before tech innovation
  6. Some specific technologies viewed suspiciously
  
- **10 years:**
  1. Tech in private hands, jobs disappearing
  2. Tech regulation is strengthened
  3. EU Quality Institute must certify all new tech
  4. Developing tech safety assessment creates few jobs
  5. Policy guides tech development
  6. New tech applications authorized case by case
  
- **15 years:**
  1. Robophobia expands
  2. EU tech standards the most stringent globally
  3. Tech in hands of a few large players
  4. R&D moves largely out of EU
  5. Less tech diversity than elsewhere
  6. Certified tech applications slowly gain acceptance

**Table 4: Main elements of Scenario 2: “Protect us from Tech”**

Parameter	Scenario 2: Protect us from Tech
Society and values	<p>Risk averse, fearful society. Overall, society doubts technology, especially when coming from private sector innovation</p> <p>People look at government for protection - Trust in government experts only</p> <p>People seek influence through centralized/higher level NGOs or national/EU dialogues.</p> <p>Collectivist trends</p> <p>Strict and standardised technological risk assessment</p> <p>Individual actors feel they have little scope for action</p>
Technology	<p>Rational, systematic, centralised pursuit of safety: public R&amp;D focused on safety</p> <p>New tech must prove its worth before allowed on market</p> <p>New tech mostly promoted by large private interests</p> <p>Technology is only used where society perceives it is absolutely needed</p> <p>New tech needs to prove itself before entering the market</p> <p>Frugal technologies instead of high-tech → technologies that also function in low-tech environment, but that are still implemented in a standardized and centralized fashion</p> <p>Preference to use existing tried and tested solutions to solve problems instead of new fancy technologies that could have their own problems</p> <p>Battle of interests: industry wants to innovate, but government and society want to regulate.</p> <p>Industries have to lobby with the government, which is difficult, but now and then they reach an agreement</p>
Environment	<p>High environmental awareness spread through central mechanisms, such as education → strong societal focus on environmental protection</p> <p>Centrally organized inspection to control technological development → everything needs to be certified</p> <p>Many rules and regulations on what you are allowed to do (and what not)</p> <p>Risk management and risk assessment are separated</p>
Economy	<p>Planned economy</p> <p>General dynamics of the system is slow → technological development becomes slow.</p> <p>Stable economy, stagnation</p> <p>Economy must respect many rules: very protective, trying to control</p>
Policy	<p>Lobbying from industry to get tech authorised, incentives for bribing authorities</p> <p>Lots of government control</p> <p>Moratoria on technology roll outs</p> <p>This pushes industry to move R&amp;D operations outside of the EU</p>

### **3. Integration of technomoral aspects into the scenarios**

### 3. Integration of technomoral aspects into the scenarios

The purpose of the Scenario Exploration Game is to have participants experience and act through plausible alternative futures (i.e. the scenarios described in the previous section), by thinking and conversing systemically outside of their usual frame of reference. For the purpose of the national multi-stakeholder dialogues in which the game is played, we also wanted the participants to think about potential *moral* implications. In the subsequent paragraphs, we will first explain how we decided on which moral aspects we would integrate in the game, and then focus on how we integrated the selected moral aspects in the game structure.

#### 3.1. Selection of technomoral aspects

With respect to the selection of the moral aspects, we decided that we did not want to come up with a selection ourselves, but that we wanted to use citizen perspectives that were explored at an earlier stage in the project. In 2017 a number of citizens dialogues were organized across Europe (SE, PL, FR, IL, ES, IT), each of them focusing on one of the three specific nanotechnology applications: nano in textiles, nano in medicines, and nano in brain computer interfaces. In these dialogues, citizens created their own narratives of the future. The narratives served as a fruitful starting point for a moral discussion on societal needs, concerns and values related to nanotechnology research and innovation. The outcomes of discussions held in the various countries were analysed and this resulted in an overview of most important needs, concerns and values expressed by citizens in the various countries.

#### 3.2. Integration of technomoral aspects

To integrate the needs, (moral) concerns and moral values of the citizens into the structure of the game, we adapted a particular game element in the original version of the SES: the Public Voice. In the game, four characters (a policy maker, a business, a researcher, and a civil society organization) take actions to reach their visions over three rounds in a 15-year time horizon. The Public Voice is the fifth player and judges the actions taken in every round. We decided to give the Public Voice a particularly prominent role in the NANO2ALL version of the game. He or she gets to introduce him/herself elaborately at the start of the game. What are his/her needs with respect to new technologies? What concerns him/her about the potential (societal) impacts of the nano application? What (moral) values and principles are important to him/her? In addition, the Public Voice gets to reflect on all of the actions taken by the other players in each round of the game. Did they take his/her concerns into account? Are they in conflict with his/her values? The Public Voice receives the chance to explain what he/she likes or does not like about the actions of the players. The judgement of the Public Voice also has a real impact on the scores of players, because he/she can distribute a number of impact tokens that can multiply the scores players can receive with their action. The idea is that this creates incentive to actively take the Public Voice's perspective into account.


To make sure that the participants playing the Public Voice actually bring forward those needs, concerns and values that were discussed in the citizen dialogues, we decided to do two things:

1. First of all, we invite two citizens who attended the citizen dialogues in the spring of 2017 to each of the national multi stakeholder dialogues. When playing the game, these "citizen dialogue representatives", will get

assigned the role of the Public Voice. This way, the Public Voice is played by someone who was actually part of the moral discussions that took place amongst citizens.


