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Nanotechnology: Public Engagement with Health, Environment and Social Issues

STRIVE
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2007-2013

SSTI
Science Technology and Innovation

Comhshaol, Oidhreacht agus Rialtas Áitiúil
Environment, Heritage and Local Government

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EPA STRIVE Programme 2007–2013

Nanotechnology: Public Engagement with Health, Environmental and Social Issues

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STRIVE Report

Prepared for the Environmental Protection Agency

by

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Executive Summary

This EPA STRIVE research fellowship report presents a literature review and fieldwork data for a project that investigated how the topic of nanotechnology can be engaged with by both experts on the topic and non-experts.

The first objective was to map out what can be said about knowledge of nanotechnology in contemporary Ireland. All perspectives on nanotechnology were taken on board, analysed and synthesised, including deviations from the accepted truths about nanotechnology. While perspectives on environmental and health implications were of particular interest, they were not the primary focus in discussions, unless raised by participants and commentators. Methods used for this study included an awareness survey and media and document analyses.

The second objective was to pilot a series of nanotechnology communication events, which would provide the basis of a future communications/ consultation strategy for policy-makers. The types of activities used in these events included focus groups, a 'citizens' jury', online forums and an installation in the Science Gallery in Dublin. The contributions from these activities also added to the first objective of addressing nanotechnology knowledge.

The third and final objective was to report to the EPA, in order to aid future environmental research associated with public communication and wider science communication and technology assessment policy by the Irish government.

The following was concluded from this project:

- Scientists were the most prominent voices in public discourse about nanotechnology, but mostly in the context of commercial exploitation and innovation.
- Environment and health risks and benefits were tied to social and ethical considerations very closely and participants in public engagement activities were at least as concerned about governance and equity issues (in terms of how nanotechnology is controlled) as they were about the environmental and health implications.
- Where nanotechnology was described in the media, it tended to be either framed in commercial terms, or in basic, scientific, didactic terms for education and outreach, for example, 'nanotechnology is …' Both representations reduce the chances for nanotechnology risks, of any kind, to be discussed, and are at odds with policy measures of nanotechnology public engagement in other countries.
- *Dialogicality* (expressing multiple voices and views on a topic) was weak in many official nanotechnology texts, new media approaches provided more opportunities for dialogue.
- The concept of nanotechnology as an 'entity' was important – for young participants in particular.
- Levels of attendance at public engagement events were low for the open-invitation focus group and the citizens' jury pilot especially.

The following recommendations are made:

- Establish a Convergence Technologies Forum;
- Ensure that dialogue initiatives are included for future nanotechnology;
- Use all communication channels, including new Web 2.0 media;
- Learn from the public engagement mistakes of other emerging technology debates, such as genetically modified organisms (GMOs);
- Link to global networks already involved in nanotechnology and emerging technology public engagement;
- Include social sustainability as a criterion in future EPA- and exchequer-funded research and technology assessment.

Even though there is little media or public interest, Nano-Innovation discourses are growing. In any future campaign for nanotechnology, media exposure and public relations require considerable investment. In other countries, *dialogue* is considered as important as promoting the technology itself. This report offers a

'menu' of dialogue models for policy-makers to address the many objectives of nanotechnology strategy, from less dialogic information transfer to public-led dialogue and the public imagining of a future with nanotechnology.

If only some of the predictions are accurate, nanotechnology will have many social implications. Much work is necessary to ensure nanotechnology public engagement is taken seriously in Ireland if the technology is an economic priority, or indeed if it has some bearing on progress in health, environment and technology. This report confirms what is found in international studies of science and society – public engagement needs to be about what can be accepted, not what can be sold. This report recommends that, for a more inclusive approach to nanotechnology knowledge – and to avoid another 'GM scenario' – dialogue must form the basis of the communication strategy with embedded 'triple bottom line' values, that is, where society and environment are given the same level of importance currently granted to the economy.

1 Context and Background to Nanotechnology and Public Engagement

1.1 Introduction: the EPA STRIVE Programme and Public Engagement with Science and Sustainability around the 'Smart Economy' Concept

Within the two-year lifespan of this Environmental Protection Agency (EPA) STRIVE research fellowship, dramatic events occurred in Ireland. There was a sharp downturn in the Irish economy, exacerbated by a global economic crisis. There are many challenges ahead – economic and social, but also environmental. Accumulating scientific evidence of climate change in the late 2000s by climatologists and environmental scientists is now mainstream knowledge, provoking action. The challenges of this so-called 'triple bottom line' (the economic, the environmental and the social) may have a cultural resonance, a societal tipping point. Or has it? Might it be that a social and environmental focus on science technology and innovation (STI) is, quite literally, an academic exercise? Despite many cutbacks, areas of science and technology, particularly sustainable technologies, has remained relatively unscathed and indeed promoted as important to a 'smart' and 'green' economy. The 'social' element of this – public acceptance of such technologies and an assessment of their sustainable credentials – is less visibly promoted, except within the social sciences.

Nanotechnology has been presented as one such important technology for Ireland. While this importance seemed to fade in the mid-to-late 2000s, the hype has started again since the recession. Nanotechnology has been seen as contributing to a way out of global recession through green innovation (EuroNanoForum, 2009; Sustainable Development Technology Canada, 2009; Safer Nanomaterials and Nanomanufacturing Initiative, 2009) while the Organisation for Economic Co-operation and Development (OECD, 2009) predicts 2 million new jobs could be created because of it. Investments from the EPA, but also the Science Foundation Ireland (SFI), the Programme for Research in Third Level Institutions (PRTLI) and collaborative structures such as the SFI, Trinity College Dublin's (TCD) Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN) and the Tyndall Institute, Cork have created the infrastructure to develop nanotechnology, it is proposed, for a new 'smart economy'. A Higher Education Authority (HEA)-funded consortium of third-level interests has emerged, the Integrated Nanoscience Platform for Ireland (INSPIRE), which actively promotes a strategic national nanotechnology agenda, as well as the Enterprise Ireland and Industrial Development Agency (IDA)-supported Competence Centre for Applied Nanotechnology (CCAN). These two consortia are jointly the industry/academia body NanoNet, representing Irish nanotechnology interests to actors abroad and organisers of the annual Nano Week. In 2009, there was a further ramping-up of public communication of nanotechnology (covered extensively in *The Irish Times*' *Innovation* magazine in December 2009 and in technology blogs [Kennedy, 2009a; 2009b]). The then Tánaiste Mary Coughlan, speaking at the launch of Nano Week, and coming soon after a major international symposium on nanotechnology at TCD, re-emphasised the importance of nanotechnology to the Irish economy, declaring that 10% of the €150 billion Irish exports in the year previously were 'nano-enabled', and that that figure would rise to 20% by 2015 (International Scientific Symposium on Nanotechnology, 2009). Around the same time, Minister for State for Science, Technology and Innovation, Conor Lenihan spoke to an SFI audience of researchers on how important it was that society knew the 'value' of science. These are all parts of the connected 'innovation' and 'green economy' narratives that characterise a strategic calling to arms to embrace technology for a return to growth. Here was one minister encouraging scientists to ensure public knowledge of their worth, while another announced huge economic gains for a technology of which so few are aware (as the current project demonstrates). This poses the question: why is a technology of such supposed economic worth not already part of public recognition of societal value?

Rather than framing the project from the beginning by offering a full definition, this first section will first work through issues around defining nanotechnology (see

Box 1.1 for some nanotechnology definitions). Two factors complicate this. The first is descriptive: a wide variety of scientific disciplines is involved in nanoscale research, and in many cases there is international disagreement over the boundaries of what constitutes 'nano', and indeed the importance of the term and the entire concept. The second factor is that there are risks associated with nanotechnology, and indeed many scientific uncertainties, for both health and environment, and these issues have tended to mean there is mixed opinion on the topic in other countries. Together, these two central issues – shared or contrasting understandings of nanotechnology and the acknowledgement, or not, of risk – have created a constellation of discourses that has placed nanotechnology, it could be argued, in a historically unique place with regard to both institutional and public discussion on the application and governance of emerging technologies.

The simple, popular definition of nanotechnology is that it concerns the manipulation of matter at its most fundamental, at scales below 100 nanometres, or 1/100000th of the diameter of a human hair, where properties differ greatly from larger scales. This is a profound development in science and technology, a struggle to keep up with, or go beyond, Moore's Law since the discovery of fullerenes and carbon nanotubes by the scanning tunnelling microscope (STM) in the 1980s ('more than Moore' has been a mantra). It may well mean the possibility of vastly more durable and smaller materials with huge amounts of data storage, and more.

There has been much, and varied, speculation about the future impact of nanotechnology. Predictions made before the global financial crisis estimated it to be worth $2.6 trillion to the US economy by 2014 (Lux Research, 2008). According to Hullman (2006a) nanotechnology would have the same global economy 'spiking' effects as caused throughout the history of technology by electricity, automobiles and integrated circuitry. As with other supposed hi-tech waves, nanotechnology enjoys high levels of political support in many countries, so much so that there are suggestions that the spiking effect may be bigger (Allen, 2005; Lane and Kalil, 2005).

Whether old or new, beneficial or risky, revolutionary or evolutionary, some level of scientific and social responsibility is required in order to consider 'the consumer'. Upstream communication (as discussed in more detail below) is public dialogue at an early stage of nanotechnology development. If 10% of Irish exports are nano-enabled, then we are some way 'downstream' already.

According to the inventory from the Project on Emerging Technologies (2010), developed jointly between the Woodrow Wilson International Centre and Pew Charitable Trusts (with data from 2008), there are over 800 products on the global market with some nanotechnology-enabled aspects. Of these, approximately 500 were identified as 'health and fitness' products, approximately 90 'home and garden' appliances, 80 'food and beverage', with the remainder spread across electronics, computer applications, the auto industry and products identified as 'goods for children' and 'cross cutting'. A list of existing products compiled by the National Nanotechnology Initiative (NNI) (2009) website in the US includes vehicle parts, paints and coatings, sunscreens and cosmetics, metal-cutting tools, sports equipment, dental products, stain-free clothing, wound dressings and ink.

Early predictions for nano-enabled products are some way off. Products to date have been relatively mundane in their application – everyday appliances rather than the science fiction-oriented forecasting of the early years (Drexler, 1986). Nonetheless, this type of forecasting is part of the 'imaginary' process of nanotechnology. Irish scientists involved in nanoscale work have made many attempts to highlight the more grounded practices of nanotechnology, the continuation of current scientific fields and natural order that already exists. Yet it is also hyped as 'the next big thing' for Ireland (Lillington, 2009). In this sense, nanotechnology is a paradox – it is described as both old and new, always existing yet revolutionary.

The visions proposed by those writers who first described nanotechnology – such as Richard Feynman in 1959 or Eric Drexler in 1986 – might be dismissed as unrealistic or unhelpful to current nanotechnology communication. It can be argued that the science fiction narrative of nanotechnology has an ambiguous relationship with the way technology discourses have developed, as explored by Erickson (2005) in his descriptions of 'exoteric' discourses outside labs combining with the 'esoteric' discourses of nano lab facilities. There is also an argument that, with such a strategic interest in nanoscience and public engagement, the sci-fi link can create opportunities

(Thurs, 2007). Most governments and regulatory agencies in the OECD countries have had some engagement with the increasingly 'social' aspect of nanotechnology, particularly how such technologies might be controlled within society and how, in turn, societies may respond to the technology, or range of technologies. Much of the public engagement work is described as environmental health and safety (EHS) issues or environmental, legal and social implications (ELSI), separating them from the science of nanomaterials. Public perception and media coverage data however both show a high level of sci-fi references (Anderson et al., 2009; Erickson, 2008; O'Mathuna, 2009; Thurs, 2007).

In the past, science policy tended to rely on principal stakeholders (commercial interests, higher education institutions, or the health-care sector). However, there is now a wider international and interdisciplinary context. There is a move towards a more embedded approach to science and society, with the concept of sustainability as a key point of action. In the UK, for instance, since the House of Lords Science and Society (2009) report, public engagement (rather than what was once more condescendingly known as 'public understanding of science') has been considered within policy-making as a higher priority. This has contributed significantly to education and outreach and science careers promotion. At the 2009 EU conference, *Putting European R&D at the Service of Sustainable Development*, attended by policy-makers, non-governmental organisations (NGOs), scientists and business interests, the then European Commissioner for Science and Research, Janez Potočnik (European Commission, 2009c) challenged delegates to use EU research to boost sustainable development and the economy while ensuring a multidisciplinary approach towards sustainability goals. This would, he said, create a forum where industry, academia and civil society could discuss how research contributes to sustainability.

Science and society are not separate entities. If nanotechnology has implications for security and environmental health, then it is imperative to have some level of public access to information *and* decision-making. This means there must be greater dialogue between specialist and non-specialists. The question is: Who should be involved in this dialogue? And should it be as wide and as diverse as possible? Several sociological perspectives of science address this, and indeed most see new processes of socialisation, social differentiation and politicisation within the sciences that make them embedded and 'latticed' within society already. 'Post-normal science' (Funtowicz and Ravetz, 2008), 'mode-2 science' (Gibbons et al., 1994; Nowotny et al., 2001), 'reflexive modernisation' (Beck, 1994; Giddens, 1994; Lash, 1994), 'risk society' (Beck, 1992) are all terms (briefly explained in Section 2), which describe science continuously as being entangled in practices beyond the old idea of objective laboratory techniques and old explanations.

In these complex processes, it is not enough to find out what 'the public' think of a particular science and technology to gauge reaction. New methods of public engagement challenge 'public opinion' as the only indicator of public response. Science and technology (S&T) is so omnipresent that it is impossible to detach ourselves to offer a firm 'unbiased opinion' on it. This is mainly because of the multitude of possible responses, but also because of a shift in the way social science researchers in this area perceive public knowledge itself. The 'co-production of knowledge' (Jasanoff, 2004; Nowotny et al., 2001) is now a key concept for science/society issues. Although the same issue arises as for public opinion – whose authority, and who is the producer of this knowledge? – what now has broad acceptance in technological decision-making is not the domain of scientists and science expertise alone. Nor should the perceived fissure between 'science' and 'society' be reduced to academic or economic principles; as Jasanoff puts it:

> The dominant discourses of economics, sociology and political science lack vocabularies to make sense of the untidy, uneven processes through which the production of science and technology becomes entangled with social norms and hierarchies.
>
> (Jasanoff, 2004, p2)

And although nanotechnology is viewed more than ever through an economic lens, one influential EU report (written by social scientists) claimed that 'technological innovations are really socio-technical innovations' (Felt et al., 2007, p21). Social science researchers, embedded in EU policy, are effecting social embeddedness, potentially a social sustainability (see Section 4.9).

Within this context of the increased socialisation of science and technology is the growing trend internationally to have 'ethical and social' dimensions included in nanotechnology strategy. The National Nanotechnology Initiative (NNI), which was set up by the Clinton administration, included ethical, legal and social implications (ELSI), similar to the Human Genome Project, where those issues on which the impact of nanoscience on society could be assessed. Irish nanotechnology is not detached from this, and indeed the EU-funded network of environmental research, SKEP ERA-net, is a good example of internationalisation (SKEP ERA-net, 2009). Philosopher Bernadette Bensaude-Vincent, in her keynote speech to a SKEP ERA-net conference on emerging issues for future research planning, referred to mode-2 science, which is a non-linear, socialised science (in the sense that it has many actors contributing, talking about it and to it, including economic arguments for scientific progress; see Section 2.1 below for an explanation of mode-1 and mode-2). In this science, objectivity is not guaranteed.

For science to be truly sustainable and embedded socially, feedback loops, reflections and various knowledge elements other than science enter into the overall scientific process (ibid.). As part of the oversight of these technologies, particularly nanotechnology, policy-makers and academic science established 2–5% of its total funding to ELSI issues in the US, the NNI and the Environmental Nanoscience Initiative. In the UK, a House of Lords select committee ran a public inquiry style engagement exercise into the use of nanotechnology in food (House of Lords Select Committee on Science and Technology, 2009). Fern Wickson (2009), presenting for the Australian Institute to the *Asia-Pacific Science, Technology and Society Network* conference, recommended mandatory reporting on all products containing nanomaterials, health surveillance and environmental monitoring of high potential exposures, and a parliamentary inquiry into any process with nano-enabled components. In Asia, Kyunghee (2003) describes the emergence of ethics in that region's nanotech development.

In contrast, there is little or no mention of public engagement in the Strategy for Science, Technology and Innovation (SSTI) in Ireland (Department of Enterprise, Trade and Employment, 2006). This current report addresses how nanotechnology is understood and communicated in various 'locales' of the public sphere, that is, where nanotechnology might be publicly discussed and what kind of activities might better facilitate public engagement. Technology funding agencies such as the SFI do not consider such 'ethical' or safety issues in their strategic plans. Likewise, Forfás, the Irish technology advisory agency, has not demonstrated any interest in attending to the social take-up or response of nanotechnology. NanoIreland (2006) was a technology assessment initiative that was initiated by Forfás in 2006 to look at the scientific and commercial context for nanotechnology in Ireland. That initiative quickly ran out of steam. In 2008 the Integrated Nanoscience Platform for Ireland (2010) (INSPIRE) was founded. Arguably, the new driver of this so-called strategic nanotech 'ecosystem' (ecological terminology has been used to describe the connections) is the Competence Centre for Applied Nanotechnology (CCAN), a state agency-backed consortium which includes multinational companies such as Intel and Analog Devices and indigenous companies such as Creganna and Aerogen, among others. The remit of CCAN is to translate university nano-research to industry as quickly as possible. With such large-scale commercial interest, is it too late to consider socially and environmentally acceptable development? Can there be, in Ireland, an integration of expertise, social response and policy measures for a (supposedly) transformative technology such as nanotechnology?

With the current global climate and economic crises, there is arguably more justification than ever for public input into sustainability and health issues concerning the current emphasis on emerging technologies, green energies, research and innovation, and health-care, as understood and recommended internationally. With the main exception of the 2009 INSPIRE BioNano International Conference (2009), *Inspiring Responsible Development for Society and the Environment* in Dublin, this context is missing from this Irish nano-nexus created by the CCAN and INSPIRE consortia. The other exceptions in Ireland are the Food Safety Authority of Ireland (FSAI) (2008) and the Health and Safety Authority (H&SA) (2010), each of whom have published safety statements about nanotechnology. This is not to say that the Irish approach to strategic nanotechnology differs greatly from elsewhere; the modus operandi for many of the initiatives above,

particularly in the US and EU is to compete globally; there is a race, imagined or otherwise, to a nano prize (Allen, 2005; Felt et al., 2007). However, what is unique about Ireland is the degree of absence of discussions about risk, uncertainty and social sustainability from nanotechnology discourses.

Nanotechnology in Ireland may also be positioned within the context of the wider scientific communities' interest in sustainable emerging technologies, particularly under the paradigm of convergence technologies (a bringing-together of the combined efforts of so-called NBIC [or nano-bio-info-cogno-technologies]) for sustainable development and human longevity, which has contributed to the shaping of future directions in connected EU research programmes (Nordman, 2004). Even SFI director Frank Gannon wrote an editorial in the influential *EMBO Reports* on the topic of 'convergence workers' at the interface of science and society (Gannon, 2009) (provoking a response from leading nanotechnology social scientist Arie Rip [Rip, 2009]). There has also been a 'green growth' narrative, a predicted economic upturn caused by innovation in renewable energies and emerging technologies to combat climate change and environmental damage (EPA, 2009; High-Level Group on Green Enterprise, 2009).

A further interdisciplinary and international context to nanotechnology and the possibilities for public engagement is learning from the past. Emerging technology debates are still ongoing: genetically modified (GM) organisms, nuclear energy, incineration, human embryo technologies. Macoubrie makes it particularly stark:

> Public perceptions of emergent technologies have become increasingly important to understand, in part due to the worldwide backlash against genetically modified foods, which effectively stalled a new industry.
>
> (Macoubrie, 2006, p221)

For nanotechnology, concerns reported in the literature include health and environmental safety, privacy and rights issues where nanoscale surveillance devices are employed; the ethics of human enhancement or operating at that fundamental level of nature; and the use of worldwide power inequities in distributing nanotechnology knowledge and capabilities. The perceived failure for strategic public engagement about genetically engineered crops across Europe throughout the decade (Gaskell, 2003) has provided the impetus to 'get it right this time'.

This report's principal argument is that it is necessary to be mindful of *assumptions*, in order to prevent ideological ring-fencing of ideas, scientific or otherwise, about nanotechnology, and to guard against over-reliance on *consensus* within texts that might prevent other voices and perspectives from entering into public processes of knowledge construction. This research presents a case to the EPA for how future environmental policy might incorporate current international best-practice models of public engagement into consultation plans and which recognise these multiple knowledge constructions. This STRIVE report investigates how nanotechnology is understood and utilised within various locales and fields of practice. It tests and evaluates those communication models to see what might best suit the Irish context. There is a context of varying and changing 'publics' – the plural is chosen here to emphasise the heterogeneous nature of public discourse and action, avoiding the trap of constructing the public as a single object, a tendency of political science for many years (Lippman, 1927). This has further implications for other future emerging technologies.

This report presents findings from the field about nanotechnology knowledge constructions, in a theoretical context from emerging thinking on science/society interactions. It outlines policy recommendations for how a more effective public engagement can take place in the concepts and applications of environmental and health science and technologies. Future research evolving from the STRIVE programme must take these new concepts of 'responsible innovation' on board – a vague term that can encompass science, economy, people, society and environment.

This report takes Shovelin and Trench (2007) as the starting point to examine the disconnect those authors have found between high-level business and academic discourses of nanotechnology on the one level, and low media coverage on the other. The extent and mechanisms of this disconnect are examined through empirical work on specific areas: public awareness, evaluation of various public engagement models and newspaper coverage of nanotechnology over ten years. Content and discourse analysis is used to explore

theoretical aspects such as emerging 'discourse sites' of nanotechnology in Ireland and how concepts such as 'framing' (emphasis and omission of ideas and facts, at its simplest definition) and 'dialogicality' (the propensity for multiple views and voices to be expressed) occur within and across these sites. The possibility of eight types of discourse sites of nanotechnology are discussed – of which six are emphasised as having potential opportunities for public engagement in Ireland.

Public policy for STI in Ireland has tended not to include marginal voices representing social and environmental matters. Recently, however, there have been recommendations from an Irish think tank calling for a 'Green New Deal' that includes a new social contract with the environment (Comhar Sustainable Development Council, 2009). These are no longer marginal voices. The political consensus-building that climate change scientists needed, but did not always get, in debates in the run-up to the COP15 Copenhagen Summit is evidence of growing movements in support of social and environmental awareness. Scientists are, more than ever, dependent on dwindling public support for their authority on environmental science. (Do we really need consensus to tackle climate change, and by extension the use of emerging technologies? In wider political spheres, the Aarhus Convention [Directive 2003/4/EC; Directive 2003/35/EC], which is yet to be ratified by Ireland, will set in European environmental law the rights of publics to be involved in policy decision-making processes. This report demonstrates why we may not.) Public engagement then becomes the important focus, giving substance to nano- and other emerging technologies in society.

1.2 Descriptions of Nanosciences and Nanotechnologies

Wilsdon and Willis (2004) have usefully categorised the way nanotechnology is framed: the 'nanoradicals' (those, following Drexler [1986] and Kurzweil [2006], who envisage a complete future transformation due to nanotechnology), the 'nanorealists' (arguably the dominant Irish narrative now, with more realistic short-term targets) and 'nanosceptics' (with various reasons why nanotechnology should, at the very least, be highly regulated). These simplified categories explain something about the source of descriptions about nanotechnology, and the way the technology is framed, which is discussed in more detail below.

Box 1.1. The many constructions of the definition of nanotechnology.

Defining 'nano'?

'Nano' is derived from the Greek word *nano* ('dwarf'). It now more commonly refers to a measurement of 100×10^{-9} or a billionth. The most common elements in definitions are 'scanning' and 'manipulation of matter' on the nanoscale, generally below 100 nanometre (nm) (so 100 x I billionth of a metre). A very common, at this stage clichéd, metaphor is 1/100,000th the size of the width of a human hair. Nanoscience or nanotechnology primarily works on the nanoscale, although this definition would satisfy few. Nanoscience is often referred to as 'horizontal', 'key', 'disruptive' or 'enabling' since it can pervade virtually all technological sectors. It often brings together different areas of science and benefits from an interdisciplinary or 'converging' approach. It has applications in areas such as nanomaterials, nanochemistry, nanobio, nanophysics, etc.

Nanotechnology is often described as the manipulation or self-assembly of individual atoms, molecules, or molecular clusters into structures to create materials and devices with new or vastly different properties. In its conception, this means anything can possibly be created. In actuality, nanotechnology comprises any technological developments on the nanometre scale, usually 0.1–100 nm (e.g. photonics applications in nanoelectronics and nanoengineering) or by manipulating individual atoms and molecules into nanostructures, which more closely resembles chemistry or biology.

