

## **APPENDIX 1. NANOTECHNOLOGY FORESIGHT SCENARIOS**

### **Nano-phobia phobia**

- Where governance style is mandatory, formal, reactive and closed;
- Where governance scope is fragmented and nano-specific;
- Where the public is erroneously perceived as not accepting of nanotechnologies in products.

In 2014, the development of nanotechnologies in Europe was being held back as the result of a misplaced fear that the public was ‘anti-nano’ as a consequence, disclosure around who was doing what with nanotechnologies was minimal and, where it took place at all, it was only the barest minimum to comply with mandatory reporting requirements.

By 2034, however, stakeholders have still not realised that it is their own fears that are misplaced. The general public around Europe are (as they have been for decades) generally pro-technology; they see that it makes life easier, safer and healthier; that it creates jobs and it helps to solve many of the world’s big problems like climate change, water pollution, obesity and food shortages.

But nanotechnologies haven’t gone away and they remain focussed as a way of achieving small improvements in materials and no significant innovation is taking place in any sector. There is negligible progress on ‘soft’ nanobiotechnologies, even in the medical sector, in part due to funding constraints early in the research stage, fuelled by some nervousness about how the public might perceive the use of nanotechnologies in the human body.

Policy makers, anxious to avoid being seen to ‘cave in’ to business insistence on nano’s lack of ‘specialness’, remain focussed on the safety of nanomaterials. There is no agreement for a way forward and positions remain entrenched. Meanwhile, NGOs sporadically turn their attention to nanotechnologies when a new application is launched, particularly in the food and medical sectors.

The lack of disclosure created by nano-phobia phobia create a vicious circle of entrenchment, further non-disclosure and further erosion of trustworthiness in the eyes of policy-makers and NGOs. Consequently, despite much lobbying by industry for harmonisation of legislation in a more generic form, policy-makers feel unable to move away from demonstrating that they are in control of nanotechnology, despite no major nanotechnology-related risks yet being manifest.

The legally-focussed approach, exemplified by the Mandatory Nano-Products Register (which has been in place since 2025) together with developments in characterisation of nanomaterials allows for legal challenges against non-disclosure but, with little consensus on legal standards, court cases roll on for years, with little information forthcoming and little resolution.

Meanwhile, outside of Europe, and in many Asian countries in particular, nanotechnologies are developing rapidly. Pro-technology attitudes are more widely recognised and with greater emphasis on technology-led innovation as an economic stimulus, nanotechnologies are emerging as powerful differentiators in products.

### **Size Still Matters**

- Where governance style is managed, anticipatory and open;
- Where governance scope is fragmented and nano-specific;
- Where the public are erroneously perceived as not accepting of nanotechnologies in products.

In the twenty-teens the mistaken belief that the public did not accept nanotechnologies ensured that policy-makers, NGOs and industry remained focussed on nanotechnologies as something ‘special’ – still victims of the ‘nano-hype’ that gripped much of the world at the turn of the 21st century.

Nanotechnologies developed along the path of enabling the realisation of small, incremental advances in materials but the ‘hype’ dwindled to be replaced by questions about what was ‘nano’ and what was not. Gradually, companies began to quietly drop the nano connection; the name was removed from packs, taken out of advertising and off websites. Many of the consumer-facing industries began to make a point of claiming that their products didn’t in fact use nanotechnologies at all, though in fact little had changed in formulation terms.

However, failing to realise that the public were on the whole, unconcerned, NGO and consumer group campaigns about safety grew more vocal and focused on the use of the technology coupled with lack of transparency about where and how it was being used. Concerned about the potential for such campaigns to turn public opinion, and thus derail the much needed innovation to lift Europe out of the recession, policy makers looked to find ways to enable innovation to proceed in a socially-robust way, taking account of the hopes, expectations and concerns of a wide range of stakeholders.

However, by 2034, the focus still remains on ‘size matters’. Policy makers dare not challenge the position that ‘nano’ is different and, for the sake of consumer confidence, nano-specific regulation is the main agenda item. Some member states have more powerful civil society organisations than others and their politicians feel the need for high profile statements to build confidence and some mandatory nano registration schemes are put in place and sector specific nano regulations are introduced.

After intense lobbying and following threats of sweeping mandatory nano-specific regulation, industry finally agrees to support a Europe-wide Responsible Innovation Charter for Nanotechnologies, a voluntary approach developed collaboratively with NGOs by the European Commission with wide support from member states. Threats to make this mandatory within a year, together with leadership from large chemical companies bring

support from most companies. High-profile campaigns by NGOs focus on areas where industry is quiet - uncertainty about particle use is suspected but not proven.

Companies are required to disclose the results of their safety testing to a confidential NanoRegulation database, giving top line details on their websites where they must also demonstrate the benefit of the use of nano in their products. Nano-labelling is also required as part of the scheme with “(nano)” appearing as part of the ingredient list on consumer products and detail disclosed down the supply chain. NGOs and consultants act as verifiers of the procedures, with annual tables published on nano products, benefits and risks, which to the surprise of many, are rare.