2. Secondly, we will provide the person who plays the Public Voice with a role description. In this role description, the Public Voice is reminded of the main outcomes and discussion points of the citizen dialogue (see Fig.2). He/she can actively use this information to judge the actions of other players in the game and voice his/her feedback. To account for national differences, the role descriptions have been made country-specific and we used terminology similar to terminology used in the national citizen dialogues (see box 1-6 for the information provided in each of the national contexts). This way, it might be easier for “citizen dialogue representatives” to remember parts of the citizen dialogue they attended.

By integrating moral considerations and citizen perspectives into the game, we aspire to enrich the reflection processes of stakeholder participating in the national multi stakeholder dialogues. The game experience could help participants in subsequent dialogue exercises to think of future strategies to align scientific values and objects with societal values and needs.



## PUBLIC VOICE

### Actor profile



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In this session, you represent the participants of the citizen dialogue that you attended in the spring. Today, your role is that of the 'Public Voice' and you will explain to the other participants what issues are important to you when it comes to **[topic field]** developments. You have a powerful voice. The role of the Public Voice is to express how society talks about nanotechnologies. BOX 1 below summarises what values, needs and concerns were formulated at the citizen dialogue that you attended. These might help you position yourself as the 'Public Voice' and to respond to the actions of other participants throughout the session.

Think back to the citizen dialogue that you attended and what you discussed there. What needs, concerns and values were particularly important to you personally? Please write that in BOX 2.

BOX 1: France	BOX 2: What do you find important as the public voice?
<p><b>Values</b></p> <ul style="list-style-type: none"> <li>• Everyone should have equal access to technologies that can improve health</li> <li>• Everyone should be able to participate normally and autonomously in society and to engage in social life</li> <li>• People should be able to decide for themselves whether they would like to make use of a technology.</li> </ul> <p><b>Needs</b></p> <ul style="list-style-type: none"> <li>• Involvement of citizens in the development of new technologies</li> </ul> <p><b>Concerns</b></p> <ul style="list-style-type: none"> <li>• Unethical or inappropriate use of the data acquired by <b>BCIs</b>.</li> <li>• Health risks of brain implants</li> <li>• The use of <b>BCIs</b> outside the medical context. For example: to improve human functioning or to create new capabilities.</li> <li>• The effect that <b>BCIs</b> have on the boundary between "being human" and "being a machine"</li> </ul>	<div style="border: 1px solid black; height: 150px; width: 100%;"></div>

At the start of the session, you introduce yourself as the 'Public Voice' and you explain to the others what issues are important to you when it comes to **[topic field]** developments (what you have written in BOX 2).

What you consider to be important may change as events develop during the session! Let's see. How you respond to the actions of the other participants is entirely up to you.

Fig. 2 Role description form – Public Voice

**BOX 1: France**

**Values**

- Everyone should have equal access to technologies that can improve health
- Everyone should be able to participate normally and autonomously in society and to engage in social life
- People should be able to decide for themselves whether they would like to make use of a technology.

**Needs**

- Involvement of citizens in the development of new technologies

**Concerns**

- Unethical or inappropriate use of the data acquired by BCIs
- Health risks of brain implants
- The use of BCIs outside the medical context. For example: to improve human functioning or to create new capabilities.
- The effect that BCIs have on the boundary between “being human” and “being a machine”

**BOX 2: Spain**

**Values**

- Technologies should contribute to people’s well-being and quality of life
- Everyone should have equal access to technologies that can enhance human beings.

**Needs**

- Improving health; using BCI’s to recover functions in people suffering from problems with cognition or movement.

**Concerns**

- Misuse and manipulation of people that use the BCI. Think of individuals or groups hacking BCI devices, or using the data to exploit or label people.
- The use of BCIs as intelligence- or strength enhancing devices. Without equal access to these types of application, new social inequalities could emerge.

**BOX 3: Italy**

**Values**

- Everyone should have equal opportunities
- People should show solidarity with one another.
- Technologies should contribute to health and well-being
- Technologies should contribute to collective and individual security

**Needs**

- Citizen involvement in setting research goals
- Citizen involvement in discussing responsible use of technologies

**Concerns**

- The search for improved collective health and security might come at the cost of individual privacy, particularly in the case of nanotextiles that can monitor bodily functions or environmental conditions
- Data acquired by new nanotextiles can be used to make new distinctions between people, which could lead to exclusion and discrimination of certain groups.

**BOX 4: Poland**

**Values**

- Technologies should contribute to health & quality of life
- Technologies should protect us from physical harms and health threats
- One should take care of the environment

**Needs**

- Technologies that make life more easy, efficient and comfortable with the aim to increase quality of life.
- Technologies that are sustainable

**Concerns**

- Technology-dependence; people might lose personal control and the ability to think for themselves
- What happens if technology fails or breaks down?

**BOX 5: Sweden****Values**

- Everyone should have equal access to new technologies
- Everyone should be able to participate in society and lead a good and dignified life

**Needs**

- Accessible nanomedicines
- Affordability nanomedicines

**Concerns**

- Physical side-effects of nanomedicines
- Obsessive striving for perfection or perfect health
- Social inequalities (both at national and international level) due to unequal access to nanomedicine
- Knowing too much about the state of our bodies and health might make us feel sicker than we truly are (hypochondria).

**BOX 6: Israel****Values**

- Everyone should be able to participate in society and lead a normal life.
- Everyone should have equal access to nanomedicines
- Everyone should take responsibility for their own fate

**Needs**

- Treatment of people under stress and trauma
- Treatments for people with disabilities

**Concerns**

- The use of nanomedicine to improve normal functioning and natural abilities. Without equal access to these types of application, new social inequalities could emerge.
- Developments in nanomedicine may lead to loss of certain jobs and professions



Malsch  
Techno  
Valuation



NANO*futures*

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