Historically, nanotechnology has its origin myths with 'visionaries' such as Von Neumann, Drexler (1986) and Feynman (1959) describing a future with assemblers creating new matter out of atoms and molecules. Feyman's speech, 'There's plenty of room at the bottom', is credited as a seminal point (ibid.). Even Ireland has its own creation myth (in Gaeilge [native Irish], 'nano' is translated as *mion*, also meaning 'minor'). Flann O'Brien has been credited with being a 'godfather of nanotechnology', with tongue-in-cheek, as he used assembler-type concepts in his novel *The Third Policeman* (O'Brien, 1993 [1967]). This pre-

dates another early 'nano-fiction' work, Heinlein's (1942) *Waldo*.

There are many varying definitions, and some inconsistencies. 'Bottom up' refers to that branch of nanotechnology that builds atoms, while 'top-down' refers to solid-state 'traditional' sciences that are moving down ever smaller scales. There are also distinctions between US and UK definitions (1 and 100 nm for the former, between 0.2 and 100 nm for the latter). An 'A to Z' of nanotechnology (2008) from Australia, sourced from the National Nanotechnology Institute Japanese, is at variance with the 50 to 100 nm range classified as 'ultrafines'. The Centre for Responsible Nanotechnology (2010), seen as carrying the applied legacy of Eric Drexler's vision (he is on the board of advisors), calls its work 'molecular manufacturing', a deliberate dissociation from nanotechnology and 'mere' materials science. In an OECD statement, 'nanotechnology' is described as covering both nanosciences and nanotechnologies. To address these perceived inconsistencies, a Nanotechnology Task Force was set up in Ireland to agree a 'national definition' (Irish Council for Science Technology and Innovation, 2004).

The term used throughout this report is 'nanotechnology', intending to mean the plural 'nanotechnologies' and also 'nanosciences', 'nanomaterials' and 'nanoscale research'.

A report from the Royal Society and the Royal Academy of Engineering (RS/RAE) 2004, commissioned by the UK government to address concerns about nanotechnology – and subsequently considered one of the key statements about this from Western Europe – offered what it considered a non-commercially biased opinion. It identified present and future applications in the areas of nanomaterials, metrology, electronics/ICT, bionanotechnology/nanomedicine, and industrial applications (ibid.) According to a nanotechnology statement from the Irish Council for Science Technology and Innovation (ICSTI) (2004), potential applications include electronics, photonics, pharmaceuticals, agri-food, environmental technologies, plastics and construction, using such esoteric technologies as spintronics (creating ones and zeros by controlling the spin of electrons) and quantum dots (semi-conductor nanocrystals). In addition to the practical applications and lab practices, there are many philosophers of science, sociologists and ethicists who speak of nanotechnology as new ways of seeing the world (for examples, see Bensuade-Vincent and Newman [2007], Campbell [2007] and Wickson [2008]). This visualisation extends back through the process of 'discovery' to STM and scanning lab equipment. Bensuade-Vincent argued in her keynote to the inaugural international Society for Nanoscience and Emerging Technologies (SNET) event that this visual object created in the lab object *is* nanotechnology.

Within systems of nanotechnoscience, the possibility has emerged in academic research to map out and track the evolution of nanotechnology through global nodes of patented activities and products available through web-based databases (Li et al., 2009). Porter and Youtie (2009) have also published a bibliometric 'science map' that shows nanotechnology fragmented into 175 subject categories. In an analysis of 6000 articles in the *Science Citation Index*, increased publication activities were found around the areas of materials, engineering and chemistry and more cross-citation intensity around the areas of health, particularly cognitive sciences, clinical medicine, infectious diseases and biomedical sciences. While 'green nanotech' is a recent discussion point, it is not yet a major player. With the rapidly growing use of nanoscale within many different disciplines, there is of course every possibility that 'nano' may not be used very soon. The responses from both journalists and scientists in Anderson et al.'s (2009) study of nanotechnology risk and news coverage suggests a perceived cynicism in latter years by the use of the 'nano' prefix. Mark Erickson (2008) has declared that perhaps nanotechnology does not exist in any real sense. While such comments might suggest a general confusion about nanotechnology, leaving it open to hype, we suggest this adds to its complexity.

What are the likely public concerns about nanotechnology? These are explored throughout this report. In a simplistic way, concerned perspectives on nanotechnology (expert and non-expert) may be divided into (i) issues of *safety* (e.g. nanoparticles and nanomaterials), (ii) issues of an *esoteric* nature (human enhancement, grey goo, identities), and (iii) *governance* (power and distribution). These are over-simplified but helpful categorisations; as demonstrated in this report, there are interconnections between various responses

to, and understandings of, nanotechnology in local public group settings.

The next section will focus mainly on scientific discourses of promise and risk for nanotechnology. Section 2 examines definitions of risk.

1.3 Discourses on Nanotechnology Benefits and Risks

This chapter looks mainly at scientific discourses on nanotechnology (the embedded assumptions and normative descriptions within scientific disciplines), but also how these have a bearing on how others are beginning to view it externally – similarly or differently – for good or for ill. The main nanotechnology fields in Ireland, as outlined by the INSPIRE consortium, are bionanotechnology (including nanomedicine), nanoelectronics, and nanophotonics (using 'light to obtain, convey or process information' [Integrated Nanoscience Platform for Ireland, 2010]). The original NanoIreland strategy document, now removed from the Forfás website, also listed nanomaterial development as a strategic objective, which includes nanoparticles, nanotubes, nanostructured materials and coatings and nanocomposites (NanoIreland, 2006). These segregations into nano-types can result in confusing terminology – for instance, how can the difference between a nanoscale device used in 'nanoelectronics' and a 'nanostructured material' be easily explained? When the societal impact of nanotechnology is discussed, it can often also refer to health and environmental matters. These issues are now discussed in detail.

1.3.1 Balancing sustainability and environmental risk

Many discussions about nanotechnology concern the impact on the environment. This has been presented as either positive or negative. Examples of 'green nanotech' include: increasing research interest in the use of nanoscale environmental sensors for the detection of biotic compounds in seawater or drinking water; nanoparticles used for waste remediation; precision farming where computers, global satellite positioning systems, and remote sensing devices measure local environmental conditions for agro-efficiency during seeding, fertiliser sprays, watering, and harvesting (Joseph and Morrison, 2006); photovoltaics and other compact energy sources for expected cheaper and more efficient fuel production; more controversial geo-engineering projects where, through nanotechnological processes, large-scale geo-engineering of the planet reduces sunlight and/or carbon emissions to combat global warming; and cerium oxide nanomaterials which can combat diesel emissions, while iron materials have been used to remove contaminants from soils and groundwater (US Environmental Protection Agency, 2007).

But there are also growing environmental health concerns. This is not to say that everything with 'nano' is potentially harmful – a nano process generally means working on the nanoscale, and is thus not a 'product' in itself. However, the main health and safety concerns relate to how operating on the nanoscale presents more uncertainty about the fate and behaviour of the subjects and side-products of the technology than on the macro scale, owing to the very different properties at this scale. The RS/RAE (2004) report was satisfied that the main potential risk to environment and health came from 'deliberately manufactured nanoparticles and nanotubes that are free rather than fixed to or within a material'. The *Journal of Nanoparticle Research* publishes an increasing number of papers on nanotoxicity research. Other environmental health journals have published reports on potential toxicological impact of colloids (Oberdorster et al., 2007; McCarthy and Zachara, 1989) and amyloids (Sealy, 2006).

Health risks associated with nanoparticles have traditionally been investigated by particulate toxicology on the nanoscale for naturally occurring nanoparticles in the environment such as volcanic dust or certain bacterial or mineral composites. Contamination has been identified as the consequence of mass production and transport, as well as spillages and waste associated with nanoparticle-containing consumer products such as cosmetics and industrial waste (Albrecht et al., 2006, citing Oberdorster et al., 2005). Other materials are labelled 'high risk' such as asbestos or silica (Oberdorster et al., 2007). Particulate behaviour studies from virology and other areas contribute to the overall knowledge, where air pollution particles below 10 μm in size (ibid.), are often called 'ultrafines' or 'incidental' nanoparticles, by-products of macro processes of production. Early studies show rats exposed for 30 minutes to 20 nm polytetrafluoroethylene ultrafine concentrations of 106

particles cm^{-3} died within 4 hours. Other streams of information contributing to a larger toxicology picture come from genetic and epidemiological disciplines, for instance, genetic predisposition for respiratory and cardiovascular illnesses. The traditional types of nanoparticles — natural and incidental — are often distinguished from what are termed 'newly engineered' nanoparticles, which include dendrimers, quantum dots, carbon nanotubes and metallic nanoparticles. These are the new products of nanotechnology. Much has been learned about engineered nanoparticles from the study of natural and incidental particulates. There is an opinion, however, that nanoparticulates represent a whole new area of toxicology. An important element for characterising nanoparticles and their toxicology is studying states of agglomeration (particles' coagulation after turbulence in liquids or gases) and aggregation (particle attraction through van der Waals forces) (Oberdorster et al., 2007).

In the US and the EU, scientists have begun making representations at the highest political level to ensure not just regulation for these products and processes, but to re-evaluate the whole way that safety and risk are understood (House of Lords Select Committee on Science and Technology, 2009; Maynard 2007). According to Hannah and Thompson (2008, p7), ' "free" manufactured nanomaterials present a risk of exposure to humans and the environment during their entire life cycle'. High-level British reports have questioned the adequacy of the REACH directive (explained in Section 1.3.5), which classifies nanoparticles as 'chemicals' in the EU (RR/RAE, 2004; Royal Commission, 2008). According to the FSAI:

> The dose metric is of major importance in assessing the risk of nanoparticles in the body as well as the environment. The use of mass concentration data alone for the expression of dose in toxicology testing is insufficient, and the number concentration and/or surface area needs to be taken into account, as well as the aggregation state.
>
> (FSAI, 2008, p55)

A major report by the Woodrow Wilson Centre (Davies et al., 2009), which looked at social, environmental and health concerns, warned that current methods of regulation and risk assessment are inadequate for future technology assessment. This is the broadening of risk conception that Irwin (2006), Wynne (1992) and to a certain degree, Sandman (1993), suggest is important (see Section 2.2).

1.3.2 Bionanotechnology and health

In Ireland, nanotechnology's positive impact on health care is perhaps the most discussed on a strategic level, after economic benefits (the newspaper analysis demonstrates this in Section 5). However, across all the discourses of nanotechnology, the positive implications of bionanotechnology, biomedicine and diagnostic devices are only part of the story. Nanotechnology, particularly nanoparticles, has also been described as a health risk. Since the original NanoIreland brief, Ireland has positioned itself as a potential hub for bionanotechnology and the discourse around this seems to be intensifying (CRANN, 2010; INSPIRE BioNano International Conference, 2009). There is a growing alliance of European Commission and industry forming around the European Technology Platform on Nanomedicine focusing on targeted drug delivery, biodiagnostics, and regenerative medicine across Europe (European Technology Platform, 2005). This fits within Ireland's recent turn to the biosciences and healthcare (Advisory Council for Science, Technology and Innovation, 2006).

Accurately measuring nanoparticle concentration levels and exposure rates appears to be difficult, although toxicology studies show a potential risk for respiratory and immune systems, and carcinogenic effects (Anderson et al., 2009 citing Handy and Shaw, 2007 and Hannah and Thompson, 2008). According to Shvedova et al. (2008), there is a particular concern for crossing the blood/brain barrier in mammals owing to the significantly small size of nanoparticles and its relation to surface area. Carbon nanotubes, metal nanoparticles, fullerenes and quantum dots have been identified in this range, based on toxicology studies in rodents (Oberdorster et al., 2007). A 'no observed adverse effect level' system (NOAEL) is applied by regulatory agencies such as the EPA, which assumes that everything at a certain dosage level is harmful. However, as Maynard (2007, p3) stresses: 'we can no longer rely on hazard evaluations, risk assessments or regulations that are based on our understanding of chemicals alone'.

There are many questions raised by the occupational aspects of nanotechnology (National Institute for Occupational Safety and Health, 2008), the primary one being: if there is to be a large nano-industry and little current regulation, how are current nano-researchers being protected? Agencies such as the National Institute for Occupational Safety and Health (NIOSH) in the United States, the US Food and Drugs Administration (FDA) and the European Food Safety Authority (EFSA) are looking at the safety of nanotechnology. International unions such as Amicus (2010) have focused on the potential threat to workers in nano-facilities.

1.3.3 Food and agriculture

Future farming technologies raise technical and social issues for future humans; but there are also philosophical problems regarding the control of nature. What relationship is required of the increasing interconnections, and rather flimsy boundaries, between 'nature' and 'society'? Food and feed are areas where environmental, health and ethical/governance issues intersect. Food is a potential flashpoint for social (non) acceptance. A European Food Safety Authority (EFSA) opinion report in 2009 recommended routine methods to detect, characterise and quantify nanomaterials in food and feed, and improvements in test methodologies to assess their toxicity (EFSA, 2009). Opinion varies, but some social scientists, policy-makers and scientists feel there is currently a soft law on food nanotechnologies (Davies et al., 2009). The House of Lords Sub-Committee on Nanotechnology and Foods concluded that there is little transparency in the food sector over this (Ghosh, 2009; House of Lords Select Committee on Science and Technology, 2009).

There is a growing lobby promoting the use of nanotechnology for the developing world. A United Nations Educational, Scientific and Cultural Organization (UNESCO) report (Salamanca-Buentello et al., 2005) claims that nanotechnology will address key United Nations Millennium Development Goals, and particularly have an impact on water treatment and remediation (e.g. nanomembranes), agricultural-productivity enhancement (e.g. sensors for soil- and plant-health monitoring) and energy storage and conversion (e.g. photovoltaics). The warning from ethicists is that valourising technology in this way creates definitional issues about what constitutes the developing world (O'Mathuna, 2009) and could well create deeper inequities worldwide, as have other technologies (Schummer, 2007). Richards (2005) stresses that a local community's control of, and relationship with, traditional farming values with regard to food should be seen as a fundamental right.

1.3.4 Governance, security and identity

The RS/RAE (2004, p52) report imparted authority on concerns raised in the previous sections by warning against viewing nanotechnology as a panacea or a global 'technical fix'. There are also concerns about an over-reliance on a military framing of risk justifying the use of nano-weaponry. As the US Department of Defence has major investments in military uses of nanotechnology (the NNI is actually the largest investor with over 25% of the US$1.6 billion total agency investment for 2010 [National Nanotechnology Initiative, 2010]), so information on this becomes part of the accepted story of how best to use nanotechnology (against terrorism, for example). A whole new type of nano-warfare is envisaged, from weapons to military equipment (Army Environmental Policy Institute, 2005). It has become almost inevitable to draw comparisons with sci-fi imagery of future war when discussing military applications of nanotechnology. And indeed there is a close relationship. Milburn (2005b) noted the striking similarities between an image of a female 'soldier of the future' from the Massachusetts Institute of Technology (MIT) Institute for Soldier Nanotechnologies and a character from the comic book *Radix*. MIT's soldier was a serious proposal, the project having been awarded US$50 million from the Army Research Office.

Emergent nanotechnology research and applications raise fundamental questions about the risks they potentially pose to privacy, identities, and gender equity, while exacerbating the nano-divide between the developing and the developed world. The issue of identity is especially complex: nanotechnology as a convergence of the nano-, bio, cogno- and info-sciences presenting the possibility of human/machine interfaces. Fukuyama (2002) and many others are negatively disposed to the thought of a posthuman future, where cyborg technologies alter human form. But others, such as Hayles (2004) and Milburn (2002, 2005a, 2005b) see a future already here in a collective cultural gaze. Donna Haraway (1991) writes that we are already part of cyborg collectives and these too have gender implications: emergent practices of information

and communication technologies, genetic engineering, objects and things shape our identity. While it may seem a threat to many, identity is in a constant state of 'becoming', including the processes of describing, seeing and feeling a nanoworld through Hollywood, news media and the cultural imagery of marketing and advertising (Campbell, 2007).

1.3.5 Legal and regulatory concerns

Much has been made of the problems regarding legislation and insurance for platform technologies that have as yet no direct applications and whose impact on the environment and health is still unclear. As a result, there are global oversight structures, although to what ends and for whose main benefit may still be debated. Civil society organisations (CSOs) (the official European name for non-governmental organisations [NGOs]) have called for a moratorium and, to a degree, their requests have been listened to, if not responded to, within the EU. In the US there are investments to the NNI by many agencies including the National Science Foundation (NSF) to look at the 'responsible use' of nanotechnology. As noted above, agencies, such as the National Institute for Occupational Safety and Health (NIOSH), the FDA and the EFSA are looking at safety issues. Meanwhile, the International Risk Governance Council (2007) and the Responsible NanoCode (2008) are defining broad strategies suitable for food and cosmetics, as examples. EU-funded mapping studies such as the FramingNano (2010) project attempts to use a multi-stakeholder approach to legislation.

Although regulation is difficult, there are early attempts: nanoscale substances come under the US EPA Toxic Substance Control Act (TSCA) while the only EU legislation is the existing REACH Directive (Registration, Evaluation, Authorization and Restriction of Chemicals) (EC 1907/2006), which classifies nanomaterials, nanotubules etc. as chemicals. This would appear to over-simplify the potential extent of nanotechnologies.

The precautionary principle has been adopted in the European Union as a possible regulatory way forward, a post-Maastricht Treaty principle for environmental safety that enshrines the protection of human, environmental, animal and plant health where only preliminary scientific evidence exists (European Commission, 2000). However, there is opposition to this approach also, particularly from the US, on the grounds that the principle is legally vague. In practical terms, it is impossible to predict the outcome of many proposed platform nanotechnologies and, therefore, detailed information would be unavailable for the courts in the event of legal challenges. The precautionary principle sets up a challenge for technology assessment – the burden of proof rests with those who wish to sell the technologies where scientific consensus on negligible risk is absent (Knébel and Meili, 2009; O'Mathuna, 2009). In principle, any stakeholder can veto the technology. A regulatory initiative that attempts more explicit links between science and society is the Aarhus Convention, the 1998 United Nations (UN) protocol for international law that links environmental rights with human rights (United Nations Economic Commission for Europe, 2010). While public participation is a focus if brought into law, there are complex issues associated with the area of 'rights' when applied to environmental information. Although a signed-up member of the Convention, Ireland has yet to ratify it.

Although these are attempts at regulation and governance under existing structures in most cases, environmental legislation is slow to be realised. Despite the transformative talk of nanotechnology discourses, regulatory and legislative agencies are still looking at this suite of technologies through old lenses. Following a review, the EC decided that, in the short term, there is no need for legislation, but there is still considerable unease within the EU – the Commission has issued several reports (e.g. European Commission, 2009a) and in 2009 called for a full review of nanomaterial regulation procedures, including REACH (European Commission, 2009b). The best that can be managed until legislation is dealt with is a high-level 'Code of Conduct', put into operation by the EU in 2008 (FramingNano, 2010). This is a set of guidelines that ensures that nano-strategists attend to public meaning, that activities are sustainable, that sufficient precaution is due, and that there is inclusiveness, 'excellence', accountability, and scope for innovation (ibid).

1.3.6 Public representations

It might be argued that nanotechnology as discussed today began as a public issue, a matter of risk, albeit a risk of minority interest. Examples include Bill Joy's (2000) *Wired* magazine article 'Why the future doesn't need us', the Prince Charles article in *The Guardian* where he denounced nanotechnology and which was

among the earliest media exposure to nanotechnology in Europe (Radford, 2003). Nanotechnology suddenly became one of a string of socioscientific controversies in the UK. The first House of Lords report on science and society in 2000 marked a significant change of language towards dialogue and public involvement in science at policy level in the UK. Social and ethical perspectives on science by academics were one thing; public perspectives on the enterprise of science quite another. This was partly in response to 1990s' conflicts, such as those surrounding GM organisms and bovine-spongiform-encephalitis ('mad cow disease').

It was the RS/RAE report (2004) however that elevated unease about nanotechnology. The report was unambiguous:

> Without a serious communication effort, nanotechnology innovations could face an unjust negative public reception. An effective two-way dialogue is indispensable, whereby the general public's views are taken into account and may be seen to influence decisions concerning R&D policy.
>
> (RS/RAE, 2004, p19)

Rob Doubleday (2007) has noted three historical phases of public engagement with nanotechnology. In the first, nanotechnology appears on the policy stage. In the second, more public voices emerge with diverse views on, and opposition to, nanotechnology. Doubleday notes an institutionalisation of public engagement by the third stage, which, it could be argued, sets strategic agendas for nanotechnology discourse, even from NGOs taking the talk beyond legitimised public concerns. The debate in the UK on active national espousal of GM foods can only serve to demonstrate further what happens when public consultation remains within its instrumental remit. Davie (2009, p17) states that the 'technology of public-participation mechanisms lags behind the science-based technologies of the 21st century'.

Some sociological and political questions are raised about nanotechnology that go to the very heart of the notion of democracy; for instance, would deliberative approaches offer more to public response to controversial technologies than representative or aggregate models? (see such a public inquiry at http://www.publications.parliament.uk. [House of Lords Select Committee on Science and Technology. 2009]). Some advocates of upstream engagement emphasise how engagement serves society better than the 'understanding deficit model' represented by education and outreach. It gives, say proponents, non-experts 'an active and constructive voice when they participate in nanotechnology policy' (Sandler and Kay, 2006). This would include addressing 'the power relations a technology embodies' and 'the balance between corporate and civil society interests and control, and challenging the agendas and practices of technoscience R&D' (Rogers-Hayden et al., 2007, p127). For other advocates of upstream engagement, old democratic ideals are not enough — new processes of science governance have emerged which demand fresh epistemologies of public science with local /global complexities (Irwin, 2006).

It could be argued that social action from CSOs combined with the sociological approaches of STS described previously have changed the landscape for strategic public engagement of nanotechnology. Suddenly a more ground-up approach has evolved and this has involved an increased depth of engagement. These representations include Greenpeace (Arnall, 2003) and the ETC Group (the CSO name, pronounced etcetera, is derived from its original brief, to look at 'erosion, technology and concentration') (ETC, 2003). However, it should not be assumed that CSOs represent popular public opinion. Public opinion surveys add to the data, but generally science studies tend to use more qualitative or sociologically or historically grounded methods to address public knowledge and tendency for action toward a topic like nanotechnology.

Increasing developments on the internet such as 'Web 2.0 forums' – which include so-called social media such as Facebook, Twitter, YouTube and other video logs as well as scientists' blogs – have opened up new public spaces for science communication. It was recently claimed that the internet has now overtaken television as a main source of science news for publics (Editorial, *Nature*, 2008). This evidence supports media anthropological work such as that of Couldry (2004), who studies how embedded all types of media have now become in crucial day-to-day practices.

There is also much more to be learnt about the nature of public engagement in science and technology issues generally, in this 'new politics'/active citizenship sense, when we refer to the public sphere. We have

snapshots globally, but a fuller picture is beginning to emerge of a world where there are wildly varying levels of engagement from country to country on socioscientific issues. Why have so few people heard of nanotechnology? Why is the majority of the population in many countries not engaged by the idea of a future transformative technology? For this reason, the news coverage in Ireland and web coverage of policy/informal discourses on nanotechnology in more 'Western Anglophile' countries were analysed for this report.

1.4 Nanotechnology and Policy

As an international policy organisation, it is telling that the OECD has considered seriously how nation-states and multinationals should guide responsible innovation in nanotechnology. The term 'responsible innovation' may be problematic, and it is referred to here occasionally, but it does have a certain currency for integrating nanotechnology, environment and society. This has ramifications for environmental monitoring and regulation.

Economically, there is a lot at stake. Forfás' 'NanoIreland' technology assessment exercise in 2006 addressed the strategic business case for potential nanotechnology policy and investment with key stakeholders. This process never came to fruition, although actors are mobilising again within industry and academia at the turn of the decade. In the early NanoIreland documentation, it was claimed that of Framework 7 funding of €53 billion from the EU for R&D, 3.5 was for nanotechnologies (Lambkin, 2005). In the US, US$830 million is spent on public research annually, mostly through the NNI (ibid.). The competitive edge for science policy now has Europe and the US looking towards Asia: Japan spends approximately €675 million per year, South Korea €170 million, while Taiwan has more than €83 million in annual investments (ibid.) China, a new superpower, had investments of €83 million per year in 2005, according to Lambkin (ibid.), but there are indicators that this expenditure is rising. Contrast this with Germany, which has €300 million expenditure annually on nanotechnology, which crucially is no less than 60% of total national EU spending (ibid.). This competition is what is driving policy. Section 4.2 will also look at in more detail at distinct practices of policy that have an impact on public engagement.