### **Nano for Growth**

- Where governance style is mandatory, formal, reactive and closed;
- Where governance scope is harmonised and generic;
- Where the public are accurately perceived as accepting of nanotechnologies in products.

Spurred by the need to lift Europe out of the 20teens recession, technology innovation is seen as the major driver of growth. Renewed vigour in innovation is stimulated by global competition in areas which many EU countries felt was their heartland - nano and bioscience, chemicals, energy. In addition, Europe’s politicians began to see more clearly the impacts of an ageing population and the now pressing need to focus greater attention on energy needs due to increased commodity prices and climate change.

By 2034, new data collection technologies that allow real time polling on products and services shows the general public is very supportive of the benefits of technology, and the growth and jobs it stimulates and though the ‘nano’ aspect has been forgotten, the image of

‘technology and science’ is dramatically improved. Meanwhile nanotechnologies enable products in all major sectors and benefits are clearly being delivered.

For Europe to capitalise on these developments quickly, ‘before everyone else does’, international consensus on regulation and safety is sought as a matter of urgency with multinational business taking the lead. The more time-consuming multi-stakeholder collaborative processes are sidelined in favour of a more centralised approach through the World Economic Forum, OECD and the WTO. As part of harmonisation, it is agreed that nanoscale materials have no significant size-related risks and are brought under general chemicals and product safety regulations.

NGO opinions have been marginalised by a consensus on the need for economic regeneration and on the basis that the public is generally accepting of the technology and the promised benefits are being manifest. While a small number of risks emerge from time to time, the benefits are widely seen as outweighing the risks.

With the requirement to demonstrate impact and innovation more of a priority than concerns about safety, businesses focus their communications activities on talking up the ‘scientific’ aspects of their products. It is not clear whether safety research is being carried out within companies as this information is not widely available despite disclosure regulations.

The focus on marketing products has decreased expenditure on safety research by governments and, as nanoparticles in many products become ubiquitous, concerns become more widespread about the inability to track their impact on the environment and in waste streams. These worries escalate as nano-silver is shown to be widely present in sediments and in combination with other biocides, negative impacts are beginning to be seen; related to a combination of their ubiquity and their unusual association with newer biocides.

Legal challenges, led by disaffected NGOs, are mounted in various jurisdictions, and show signs of being successful. NGO voices and media attention stress a relative lack of emphasis on safety and cracks in the process begin to show. The public, now used to the benefits that technology has brought, start to question what the trade-offs may have been made in the name of progress and growth.

### **Open Channels**

- Where governance style is managed, anticipatory and open;
- Where governance scope is harmonised and generic;
- Where the public are accurately perceived as accepting of nanotechnologies in products.

In the 20teens, a second wave of communications and outreach activities was undertaken with Horizon2020 funding and in support of Europe-wide approaches on nano safety and various country-specific nano action plans. Annual EU attitudes surveys continued to show the generally positive attitude broadly unchanged over 20 years, though understanding remained limited and the emphasis on safety and need for precaution continued.

During the 2020s, high profile developments in synthetic biology and robotics kept attention focused on the need for a genuine social benefit to the use of the technology, but also began to divert attention from nano, which became generally seen as a materials technology with the soft nano approaches being more closely associated biotechnologies. Business confidence grew and, in 2030, a new Global Reporting Initiative supplement for Responsible Innovation was agreed and became more widely used, stimulating a new openness in companies about their innovation processes and use of new technologies for social and environmental benefit.

Towards the end of the 2020s, following high profile campaigning from NGOs, nano-silver, along with a number of other biocides, were found to be of significant concern in the aquatic environment and restrictions put in place on applications where ions and particles may accumulate and a list of specific restricted substances agreed. Nanoscale particulates in other areas, such as nano-carbon black in pollution, received high profile in the late 20teens, but did not have a negative knock-on effect on other nanotechnologies.

As the characterisation and measurement systems improved it became clearer to regulators and to NGOs where HSE attention should be focused and restrictions put on specific areas, notably on inhalation, digestion and environmental release of certain nanomaterials. In general nanomaterials regulation was incorporated within wider product safety and materials regulation.

Regulation in the emerging areas of soft nanotechnologies focused on the strengthened regulation for biotechnologies following the growing number of applications of synthetic biology. High profile international initiatives, with celebrity champions, stimulated by the World Economic Forum and UN developed a high profile voluntary initiative and aspects of this were incorporated into the updated EU biotech regulation. By 2034, the voluntary initiative, and its distinctive logo, still remains popular with business and government from a reputational perspective, with organisations paying significant sums to standards bodies and NGO consortia for verification processes.

Progress is being made in developing international fora in which stakeholders convene to agree visions and sets of operating principles for the governing of human and environmental enhancement. These are directed towards developing international consensus on certain social, economic and environmental outcomes and involving responsible management by all involved: from research to recycling and reuse.

Some governments, businesses and some civil society groups decide to stay out of these processes for a range of commercial, political and values-based reasons, but on the whole the consensus is widespread that the principles and codes that emerge from this process are helpful in stimulating and supporting innovation.