However, the 'risk society' that Beck (1992) refers to, and which is further theorised by Giddens' idea of 'life politics' (Giddens, 1991), suggests that, although a technoscientific culture demands 'hard science' solutions, human anxieties creep back into instrumental, de-humanised processes. Nanotechnology is in such a radically political space. This point may well be resisted by many nanoscientists, and indeed policy-makers. In fact, Ferrari and Nordmann (2009) argue that it needs to be politicised further, taking it way from the blocking discourse of traditional ethics, where answers are not urgently put forward, nor required. New thinking is needed on publics and policy. Diplomacy and solutions are required for it to work in public spaces, in the *polis*. But it must be a sophisticated type of political solution, a policy formed around uncertainty, that allows critical talk while not dominated by debate alone (von Schomborg and Davies, 2010).

1.5 Researching Nanotechnology and Society

Outside of scientific disciplines, nanotechnology has become an exciting area of discussion in the social sciences within the last five years, particularly in STS and the sub-discipline of science communication. The rationale is that the social sciences open up the normative assumptions and power relations within discourses about nanotechnology. There is a growing realisation that the 'old' social science methods of finding 'public opinion', or surveying 'attitudes' and extrapolating 'determinants', although useful across large populations, have limited value of mapping complexities of how societies deal with an issue in the growing information-rich and knowledge-intensive world in which we live. Now writers in the field of science studies in particular look for new ways of capturing how people behave and act in real-world situations.

There are two prominent institutions that have similar but different philosophies on nanotechnology and society, and these are mutually complementary – the Centre for Nanotechnology and Society at Arizona State University (CNS-ASU), with 'real-time' technology assessment as a central methodology (Guston and Sarewitz, 2002) and Arie Rip's 'constructive' technology assessment based on work in the University of Twente in The Netherlands (Schot and Rip, 1997). From these institutions – and many others – a myriad of tools has emerged for looking at how differences appear or disappear within texts. What they share is a polemical

voice for a new turn to 'social sciences', to have them embedded in policy and consultation for science and technology governance, to better understand social processes, practices and action (Davies et al., 2009; Kearnes et al., 2006; Laurent, 2007; Macnaghten et al., 2005a).

Such social science techniques would assist in public engagement, giving space in various texts for multiple social perspectives, observing and listening in to conversations, and attempting to get technoscientific practices to respond to these conversations. Social science techniques also make interpretations from 'imaginaries' and help define the best models of communication. The concept of the 'imaginary' should not imply that acts of imagination are used to perceive nanotechnology not founded on reality. In sketching out imaginaries, extremes from a utopian technoscientific nano-future to the nightmare 'grey goo' scenario and much in between are found. 'Imaginaries' are therefore the imaginings of nanotechnology; and within these imaginaries scientific and non-scientific descriptions are interwoven. Far from a perceived scientific reality, however, the cultural capital that can be drawn from narratives of ultra-durability, unlimited information storage, rearranging matter, developing devices that can enter the body and self-replicate, is powerful.

As noted above, the unreal, often surreal, nature of nanotechnology has opened up new avenues for arts and humanities for an example of cultural representations (see Julie Freeman, Fig. 1.1). The scanning techniques used to visualise nano-structures have an aesthetic that crosses art/science boundaries. As has been well documented and researched, nanotechnology has become a common Hollywood technology (O'Mathuna, 2009; Thurs, 2007), imagining future worlds while also adding a new twist to the powers of old superheroes and other stories (for examples, see *Iron Man* [2008] or *Spider-Man* [2002]).

Discourses centre around objects and imaginaries; elements of spin, of rhetoric, are the real mechanics of all discourses, and that includes science. Conversations and media constantly construct risk, 'the public', and 'public opinion'. The literature refers to 'framing' effects (Cobb, 2005; Nisbet and Mooney, 2007; Scheufele and Lewenstein, 2005; Schütz and Wiedemann, 2008). Somewhat analogous to framing are the 'archetypal stories' in the DEEPEN report (Davies et al., 2009), a European research project into knowledge of nanotechnology, but they serve a similar function in explaining shared ways of viewing the world. This report refrains from overtly calling the coded results of its framing analysis 'frames', as frames are contentious in discourse and political analysis in terms of how they are defined. Identifying what Goffman (1974) would call a frame requires a high quantity of data and an organising consensus and identity – a social movement. These frames emanate from 'thought communities', a concept by one of the earliest contributors to STS thinking, Ludwik Fleck (1979 [1935]). Here frames are referred to as 'framing' , 'potential frames', or 'narratives'. Bakhtin's dialogical theory (Fairclough, 2003) and frame analysis are chosen here, as described in the following chapters for both existing discourses of nanotechnology around Ireland, and grounded practices that shape, and are shaped by, these nanotechnology discourses and the absence of risk discourses.

1.6 Contextual Summary for Nanotechnology Public Engagement and Environmental/Health Issues in Ireland

To divide current and future applications of nanotechnology neatly into risks versus benefits is simplistic, and must be resisted. Equally, from an emerging science communication perspective, segregating 'health' and 'environmental' concerns neatly from 'social' or 'ethical' ones may miss the meaning-making potential between an array of connecting discursive practices when talking about nanotechnology futures. There is a future orientation with nanotechnology and new definitions of risk are needed to capture hopes and anxieties. The discourses of nanotechnology are notably driven by knowledge economy interests, with some newer framing connected with sustainability and the green economy. The emerging, underlying discourses of public engagement, however, have not yet taken root in Ireland. The literature suggests that stories about the future, be they science fiction narrative or imaginaries, have a use in not just explaining but defining nanotechnology. There are difficulties with the knowledge inequities that Irish nanotechnology presents, the insular business/academic science/policy nexus that constructs both knowledge of science and risk appears to be removing the latter from discourse. How can Irish nanotechnology be discussed in terms of risk, regulation and trust?

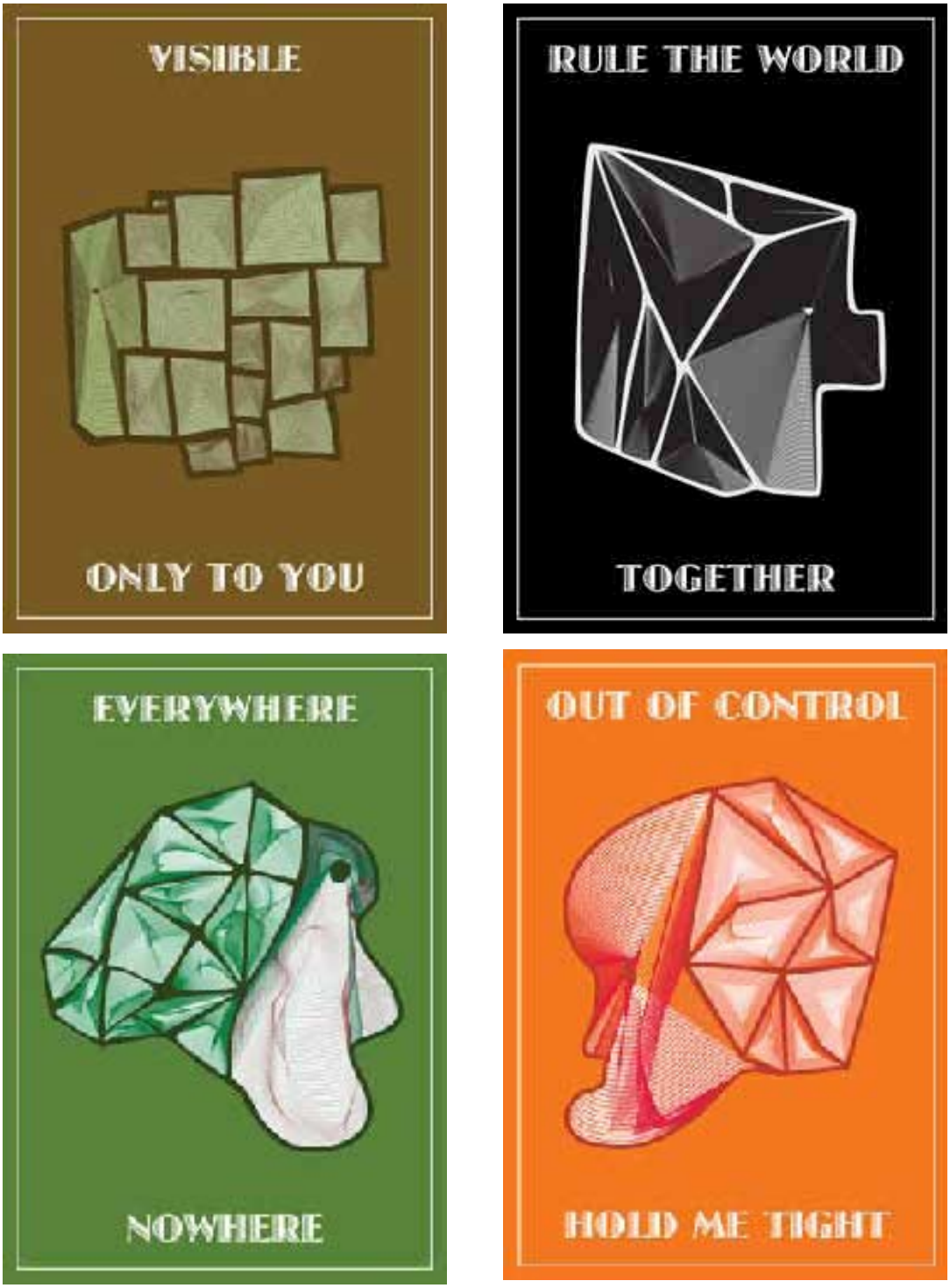

Figure 1.1. Some of the illustrations from 'Nano Novels©' by Julie Freeman, artist-in-residence at the Microsystems and Nanotechnology Centre, Cranfield University, UK. The In Particular project is a collaboration with Professor Jeremy Ramsden and funded by the Wellcome Trust (in-particular.net, 2010).

2 Public Engagement Literature Review

2.1 Mode-2 Science, Risk and Political Ecology

As an introduction to the relevant literature, and to examine the historical landscape for this project, this first section will briefly examine current thinking in social theory about how society interacts with concepts of technological modernisation and concepts of nature. This sets a wide theoretical context for why publics may accept or resist nanotechnology, to put it simply, or engage with it somewhere 'in between', to put it more realistically. There are some interlinking concepts to be considered here which are widely discussed within STS, the field in which this research is placed: mode-2 science, post-normal science, risk society and reflexive modernisation. The first concept, mode-2 science, describes a potentially emerging type of science and technology which has formed around multiple disciplines and areas of practice, not just of the sciences, but of knowledge itself (Gibbons et al., 1994). Mode-1 science was characterised by theoretical and experimental science, with internal disciplines, a scientist acting alone at first, then later, in the 20th century, in university teams (Nowotny et al., 2004). Mode-2, by contrast, is socially distributed, application oriented, trans-disciplinary, and subject to multiple accountabilities, existing in large parts outside of academia.

'Post-normal' science does not differ greatly from this concept. It shifts attention away from lab science, in the manner of mode-2, and sets new parameters for quality assurance based on 'uncertainty, value loading, and a plurality of legitimate perspectives' (Funtowicz and Ravetz, 2008). Post-normal science is rooted in 'ecological economics' (ibid.). What distinguishes post-normal science from mode-2 science is that the former has an epistemological and ideological basis, and insists that the 'old science' will cause social and environmental problems as well as solving them.

Using concepts from social theory, the 'risk society' of sociologists Ulrich Beck (1992) and Anthony Giddens (1991) speaks of a new reflexive risk and its management, which play a key role in social and political affairs, as well as the negotiation of issues regarding personal and ecological safety, lifestyle and decision-making. Living in a risk society does not mean we are surrounded by more risk in this stage of modernity. It goes even beyond being more aware of risk, although this is a part of modern living. In essence, the very systems of technoscience, what Giddens (1991) calls 'abstract systems' that include the 'black box' of nanotechnology, organise our thinking about risk; we are occasionally reminded by hazards, but paradoxically they are shielded from us most of the time – risk is managed in the abstract. A related concept closely examined by Ulrich Beck, Scott Lash, and Anthony Giddens is 'reflexive modernisation'. Beck gives a definition: '(institutional) self-confrontation with the effects of the risk society that cannot be dealt with and assimilated in the system of industrial society' (Beck, 1994, p6).

All these describe something new about science. They open science policy and science governance up to continuous new framings. In a similar space is 'boundary work' (Gieryn, 1983), 'hybrids' (Haraway, 1991), 'co-production' (Jasanoff, 2004) and relational /translational networks (Law and Callon, 1992; Latour, 2004). For environmentalism, these concepts represent a kind of political ecology – how science-based reflexivity allows ecological concepts to become politicised (so clearly demonstrated by current climate change debates). For Barbara Adam (1998), nature tends to be understood by society as as being 'out there', a wilderness unspoilt, and not as something more proximal that can be rendered an environmental hazard by something like nanomaterials. Many such hazards, Adam argues, are invisible and, in conceptual terms, immaterial – examples are caesium, perflourinated carbons (PFC) – and effects become clouded over time. Could nanotechnology, too, lose its 'toxic-discourse' value over time? These are technoscientific problems, caused, identified and solved by the same system: '[T]he more science becomes part of the governing process, the greater its role becomes in defining the problems that it is then asked to solve' (Weingart, 2002, p704). Although his argument plays in a literal sense with the notion of political ecology, Latour's (2004) *Politics of Nature* imagines how it might

be different were we to search for the common good life with a different understanding of 'nature', breaking free from what Fleck would have described as 'thought communities' (Fleck, 1979 [1935]).

2.2 New Understandings and Definitions of Risk

The risk society explains some of the context for how modern people engage with the concept of risk – a heavy smoker may be nervous about air travel; a scientist can be superstitious. Logic and rational thought do not explain this feeling of harm. Nanotechnology experts explain that one unique feature of working on the nanoscale, where atoms are literally put together, is that the physical properties of objects behave differently than on the microscale or larger. However, the amount of uncertainties about health and environmental impact has caused some concern. These uncertainties apply to public expectation but also to engineers themselves working at the nanoscale, or close to the nanoscale. Concerns have arisen about, for example, the potential toxicity and environmental impact of nanoscale materials in food and healthcare. Smaller particles are known to have larger surface reactivity, with potential environmental and health implications.

Wynne (2005) has stressed how the scientist/policy-maker construction of public expectation of zero risk is simplistic. On the regulator's side, and in line with current STS thinking (Wynne, 1992, 2005), this project challenges concepts of risks that actually are explained in scientific or monetary terms only. Toolkits such as Life Cycle Assessment (LCA) have been useful for analysing scientific and environmental behaviours at the edges of 'translation' or application to society (Styles and Jones, 2008). Emerging types of environmental political discourse require more sociological tools, such as that used by Wynne. Writers such as Wynne, Alan Irwin, Scott Lash and Peter Sandman have made sociologically informed challenges on the use of instrumental and scientific forms of risk assessment only, without considering hermeneutics, values and irrationalities that characterise response to risk and risk events. Sandman has added subjectivities to the standard model of risk with what he calls 'outrage'. Outrage consists of a sense of voluntariness, control, fairness, trust, responsiveness, morality, familiarity, memorability, dread and diffusion in time and space (Sandman, 1993; Sandman and Leonard, 2005). It is interesting to note that reactions to nanotechnology discourses at the highest levels demonstrate this feeling of inadequacy regarding official risk assessment (Davies, 2009; European Parliament Committee on the Environment, Public Health and Food Safety, 2009; von Schomberg, 2010). What this mounting literature tells us is that while life cycle and standard risk-assessment models have been the norm, they now need to be supplemented by embedded social, ethical and political dimensions.

So what has the research said about the 'social and ethical concerns' of publics? Based on Eurobarometer reports and subsequent follow-up surveys, Gaskell et al. (2005) found that 50% of the sample from the US responded that nanotechnology will change their lives for the better, while 35% did not know. There was a reversal in EU responses with 29% responding positively and 53% responding with 'don't know'[1]. The study also found that people in the US are also more optimistic than Europeans about more familiar technologies. Another US study carried out by Macoubrie (2006) showed low trust in how government manages risks, and that medical and industrial uses were related to lowest trust in government to manage risks. It is important now to look at how media contribute to public knowledge, particularly news media.

2.3 Nanotechnology and the Media

Many science-communication analysts highlight the significant role the media plays not only in shaping nanotechnology opinion, but also in the complex relationships between central and peripheral actors, as transmitters and consumers of science discourse, particularly those working in mass media analysis (Anderson et al., 2005; Anderson et al., 2009; Cobb, 2005; Cobb and Macoubrie, 2004; Gaskell et al., 2005; Gorss and Lewenstein, 2005; Hornig Priest, 2006; Stephens, 2005; Scheufele and Lewenstein, 2005; Schütz and Wiedemann, 2008).

Anderson et al. (2005) and Cobb (2005) present empirical evidence of greater coverage by far of the benefits of nanotechnology over the risks. Stephens

1 There are considerable amount of other questions to be asked of those respondents who reply 'don't know' in surveys. It must not be assumed 'don't know' means 'no knowledge of'.

(2005) has shown that, where negative coverage does occur, it tends to be more high profile, on the front page or in the main news sections of papers, as well as in book reviews, while the more discussed positive implications are found in the business and innovation sections. This supports the well-documented view that nanotechnology is embedded in business and economics discourse as a means to mobilise and crystallise opinion for further funding (Anderson et al., 2009, citing Randles et al., 2005). Anderson et al. (2005) also show how a celebrity can be a catalyst for increased media comment, as when the UK media covered Prince Charles' objection to the use of nanotechnology. There is a realisation that there has been hype in all 'sides', particularly in the early years, but there has always been a future utopian/dystopian vision of nanotechnology (Drexler, 1986), and some of this continues today (Joy, 2000; Kurzweil, 2010; Centre for Responsible Nanotechnology, 2008).

Anderson et al. (2005), Cobb and Macoubrie (2004), Cobb (2005), and Scheufele and Lewenstein (2005) are well-cited studies of the framing of nanotechnology in the media. This type of framing is often a top-down analysis, presumptions of how a publication frames for the reader. There is a strong argument from current 'culturalist' audience research to consider both audience/reader and producer framing in terms of a dialectic process of common understanding. This is especially true for complex ideas in socioscientific issues such as biotechnology and nanotechnology, where there are complex interactions between concepts of science, nature, technology and society. The constructivist paradigm in media studies has changed this linear view of media effects, considering instead how other modes of thinking and salient imagery are caught up with the effects of media on readers (Scheufele, 1999), and more appropriately 21st century media effects on the active audience, taking in also public representations from, for example, social media (Web 2.0). Political theorists such as William Gamson have looked at how focus groups frame the news (Gamson, 1992).

The dichotomised idea that a transformative technology could lead only to a utopia or dystopia is inspired and constructed by science fiction. It feeds into people's expectations. Several scenario methodologies have been utilised to capture cultural expectations in this way (see, for example, the constructivist technology assessment of Arie Rip [Schot and Rip, 1997] or Dave Guston and Dan Sarewitz's real-time technology assessment [Guston and Sarewitz, 2002]). But such scenarios are not too far removed from futuristic visions set out by Eric Drexler (1986), one of the earliest proponents of nanotechnology. These narratives may perhaps be within what Erickson (2005) has called the 'exoteric' realm. 'Exoteric and 'esoteric' discourses within science are Erickson's updating of Ludwik Fleck's thought communities of science (Fleck, 1979 [1935]). Esoteric thought communities concern those practices of everyday lab science and applied technology while exoteric thought communities draw on discourses of science that occur outside these practices.

2.4 Defining 'Upstream' Models of Dialogue and Public Engagement

From the Lisbon Treaty 'downwards', clear and vigorous communication using the best modern communication methods is at least notionally promoted. However, a 'deficit model' approach is still rooted. Theories of public engagement have advanced significantly over the past two decades. Early perspectives tended to come from a deficit position, that is, where scientific facts are imparted to an ignorant public who then gain greater knowledge and support for the scientific viewpoint. The focus now within STS is on two-way communication, public engagement and public dialogue, particularly for various sustainability objectives and deliberation on public perceptions of risk (MacNaghten et al., 2005b). Dialogue is not about providing a platform for scientists to explain to laypeople how the world works. Instead, it is a context in which society, of which scientists are a part, can address issues that involve science. Scientific research is located in a wider social context that enables other relevant expertise to be included regarding the implications of science and technology. Dialogue, as defined by the influential House of Lords Science and Technology Committee Report in 2000, is:

> ... an open exchange and sharing of knowledge, ideas, values, attitudes and beliefs between stakeholders (e.g. NGOs, commercial organisations, interest groups), scientists, publics (e.g. members of the general public, farmers, consumers) and decision-makers (local, regional, and national).
>
> (Jackson et al., 2005 p350)

There are commonalities in how publics understand, accept and resist emerging science and technology as solutions to global problems, such as the use of embryonic stem cells, genetically modified organisms or nanotechnology. Much public debate centres on connected issues of trust, accountability and concepts of technology versus nature. Furthermore, as with many other controversial science and society issues, while there may be some media debate, there is little clarity on how these issues are positioned within interlinking policy and media agendas. There often appears to be an avoidance of these socioscientific issues at policy level by public representatives because of their controversial nature. This creates the significant difficulty of trying to encourage public deliberation on an issue virtually absent from policy agendas.

If publics are defined as actors in socioscientific debate then there are, historically, three stages of dialogue (see Box 2.1).

Box 2.1. Stages of science technology and innovation (STI) dialogue, chronologically and in order of communicative action.

Stage 1 – Deficit model (the scientist knows, 'the public' needs to be educated).

Stage 2 – Diverse publics (there is no homogenous public, knowledge construction is shared).

Stage 3 – Communities of practice (knowledge and know-how comes from groups of homogenous or heterogeneous actors organised towards something).

The area of science communication is – in theory at least – generally moving from public understanding of science to models that involve more dialogue and mutual learning. Nanotechnology has been a good test case for this: in many cases, the urgency in attending to nanotechnology public engagement is caused by the perceived failure of deliberation on GM organisms in the early 2000s (Gaskell, 2003). In the UK, the GM debate failure was attributed to the framing processes of both the UK government and facilitators.

The concept of 'engaging the public' with nanotechnology is then a hot topic. There are several policy examples worldwide. In the UK these have been more prominent since the Royal Society and Royal Association of Engineers (2004) report about nanotechnology, public perceptions and consultation (also see HM Government [2005]). The area of science communication is – in theory at least – generally moving from public understanding of science to models that involve more dialogue and mutual learning (see Box 2.2 for a description of how these have developed in recent years).

Box 2.2. Broad categorisations of 'upstream' processes of science communication, listed in increasing order of non-expert involvement.

Information transmission – One-way flow of information from expert to non-expert; danger of deficit assumptions. Examples: lectures, seminars, 'Web 1.0' websites, 'education and outreach' shows.

Dialogue emphasis – Single-event exchanges between various levels and fields of expertise; multi-way communication. Examples: focus groups, *cafés scientifiques.*

Examples in deliberative approaches – Large-scale, relatively long events where shared meanings and multi-way exchanges are optimised. Examples: consensus conferences, citizen panels.

Community-based learning and research – Processes by which communication and knowledge construction, and indeed the practical outcome for a product or service, is driven by the non-expert outside of science. Difficult to manage and largely outside science communicators' control. Example: science shops.

It is also necessary then to clarify what is meant by 'engagement'. The Merriam-Webster Online dictionary gives the word a sense of emotional commitment, an arrangement that places parties in forward gear, while operating in a set time and place. It can be a confrontational arrangement, as in military engagement. The Oxford dictionary also stresses the importance of conversation in the word engagement. It is has STS connections with words like assemblage (Irwin and Michael, 2003), or agencement. A community can emerge in such an arrangement to talk about nanotechnology on its terms. It should not, therefore,

mean a type of science communication where the actor/audience/listener has a passive role. This is a move away from top-down information transfer about nanotechnology, and towards co-production of knowledge in an era of ecological modernisation. This requires that more sophisticated methods of public engagement are employed. Public engagement becomes a continuum.

There have been some attempts at having medium- to large-scale events that include a mix of experts and non-experts, such as citizens' juries and consensus panels. The citizens' jury model is designed for the discussion and deliberation of controversial public issues among a small sample of people (10–25) who listen to experts, then make recommendations based on what they have heard. They have been especially successful in The Netherlands and Denmark but also in other Western countries. The rationale behind a citizens' jury is that a small sample of a given population (randomly selected from an electoral register or otherwise) can, following informed discussions and deliberation, represent public opinions on a topic (although how such public involvement leads to policy is an open question). Topics typically have been local issues such as combating drug crime or anti-social behaviour. As well as being more inclusive for technological decision-making, there is a sense that, with juries, there is a greater depth in finding representations of 'public opinion' than in surveys or opinion polls. Selected non-specialists from various public demographics must spend a lot of time learning and reflecting within this process. Jurors hear from expert witnesses providing varying and complex perspectives on a given topic and provide recommendations. Jurors are given time to reflect and deliberate freely with each other on the questions at hand — often referred to as the 'charge' — usually assisted by a team of facilitators.

One of the most high-profile public engagement events was the Nanojury (2005), where local communities discussed nanotechnology and local crime issues in tandem, organised by two British universities (Universities of Cambridge and Newcastle), *The Guardian* and Greenpeace. The main objective of this exercise was to construct a ground-up process that allowed a highly complex and contextualised topic like nanotechnology to be brought into a discursive environment on the participants' own terms, insofar as this was possible. This was to address the perceived inequity where emerging technology public engagement exercises, such as *GM Nation?*, were seen as engineering public consent rather than allowing genuine public input into socioscientific decision-making. A twin-track approach was used: first, communities from West Yorkshire were urged to set up a pre-designed jury process on any topic they wished. Second, the research organisers introduced nanotechnology into the instrument. The process engaged participants enough for them to script a drama on the topic; on the flip side, the artificially adversarial nature of the 'courtroom' setup skewed the power relations in favour of the organisers and specialist experts, and did not facilitate an adequate meeting of perspectives (Singh, 2005).

Consensus panels, or larger-scale consensus conferences, attempt to overcome the epistemic barriers of expert/non-expert dichotomies by tackling highly complex technologies that also happen to be controversial in society in an open forum. The key, according to Seifert (2006), is that:

> … participation and deliberation are associated with normatively demanding 'models of democracy,' which disapprove of legalistic or technocratic state conceptions, [and] add to and go beyond the set of constitutionally prescribed procedures of representative democracy.
>
> (Seifer, 2006, p74)

Other initiatives at the 'upstream' level included NanoDialogues, a UK process framed around risk and organised by Demos, a UK think tank on democracy that takes a special interest in socio-technical matters, and partner organisations (Stilgoe, 2005); Small Talk (2006), organised by a UK government public understanding of science group; Nanologue (2008) a Germany–UK–Swiss joint project using future scenario workshops, and NANOPLAT, which aim to develop a platform for deliberative processes on nanotechnology in the European consumer market (von Schomberg, 2010). Nanodialogues was a process coordinated by Demos, along with Practical Action and the Universities of Lancaster and Durham to get publics involved in the politics of science (Stilgoe, 2005). Four 'experimental' discussion events were set up with an 'organisational partner' such as the Environmental Agency or Unilever with non-expert publics also attending. What emerged

from deliberations were concerns about access to information and power inequities as much as health and safety issues of nanoparticles. A similar British initiative was the Nanotechnology Engagement Group (NEG), funded by the British Office of Science and Innovation's Sciencewise (2008) programme, openly inviting social scientists onto discussion platforms. The Small Talk (2008) set of dialogue initiatives were mainly meeting places for scientists and policy-makers rather than non-expert publics, although these did contribute to certain events. Again, it was notable that for those publics that participated, there was a concern for regulation and policy decision-making rather than for direct dangers associated with nanotechnology. The Nanoplat EU Framework 7-funded project also had the objective of addressing nanotechnology policy expectations of publics and the substantive issue of public engagement itself. And while ethical and philosophical issues were raised, the main focus was identifying the public 'knowledge gap' and thereby creating an easier route to the marketplace.

These are some upstream models that have gained popularity for nanotechnology, and are often driven by academic discourse and action. But all these serve to highlight the concern that such processes will always be 'framed' by the organisers, as conceded by one of the facilitators of the Nanojury process (Singh, 2005). Strategic funding available from the EU and the NNI in the US to third-level institutions and civil society organisations seems to be addressing this power imbalance. Similarly, the OECD has begun work into looking at global standards of public engagement and worked them into a best practice set of formulae that is contextual, but is also public-oriented (OECD Directorate for Science, Technology and Industry Committee for Science and Technological Policy, 2008).

Other face-to-face forums for socioscientific public engagement include focus groups and cafés scientifiques. Focus groups now have a tarnished reputation following the Tony Blair-era GM Nation? process, when they were widely considered as an information-gathering device only (Gaskell, 2003). Modest in design, when well designed and facilitated, they still can be effective communication forums for dialogue. While focus groups are organised to optimise social dynamics to achieve results quickly, cafés scientifiquess are held in a café or a pub, where generally a speaker frees herself from the formality of the lecture hall to speak freely on a subject. They have French philosophy origins but have spread across Europe, including Dublin (Alchemist Café, 2010). Both the focus group and cafés scientifiques format were used for the current research.

Deacon et al. (1999) caution about not being careful about who said what in small-group engagement models. In addition, mixed methods approaches can complement each other in the manner of 'thick descriptions' (Geertz, 1973) meaning-making, or Irwin and Michael's (2003) 'epistemic assemblages'. This is a constructivist approach, although this term does not always sit easily within common practices of science communication. Nevertheless, it is important to report the relationship and interactions between social action (everyday practices, responses to new unsettling events), the public sphere (public affairs media, broadcast and print media, meetings, debates) and cultural texts (film, art, literature, online and 'popular' cultures).

The much-heralded 'Web 2.0' revolution provides a new area for nanotechnology public engagement. It was recently claimed that the internet has now overtaken television as a main source of science news for publics (Editorial, *Nature*, 2008). This evidence supports media anthropological work such as Couldry (2004), who studies how embedded all types of media have now become in crucial day-to-day practices as well as public discourse. In recent years, blogs, Facebook groups and Twitter have all added more complexity to the way nanoscience is communicated and publics respond. There is a certain type of interested public that interacts with nanoscientists, whether it is with the musings of physicist Richard Jones on his blog Soft Machines (2009) – which covers a wide range of social and ethical considerations as well as the science – to the fact/fiction future scenarios of Ray Kurzweil at KurzweilAI.net (2009).

'Science shops' might be considered the most involving of public engagement activities. In fact, 'public engagement' may be an inaccurate description, as it is designed to be very much a community-driven R&D activity developed on campus and can be of more direct benefit to those in and around the community of the university. The objective of the 'science shop movement' is to bring universities closer to the community, to carry out research requested by the local community or CSO. The Living Knowledge network is a coordinating resource for these around Europe.

It is important to define 'dialogue'. Conversation and tacit non-verbal communication follow language rules. Discourses trap us all into rules of engagement (Fleck, 1979 [1935]). The openness of discourses to dialogue relies on how different meanings can be brought to concepts. Currently, many within what has been termed the nanotechnology field dispute that such a field exists. In contradistinction to this, media commentators and 'education and outreach' specialists constantly refer to an 'enabling technology'. Is the revolution language still largely being applied? Is it more subtle language, suiting the many different disciplines that claim to be involved? Crucially, does the language open discussions out to the possibilities of risk? An area of analysis that brings insight to this is Norman Fairclough's work on how consensus can actually place limits on dialogue (Fairclough, 2003). Fairclough maintains that 'real dialogue' facilitates a forum where people enter freely, get access, have equal opportunity, disagree or form consensus if they wish, are free to leave and return, and this commitment leads to action in the form of policy change (ibid.). At the level of texts, Fairclough suggests a continuum of difference, with multiple voices represented within the text. Box 2.3 outlines the five categories of this continuum.

Box 2.3. Five scenarios representing the 'dialogicality' theory of use of language to accept or express difference in text, based on Bakhtin (Fairclough, 2003, pp41–2).

1. An openness to, an acceptance of, recognition of difference; an exploration of difference, as in 'dialogue' in the richest sense of the term;
2. An accentuation of difference, conflict, polemic, a struggle over meaning, norms, power;
3. An attempt to resolve or overcome difference;
4. A bracketing of difference, a focus on commonality, solidarity;
5. Consensus, a normalisation and acceptance of differences of power which brackets or suppresses differences of meaning and norms.

There is a crucial reason why dialogue may be closed off in a text. A unified voice imparts authority. According to Fairclough, 'a [word] becomes relativised, de-privileged, aware of competing definitions for the same things' when it is dialogic (Fairclough, 2003, p42, quoting Holquist 1981, p427). He goes on to say that 'Undialogized language is authoritative or absolute' (ibid.). Consensus is considered a 'low form of dialogue' only in the methodological sense applied here, that is, consensus within text removes multiple voices or points of view. This is not to say consensus in other forums removes difference or indeed is not forged from differences.

This is essentially how events and texts differ on the extent of exposing difference. Fairclough sees Giddens' 'triangular' idea at work here – meaning, order and power are all negotiated depending on how much difference is displayed (Fairclough, 2003). It is important then, in describing the continuum from consensus to dialogicality to give due credit to the balancing act required between authority and openness to difference; both are required. The future of public engagement with science and technology, as the many studies here testify, is moving away from expected trust in the institutions and expertise of science and towards new knowledge structures involving processes and practices external to science, as well as representations of citizens and communities (Chopyak and Levesque, 2002).

What then of Irish public engagement? The ICSTI (ICSTI, 2004) statement on nanotechnology recommended the setting-up of a National Nanotechnology Forum. However, a similar call had been made for a 'national conversation' on biotechnology five years earlier (ICSTI, 1999), which never materialised. In a 2006 Eurobarometer survey, Ireland is ranked lowest in terms of awareness and acceptance of nanotechnology among 25 European respondent countries, which is a concern to policy-makers, educators and engineers. However, other Eurobarometers show a distinct lack of engagement in general among the Irish with regard to sociotechnical matters. This would prevent us from concluding that the Irish would be more inclined toward outright rejection of nanotechnology than their European counterparts; rather, they are less engaged by it. There have been some attempts at public engagement with varying degrees of exposure and success, such as the Nanoquest (2006) game (which was relatively successful in schools) and the *The Resistors* (2007) TV show (which was less successful), both developed by the Discover Science and Engineering programme, an initiative by Forfás.

Much of this is in the 'education and outreach' and linear mode of communication – seen as key to winning the hearts and minds of young people about the importance of science. Important though science is for the future economy, the old deficit arrangement of assuming publics need to be educated still exists, leaving a disconnect between the work that social scientists and CSOs are doing for wider political involvement in technological decision-making and science communication programmes.

A baseline awareness survey is presented in this report. This gives an indication of the cultural resonance of the term nanotechnology and associated other emerging technologies. We cannot make claims in this type of research about 'what Irish society thinks' about nanotechnology. The groups of participants and participant perspectives must be seen as contextual – the topic that will engage a group of people this week may not engage the same people next week. Where there is a positive evaluation of a public engagement model, it should prompt the frequent use of this methodology, armed with results from previous research with the type of responses that contribute to an event, rather than engineering events to respond to groups of people that have a particular viewpoint. This centralises the event itself. Public engagement events are designed and managed, but they are largely unpredictable. Section 4 argues that locating 'sites' of discourse about nanotechnology and developing activities there aid this planning and managing process.

2.5 Criteria for Evaluating Public Engagement

Criteria for public engagement must be established from the outset. This project benefited from an extensive literature review on which to base these criteria. It was decided, following early OECD involvement in this area, that public engagement must be deliberative, inclusive, substantive and consequential, following suggested guidelines by Rob Doubleday based on Gavelin et al. (2007) (Box 2.4). Further, the substantive part must be socially robust, in that technical issues should be open to external questions. In this project, this evaluative instrument is supplemented with a variation of Fairclough's Critical Discourse Analysis (Fairclough, 2003), already applied to the area of biotechnology (Doolin, 2007).

Box 2.4. The elements of good practice for nanotechnology public engagement as suggested initially by Gavelin et al. (2007) and developed by Doubleday for the OECD Working Party on Nanotechnology (OECD Directorate for Science, Technology and Industry Committee for Science and Technological Policy, 2008).

Deliberative – Emphasising mutual learning and dialogue;

Inclusive – Involving a wide range of citizens and groups whose views would not otherwise have a direct bearing on policy deliberation;

Substantive – With topics that deal with issues related to technical questions, and appropriate to exchange;

Consequential – Making a material difference to the governance of nanotechnology.

2.6 Public Engagement in the Context of Nanotechnology Strategy

In the US in the late 1990s, the Clinton administration launched a series of initiatives that by 2001 prompted the establishment of the NNI, a programme involving 23 government agencies, and the research and development infrastructure that would exploit and promote work on the nanoscale. As part of oversight structures, less than 1% of total funding was invested in ethical legal and social issues (ELSI), a similar model to that used in the Human Genome Project (Bennet and Sarewitz, 2006). During the period (2001–2004), Japan, Taiwan, Canada, Australia, South Korea, Israel and many parts of Europe established similar programmes to promote and develop nanotechnology.

There are now global structures of nanotechnology governance. While there may be a slight leaning towards 'dialogue', as it has been defined above, main players still do the talking. An *Asian Times'* report in 2004 stated that China, Korea, and Taiwan had a combined proposed expenditure of US$4 billion at that time (Iyengar, 2004). Pre-recession world market forecasts for nanotechnology products made in the early 2000s differ wildly, between US$150 billion and US$2.6 trillion from 2010 and 2014. Economy and policy interests often frame the industry in terms of global nano-superpowers

(such as China, the EU, India, Korea, Russia, and the US) in competition with each other (Hullman, 2006a). Engagement in the sense required by the recent turn to 'responsible' innovation requires other publics to discuss these global movements and make decisions on them. 'Responsibility', to use the current term that is potentially quite diffuse, may in fact have the right cachet to be 'dialogic'. In the Lisbon Strategy, EU heads of state set the challenge for Europe to become 'the most competitive and dynamic knowledge-driven economy by 2010'. The three pillars of economy, society and environment, the so-called triple bottom line, are supposed to be enshrined in the Treaty. However, it ties together terms such as 'innovation', 'learning economy' and 'sustainability'. Phillip Busquin, then European Commissioner for Research stated in a strategy report:

> Nanotechnology is expected to contribute towards improving our quality of life, in particular, for sectors such as materials sciences, healthcare, information technology and the environment. Many products have been enhanced by nanotechnology to provide improvements and are already on the market e.g. heart-valves, coatings, scratch-free paints, tyres, sport equipment etc. At the same time, we should be vigilant in addressing any drawbacks of nanotechnology and to ensure that research is carried out in a responsible manner. Any negative impacts on public health, safety or the environment must be addressed upfront and as an integral part of the technological development process. Such an integrated approach should also help to ensure a high-level of confidence from investors and consumers.
>
> (European Commission, 2004a, p1)

The same publication also notes that:

> An effective two-way dialogue is indispensable, whereby the general publics' views are taken into account and may be seen to influence decisions concerning R&D policy.
>
> (European Commission, 2004a, p19)

The tools are available for this to happen.

2.7 Literature Summary and Theoretical Position

In this period of late modernity and risk (Beck, 1992, 1994; Giddens, 1991), practices of science have become too complex and diffuse within society to act as if they stand separately. Science is embedded in social practices. For democratic and moral reasons, it is necessary to involve publics more in the processes of science. This report argues that communities of practice can do this – not just by trying to make the science easier to communicate, but by constructing particular models of communication that facilitate shared practices and meanings. This also means inspiring public interest and maintaining it, knowing when to 'open up' to dialogue and 'close down' where necessary (Stirling, 2005). Fleck's (1979 [1935]) concept of thought communities, Gamson's (1992) framing methodologies, Schatzki's (2002) sites of practices and Wittgenstein's (1959) language rules are all drawn on here to see nanotechnology discourse as sites of talk as practices. Consensus builds up in discourse sites. Following Bakhtin's dialogical theory of language, consensus may neither be possible nor desired (Fairclough, 2003).

The concern may be: 'will it harm me or my loved ones?' These are issues of safety – health and environmental – but they are about more than physical harm. There are wider concerns about ecological trust – 'man' as steward of 'nature', changing relationships between machines, the artificial, humanity and nature. What will nanotechnology mean for being human? Moreover, future transcendence with the practices of late modernity/risk society are also brought into the mix. Rather than focus solely on scientific environmental and health risk, the question then becomes: what are the perspectives on nanotechnology that can be said to be shared knowledge between nano-specialists and non-specialists?

This project takes a Science and Technology Studies (STS) position within science communication. This project combines theory and action, one informing and configuring the other. To this end, there were various fields of inquiry used for the more empirical chapters, Chapters 5 and 6: policy documents and official commentary; newspaper coverage; a public opinion survey; 'field' research in schools and public engagement activities. These fields or arenas are

looked at as discourse sites, where high level orders of meaning are grounded in real-life practices, or ‘co-produced’ and types of discourse analysis used as methods of inquiry, investigating how strategic nanotechnology is ‘responded to’ within society, as well as the potential power implications. In real terms, new knowledge constructions are formed within the public engagement activities themselves developed for the purpose of this project (where nanotechnology may be talked about among participants for the first time).

3 Aims and Methods

3.1 Research Objectives

This EPA STRIVE project had three objectives:

1 Define what 'nanotechnology' means to various Irish publics by mapping 'local knowledges' of nanotechnology and potential environment-health-society implications;

2 Pilot a set of communication activities, going towards a model consultation process;

3 Report to the EPA, to inform strategic communication policy for nanotechnology.

3.2 Methods

3.2.1 Upstream communication models: overview of 'Nanotalk' activities

The upstream literature outlined in Section 2 guided the selection of activities. The initial plan involved having focus groups, an online forum and educational activities. Data analysis through discourse analysis was also planned from the proposal stages, with frame analysis. Where pre- and post-test surveys might have captured some level of 'traditional' knowledge and awareness of nanotechnology, the interactions were best captured qualitatively through analysis of 'nanotalk.' As the context for public engagement in Ireland – and the challenge of attracting various publics to such events – became clearer, the number and methodological range grew. The final nanotechnology communication activities presented here are: (i) media activities for secondary education (YouTube overview presentation of nano, then TV news report exercise for students); (ii) Your Science Your Say: Nanotechnology (YSYS:N) (2010), a Science Gallery installation with supporting online forum; (iii) Alchemist Café 'science in the pub'; (iv) a focus group with open invitation participants; (v) a focus group with pre-existing group participants; (vi) a 'citizens' jury' test run; (vii) local, informal, community group meetings. Regrettably, there was a last-minute cancellation of a proposed eighth event (a Nano Week roundtable debate with stakeholders).

3.2.2 Sampling and participant recruitment

Various methods of 'snowballing' techniques were used to encourage participation to the organised activities. Four nanoscientists participated in YSYS:N. Selection for this was on the basis of nanotechnology topic, gender, willingness, communication abilities, higher education institution, and experience. One focus group was random sampled in the sense that it was based on responses to advertising through a local newspaper and the most popular Irish online discussion forum (www.boards.ie). Another focus group used pre-existing members, such as local community visits. Groups with pre-existing members are already formed. Participants know each other. No activity used 'stratified' sampling techniques to represent a notional demographic spread. This further complements the move here away from 'opinion' or 'attitudinal' concerns in constructed groups and towards knowledge construction, meaning-making and articulation around communities of practice. Focus group transcripts were created and analysed, as were ethnographic notes from all activities, including YSYS:N. For the awareness survey, a national panel of 1000 consumers aged over 15 years was targeted as 'interested communities' for S&T issues, carried out by a contracted omnibus consumer survey company (see Section 3.2.5).

The rationale for, and range of, newspaper coverage of nanotechnology is covered in the next section. TV coverage of nanotechnology for the late 2000s returned only two links from the RTÉ website. They were two news items, described elsewhere in this report. As a demonstration of the type and extent of nanotechnology blogging, a Google search was carried out on 3 July 2009. It returned 543,000 links for 'nanotechnology blogs'. The first seven webpages of links were reviewed for content, and the dialogicality typology applied. Of the 73 links on these seven pages, 42 were deemed 'nano forums', that is dedicated, episodic discussions or blogs about varying aspects of nanotechnology. From this search, the following forums were selected for analysis: Soft Machines (2010), Howard Lovy's Nanobot (2009), Nanotech Now (2010) (Foresight Institute blog), the Centre for Responsible Nanotechnology (2010) blog, the Nanowerk (2010) portal and blog¦nano (2009). Also included, although outside the 'first seven-pages rule', was one particular discussion about nanobots and food on Accelerating Future (2009).

Box 3.1. Sample list of documents and media elements analysed for presences of dialogicality.* **

1 European Parliament Committee on the Environment, Public Health and Food Safety (2009) Draft report on regulatory aspects of nanomaterials http://www.europarl.europa.eu/meetdocs/2004_2009/documents/pr/763/763225/763225en.pdf **Policy**

2 European Technology Platform (2005) Vision document http://cordis.europa.eu/nanotechnology/nanomedicine.htm **Policy**

3 European Science Foundation (2006) Consensus conference report http://www.nanowerk.com/nanotechnology/reports/reportpdf/report53.pdf **Policy, public input**

4 European Commission (EC) (2006) Nanotechnology Action Plan http://ec.europa.eu/research/industrial_technologies/pdf/nano_action_plan_en.pdf **Policy**

5 EC (2006) Environment and health action plan 2004-2010. (2004) http://ec.europa.eu/ **Policy**

6 Strategy for Science , Technology and Innovation (SSTI) (2006) **Policy**

7 Building Ireland's smart economy (2008) **Policy**

8 ICSTI statement (2004) **Policy**

9 NanoIreland brief (2005) (Lambkin, 2005) **Policy**

10 FSAI report and public information leaflet (2008) **Policy, scientist-to-consumer**

11 Which? (2008) *Small wonder?: nanotechnology and cosmetics* **Consumer association-to-consumer**

12 McCarthy (2007) Nanotechnology matters. [Online]. BusinessWeek Special **Business-to-consumer** http://www.businessweek.com/adsections/2007/pdf/03262007_Nanotech.pdf

13 FramingNano Report (2010) **Industry/academic-to-consumer**

14 ETC Group (2003) The Big Down **CSO**

15 Greenpeace *Future technologies, today's choices* (Arnall, 2003) **CSO**

16 Royal Society /Royal Academy of Engineers (2005) Report **Academic, social sciences**

17 See-through science (Wilsdon and Willis, 2004) **Academic, social sciences**

18 Albrecht et al. (2006) Green chemistry and the health implications of nanoparticles in *Green Chemistry* 8: 417–32 **Academic, physical sciences**

19 CRANN, http://www.crann.tcd.ie/index **Scientific institute website**

20 Tyndall National Institute, http://www.tyndall.ie/ **Scientific institute website**

21 *The Investigators* 'Nano' Episode (2008) **Documentary**

22 RTÉ *6.1 News* (2008 and 2009) **Public Affairs Media**

23 Soft Machines: Thoughts on the future of nanotechnology from Richard Jones http://www.softmachines.org/wordpress/ **Web 2.0/fictive**

24 Howard Lovy's Nanobot http://nanobot.blogspot.com/ **Web 2.0/fictive**

25 Foresight Institute blog http://www.nanotechnews.com/ **Web 2.0/fictive**

26 Centre for Responsible Nanotechnology blog http://crnano.typepad.com/ **Web 2.0/fictive**

27 Nanowerk portal http://www.nanowerk.com/ **Web 2.0/fictive**

28 Singularity Hub http://singularityhub.com **Web 2.0/fictive**

29 blog¦nano http://www.nanotechnology.com/blogs/blognano/ **Web 2.0/fictive**

30 Accelerating Future http://www.acceleratingfuture.com/michael/blog/ **Web 2.0/fictive**

*The rationale for categorising the samples (in bold text) is explained in Chapter 4.

**The sampled websites were the highest ranking in Google searches

3.2.3 Content analysis of newspaper coverage

Part of the methodological approach involves considering the qualitative experience of what nanotechnology means for Irish people during the 2000s. The approach was used as a more in-depth analysis of public affairs media. The following newspapers were analysed using the online database LexisNexis for the period 1 January 2000 to 31 December 2009: *Irish Times* (IT) (n=234), *Irish Independent* (II) (n=21), *Sunday Independent* (SI) (n=3), *Irish Examiner* (IE) (n=13), *Evening Herald* (EH) (n=0), *Sunday Business Post* (SBP) (n=11), and *Sunday Tribune* (ST [n=16]). The search keywords 'nanotechnology', 'nano-technology', 'nanoscience', 'nano-science', 'nanoscale', nano-scale' and 'nano' were entered into LexisNexis for the seven Irish publications and the print versions validated for the period for the *Irish Times*. In total, 298 articles were retrieved and validated, in the narrow or broad area of nanotechnology. It is acknowledged that in certain articles about nanotechnology, the term may not be described and thus omitted.

A combined qualitative and quantitative analysis was carried out using a type of content analysis with protocol and codebook and drawing from Critical Discourse Analysis (Fairclough, 2003). It was analysed using SPSS, synthesised here for this final report. Articles were coded for date, genre, word count, style, source, author, actor (who is described, or what entities are contributing?). A simple positive/negative tone code was also used regarding the overall message. Preliminary themes that had potential to be 'frames' were coded where possible, as were the five-point scale of 'dialogicality' (both explained in Section 3.2.4) and whether or not nanotechnology was attributed to be a risk, of any kind. A simple foreground/background code was also developed. A 'background' article contained 'nano' keywords but nanotechnology is not the focus, whereas nanotechnology is the subject of 'foreground' articles. A limitation for this analysis is the absence of Irish tabloid news in online databases, and the limited time available to conduct a comprehensive library review of tabloids. However, nanotechnology coverage was followed up over five years of the *Irish Daily Star* (the most popular Irish publication with the highest circulation figures for a tabloid in Ireland, almost 10,300 from January–June 2009 [National Newspapers of Ireland, 2010]). Another limitation is the exclusion of online content from publications on LexisNexis – for example, syndicated articles from *Silicon Republic*, the online technology magazine, might appear on the *Irish Independent* online but not in the print version, and thus not on LexisNexis.

3.2.4 Discourse analysis of 'nanotalk'

The problem with many focus group and attitudinal methodologies is that the organisers have no theoretical framework of what they are looking for beyond 'what society is saying about nanotechnology'. While reception studies were traditionally used to assess how subjects experienced TV, now sociologically aware researchers look at how media is used in everyday practices, and in the public sphere – whether informally through YouTube, or blogging, or in more formal practices of 'grey literature' and new media for action and expression (Couldry, 2004). There is a transition from traditional audience studies to media practices, the study of an active audience increasingly caught up in networks of practice and content developer in their own right and from 'public opinion' to 'public discourses' research, as discussed in Section 2, although opinion research is still very much a rich area of analysis (Anderson et al., 2005; 2009; Bainbridge, 2002; Cobb, 2005; Cobb and Macoubrie, 2004; Hornig Priest, 2006; Scheufele and Lewenstein, 2005). Nisbet and Goidel (2007) have also studied qualitative and quantitative methods for science controversies. There must be caution in assuming that the majority of publics have the means to also be creators, however. There may exist a kind of 'passive interest' in nanotechnology, but more active interest in matters of environmental and health risk. Goffman (1959) and Wittgenstein (1959) have shown how cultural, everyday action, rules of engagement, language, games, affect how we interact and produce media. We cannot remove ourselves from these power plays. The ethnography of Hine (2002) and Marcus (2008)'s (1973) 'thick descriptions' show patterns of shared practices at multiple sites. For discourse analysts concerned with language and the disparity between expertise and non-expertise, Fairclough's (2003) CDA is a type of multimodal discourse analysis that looks at texts in shared communities of practices. This is a response to what Fairclough would wish for as a 'transdisciplinary' way of looking at social action through discourse. Fairclough's methods look at the discursive and power implications of theories of practice (ibid.) (see also Iedema and Wodak [1999] and Reisigl

and Wodak applying a form of CDA to climate change discourse [2009]) and already applied to the area of biotechnology (Doolin, 2007). A CDA approach would contribute significantly to understanding the complex fields of nanotechnology in everyday discourses and practices. The language of science, or business, or education, in Fairclough's perspective, forms the social structure of each field. Fairclough proposes a lower order than social structures, called social practices, which are combined here with Schatzki's idea of 'sites of the social' (Schatzki, 2002). Social practices are located in local orders of discourse, such as a scientific institute, a business or a school. What this report focuses on is the action at these discourse sites associated with, or which may facilitate, engagement with those considered non-experts, outsiders to the sites of practice, in this case the practices of nanotechnology expertise. There are specific genres of discourse – a feature article, an interview, a seminar, that present a particular range of styles – identities. These are examples of how social differentiation can be accommodated in practices of, for instance, report writing, teaching, journalism or consultation.

This was the theoretical position taken in this project, as described in the previous section, which takes consensus to the lowest point on the scale with regard to dialogue, a position that conveys a refusal of difference. Following Fairclough (2003), each sample media element was analysed – at a primary level – by organising text into a five-point dialogicality schema: (i) openness to difference; (ii) conflict emphasised; (iii) conflict resolution; (iv) conflict downplayed; and (v) consensus (see Box 2.3). The sample list is shown in Box 3.1.

3.2.5 The 'Interested Public': awareness survey

Anderson et al. (2005) reported on a perceived gap in understanding about nanotechnology in the UK: 29% of respondents ever hearing of the term, and 19% could provide a definition. However, when what a particular demographic of publics says about nanotechnology was investigated, it was found that the gap is not so wide.

As noted above, an online survey of a national panel of 1000 consumers aged 15 years+ was carried out, which would be targeted at 'interested communities' for S&T issues. This was part of a monthly omnibus consumer survey carried out by iReach. The main objectives were to determine basic awareness of the concept and areas of application associated with nanotechnology, finding out basic 'concerns', and allowing suggestions as to who has responsibility for maximising new technologies. Of the 1000 respondents (47% male, 53% female) in the national panel online survey, the 488 people who responded positively to awareness of nanotechnology were included in the rest of the analysis. Of the full cohort of 1000, a significant number considered themselves 'uninformed' about biotechnology (60%) and biomedical diagnostic devices (72%).

On one level, this number of 'aware' respondents from 1000, close to 50%, would appear to represent an increase in awareness from a similar survey carried out three years previously in Ireland, where 34% claimed awareness (Shovelin and Trench, 2007). This earlier study was a national representative study, however, while the current study targeted a cohort of 'interested publics' via an online survey (52% had third level education, for example). A significant number of respondents could describe approximations of what nanotechnology is, such as 'micro-sized' technologies, 'molecular level machines' or 'smaller than cells'.

The study was coded for demographic profile, age and education. 'Younger generation' (<34 years old) respondents accounted for 50%, 'mid-aged generation' (35–54 years old) 45%, and 'mature generation' (55+ years old), 5%. For those who stated they had heard of nanotechnology, 49% believed it to be technology on 'a micro scale' while 19% perceived it to be the study of the control of matter on an atomic and molecular scale. A further 8% believed it to be used in medical devices and 5% saw it as a form of engineering. The remaining 19% could not explain what it was. Almost 65% of males respondents and over 38% of females had heard of nanotechnology. In the 55–69 age group, 60% had heard of nanotechnology, while in the 25–34 age group 45% had, bearing in mind that this cohort of respondents were selected as 'tech-savvy'.

While only 20% of respondents indicated concern for nanotechnology, of those, a significant number were concerned about the safety aspects. 'Scientists' and 'government' were identified as the main agents for nanotechnology regulation. From the 20% that agreed they did have concerns regarding nanotechnology, the majority, 44%, were worried about its safety; 35% were

worried because of their knowledge of nanotechnology and a further 33% were concerned because of poor perceptions of regulatory agencies. This suggests people have a worry about what they perceive as their 'their lack of knowledge' almost as much as the technology itself.

Having obtained this 'awareness snapshot' of a particular demographic of publics, it is important to state that this level represents a small part of the overall picture of knowledge construction about nanotechnology. Survey responses are fleeting, subject to Wikipedia pilfering and, when not coded for it, can be quite random. Nevertheless, as with opinion polls, it is a baseline indicator that may identify trends and 'hotspots' in public knowledge construction. The next chapter deals in a more thorough way with how nanotechnology knowledge may be arranged in a more organised way around 'discourse sites'.

4 Discourse Sites of Nanotechnology

Much of the literature review explored concepts around how facts are constructed as ways of seeing the world, and organised around collectives of people, places, ideas and objects. Although they have different emphases, they might be termed 'framing' (Gamson, 1992; Gamson and Modigliani, 1989), 'narratives' (Davies et al., 2009) or 'thought collectives' (Fleck, 1979 [1935]). Ludwik Fleck's *Genesis and Development of a Scientific Fact* is considered one of the first STS works to describe how thought collectives create scientific facts. The social meaning of practices in emerging sciences is produced by an amount of 'talk'. It can be suggested that the term 'site' be used here in the context of Schatzki's (2002) work on site ontologies. It is an intersection of discourses where particular practices are identified that set parameters, a space where framing and thought collectives occur. A site is not just a spatial boundary: it can be a political site of activity, a school or an online chatroom. Hilgartner and Bosk (1988) developed a similar model for explaining how social problems are arranged around collective definitions, as have Munshi et al. (2007), who called them 'nodes of discourse'. What distinguishes sites are the rules and social practices that exist around a particular spatial or conceptual area in a complex of people, habits, things and social order (Schatzki, 2002). At sites, there are normative understandings of what is, and is not, important. The discourse sites identified here have positions of some power over processes and people, from modest to high. In this context, it is worth repeating that the discourse site is not analogous to a physical location per se, or even a space where practices occur that keep a field together. There is also some interaction between sites. The language must be the same, or similar; the actors are working towards some common purpose; thus, the INSPIRE consortium is a hub for the Nano-Innovation discourse site, where academic and policy practices align with private industry. Eight such sites will now be examined.

4.1 'Nano-Innovation' Discourse Site

Box 4.1. Characteristics of Nano-Innovation discourse site.

> *Nano-Innovation* – Business, industrial, technoscientific; highly strategic; local/ international; relationships between knowledge economy interests and nanotechnology facility developments in shared networks of practices, outreach, etc.

Nano-Innovation as defined here is a type of 'technoscience' (Haraway, 1991, 1997; Latour, 1987), which is a highly contextualised network of technologies, markets, people and practices that drive a notion of 'science' (rather than the reverse which is anticipated by the 'research and development' model). It is a commercialised space, developing technoscientific relationships between macro politics, knowledge economy interests, nanotechnology facility construction and higher education institutes (HEIs) in shared networks of practices. Although Giddens (1994) would suggest such discourse sites demonstrate a high level of institutional reflexivity, the public engagement remit of such practices in Ireland is limited to 'education and outreach', a one-way transmission of scientific knowledge, which has a tendency towards heavy marketing (see Davison et al., 2008 for an overview). Nano-Innovation is the space where industry and higher education institutes (HEIs) meet. The practices at this site feed into another, Science Education. It may seem somewhat controversial to combine the knowledges of higher education with business, but the practices surround the same shared outcomes – commercialisation. There is an all-pervading language, the buzzwords of business, exemplified by the relationships between CCAN, Centre for Research on Adaptive Nanostructures and Nanodevices (CRANN) and Intel with higher level institutions, for example.

'Innovation' is an ongoing theme in *The Irish Times*, as demonstrated in Section 6. Such discourses are to be distinguished from the actual practices of the laboratory, part of the esoteric discourses that can be embedded much deeper within these discourses. Lab talk alone could not be shared among non-expert communities, although many hope for a type of scientific citizenship where the inner workings of experimentation and data collection become publicly debated activities in the public sphere. Glimpses are only offered of lab practices through the appearance of Nano-Innovation equipment in the YSYS:N (2010) activity – as with much TV science (Section 6.2) – or in highly specialised regimes, such as the publications section of the INSPIRE website (Integrated Nanoscience Platform for Ireland [INSPIRE], 2010). It is important to emphasise that these communities of practice are codified, specialised places. There is no way of knowing how much research analysis the scanning electron microscope on public show in YSYS:N footage actually carries out. It is an object within a Nano-Innovation presentation to the public sphere.

Nano-risk assessment has also been re-branded for Nano-Innovation framing. For example, 'nanotoxicology' has been re-framed as 'nanosafety', moving from a negative connotation to a positive one. A nanotechnology special from the US publication *Business Week* contains an article with the subheading, 'Government, academic and corporate R&D open doors to better medicine, faster PCs and a cleaner environment' (McCarthy, 2007, e1). These are the standard positive framings of a business story. However, within the article, reference is made to potential toxicological risk. This can be contrasted to the media references on the CRANN website, with local press headings such as 'Investment in research and education is key to future', 'Keeping investment Irish', 'How small science will have a big impact on Ireland's economic future, The magic of nanotechnology', 'Investment key to technology innovation, claim experts' (CRANN, 2010). These articles appeared around Ireland's Nano Week, 31 November–4 December 2009. None of them contained any reference to risk, except those that were linked to the relatively low economic risk in investing in 'entrepreneurship', 'competitiveness', 'world-leading' expertise and 'research excellence', and adopting a 'brutal weed and feed' approach. Of course, business promotion will naturally accentuate the positives and take a combative stance; with Nano-Innovation, however, business and third-level research is tied to a strategic economy frame.

4.2 'Policy' Discourse Site

Box 4.2. Characteristics of Policy discourse site.

Policy – Local/international; organisation and policy-making around nanotechnology in national and international contexts; highly strategic, economy focus in Ireland; internationally a turn towards science and society interactions.

What distinguishes policy media output most from others is its language, which is society-oriented and conciliatory. Policy reports might seek 'an integrated approach involving closer co-operation between the health, environment and research areas' (European Commission, 2004b, p3). Often the modus operandi of policy output is to achieve consensus. One aspect of a consensus approach to the text is where scientific information that has been disputed elsewhere is presented as a 'given'. There is a tendency to bracket the science from the social. For example, a review of the tables of contents of the policy reports under analysis, of those that reference social issues, there are distinctions made between 'social', 'environmental risk', 'public health risk', 'public engagement' and 'regulatory' domains. These are the expected divisions in nanotechnology and society research and a similar organising structure is used in this STRIVE report. However, it must be strongly emphasised that these policy-constructed domains are heavily linked. The next level on Fairclough's (2003) schema, commonality, may not necessarily demand consensus but conflict is downplayed. The EC *Nanotechnology Action Plan* explains how 'public attitudes can play a crucial role in realising the *potential* of technological advances' (European Commission, 2005, p xi, emphasis added) that might 'foster a useful, beneficial, profitable and consensual *exploitation*' (ibid., p12, emphasis added). The status quo for technology assessment is enough for the RS/RAE report:

> We recommend that a series of life cycle assessments be undertaken for the applications and product groups arising from existing and expected developments in nanotechnologies.
>
> (RS/RAE, 2004, p32)

The RS/RAE report has been praised for its sophisticated approach to the complexities of nanotechnology. However, it is careful to allow traditional disciplines deal with issues as they arise, and in the process resist a more dialogic element:

> The issue of specific human enhancements is also likely to fall, initially at least, squarely within the medical domain, where there is an established history of considering emergent ethical issues and the societal acceptability of particular procedures.
>
> (ibid., p54)

There is much interaction between policy and higher education also: in fact, senior social scientists and STS experts throughout Europe are advisors to policy bodies. It is no surprise then to find research reports outlining EC policy often written or co-written by social scientists, which is either highly dialogic or else involved in the task of conflict resolution (see Davies et al., 2009 and Ferrari and Nordman, 2009 for an example for a dialogic 'twin-report'). A European Technology Platform Vision (2005) document asks that 'An approach to the safe, integrated and responsible introduction of nanotechnology into medical practice ... be included at a fundamental scientific level' (ibid. p33). While a European Science Foundation (2006) consensus conference, not surprisingly, sought consensus, it was necessary to have this only after 'an open and continuing dialogue' (ibid., p10). However, consensus is framed from the outset: the intention is:

> ... to ensure all interested parties, including the general public, are well informed as to the ongoing technology developments in the field of Nanomedicine. As much has been written in the popular press, quality information is required to assist policy makers and scientists to distinguish 'science fact' from 'science fiction'.
>
> (ibid., p10)

The ICSTI statement on nanotechnology (ICSTI, 2004) however has strong similarities with Irish Nano-Innovation presentations. Conflict resolution or negotiation are not given priority in this language. It is rhetorical only, a work of attempted persuasion. According to the report, it was published:

> ... following extensive consultation, and with particular reference to .. evolving economic development strategies ... it is clear that the greatest opportunity lies in increasing competitiveness.
>
> (ibid., p7)

In the Recommendations section, the report states:

> It is essential that ... recommendations [in this report] be implemented in full if Ireland is to derive the social and economic benefits presented by the nanotechnology opportunity.
>
> (ibid., 76)

4.3 'Public Affairs Media' Discourse Site

Box 4.3. Characteristics of Public Affairs Media discourse site.

Public Affairs Media – Local/international; determines the amount and extent of media coverage on nanotechnology; based on distinct media practices and genres, e.g. current affairs need controversy, business reports need commercial facts and performance indicators; critical, investigative, setting up protagonists and issues, deadlines and angles.

Scientists – and indeed other technical professionals – often complain about how media misrepresent their work. Hype and controversy are seen as the enemy of science. Yet what should be remembered is that news media and journalism operate in a different arena of action with distinct rules of engagement. If Prince Charles' nano goo was news gold in 2003, a story about a new integrated PC chip on the market is more specialist. The Public Affairs Media discourse site can be defined as encompassing all-media news and current affairs. What distinguishes the discursive practices of this site is its currency of conflict, tied into contemporary events. Economy stories will have particular salience in present-day Ireland. O'Mahony and Schaffer (2005) talk of the intertextual knowledge of

issue cultures' production that ties actors, public interest and media orientation. In the issue culture process, the life cycle of a newsworthy issue is dependent on a storyline 'incorporating new events into its interpretive frames' (Gamson and Modigliani, 1989, p4). There are competing actors and events in public arenas (Hilgartner and Bosk, 1988; Anderson et al., 2009). As a general rule, only a small number of issues will occupy news space at any one time. As a topic for public engagement, nanotechnology has rarely appeared in TV news items because, it must be assumed, of its lack of controversy (there were two promotional news reports, a Science Week special report on nanotechnology on RTÉ's *Six One News* of 11 November 2008 and on Nano Week on the same programme on 30 November 2009). For public interest, environmental nanotechnology may be expected to have modest interest; a cure for well-known disease through nanomedicine will have more news status. There are many issues that science news and popularisation throw up regarding the tensions between scientific knowledge and media reporting (Hilgartner, 1990). Many consider it either 'pollution' of real knowledge or, at best, 'simplification' (ibid.).

4.4 'Web 2.0 /Fictive Media' Discourse Site

Box 4.4. Characteristics of Web 2.0/Fictive Media discourse site.

Web 2.0/Fictive Media [including action research through author's activities] – Local/international/ wider cultural online ephemera, a trend within the culture of nanotechnology where science fiction and futuristic narratives are used prominently on new web forums; where there is, overall, an ambiguous relationship between nanoscience and culturally embedded concepts from science fiction realms; mixing esoteric with exoteric discourses; largely utopian but nano risks discussed openly.

The Web 2.0 discourse site may well be the most dialogic for nanotechnology public engagement. Internet forums and blogs in particular have been lively places for speculation and debate. Key thinkers about nanotechnology have their own blogs. Ray Kurzweil has KurzweilAI.net; Eric Drexler writes on Metamodern, but much of his writing is also carried in his Foresight Institute blog. Another Drexlerian, Robert A. Freitas, writes on the fiction-inspired Nanomedicine. One of the more content-filled and more prominent in searches, Howard Lovy's *Nanobot* has closed down, due to lack of funding, which seemed to be a common phenomenon in 2009.

Why combine blogs with the idea of the 'fictive'? Most of the sample websites are fully scientific in orientation, with no fictive elements. Yet the practices of forums, blogs, video blogs, and other social media facilitate an easy dialogue between the experts in engineering, for example, and futurist speculators who operate somewhere outside of the mainstream sciences. These forums have a thriving specialist interest – new science enthusiasts, nanoscientists, neuroscientists and sci-fi fans will interact on speculating the future. There are few formal linguistic practices for web forums – scientists use informal or semi-formal language:

> <Hello all. I described the nanofactory concept to someone and they responded with the following statements. I would like you all to examine this and pick apart their claims. Here is what they said to me:
>
> 'Thanks for your article. I haven't read too much on the subject, but one of the obstacles I see….' >
>
> (Posted by solidstatefusion, *Nanotech Skeptic: How Do You Answer This?* Saturday 12 December, 2009, 4.25 p.m. [Centre for Responsible Nanotechnology, 2010])
>
> <2009 saw a lot of mainstreaming of 'transhumanist' ideas, foci, and emphases. As I recently pointed out, *Foreign Policy* magazine gave this phenomenon a nod by including two transhumanists on their list of 100 global thinkers.>
>
> (Posted by Michael Anissimov, Wednesday, 9 December, 2009, 4.56 a.m. [Accelerating Future, 2010])

Strict codes of conduct must be adhered to when becoming part of web communities. There were early explorations by the researchers in this STRIVE study who facilitated *The Investigators* (2008) TV programme focus group on www.boards.ie. The intention was to send out 'feelers' to attract interest in nanotechnology discussions,

to discuss the project and recruit participants on various forums. This action was deemed unacceptable by the moderators and a ban imposed. It can be assumed, from the moderator comments that (i) these actions gave the impression of a marketing initiative, despite research credentials and (ii) they were seen by moderators as upsetting the community-building and collegial practices of internet forums. A code of ethics had been breached – as new members to the boards, it was necessary to spend time integrating to the communities first, in a dedicated board for new members discussing media. Public forum comments from the specially created activity for this STRIVE project, YSYS:N did not conform to the normal web forum practices described above, or on www.boards.ie (Boards.ie, 2010) (see Section 6.2). These may not be 'community' bloggers – they may be frequent web users responding to an 'offline' event.

4.5 'Science Education' Discourse Site

Box 4.5. Characteristics of Science Education discourse site.

> *Science Education* (local) [including action research through author's activities] – Pedagogy and teaching materials in second level education; applied formal science, practices detached from 'exoteric discourses'.

Science education is traditionally a didactic set of practices. The sciences are school subjects that are prime examples of top-down knowledge transfer that is central to how education systems have worked for centuries. There have been moves to include a more 'constructivist' approach to science education, that is, educators trained to be more in tune with student experiences, beliefs and cultures (Aikenhead, 1996; Driver et al., 2000). Nonetheless, constructivist principles can be powerless against the discipline and power of the traditional classroom (O'Louglin, 1992) and intensive and extensive examination, timetables and other such group practices. For science teachers, there is often a struggle for acceptance of narratives outside the classroom (Murphy, forthcoming): science fiction, science as culture, the nature of science, science controversies, topics of many new science education research programmes, and the exoteric discourses that have followed nanotechnology such as fantastical future applications (Erickson, 2005). The one exception may be, as the last section of this chapter shows, external connections made to the classroom from Nano-Innovation. The main Nano-Innovation concern in education territory is the potential lack of engineers in a future 'smart' Ireland.

The risks associated with new technologies is only lately been introduced to second-level curricula, through the inclusion of the science, technology and society strand through all levels (for the Leaving Certificate Physics example, see Department and Education and Science [1999]). However, nanotechnology is not a formal part of the curriculum (ibid.). That means it takes imaginative means for educators to introduce these concepts to students. Podcasting workshops, debates and nanoscientist presentations formed part of the activities external to the science curriculum that were contributed to the Science Education discourse site in this project.

4.6 'Social Sciences and Humanities' Discourse Site

Box 4.6. Characteristics of Social Sciences and Humanities discourse site.

> *Social Sciences and Humanities* – Theoretical, abstract, main constructions of nanotechnology along with formal science; international; low occurrence in Ireland.

This site is a different aspect of education, far removed from second level, and so naturally a separate prospect of nanotechnology engagement. In many ways, the social sciences and humanities (SSH) have been the most proactive site for engaging with the complexities of nanotechnology. It might be expected that a social science paper should be more dialogical in its essence; and the DEEPEN reports (Davies et al., 2009; Ferrari and Nordmann, 2009) and Wilsdon and Willis's (2004) *See through Science* in particular have a narrative quality, allowing different tones and voices, beyond objective, detached research and reporting. Nevertheless, the seminal research paper from the decade just gone – although embedded in the social sciences it also manages to be an authoritative source for and from the physical sciences – is the RS/ RAE report (2004). The output of the social sciences

approach to nanotechnology is often considered 'grey literature' outside the main discourse of nanotechnology.

Of course, the nature of science allows an invitation for dialogue between other scientists, such as in the phrase '... although the extent of effects on health are [*sic*] inconclusive ...' (Albrecht et al., 2006, p417).The SSH site however has a massive reservoir of knowledge to call on: political economy, history, the arts, literature. Nanotechnology is sometimes appreciated less for its science than its aesthetic power in these arenas. Everyday objects, the main focus of a new nano-realism, are not as important to the nanotechnology discourse site found within the social sciences as more abstract and 'noble' subjects such as governance, ethics, democratic ideals. This report is positioned within this site. We maintain however that nanotechnology within the social sciences has not yet developed enough to be a site of discourse in Ireland, at least not yet. While it can offer facilitation – and certainly draws attention to risks associated with power and ideology – it is better that 'nanotalk' does not get trapped within this academic discourse; rather, public engagement should instead be organised around public practices.

4.7 'Civil Society Organisation' Discourse Site

Box 4.7. Characteristics of Civil Society Organisations discourse site.

> *Civil Society Organisations (CSOs)* – Combative, framing as 'harmony with nature'; safety rather than risk, big statements; accentuation of difference; absent as a site of nanotechnology public engagement in Ireland.

Civil society organisations (CSOs) have not been prominent actors in nanotechnology discourses with the exceptions of Greenpeace (Arnall, 2003) and the ETC Group (2003), organisations that are actively involved in campaigns either against nanotechnology or interested in its socially and environmentally responsible development. Civil society organisations can be social movements that organise and position themselves as political entities around one or more issues. The successful ones thrive in the 'game' of media interaction (Bedford and Snow, 1988). The message is clear, meaning a single issue can be of most benefit. *Future Technology* by Greenpeace (Arnall, 2003) and *The Big Down* by the ETC Group (2003) are polemic in parts; in Fairclough's (2003) dialogic typology, these texts tend to 'emphasise conflict'. There is a battle to be won, although Greenpeace has been involved in initiatives that promote dialogue that is 'more than just a sophisticated means of engineering user-acceptance' (Arnall, 2003, p8). The ETC Group report even created a new term 'Atomtechnologies' to establish its identity in debate (ibid., p7), while also recalling the biblical parable of David and Goliath, which also works metaphorically for the ETC Group against Big Business. With confrontation and identity-building, however, come the potential for less dialogue, to create consensus when 'defending nature' and resisting 'big business'. European Framework 7 funding calls are increasingly asking that NGOs/CSOs be included in university or private industry applications, which will bring these organisations into a more central role (European Commission, 2009c).

4.8 'Local Community' Discourse Site

Box 4.8. Characteristics of Local Community discourse site.

> *Local community forums (local) [including action research through author's activities]* – Exploring the potential for a local community-based approach to nanotechnology decision-making, or at least, nanotechnology discussion, such as citizens' juries; educational or meetings of concerned locals, assumed to be separate from the discourses of nanotechnology.

This site is different in that there is not a distinct set of practices, or rather there are many. It could be, in some respects, considered everything else that is a discourse site but that is not included here. The main characteristic is a community bound by spatial locality and objects. This community is 'offline' in contradistinction to the Web 2.0 site. A distinction is also made here between CSOs, who often claim to represent 'the public' and local community sites of discourse, where actual real public action takes place. While a local discourse site may not be as organised politically as CSOs, they may well be organisations. In fact, a nano-facility could even be

considered a Local Community discourse site. A Local Community discourse site is perhaps furthest removed from nanotechnology discourses as defined here. And, paradoxically, a section of a nano lab and its personnel may have little or no connections with nanotechnology health, environment or social debates. Initiatives such as the UK Nanojury (2005) attempted to bridge this apparent gap between nanotechnology discourses and development and community action.

As public awareness and involvement in nanotechnology are very low in Ireland it might be expected that this would be a potential discourse site with no actual activity. However, when nano-strategists speak about 'educating the public' about nanotechnology, the contributors to this discourse site are the people they probably mean. While it is crucial that communities who have not traditionally been given a voice are given the opportunity to do so, this must be accomplished without being condescending or patronising. Participants to this discourse site can be any number of 'us', and all of us. Fairclough's (1995) idea of 'conversationalism', a move from formal discourse to increased 'everyday talk' in media, has contentious (perhaps dated) implications. In a new paradigm of 'upstream engagement' there is a tendency toward democratisation of discourses and social relations, new relationships with authority, new prestige for ordinary values. Yet these values of science may not be a concern of the 'local community'. These communities only become organised against a socioscientific issue when there is a threat to safety that needs resistance – a justification to become a 'community of concern'.

4.9 Conflicts and Commonalities across Nanotechnology Discourse Sites

In this section, the Fairclough/Bakhtin dialogical model is applied across the discourse sites, particularly looking at the sharing and mixing of ideas between them. To recap, Fairclough's typology, while not assumed to be a hierarchy, consists of (i) openness to difference, a dialogue of voices within the text; (ii) conflict emphasised, at the least acknowledging an 'other', if only in a derogatory way; (iii) conflict resolution, where balance is attempted between opposing voices; (iv) commonality, where difference is downplayed; and (v) consensus, where difference is ignored within the text (Fairclough, 2003). It will be demonstrated how this can allow uncertainties to be dealt with in a discursive way (see Box 3.1 for a list of sample documents and media elements and Box 4.1 for examples of dialogic or less than dialogic phrases).

It was noted above that the social sciences have a more dialogical way of framing nanotechnology. Nonetheless, there is, particularly for any text for public or mixed-expertise view, a trade-off between dialogicality and a unifying authority. There is evidence of how closely linked are the discourse sites of Policy and Nano-Innovation and how a stewardship role is claimed, not just for nanoscientists, but also for those 'principal stakeholders' engaged in the practices of nanotechnology. A report on a European Science Foundation (2006) consensus conference states that:

> The benefits and the threats of Nanomedicine need to be clearly articulated to the politicians and policy makers. Benefits include employment potential and the ability to meet the needs of the ageing population. Threats include losing out on important economic opportunities and not meeting the aims of the Lisbon agenda.
>
> (ibid., p23)

There is obvious framing in outlining the ultimate political cost in not adopting nanomedicine in a European country – for example, the risk of losing out on 'competitiveness'. On the other hand, acknowledging uncertainty can be seen as a dialogic activity, an openness to difference and amendment. Consumer reports were also included in the analysis, as they are caught within the Nano-Innovation discourse site. The Food Safety Authority of Ireland (FSAI) (2008) published both a report and a public information leaflet. These publications carefully position themselves within the realm of scientific evidence-based food safety but in comparison to many others in the policy arena, the FSAI reports were quite dialogic in their approach, for example: 'Understanding and control of matter and processes at the nanoscale [is] typically, but not exclusively, below 100 nanometres in one or more dimensions' (p8, emphasis added). This scientific report also states that there are significant knowledge gaps in nanoparticle effects on biota, but warns on available

evidence; there is 'concern regarding the safety of nanoparticles is the possibility for these small particles to evade the protective blood-brain barrier and enter the brain' (p34). There is a 'struggle for meaning' in the Fairclough/Bakhtin terminology, as the authors wrestle with both known and unknown unknowns, to borrow Donald Rumsfeld's infamous phrase that has become another cliché for describing nano uncertainties. It deals with much uncertainty. The FSAI report is littered with phrases such as 'There is limited information available' (p30), or 'There are many gaps in knowledge' (p45). The FSAI's report on nanotechnology is quite accessible, and there is a summary leaflet for public readership, both of which have been included in this analysis. The FSAI public information leaflet states:

> Nanotechnology involves the use of very small particles (nanoparticles) that have an average size, in at least one dimension, of one hundred nanometers (nm) or less. A nanometer is one hundred billionths of a metre. The chemical and physical characteristics of nanomaterials can vary considerably from those of their larger counterparts, *often turning an ordinary unreactive material into a highly reactive substance*.
>
> (FSAI, 2008a, p2) (emphasis added)

This unusual description (printed in large font) is almost unsettling, when taken out of context. However, it is the first sentence in the booklet. The FSAI report constantly draws attention to 'gaps in knowledge'. While this moves toward dialogicality in its acknowledgement of uncertainty, there is little doubt what is meant is that more certainty can be achieved through science, so this is not completely open to non-consensus. Nonetheless, while the FSAI are a body involved in policy-making and as such this publication fits into this discourse site, it is not a Policy conversation, nor is it a Nano-Innovation one. This is an example of scientist-to-consumer communication, via a semi-state agency; it removes itself from Nano-Innovation which is tied into the practices of business and strategy; it is a report by a working group of scientists, notionally detaching themselves and reporting what are perceived facts and unknowns about nanotoxicity.

Some EU policy documents are beginning to contain a certain level of dialogicality not seen before (RS/RAE, 2004). Research reports that have a strong policy element such as the final DEEPEN report are highly dialogic – it is essentially two reports in one (Davies et al., 2009; Ferrari and Nordmann, 2009). But what is perhaps surprising to find is outright animosity between policy reports. One European Parliament report not only contained dissenting voices on the regulation and oversight of nanotechnology products, but openly criticised an earlier European Commission report on the safety of nanoparticles. A strongly worded response by the European Parliament Committee on the Environment, Public Health and Food Safety (2009) (written in a quasi-legal list of what seems like individual contributions) contradicts an earlier European Commission statement's 'misleading' proposal for nano regulation (European Commission, 2008b):

> ... the Commission's analysis is based on a one-dimensional, legalistic overview of the current rules, but those rules are about as effective in addressing nanotechnology as trying to catch plankton with a cod fishing net.
>
> (op. cit., p7)

The European Parliament document takes issue with the European Commission document, particularly on arguments around the REACH approach of 'no data, no market', the precautionary principle and concentration on particle size rather than dimension. This was reported by the nanotechnology news website Nanowerk (2010), albeit with erroneous information, and copied almost directly by the Friends of the Earth website (http://nano.foe.org.au/node/329). In parts, this report is as polemical as expected from a CSO. This may indicate that consensus is breaking up on nanotechnology policy on a European level.

Box 4.9. Examples of text taken from sample media across discourse sites demonstrating varying degrees of dialogicality.

Consensus

- European Science Foundation (2006) consensus conference report. *Nanomedicine: an ESF /European Medical Research Councils (EMRC) Forward Look report*:

'The benefits and the threats of Nanomedicine need to be clearly articulated to the politicians and policy makers. Benefits include employment potential and the ability to meet the needs of the ageing population. Threats include losing out on important economic opportunities and not meeting the aims of the Lisbon agenda.' (p23)

Commonality/conflict downplayed

- EC *Nano Action Plan* (2006):

'Due to the enabling character of [nanotechnology] (p7) ...'

'Risk assessment ... should be responsibly …' (p10)

'Performing a range of activities so to accompany and foster a useful, beneficial, profitable and consensual exploitation' (p12)

Conflict resolution

- European Technology Platform *Vision* document (2005):

'An approach to the safe, integrated and responsible introduction of nanotechnology into medical practice should thus be included at a fundamental scientific level.' (p33)

- European Science Foundation consensus conference report (2006):

'Most importantly, an open and continuing dialogue is required to ensure all interested parties, including the general public, are well informed as to the ongoing technology developments in the field of Nanomedicine. As much has been written in the popular press, quality information is required to assist policy makers and scientists to distinguish "science fact" from "science fiction".'

Conflict emphasised (e.g. 'us' and 'them')

- Greenpeace – *Future technologies, today's choices*:

'… more subtly, the interests of those who own and control the new technologies largely determine how a new technology is used. Any technology placed in the hands of those who care little about the possible environmental, health, or social impacts is potentially disastrous.' (Foreword)

- European Technology Platform *Vision* document (2005):

'Nanotechnology offers great promise for medicine, but much of this lies in the future. This future orientation has made nanotechnologies vulnerable to the current zeitgeist of over claiming in science, either the potential benefit or harm.'

Openness to difference

- European Parliament Committee on the Environment, Public Health and Food Safety. Draft report on regulatory aspects of nanomaterials (2009):

''Nanotechnology is the art of engineering at a new level, where fantastic results can be achieved in energy, manufacturing, consumer products and other sectors ... But all these dreams may turn to ashes unless ...' (p7)

'… there is not even an established warning symbol!' (pp7–8)

RS/RAE is one of the more dialogic reports on nanotechnology. It acknowledges the great uncertainties of nanotechnology:

> If it is difficult to predict the future direction of nanoscience and nanotechnologies and the timescale over which particular developments will occur, it is even harder to predict what will trigger social and ethical concerns [*sic*]. In the short to medium term concerns are expected to focus on two basic questions: 'Who controls uses of nanotechnologies?' and 'Who benefits from uses of nanotechnologies?'. These questions are not unique to nanotechnologies but past experience with other technologies demonstrates that they will need to be addressed.
>
> (RS/RAE, 2004, p5)

Where nanoscience is presented throughout the report, however, it is done so with the assumption of consensus. But it balances important perspectives from social and the physical sciences. Another important report which straddles the Policy and Social Sciences discourse sites is the *See-through Science* report from Demos, the UK think tank on democracy (Wilsdon and Willis, 2004). It singles out the RS/RAE report as seminal:

> The Royal Society's *production* on 29 July surprised the critics. Its year-long inquiry into the health, environmental, ethical and social implications of nanotechnology had resulted in a report of unusual quality.
>
> (ibid. p14) (emphasis added)

The Demos report extends Hilgartner's 'on-stage' metaphor for expert advice – thus, the use of the work 'production'. There can scarcely be more dialogicality than describing a Royal Society report with words such as 'ensemble casts', 'staged' and 'avant garde'. At a European level, at least in report-writing practices, there is a blurring of boundaries between Social Sciences and Humanities and Policy discourse sites. More social scientists, philosophers etc. are writing what are effectively policy documents for EC research commentary in nanotechnology, but crucially with critical views on the technology.

In this extract, Greenpeace attempts to use a Nano-Innovation site argument, but the language used is from another place:

> If a single person – a computer-virus writer or a biochemist dealing with anthrax – can cause huge political and financial problems, how much more damage could those with more resources do?
>
> (Arnall, 2003, p7)

It is personal in tone; it lacks the authority required of it to be part of the Nano-Innovation discourse site.

Perhaps the best example of shared discourse is the genre-mixing between scientists and others on blogs and online forums. Richard Jones, a physicist, states in his blog *Soft Machines*:

> A water-tight definition of nanotechnology still remains elusive, at least if we try and look at the problem from a scientific or technical basis. Perhaps this means we are looking in the wrong place, and we should instead seek a definition that's essentially sociological.
>
> (Soft Machines, 2010)

Commentary on blogs from scientists, activists and non-specialists is an important new type of dialogicality. There are multiple viewpoints and formats, and posts from other forums are often spliced into debates.

Blogs are not always dialogue-based of course and indeed some span the full range of the dialogic continuum from the partly dialogic to the consensus-based. *Nanotech Now*, the blog managed by the Eric Drexler-founded Foresight Institute is a curious case (*Nanotech Now*, 2010). The Foresight Institute website itself is replete with futurist speculation about robotics, the singularity and transhumanism (Foresight Institute, 2010). This is the fictive/fact mix that blogs now present for nanotechnology. Yet there are many FAQ and 'expert' responses that are narrow in explaining 'the facts'. That said, an overall definition of nanotechnology does 'sit on the fence' a little:

> What is Nanotechnology? … At the most basic *technical* level, [it] is building, with intent and design, and molecule by molecule… incredibly advanced and extremely capable nano-scale and micro-scale machines and computers ... At the most basic social level, [nanotechnology] is going to be responsible for massive changes in the way we live, the way we interact with one another and our environment, and the things we are capable of doing.
>
> (Nanotech Now, 2010, emphasis in original)

Nano-Innovation becomes the dominant discourse site in terms of influence over others; Policy and Education being particularly influenced. With the notable exception of the *Debate Science Issues* series for senior level science, now an established annual inter-schools competition organised by Discover Science and

Engineering, dialogicality does not fit easily within this discourse site. Consensus is necessary to achieve the objective set by the Nano-Innovation site for the Science Education site to entice more students into science and engineering. There is low occurrence of nanotechnology in school curricula, however, and high incidence in 'education and outreach'. Many companies now attempt to bridge that gap between real-world technologies and the curriculum. Examples are Intel's involvement in the Science Gallery (2010) and the K'Nex challenge from the Discover Science and Engineering STEPS to Engineering programme (STEPS to Engineering, 2010). These create connections between the Nano-Innovation and Education discourse sites. But, inspirational though they may be in the shorter term, would lively guest speakers from innovation practices supply the necessary materials externally for the critical thinking and transferable skills needed by not only the modern student, but to equip a future workforce in an uncertain world?

It is suggested here to consider a continuum in two basic orders of magnitude relative to how publics engage, that is communities of interest and communities of concern. For a member of the interested community, engagement might be a requirement to acquire technical information, or satisfy curiosity or just listen and experience what is taking place, in what is generally a low scale public engagement event. For a member of the concerned community, direct action might be required, a need to influence, prevent, or help to promote within the production of scientific enterprise itself, or the production processes of knowledge, through various discourses.

Figure 4.1. shows discourse sites of nanotechnology in Ireland with the potential for public engagement in the short term. In other countries, and it is hoped in the medium term here in Ireland, sites such as 'Civil Society Organisations' and 'Social Sciences and Humanities' could be added; they are not yet embedded within the Irish context for nanotechnology although the latter can provide a facilitation role. To plan such public engagement, one must ask the broad question – is the organisational objective for such activities to cater for a 'community of interest' (more general, more passive, non-threatened) or a 'community of concern' (issue-driven, more active, threatened)? Note also lab-based nanosciences themselves are distinct, disparate and specialised practices that are not (yet?) sites for public discourses.

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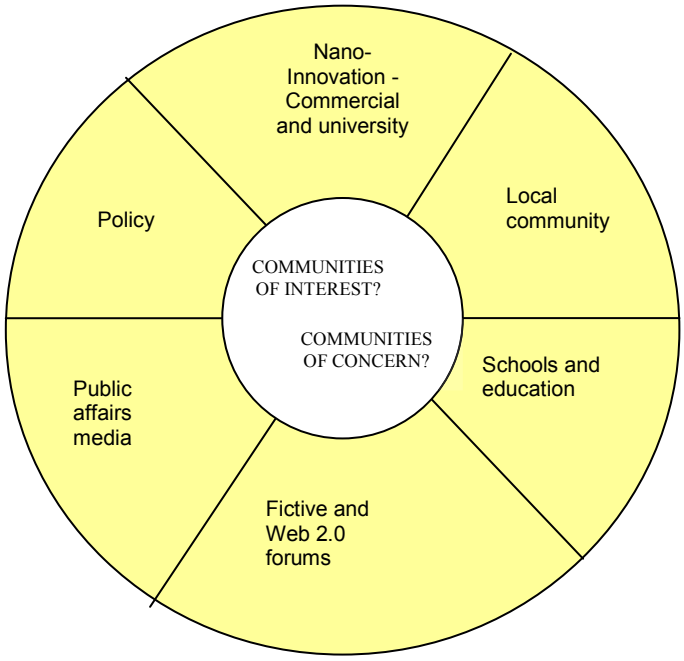

Fig. 4.1. Discourse sites of nanotechnology in Ireland with potential for public engagement.

Fairclough (2003) identifies changes in 'styles' and 'genres' across discourse sites, as well as 'genre mixing' and sharing of common styles and genres. An example of a shared genre is a news report which, while part of the Public Affairs Media discourse site in itself, can report on any of the other sites. An example of where genres and styles are mixed is the use of an 'And finally…' type of concluding news report to link young people's knowledge on nanotechnology (Science Education site) to a justification for the benefits to the national economy of investing in this technology (Nano-Innovation site), and in the process weakening this justification.

To demonstrate this, two RTÉ *Six One* news reports, separated by exactly a year, are striking in their similarity of content and form – a Science Week piece on convergence technologies on 11 November 2008 and a Nano Week 09 opening and schools outreach item on 30 November 2009. Both open with young people being asked by the reporter to explain nanotechnology. The students in both clips are shy, and give humorously offbeat answers. They represent the naïve public. Each clip next moves on to interviews with Nano-Innovation scientists, discussing the 'international race' and the benefits this will have for the economy. But this final message, an important business proposal to government, is lost in public view in the novelty of young people talking about science. There is no attempt in this promotion to link nanotechnology with real societal concerns. While many arenas in the world voice concerns about nanotechnology, as outlined here in earlier chapters, the 'item' that serves as a centrepiece in this news item for public engagement, in the main Irish nano event of the year – that real-world object that we nano-explainers crave – was the nano ice cream van (Nano Week, 2009). This tells us much about how discourses are used and the urgency (or lack of it) in Irish public discourses about nanotechnology. Discourses of risk should surely have been represented at this event.

5 Framing Irish Nanotechnology in the Media

This chapter takes a closer look at media coverage of nanotechnology, which has been low in Irish media. The main actors in this coverage are tracked, and references and utterances to contemporary events are linked.

5.1 Trends and Dominant Actors in Irish Nanotechnology Newspaper Coverage

This next sub-section reports on how 'nanotechnology' as a bounded reference is covered in seven Irish newspapers – *The Irish Times*, *Irish Independent*, *Sunday Independent, Irish Examiner, Evening Herald, Sunday Business Post* and *Sunday Tribune* in the LexisNexis database as described in Section 3.2.3. As Fig. 5.1 shows, there has been a steady increase in coverage in *The Irish Times* during the 2000s. *Evening Herald* had no references to nanotechnology during this period in LexisNexis. This was followed with selected sample periods for the *Irish Daily Star*.[2] The *foreground* articles which have nanotechnology as the main focus were distinguished from *background* articles in which nanotechnology may have been referenced briefly. A 'foreground' article would typically describe the expected definitions of nanotechnology. These demonstrate assumptions that the reader has limited prior knowledge of the subject.

As may be expected, the most pressing political issue of the late 2000s, the Irish economy, was reflected in coverage of Irish nanotechnology. However, the business and commercial aspect of nanotechnology and its impact on the Irish economy have been prominent throughout the decade. 'Actors' are considered here to mean all component parts of social interaction, human and non-human (Latour, 2005; Law, 1992). The actors most common in coverage were: devices for public use (frequency [f]=63 out of 215), scientific institutions, mainly university based (f=55), particles (f=43), scientist (f=40). Scientists were the sources most likely to be asked for a direct quote in articles, most likely research centre directors. Dominant discourse site representations are, by far, commercially orientated (f=97 out of 298 for business and economics genres, as compared with the next largest representation, f=59 for science reporting). Potential framing as coded here was f=124 out of 298 for 'strategic economy' with 'progress'

2 The *Irish Daily Star* was not available on Lexis-Nexis

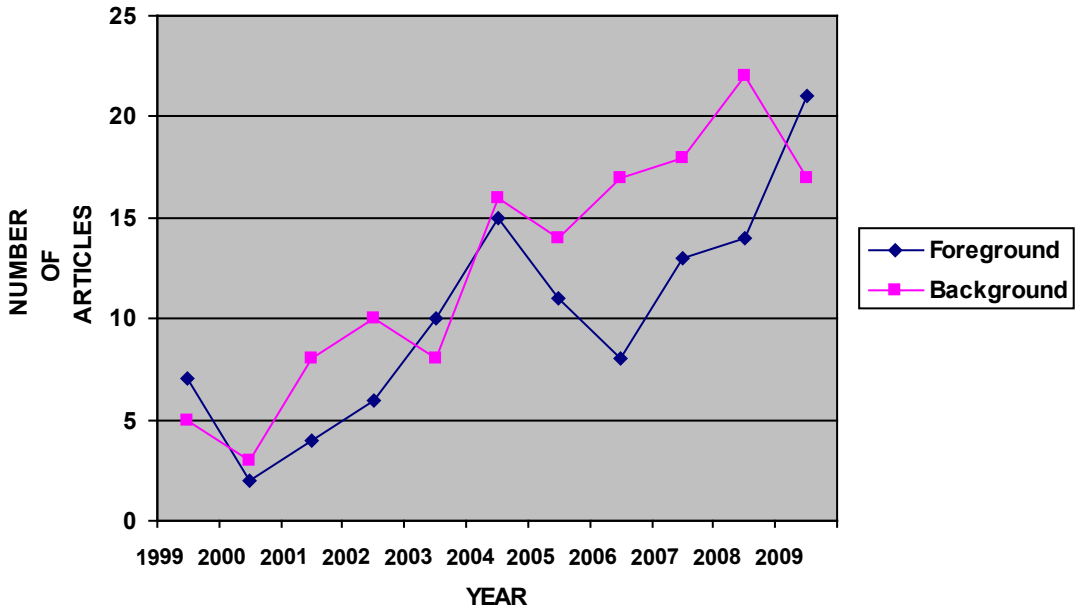

Fig. 5.1. Newspaper coverage of nanotechnology: *The Irish Times*, 1999–2009.

the next highest framing frequency (f=56). When coding for the themes 'health', 'environment', 'business', 'social' and 'other', the business theme (f=101 out of 215) is most dominant, with health next (f=49), although environment is at f=10, which is surprising considering technology sectors generally are increasingly being tied into a 'green economy' narrative.

Strategic economy framing is usually captured under the innovation theme, and indeed *The Irish Times* contains a monthly supplement called *Innovation* which covers nanotechnology extensively. There is a marked absence of risk talk, with some exceptions (risk covered, f=37, risk not covered, f=261). The only authoritative Irish report on risk for this period, the FSAI (2007) report on food and nanotechnology, was covered in one article in *The Irish Times* in September, 2008. The important RS/RAE report got one brief mention in 2004 (72 words), again in *The Irish Times* only, in the 'In Short' section under the heading 'Nano No-No' (Anon, 2004b).

In the earlier years of the decade, *Irish Times*' columnist William Reville presents a remarkably dystopian scenario:

> Machines capable of self-replication might mutate into a form where self-replication runs out of control, just as healthy self-replicating biological cells can mutate into a cancerous form, where cell division accelerates out of control. If such a mutation occurred in assemblers, the entire earth would soon become covered in a thick layer of 'grey goo'.
>
> (Reville, 2002a, p17)

This view quickly became removed from mainstream science. (In fact, Reville himself presented the benign nanorobot view only two weeks later, and the value of nanomedicine for the economy [Reville, 2002b, p17].) In the original article, Reville also used a secondary framing of nanobots invading (the headline is 'Machines on the march'). Two days before, in the same paper, Mark McGuigan had reported on how US military nanotechnology has influenced high-street fashion (McGuigan, 2002). By 2007, attempts were made by commentators and sources to 'dispel the myths' associated with nanotechnology, in other words to reverse the exoteric narratives of Drexler, Freitas and the rest. 'At times ... the public imagination runs wild, fuelled by stories of evil, self-assembling nano-robots that will take over the earth', a Dublin Institute of Technology physicist source is quoted as saying in *The Irish Times* in November 2007 (O'Connell, 2007a, p22): 'There is a lot of confusion about the science fiction, but nanobots will never exist, they are Hollywood' (ibid. p22). *The Irish Times* has a weekly science page unlike other Irish publications, 'Science Today' (the most prominent reporters on nanotechnology across publications were science journalists Dick Ahlstrom and Claire O'Connell from this section). However, this is not to say this publication always has more science coverage than other papers – for example, in 2007, a relatively major business story was Intel's new chip plant in China. Nanotechnology was central but there was greater scientific detail in the *Irish Independent* than in *The Irish Times*.

In 1999 *Irish Times*' coverage was relatively straightforward, reporting something very definitely new, reflected in the headlines of 'atom-sized machines' and 'growing computers in the future' (O'Reilly, 1999). The early 2000s' articles are characterised by explaining this new technology in half a line or more. Journalists may have been unfamiliar with the word at the time, often hyphenated as 'nano-technology' or 'nano-scale' (rarely used today). It was a specialist interest. A scientist source is quoted as saying '[Nanotechnology] may sound a bit above the ken of people outside the arcane world of academia but some of it is easily explained' (Hogan, 2000).

Figure 5.1 shows a decrease in foreground coverage between 2004 and 2007, while a steadier rise in background articles was observed for the same period. This would indicate that the term became relatively accepted in reporting, where explanation or focus was unnecessary. By late 2009, with commercial nanotechnology promoted once more, there was increased coverage of how Ireland had been left behind in the 'race' during the preceding 'quiet' period. 'Ireland may be sixth in position for the quality of its nanoscience research' is the common line referring to a commentary piece in *Nature Nanotechnology* from 2006 ('Who is winning the global nanorace?', Hullman, 2006b), in this case claimed by technology entrepreneur Chris Horn (2009). The 'hook' for these latter articles in November and December 2009 was Nano Week, a relatively high-

profile event with the main actors Intel, the Competence Centre for Nanotechnology, Tyndall National Institute, CRANN (TCD). Intel CEO Jim O'Hara and CCAN CEO Leonard Hobbs were also prominent voices during this time.

The Irish Times and *Independent* publications have been more inclined toward business or technological innovation stories associated with nanotechnology, while the *Sunday Tribune* reported curiosities (invisibility, self-cleaning suits etc. (Anon, 2004b; Bohan, 2007). In fact, the Tribune was the only publication in our sample to refer to grey goo in new reports (Lean, 2004). Surprisingly, neither *The Irish Times* nor the *Irish Daily Star* carried grey goo news stories (Reville's article being an opinion piece). For the period January 2005 to December 2009, coverage in the *Irish Daily Star* contained only eight articles with the word 'nanotechnology', all between 2007 and 2010. These were: 'New nano facility opened in Cork' (Anon, 2009, p55); 'Thousands of movies on DVD' (Anon, 2009, p19); 'Pope mourns for Holocaust victims' (Pope Benedict is presented in Israel with the Jewish bible on a 'silicon particle') (O'Brien, 2009, p6); '7m to boost research' (Anon, 2009, p63); 'Cataract cure bid' (Anon, 2009, p14); 'Magic in medicine' (Sweeney, 2008, p60); 'Boffins etch a tiny bible' (Anon, 2008, p13); 'New glue can turn on or off' (Anon, 2007, p16). The stories raged from strategic economy research to health care, to curiosity value.

There were ambiguous and largely unexplained buzzwords that characterise the Nano-Innovation site: 'disruptive' or 'lighthouse' technologies (Smyth, 2007, p13), 'joined-up thinking and joined-up action' (Ahlstrom, 2005, p13, quoting a senior Forfás executive at the time of NanoIreland), 'world-class' and 'research excellence' (O'Hara, 2009, p16). Sometimes nanodevices are personified (a 'clever little device' (Anon. 2006, p11); there are 'sexy tech areas like nanotechnology' (Lillington, 2004, p58) and glorified ('the magic of nanotechnology' [Lillington, 2009b, p36] or the 'next big thing' [Lillington, 2009a, p9]).

The Irish Times has a regular headline strategy for nanotechnology, with very similar wording, with frequent reference to size and economic purpose ('It may be small, but nanotechnology is the next big thing', [O'Connell, 2009b, p7]; 'Size the next big weapon' [Connell, 2009b, p4]; 'Tiny science leaps forward' [Ahlstrom, 2004, p12]; 'Big surprises in little things' [O'Connell, 2008, p21] 'Thinking small about big issues' [Nolan, 2007, p15]; 'Smallest things to make the big advances' [Burke 2005, p15]; 'How the very small is hitting the big time [Ahlstrom, 2009]; 'When smallest is the biggest and best [Anon, 2004a]; 'Truly tiny technology' [O'Connell, 2007b]; 'Tiniest things set to be big' [Ahlstrom, 2005].

The actors then predominantly have strategic economic interests, with scientific institutions and buildings such as the Naughton Centre and the Science Gallery in TCD adding a sense of space to the Nano-Innovation discourse site. Dialogicality in newspaper coverage for the ten years 2000–2009 is low, with the exception of occasional dystopian view, such as Hilary Fannin's review of a BBC *Horizon* episode, with the headline 'Looking at an ugly future' (Fannin, 2006).

5.2 Framing Nano, Removing Dialogue

The data from the previous sections details how nanotechnology is framed in Ireland. For the most part, nanotechnology is described in newspapers in terms of localised university institutions, particles, and devices – most scientific centres are developing nano devices or nano-enabled devices such as sensors and diagnostic kits – and also in terms of the opportunities for commercial exploitation in a competitive global market. By appealing to the *authoritative* practices of Nano-Innovation – the logic of the market, the language of business – or else the didactic practices of Science Education – calling on simple explanations about the nanoscale, the importance of future generations knowing engineering – Irish newspapers diminish the social importance of nanotechnology as a transformative force. Rather, it becomes trapped in these discourse sites as specialist knowledge. The fictive potential of nanotechnology, as has already been explained, captures diverse views in intriguing ways, suggesting alternative futures and thus increasing its dialogicality. Unfortunately, such descriptions are rare, and will perhaps become rarer as nano-strategists attempt to distance themselves from Drexlerian nano-assemblers. In addition, any approach to public explanation of such complex processes that fails to deal with the multitude of views on the topic does public engagement a disservice.

6 '*Nanotalk*' Public Engagement Activities

To fulfil Objective 2 of this project, a series of public engagement activities was developed to assess their effectiveness and suitability for nanotechnology engagement in Ireland, called *Nanotalk*. These activities were generally considered as 'interventions' around the Science Education, Local Community and Web 2.0/ Fictive Media discourse sites, as described in Section 4. Data was also collected from the recorded activities to contribute to Objective 1, mapping out knowledge systems of nanotechnology. The activities were largely based on current STS thinking on the nature of 'science' or 'sciences and technologies', and 'society'. Data was also taken from the pilot stages.

Recruitment proved difficult for the TV audience focus group, citizens' jury and YSYS:N. As reported in Section 4.4, there were difficulties in establishing a presence in forums – over-eager engagement may be seen as marketing. There is a settling-in period for any community, and early 'plugs' for an event, even a free event, draw suspicion and in one case a short ban from moderators. The citizens' jury, although not a true jury, was modest in scale when compared to the Nanojury (2005) and others. There is substantial financial investment required for the larger-sale activities such as YSYS:N and day-long events.

The rest of this chapter describes each model of communication in action with a brief evaluation in the last section. This chapter is to be considered a prototype for a technology assessment type consultation, contributing to the recommendations in Section 7.

6.1 Model 1: Supporting Second Level Science

Section 4.5 described how the Science Education discourse site, as constructed theoretically for this project, has been stuck in a confined set of discourses, with 'education and outreach' activities prominent in supporting the curriculum, with a particular objective of enthusing young people about science and encouraging them to choose it as a career. While thinking like a scientist is an important aspect of teaching science, we suggest here that we need to foster a wider critical thinking approach that argues within and around the structures, practices and concepts of science. This was the approach taken for the support activities developed for this current project.

Four different types of session with different groups of 13–16 year olds were run as part of the pilot, in different educational settings – (i) All female school, final years – nanoscience in media reporting; (ii) Centre for Talented Youth of Ireland (CTYI) at Dublin City University (DCU); (iii) DCU nanoscientists visit to co-ed school, transition years; and (iv) Debating Science Issues debate on nanotechnology. The first type of session was in an all-female secondary school, which contained a lesson plan that began with a short presentation by the researcher showcasing media representations of nanotechnology using the many visually stunning nanoscience clips, as well as 'mashups'[3] and other entertainment pieces available on YouTube. What was important from a public engagement approach at this point in the session was not to present 'benefits v. risk' simplistically, but to allow the artistry of YouTube contributors add to the complexity until the issue of risk was raised by the students. A pattern emerged over two such sessions – once particles or over-the-top representations of nanobots appeared, there were two common critical reactions, almost verbatim 'How can you get a nanobot out of your body once it goes in?' and 'But what is it? What does it look like?' This suggests a cultural framing here, a difficulty in conceptualising what nanotechnology actually is, and expectation that 'it' must be an 'object' and that must mean a foreign object entering the body.

In the second part of these sessions, a focusing exercise was assigned. The class was given the task, in groups of 3–4, of developing and presenting a short TV news report based on the information supplied through the online presentation and web-based reading material covering nanotechnological developments that might have environmental or health implications. The topics in this reading material were: (i) carbon nanotubules; (ii) general nanomedicine; (iii) a BBC online news story about a nerve centre 'brain' that might one day control swarms of nanobots; (iv) a CNN online news story about

3 Edited Youtube clips which may juxtapose audio and video segments that would not normally match.

invisibility cloaks; and (v) buckyballs[4]. Introductory material (of common, shared understandings) about nanotechnology from the Centre for Responsible Nanotechnology (2010) was also supplied. Besides the novelty factor of introducing such techniques to a science topic, there was also a theoretically guided mixing of genres across discourse sites with guidelines on how to develop their news story, which aided extra critical thinking skills.

The second session was developed in conjunction with the CTYI and a science education colleague at DCU. Here, four groups of students created podcast reports, with audio and images, on website resources from the school sessions. It was an interesting process to watch 13–15 year olds create the very types of ironic mashups on 'evil nanotechnology' that were retrieved from YouTube. In fact, although with very limited time, some artefacts were quite sophisticated in their visuals and storytelling, knowingly playing on hype and fears.

The third session was a visit by DCU nanotechnologist to a mixed Transition Year class. This researcher was a wearable technology specialist, who brought a set of props – a handheld multimeter, foam samples, a shoe and T-shirt containing wearable textile-based sensors, wireless communicators ('motes') for the students to examine. The lesson plan was: nanoscientist presentation, tangibles' demonstration, Q&A, students asked to imagine what type of technology they would like to invent for the future. This session was a typical 'education and outreach' session, but there were concerns raised about the technology. It was also interesting to note the 'What is nanotechnology?' question emerged near the end, even after the practical demonstrations.

The fourth was an external event which the facilitator had little control over. A formal debate took place about nanotechnology outside the classroom, as part of the Debating Science Issues national debate between secondary schools, in conjunction with Discover Science and Engineering in the Biomedical Diagnostic Institute, DCU and other national institutes. This provided a different educational context for young people, breaking away from Science Education practices described in Section 4.5. The debate threw up surprising findings on what is 'out there' beyond the 'interested publics'. Debate participants even suggested that 'nano' might be used subversively to attract funding, meaning this idea has crossed discourse sites and is 'out there'. A strong paternalistic military framing also emerged about nanotechnology, where one participant argued for the benefits of nanotechnology strictly in security terms. These are likely the result of the many web resources there are about US security and military use of the technologies.

What was also useful for educational support here is that 'learning objects' were developed during the course of these very interesting educational interactions, that could form part of assessment-podcasts, TV news reports, debates, and written reports about wearable technologies of the future.

6.2 Model 2: Science Centre Installation with Supporting Online Forum

Your Science Your Say: Nanotechnology (YSYS:N) (2010) was a public engagement forum that combined an installation with facilities for YouTube and web forum public response. In the installation part, computers on plinths constantly displayed the www.yourscienceyoursay.com website with looped videos in the Science Gallery, TCD, during July and August 2009. The videos showed four nanoscientists from different areas (biomimicry, pharmacogenetics, nanowires, porous membranes) and different institutions (CRANN, Tyndall Institute, UCD), who presented, in interview format, what they felt were the potential risks and benefits of their own research, and nanotechnology in general. Each participating research video was about three minutes long and broadcast on YouTube. A special 'voting booth' was installed for visitors to respond, on camera, to the researchers and discuss implications explaining which research presented the highest risk to society and which the most benefit. The research project on biomimicry was voted the 'most beneficial' technology.

Passers-by and Science Gallery attendees were encouraged to watch the videos in the booth installation, vote and record a short video message as feedback. These messages and the original scientists' videos were also broadcast on YouTube. There was also a facility for online respondents to leave a written comment and Twitter updates. While this activity is part of a public

4 Cylindrical carbon nano-structures.

opening-up to what real nano-scientists do, there is still genre-play as the discussions, via YouTube, are constructed as documentary interview genres.

For those visitors who contributed video responses, the range varied from the 'horseplay' of young people, to the uninitiated who wanted to know more, to academics who challenged assumptions about nanotechnology unregulated for the sake of progress. Posters to the text-only forum were more deliberative. 'It does appear to be an extremely time consuming and expensive way to create a porous membrane' said one poster. He continued, 'Each country would need to bring in legislation to ensure all monitoring is adhered to and there should be a central agency, maybe similar to WHO, facilitating each country'. Another poster had a democratic argument: 'Referenda to decide on their use, like you might with stem cells or using Nuclear power.' There was a comment about the lack of 'narrative' or as one poster put it, 'objective critical commentary' that might pull the technology representations together.

One academic on the video responses took particular issue with a scientist's video presentation where he expressed his wish to see nanotechnology 'exploited' in the developing world. This academic was also concerned about the 'decontextualisaiton' and 'de-materialisation' of nanotechnology discourses; how abstract, transformative processes can glibly be described as solving ecological and health crises without some material impact. Up until October 2009, the forum remained linked to the Science Gallery homepage as the thread 'Nanotechnology: what are the risks and benefits?' There were only two replies to this post however.

There was a modest amount of users of both types of online response – the Science Gallery installation in particular requiring 'mediators' to entice browsers to leave a message. Gallery staff and researcher observations showed there were many visitors, particularly young people viewing the scientists' videos, but who left no message. Nevertheless, this was a success in experiential terms by the Science Gallery's criteria, if not successful at the intended level of engagement. Up to 3000 people can visit per week during large shows like the INFECTIOUS exhibition, according to the Science Gallery's own research. This number would be lower between shows which was when YSYS:N was onsite. Because of this, the installation was not always maintained by mediators. For increased range of participation, and depth of issue engagement, such a model would need to be in support of a linked face-to-face activity. The Science Gallery operates by having large three- to four-week shows with a short break – the installation 'fell between shows' and so was promoted as a single event to one or two journalists. There are important considerations here regarding levels of engagement that science centres and museums need to consider.

6.3 Model 3: Cafés scientifiques

In Section 2.4, it was explained that the cafés scientifiques movement has increased in popularity across Europe over the last few decades, where a science speaker interacts with publics in an informal setting. The Irish version of this is the very successful Alchemist Café, which is generally held in a pub. The Alchemist Café is a group of Irish volunteer science communicators who, with modest private funding, arrange monthly science talks. In response to EPA evaluators' concerns about the numbers involved in face-to-face activities, an Alchemist Café with a nanotoxicologist was arranged at the same time as YSYS:N was running in the Science Gallery. The event was held in The Mercantile, Dame Street, a pub in the heart of Dublin city centre on 5 August, 2009. The speaker was Dr Iseult Lynch, Strategic Research Manager for the Centre for BioNano Interactions, UCD. The title of the talk was 'The nano-environment: nanotechnology applications and impact on the environment'. This would be considered another 'pre-existing' group event, in that there was certain familiarity – the Alchemist Café has a regular audience. Although a holiday month, this event was well attended, with over 30 participants who stayed for the full event despite the relative informality of the setting. A public talk would appear too didactic in nature as a forum for dialogue – Dr Lynch spoke only for 20 minutes allowing questions and answers and discussion to take up over an hour afterwards. Topics raised included: nanohype, science fiction v. reality, public perceptions of nano, dealing with risks, social implications. There was also, a discussion about – an indication of the depth of engagement involved – Dr Lynch's own motivations and work duties.

6.4 Model 4: Focus Group with Open Invitation Participants

The RTÉ TV series on Irish science called *The Investigators* (2008) screened a programme on Irish nanotechnology on 11 December, 2008. A focus group was organised to capture audience responses to this programme. This was a collaborative effort within the Celsius research group at DCU, with which this STRIVE project is associated. A European Framework 7-funded project, called Audio-Visual Science Audiences in Europe, looks at science programming output on TV and audience expectations of TV science in Ireland, as compared with other European countries, using similar theoretical foundations as this project on an 'active audience'. One of the episodes in this TV series covered nanotechnology, which afforded an opportunity for synergy between the two projects. Although a TV audience focus group does not strictly fit within the present project's theoretical framework of discourse sites, it was anticipated that the audience recruited into this forum would be drawn, or have representations, from different sites, for instance, young people (Science Education), commercial technologists (Nano-Innovation), media researchers (Public Affairs Media). If recruitment within these discourse sites was not possible (as proved to be the case), then this would still be a valuable data-collection method as well as a public engagement activity that went beyond the restrictions of our theoretical boundaries to other publics.

The activity design involved placing an advertisement in advance in the local newspaper, *The Northside People*, to watch the show on the night, and attend a focus group session the following Saturday morning on 13 December at DCU. The co-researcher also advertised, conversed and attempted to recruit through www.boards.ie online forums. While publics were informed in the ad and through the forums that the 25-minute programme would be shown again at the focus group if necessary, the intention was also to allow people to record the exact practices of watching the show in their own homes, for the benefit of the qualitative method of both projects. A basic focus group protocol fulfilling both project objectives was constructed for the Saturday morning session.

Attendance to the citizens' jury was significantly below expectations. One woman responded to the newspaper advertisement (funded by the TV audience study) while those who were enthusiastic on boards.ie did not attend (three other participants were recruited through contacts with personal friends or academic colleagues).

Significant knowledge of nanotechnology must not be assumed. The particular interest of the participants may not be science and technology – it may well be the social or governance issues associated with it. However, in this instance, nanotechnology was placed in the newspaper ad, so a certain interest at least in the concept was assumed.

Although a very small group, the mix of academic and non-academic complemented each other. It was striking how sophisticated all group constructions were on reading the text and subtext of the programme. This *Investigators* (2008) episode was highly promotional and this was instantly recognised. The over-the-top Nano-Innovation narration – 'There's a revolution underway ...'; 'Investigators are now armed with new systems to exploit fresh opportunities ...'; 'There's an international race on ...' was recognised as being part of 'playing the game'. There was, perhaps sadly, no expectation from any member of the focus group that an RTÉ programme featuring scientific institutes on a small island would present the work any differently.

6.5 Model 5: Focus Groups with Pre-existing Group Participants

The all-female focus group, however, raised many issues to do with science fiction becoming reality, the benefits of human/cognitive enhancement, privacy, ethics and regulation issues, as well as comparisons to other emerging technologies such as GM food and nuclear energy. This arguably, was the most successful activity in terms of range of topics, and some passion, in the exchanges. The fact that participants knew each other was a contributing factor. But there was sophistication in the responses: while sci-fi imagery was used, for both utopian and dystopian futures, discourses became grounded very quickly to speak about health and current environmental concerns. One participant in particular was wary of the military

themes that emanate from nanotalk, while others worry about regulation:

> Cathy: ... if you heard of that as a medical application, its fabulous, a camera so small it can image your whole body you don't have to go into a scanning device, but if you're looking at it as a military development it seems sinister. I think technology has advanced beyond our moral concepts of what's right and what's wrong. You know, it's outstripped it, its science fiction off the telly becoming real. If you watch old episodes of like Star Trek the original, I mean half it's ridiculously outdated now because we are doing those things in the real world, automatic doors, that go 'SSShhhhh'.

> Sandra: I've a question: What body governs [nanotechnology]?

> Jennifer: I'm not saying it's not possible, it just, you imagine, it's like science fiction.

In this discussion, the economy, and the particular Irish situation, is never far from Cathy's thoughts:

> Cathy: If you remember 20 years ago or even less than that, when computers were taking off, a lot of them, a lot of international companies based their production in Ireland, they might only be producing something like a tiny chip, but they were producing different kinds of ones for different kinds of applications and that you had several factories in Ireland dealing with that, a friend of my daughters did science in college and she ended up working for a good few years with one such company. Now, typical Ireland - since the technology became dated and the thing closed up they [inaudible] they shipped it off somewhere else. But why shouldn't this technology come in? It should be. [Still] there's a big lot of spinoffs that can come off this, for jobs like…

Some of these snippets are key insights to what many seen as 'technology assessment' in (late) modern Ireland. But global equity is in the mix also:

> Cathy: Poverty… like your socioeconomic situation [is]going to dictate what kind of harmful technologies are you going to have in your country. If you take the thing that came out about India recently, that manufacturing isn't what it should be in a lot of instances over there, checks and balances aren't adhered to, or even they don't have any. It certainly wouldn't be the same as a factory that would be placed here in Kilcar or Dublin or Limerick or wherever. You know …Is it people's economic reality [that] dictates that they will forever be in [..] second place?

6.6 Model 6: Citizens' or Community Jury

The 'citizens' jury' method was used as part of the Nanotalk pilot series exploring the current and future use of nanotechnology. Citizens' juries are a type of public participation and decision-making process used for community-based issues across Europe and the US, and recently used for nanotechnology public engagement (Nanojury, 2005). They are designed to allow controversial public issues be discussed among a small sample of people, a 'jury,' who listen to experts, or 'witnesses,' then make recommendations based on what they have heard. The participants have a chance to listen, cross-examine and deliberate as a group of jurors. The invited 'jurors' in this event were members of north Dublin community partnerships workers. The witnesses included Professor Patrick McNally, nanoelectronics professor, Dr Deiric O'Brion, a social policy expert and Dr Donal O'Mathuna a healthcare ethicist, all from DCU. research initiatives into nanotechnology perspectives and public engagement in Ireland. Attendance to the event however was low. There had been certain expectation of this, owing to the unpredictable nature at certain periods of the social worker's day-to-day work and the relative newness of the topic. This low attendance prompted us as organisers not to stage a planned second event,

without committed numbers and more publicity. The jury addressed the following question: 'Does small science pose big problems for public policy?' with sub-questions around what questions such a technology would raise, who should address them, and what would be the possible implications for society. The 'verdict' voiced concerns about 'nano knowledge' never reaching the disenfranchised, how there is an inequity of knowledge domains. Industries producing nano-chips, and academic research, would not be within reach of the communities they represent, they said. Regarding its 'transformative' nature, nanotechnology may bring profound changes, but society will adapt. Citizens will always raise the issue of trust, the jury said. But who is imparting this technological information? And what do current governance structures, those in power, know? The jury wondered would policy-makers acknowledge the local/global issues regarding the regulation, control and consumption of nanotechnologies? Finally, participants were generally of the opinion that a group of randomly selected non-experts from their communities would not be engaged by this activity. It was generally agreed that the cohort would have to be self-selecting.

6.7 Model 7: 'Informal' Community Group Interactions

Following EPA evaluator feedback, there were two more arranged meetings with groups of people in contexts where nanotechnology would rarely if ever be discussed, and where new concepts about nanotechnology would be incorporated into existing community discourse practices. These sessions were co-facilitated, with the usual group facilitator generally driving the process, and shared as part of pilot research on TV audiences. The two settings were:

- A sustainability awareness group in local Dublin community centre (five women, 30s–50s, one female facilitator, a male and female researcher);
- A back-to-work scheme in Dublin (furniture recycling workshop) (four men, 40s–50s one female facilitator, a male and female researcher).

These more 'informal' meetings with sustainability awareness groups in 'disadvantaged areas' were challenging with respect to how nanotechnology could be raised in forums designed for other purposes. The facilitating researchers had little control over the content of these group sessions, and this made an interesting challenge for introducing the topic 'fresh' to an audience. The topics became divided down stereotype gender lines, constructed by the normal dynamic of such meetings. The 'womens' group' focused on energy and how nanosized power cells might help everyday household compliances and practices, while the 'men's group' focused on the technical detail of nano-cell energy production, while also taking up ethics and privacy issues associated with searchable items through radio frequency identification and the 'Internet of Things'. 'Radiation could be … similiar to that emitted by your mobile phone,' said one male participant. 'The real danger is the particle nature. When compared to asbestos'. Several participants talked of their experiences with people being affected by asbestos in nearby dwellings.

6.8 Evaluation of Nanotechnology Public Engagement and Communication Models

It is now possible to make an evaluation based on the four criteria outlined earlier, from the OECD/ Doubleday/Gavelin et al. model: dialogue models for nanotechnology (and indeed all merging technologies) must be deliberative (interpreted here as emphasis on dialogue), inclusive (range of participation here), substantive (the socially robust depth of issue or topic engagement) and consequential (impact).

Table 6.1 summarises the various emphases this four-dimensional relationship has for each of the seven types of activity. Fig. 6.1 demonstrates graphically the relationship between deliberative potential (that is, the extent to which the conditions are set for engagement, such as length of discussion, time to reflect, expertise level, physical environment) of each form of public engagement activity in common use for nanotechnology, and the level of engagement by participants. As the activities chosen were STS-influenced model of science communication, they were all in the medium-to-high bracket for dialogue. In terms of impact, it might be expected that these to be modest, but in actuality there are no means of as yet being certain. Policy-makers were invited to the citizens' jury but could not attend the pilot version. Their inclusion would have raised impact significantly. Any educational setting would be expected to have a relatively high impact on its participants, even if it is in the short term. For depth of deliberation on

an issue, there is little doubt that formats that permit more time score higher, such as open invitation and pre-existing focus groups, and particularly a citizens' jury which can last for days (the Nanotalk event was one day long). The structure of the school day does not facilitate in-depth engagement, and it would be unlikely that it would occur even at the curricular level, unless assigned as a Transition Year project. Interactions with community-based groups too were fleeting, but were necessary 'toe-in-the-water' exercises. In the context of this STRIVE project, double classes only were available (80 minutes). For range of participation, there has been no distinction made between more people and a wider range of people. It should be noted also that the range of participation is quite variable – it depends on project objectives, effective publicity and organisation. For the citizens' jury pilot, the community interaction was narrow in this project but had the potential to be much broader.

What the project has devised is a matrix by which nanotechnology communication strategists can develop a consultation model. Where dialogue is the primary concern, investment is needed for Web 2.0 and face-to-face forums. Where range of participation is necessary, deliberation is better suited to forums where participants are comfortable and at ease with discussions, perhaps even in semi-informal situations. Investment of time and extra resources in lengthy events are needed where depth of the issue is the needed. Finally, looking for impact requires key decision-makers and shapers of opinion to be present at events. Nonetheless, this also entails investment in the future (to use the cliché), where the empowering of young people is central to dealing with what are quite future-oriented range of technologies The key ingredient though is 'working towards some fractured thing' – a practice-based task that elevates positives and negatives to common practices that do not expect consensus.

Because nanotechnology is not such a publicly controversial issue, for the 'new' communities that were engaged, this has been done only in a fleeting way. They may become, more or less, a community of interest, but would not become a community of concern unless there was a threat of direct harm, for example. This might tend to be bottom-up engagement. Social agency would then be with the community itself, a community organised around a purpose, and eventually perhaps, becoming a social movement.

Table 6.1. An application of the OECD/Doubleday nanotechnology public engagement criteria in this STRIVE study for evaluating *Nanotalk* activities in this project (Gavelin et al., 2007; OECD Directorate for Science, Technology and Industry Committee for Science and Technological Policy, 2008).

Public Engagement Model	Emphasis on dialogue	Range of participation	Depth of issue or topic engagement	Impact
(i) Schools support	Medium	Narrow-Medium	Low	Medium-High
(ii) Science centre/public installation and web forum support	High	Narrow-Medium	Medium	Medium
(iii) Cafés scientifiques	Medium	Medium	Medium-High	Medium
(iv) Open invitation focus group	High	Narrow-Medium	High	Low
(v) Pre-existing focus group	High	Narrow-Medium	High	Low
(vi) Community/citizens' jury	High	Narrow-Medium-Broad*	High	Medium
(vii) Informal community meetings	High	Narrow-Medium-Broad*	Low	Low-Medium

* The range of participation was narrow for this project, but has the potential to be much broader, depending on objectives, effective publicity, organisation etc.

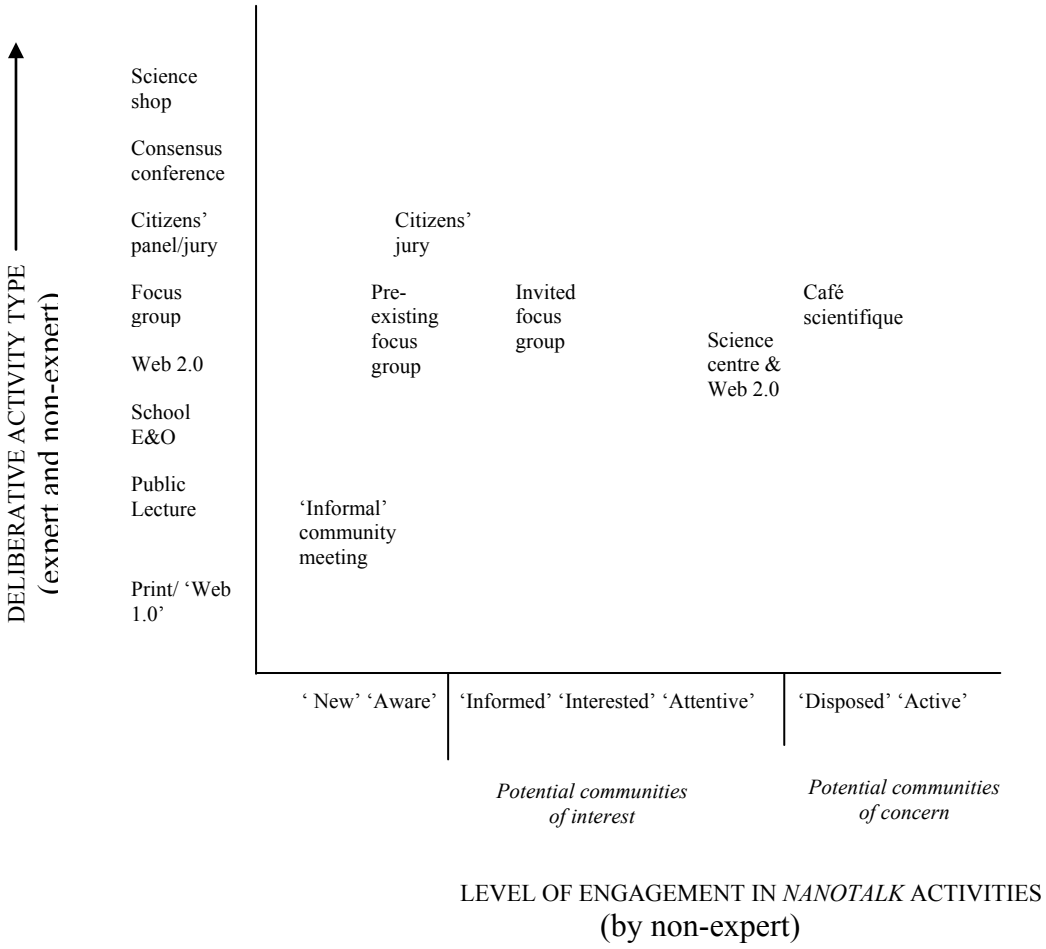

Fig. 6.1. Summary of types and levels of engagement from this project: graphic representation from Chapter 2 applied to *'Nanotalk'* activities.

7 Conclusions, Implications and Recommendations

7.1 Responses to Environmental and Health Implications of Nanotechnology Combined with Social Issues

7.1.1 Framing local knowledges as Nano-Innovation – at a cost to discourses on health, environment and society?

Throughout this project, ways of knowing and relating to nanotechnology in communities around arenas called 'discourse sites' were identified. There is a distinct power advantage for those social actors who have media presence. Business and innovation discourses are the most prominent in Ireland for nanotechnology. Although science journalists are the most common authors of articles, business actors are part of the Nano-Innovation discourse site, caught in language games. (The one state agency currently opining on nanotechnology not apparently as caught up in Nano-Innovation practices of risk-talk aversion is the FSAI, although it needs to further translate the science into non-expert public interest.) Despite globalisation, we tend to stay 'local' – though not necessarily geographically local – comfortable within our own thought communities. The result is that risk is greatly reduced, or even removed, from nanotechnology discourses. Nanotechnology concerns that are health related, environmental, 'ethical', 'social' or 'philosophical /existential', and are raised by scientists, public health bodies, sociologists, unions, ethicists and CSOs, have low visibility in Irish discourses. This confirms Anderson et al.'s (2009) findings: nano-industry promoters have simultaneously emphasised the novelty of the technology while explaining risk in terms of manageable traditional models, counter to the evidence of the many other discourses outside of innovation talk. Educational issues have been tied up with business and innovation, at second and third level. Although removed from business practices, the Science Education discourse site must now cater for the influx of education and outreach initiatives coming from the Nano-Innovation discourse site, which has its own strategic objectives.

New media and Web 2.0 show more promise for public engagement, although this strategy too requires investment in the rules of engagement for an organisation to blog and tweet authoritatively (in terms of Web 2.0 credibility) about nanotechnology. In this project, Fairclough's (2003) dialogical concept was used to evaluate existing texts (including media objects) while the Doubleday/Gavelin et al. (2007) model was used to evaluate new discourse emerging for the activities created especially for this project.

7.1.2 Concepts of risk

Environment and health (risk and benefits) were tied to social and ethical considerations very closely. Wynne (1992) and many other writers warn of being wary of placing scientific risk in isolation. Likewise, scientific progress, as this project's news media framing research shows, becomes one-sided and 'undialogic' without societal implications. On the evidence of this research project, those who contributed to public engagement activities such as the citizens' jury pilot and focus groups were, during the course of detailed discussion, at least as concerned about governance and equity issues as they were about the environmental and health implications of nanotechnology. This was also a pattern among face-to-face and online contributors, who questioned the idea of nanotechnology for global and local equity – who should own the technology, who benefits and at whose behest? This confirms many other nanotechnology public engagement initiatives and corresponding research (Gavelin et al., 2007). This is more than about scientific or economic risk assessment. Traditional methods such as LCA must include what has been referred to in other countries as ELSI. Future tracking of emerging technologies based on 'constructive' or 'real-time' technology assessment (see Schot and Rip [1997] for the former and Guston and Sarewitz [2002] for the latter) are increasing in prominence and include social and cultural risk factors as well as public perspectives in both their objectives and in the means in which the assessments are carried out.

This project took the initial action of beginning with nanotechnology as an introductory topic, expecting little awareness, although not necessarily assuming it in each case. The process allowed publics to actively construct the linkages to and within nanotechnology that may be unaccounted for by scientific communities (for example, the linkages between local economy, as

opposed to national economy, and nano-industry made by both the citizens' jury cohort [urban] and the rural-based pre-existing focus group).

Ravetz (2005) has suggested that these perspectives are part of post-normal science, which need to be considered as wider issues of 'harm' and 'safety'; these are, he suggest, traditional descriptions of public concerned and should replace the term 'risk' with its instrumental connotations.

7.1.3 Nanotechnology as object

During the pilot activities, the concept of nanotechnology as an 'entity' was important, for young participants in particular. Nanotalk tends to be abstract, and the thought of it being a non-object is unintuitive; it depends on objects for visualisation and understanding, something tangible to relate it to, some 'thing' from the real world of objects.

7.1.4 Dialogicality and genre-mixing

Genre-mixing – sharing types of practices between discourse sites such as an education and outreach show, a news report an interview – can be used for strengthening or weakening dialogicality. The interdiscursivity evident in the RTÉ news bulletin of November 2008 weakened the political case for nanotechnology by diluting the authority and public resonance of each discourse site – both Nano-Innovation and Science Education are reduced to 'what do students know about nanotechnology'. Where there is consensus, politics is not needed. The multiple-voice approach in the European Parliament nanoparticle report however strengthens its dialogicality, imparting flexibility and the ability to sustain itself in the rather complex and changing field of nanotechnology (European Parliament Committee on the Environment, Public Health and Food Safety, 2009). The intertextuality of Web 2.0 can be a useful pointer in this regard. Social science, business stakeholders as well as physical scientists interacting with policy-makers at the top level have created the opportunities for genre-mixing. While more social scientists contribute to high-level reports, there are actions that share resources across social sciences and policy arenas. Can we expect the fruits of these collaborations over the coming years with so much FP7 funding apparently demanding embeddedness of societal values, particularly in Ireland where there is a dearth of this view?

7.2 Outcome of the Nanotalk Activities and Public Response

Irish people talk and debate over many things – but a semi-abstract issue like nanotechnology is not one of them. Levels of attendance were below expectations for the open-invitation focus group and the citizens' jury pilot. Much of this was due to the author/organiser's difficulties in managing promotional efforts. Certain details could be changed for future work – for instance, more investment in media, more sustained community efforts, avoidance of terms in advertisements that have no real salience, such as the word nanotechnology itself. Low interest might also confirm Shovelin and Trench's earlier findings that Nano-Innovation discourses are growing while there is little public or media interest (Shovelin and Trench, 2007). This further reduces the opportunities for risk talk. Yet those small communities of interest, the visitors to the Science Gallery etc. will continue and may even grow over the coming years. For more engagement on the level we look for here, 'communities of concern' need to emerge – but this may only happen in the event of a crisis. In this sense, there is value in having a mid-point of more communities of interest. The events in this project did demonstrate the close connections between academic and new media nodes of discourse on such public engagement activities. What these events say about levels of public engagement then needs to be investigated further. The small numbers that arrived to some Nanotalk events set up for this project, the university-based ones in particular, suggest to us that more work is needed to engage publics, if we, the science and science communication communities, are serious about creating a culture of scientific engagement in Ireland. The more involved public engagement activities require media presence and momentum for success with added media exposure and public relations, requiring considerable investment, not to promote the technology but crucially, to promote dialogue.

This STRIVE project and process offers a menu of optional models to address the many objectives of nanoscience communication, from lower dialogue, such as exposition to schoolrooms or even explanatory text on the YSYS:N website, to public-led dialogue and public 'imagineering' of nanotechnology, such as focus groups and community discussions and the *YSYS:N* video forum. Each public engagement activity had its

own dialogic elements, that is, opportunities for multi-perspectives. The point of entry for public awareness/ public engagement is shared imaginaries – we start by 'imagining futures'. This sets the framework leading to products, tangibles, practices, objects, things.

The technical, didactic explanations of nanotechnology reduces risk in discourse. When nanotechnology must be explained, scientific detail is more likely used with information imparted as a given and with low levels of risk talk, thereby enforcing consensus. For official communication on nanotechnology as much as more 'informal' or exoteric texts, emphasising consensus on nanotechnology, which has been dominant up to now, reduces any real understanding of its conceptual, process-orientated and performative nature, an ongoing narrative, both scientifically and non-scientifically.

What impact these findings have on public acceptance or the development of nanotechnology has yet to be seen, but it is possible to speculate on impact levels by tracking where policy follows. And policy has yet to catch up on the rest of the world. The Irish Nano Week in December 2009 ommitted dialogue activities that might have explored the positive impact of nanotechnology with social responsibility, let alone the negative social dimensions or environmental or health risks. While this STRIVE report encourages strategic nanotechnology to accept public engagement, should it also be conceded that there is little public appetite to be engaged by an abstract concept like nanotechnology? Are nanotechnology interests responding to a lack of public need for engagement? These are live questions that must be asked. The implications for nanotechnology are many and they are real. Much work is needed to ensure that public engagement is taken seriously in Ireland, if it is an economic and technological priority. There is an onus on those in strategic positions – business leaders, nanoscientists, policy-makers, and science communication academics and practitioners – to avoid the pathway to a 'GM scenario'.

Further public engagement work is needed, as is research into what it is about Irish society that has an ambiguous relationship with STI since the 'turn to science' policy of the mid-1990s. Consensus should not be expected nor demanded; this has further implications for topical public knowledge of scientific theories. Should opinions critical to anthropogenic global warming be allowed into debates? Scientists involved in big ideas such as climate change and nanotechnology need to take controversy head on and be prepared to defend, using the discursive tools of dialogicality and framing, not close down debate.

7.3 Recommendations for an Integrated Public Engagement Strategy on Nano- and Emerging Technologies

This final section presents recommendations to both the EPA and STI policy-makers in Ireland.

Recommendation 1: In the same way envisaged for the proposed National Nanotechnology Forum, a Convergence Technologies Forum should be established. This would include nanotechnology with other future-oriented, and connecting, areas such as therapeutic stem cell technologies, bio-engineering, climate change and convergence technologies.

While the low numbers attending public engagement activities in this STRIVE project are partly due to weaknesses on the project team's part in generating interest, they also suggest a deeper lack of engagement with the cultures of science, as Eurobarometers describe (European Commission, 2006). On the other hand, a type of 'interested publics' fill out the Science Gallery at each show. The type of communication models evaluated and proposed in Section 6.8 for nanotechnology public engagement should be seen as a menu of options that can be 'mixed' and arranged for an integrated approach. Nanotechnology, as proposed, is too important to society not to implement serious engagement. It means making sure all stakeholders across discourse sites are involved and those publics not part of organisations also. A future strategy would be to include key decision-makers and policy-makers at focus groups and events, increasing the impact of local community forum involvement. This can be difficult to coordinate (particularly if there is uncertainty about the numbers that will participate) but it is a vital part of public engagement. A similar project by the Rathenau Institute in The Netherlands recommended not to avoid 'risk issue' (Hanssen et al., 2008). Where we disagree with that report's recommendations is in its recommendation on differentiating risk from other discussions. It cannot be pre-empted where risk talk

will occur. This means using futuristic dystopian/utopian narratives to trigger discussion if need be. There are new knowledges about emerging technology governance that have not yet been facilitated. If a 'green economy' is to mean anything, it must involve innovation that is open, creative, innovative in essence, but most of all transparent, responsible and sustainable. Ireland has moved on, and into a darker place, since the proposed NanoIreland Report so there is no expectation of this being published. However, there needs to be a continuation of the plan from the ICSTI statement of a form of national forum or national conversation about nano- and other emerging technologies (ICSTI, 2004). This could be presented as an 'Irish Sustainable and Health Technologies Forum' taking in wider discussions to gear policy towards sustainability, and ecological, social and economic issues.

Recommendation 2: Ensure that dialogue is emphasised for future nanotechnology development, that is, between multiple stakeholders across science and society, not privileged interest groups.

Dialogue and participation in technology development are vital if Irish society and the economy are to be sustainable in any real sense. In a proposed Convergence Technologies Forum, new methods of emerging science communication would be utilised, that cover, but are not confined by, economy and innovation. This STRIVE project has demonstrated at least seven such models for a consultation and engagement programme. But there must be acceptance even when the strategy is rejected. The key to success is working towards some fractured thing – an endpoint with practices organised around project-based exercises that, crucially, do not require, consensus.

There are many cultural approaches – for example, interactions between science and art. It has already been shown here that the Science Gallery is an innovative and exciting space for this to happen, and while installations do not demand civic feedback, there are TEDx-style debates about science, art and design. The problem is, however, that deliberations in the Science Gallery are in a Nano-Innovation space. These spaces can be out of reach to others not operating within these discourse sites. There needs to be access and equity to local communities, public engagement and knowledge production broadening out to those 'new communities' identified here, that have separate sites of practice.

Nano Week 2009 was a missed opportunity for real public engagement, the kind that responds to various publics, rather than transmitting bland promotion to one homogenous community. It has been a constant of public affairs media in Ireland to feature non-critically the education and outreach agenda. Risk, uncertainty, doubt, critique – these are missing from innovation discourses about science. Yet surely these, not explanation, not 'behavioural change', are the creative elements expected to spark innovation.

Dublin is the 2012 EuroScience Open Forum (ESOF) City of Science. One of the objectives, in keeping with current FP7 and ESF funding, is to 'foster dialogue on the role of science and technology in society and public policy'. It is important that the City of Science keeps to this remit. It represents a huge opportunity to engage Irish publics with the strategies of emerging sciences and technologies.

Recommendation 3: Use all communication forms available to talk about the complexities of emerging nanosciences across the many new arenas where nanotechnology is discussed, including 'traditional' media partners and new media such as Twitter, Facebook, YouTube, etc. Keep communication open, inclusive, transparent, allowing it to be both elliptical and critical.

The FSAI (2008) information leaflet, a public-orientated publication, is a good example for the Policy discourse site, with perhaps adequate social and cultural references to food. Good communication practice requires that the descriptions are narrowed when the message needs to be clear. With this strategy, Irish STI public engagement follows the linear 'education and outreach' model. There are better ways to operate around the discourse sites identified here. To this end, channelling funds towards dialogue-based communication activities is key, using face-to-face, lecture, focus group and cafés scientifiques formats, critical pedagogy for schools and of course Facebook, Twitter, YouTube, blogs and other Web 2.0 channels. Different voices need to be represented, sometimes within the one text.

Recommendation 4: Learn from the public engagement mistakes of other emerging technology debates, such as genetically modified organisms (GMOs). Over-selling and under-representing by public engagement strategists will damage the process of engagement.

Much has been made in science and technology studies and science communication literature about how lessons could be learned from emerging technology debates of the past. Stem cell research, cloning, genetic engineering, nuclear energy, thalidomide, incinerators – there are similarities to the way social response and debate occurs around these topics. The credo from nanotechnology policy-makers around the world is 'avoid another GM'. This most recent debate in the UK was widely perceived to be a failure on behalf of the UK government to engage effectively with the public (Gaskell, 2003). The issues have as much to do with trust and transparency as they do about environmental health concerns.

Recommendation 5: Link to global networks already involved in nanotechnology and emerging technology public engagement such as EU initiatives, the US National Nanotechnology Initiative, and OECD programmes.

There are currently several high-level initiatives looking at all areas of environmental, health, ethical, political and social issues, as well as the nature of nanotechnology governance, and indeed the related areas of convergence technologies – the National Nanotechnology Initiative, Human Genome project, the OECD, environmental agencies, occupational health agencies, consumer associations, as well as higher education institutions, to name but a few. This is one particular nanotechnology race where Ireland appears to be behind.

Recommendation 6: Include social sustainability as a criterion in future EPA and exchequer-funded research and state agency technology assessment, with particular attention to transparency, responsibility and public engagement.

Finally, it is worth emphasising that there has been a marked change in policy by the Irish government and the EU from a research investment focus to 'translation' or innovation focus. This means increasing the market potential of the research that has already occurred over the last decade. This has coincided with the perceived failure of politicians to agree on key sustainable goals around the world. For effective translation and to develop sustainability policies, scientists' communication strategies and public acceptance are key, and must meet at some points 'in the middle' if we are in any way serious about a 'smart, green economy'. This STRIVE project fits within these central spaces, where attempts are made to re-engage people with a type of life politics (Giddens, 1991) that matter to them, where public imaginings of sustainable futures meet strategic technology assessment. It is imperative that these 'science and society' activities continue.

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Acronyms and Annotations

CCAN	Competence Centre for Applied Nanotechnology
CDA	Critical Discourse Analysis
CRANN	Centre for Research on Adaptive Nanostructures and Nanodevices
CSOs	Civil society organisations
DCU	Dublin City University
EHS	Environmental Health and Safety
ELSI	Environmental, legal and social implications
FSAI	Food Safety Authority of Ireland
GM	Genetically modified
GMOs	Genetically modified organisms
ICSTI	The Irish Council for Science Technology and Innovation
INSPIRE	Integrated Nanoscience Platform for Ireland
NNI	National Nanotechnology Initiative
NOAEL	No observed adverse effect level
OECD	Organisation for Economic Co-operation and Development
PRTLI	Programme for Research in Third Level Institutions
RS/RAE	Royal Society and the Royal Academy of Engineering
TCD	Trinity College Dublin
S&T	Science and technology
SFI	Science Foundation Ireland
SSTI	Strategy for Science, Technology and Innovation
STI	Science and technology innovation
YSYS:N	Your Science Your Say: Nanotechnology

An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil agus Rialtais Áitiúil a dhéanann urraíocht uirthi.

ÁR bhFREAGRACHTAÍ

CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail.
- Scardadh dramhuisce

FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain.
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce.
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

NDP
National Development Plan 2007 - 2013

Science, Technology, Research and Innovation for the Environment (STRIVE) 2007-2013

The Science, Technology, Research and Innovation for the Environment (STRIVE) programme covers the period 2007 to 2013.

The programme comprises three key measures: Sustainable Development, Cleaner Production and Environmental Technologies, and A Healthy Environment; together with two supporting measures: EPA Environmental Research Centre (ERC) and Capacity & Capability Building. The seven principal thematic areas for the programme are Climate Change; Waste, Resource Management and Chemicals; Water Quality and the Aquatic Environment; Air Quality, Atmospheric Deposition and Noise; Impacts on Biodiversity; Soils and Land-use; and Socio-economic Considerations. In addition, other emerging issues will be addressed as the need arises.

The funding for the programme (approximately €100 million) comes from the Environmental Research Sub-Programme of the National Development Plan (NDP), the Inter-Departmental Committee for the Strategy for Science, Technology and Innovation (IDC-SSTI); and EPA core funding and co-funding by economic sectors.

The EPA has a statutory role to co-ordinate environmental research in Ireland and is organising and administering the STRIVE programme on behalf of the Department of the Environment, Heritage and Local Government.

epa
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An Ghníomhaireacht um Chaomhnú Comhshaoil

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