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Chapter 145: Nanotechnology, society and environment

Padraig Murphy,
School of Communications,
Dublin City University,
Glasnevin,
Dublin 9,
Ireland
Tel: +353 1 7007703
Email: padraig.murphy@dcu.ie

Debashish Munshi,
Department of Management Communication,
The University of Waikato,
Hamilton 3240,
New Zealand.
Tel: (+64-7) 8384450
Fax: (+64-7) 8384358
email: munshi@mngt.waikato.ac.nz

Akhlesh Lakhtakia
Department of Engineering Science and Mechanics
Pennsylvania State University, University Park, PA 16802-6812, USA
Tel: +1-814-863-4319
E-mail: akhlesh@psu.edu

Priya A. Kurian
Department of Political Science and Public Policy
The University of Waikato
Hamilton 3240
New Zealand
Tel: (+64-7) 838-4466 ext. 6109
Fax: (+64-7) 838-4203
Email: pkurian@waikato.ac.nz

Robert V. Bartlett
Gund Professor of Liberal Arts
Department of Political Science
University of Vermont
Burlington, Vermont, USA 05477-0114

rvbartle@uvm.edu

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Synopsis

Nanotechnology talk is moving out of its comfort zone of scientific discourse. As new products go to market and national and international organizations roll out public engagement programs on nanotechnology to discuss environmental and health issues, various sectors of the public are beginning to discuss what all the fuss is about. Non-Governmental Organizations have long since reacted; however, now the social sciences have begun to study the cultural phenomenon of nanotechnology, thus extending discourses and opening out nanotechnology to whole new social dimensions. We report here on these social dimensions and their new constructed imaginings, each of which is evident in the ways in which discourses around nanotechnology intersects with the economy, ecology, health, governance, and imagined futures. We conclude that there needs to be more than just an 'environmental, legal and social implications', or 'ELSI', sideshow within nanotechnology. The collective public imaginings of nanotechnology include tangles of science and science fiction, local enterprise and global transformation, all looking forward towards a sustainable future, while looking back on past debates about science and nature. Nanotechnology is already very much embedded in the social fabric of our life and times.

6.145.1 Introduction

The six volumes in this series have described powerful opportunities that nanotechnology presents for society, as represented by those of us who work within and around the physical sciences. But how is nanotechnology represented to and understood by the rest of society? What are the risks, benefits and other perspectives of nanotechnology that can be said to be shared knowledge among and between nano-specialists and non-specialists?

Much of the discussion on nanotechnology covered in this chapter is often placed under the banner of environmental health and safety (EHS) issues or environmental, legal and social implications (ELSI), separating them from the science of nanomaterials. We prefer, however, to fix our gaze on the shared visions of technological specialists and non-specialists alike when imagining a world with nanotechnology. As nanotechnology is seen as an important future development, scientific, technological, health and environmental issues associated with its application are expected to be closely linked to wider social, ethical and cultural concerns.

This chapter focuses then on what can broadly be called the 'public imaginary' of nanotechnology. In this context, the term 'public' needs to be defined better. We refer here to ‘publics’ rather than a singular public, reflecting the contemporary sociological view that science and technology is understood and used by various different public contexts, and that scientists of different hues are also part of these publics. We do not have the space here to present a detailed case about why understanding public perspectives on science is important. But the various perspectives of nanotechnology here will present enough evidence about the complexities of nanotechnology in nature and society. 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, we find the extremes from a utopian technoscientific nano-future to the nightmare ‘grey goo’ scenario and much in between. Imaginaries are therefore imaginings of nanotechnology, and within these imaginaries scientific and non-scientific descriptions are interwoven. Far from a perceived scientific reality, however, the ethical and philosophical import of a suite of technologies that draw on narratives of ultra-durability, unlimited information storage, or nanoscale technologies that can rearrange matter, develop devices that can enter the body, and self-replicate, is powerful. Proponents of nanotechnology see the future as

> a ‘new industrial revolution’ that will include breakthroughs in computer efficiency, pharmaceuticals, nerve and tissue repair, surface coatings, catalysts, sensors, materials, telecommunications, and pollution control (Machnaghten *et al*, 2005a, p272, citing European Commission, 2004; House of Commons Science and Technology Committee, 2004; Roco and Bainbridge, 2001)

Whether this happens or not, more skeptical social science commentators would at least say that nanotechnology represents a whole new way of looking at new technologies (Machnaghten *et al*, 2005a, 2005b), going beyond the concern merely for public acceptance of new technological development, and seeing it instead as a testing ground for combined knowledge-making by scientists of many disciplines as well as policy-makers and what used to be referred to as the ‘lay public’. Where once a new technology was seen as being exclusively developed, and thus mostly understood, by experts, and this knowledge then imparted to a non-knowledgeable ‘public’, now cultural reference points and public representations of nanotechnology are seen within the social sciences as vital to the totality of understanding. The way nanotechnology is talked about in new contexts creates new meanings for the word.

These ways of looking at nanotechnology then are necessarily cultural, and they are the foundation for how we have approached this chapter. But on top of this foundation, of course, are the very real benefits or threats that those who are currently researching, or are concerned about, the technologies refer to. The perceived potential impacts on society range from the management of nanoparticles in the environment to the philosophical and governance issues associated with the molecular manufacturing of nature.

Sandler (2009) has suggested that those of us who are looking at the sociology and public response of nanotechnology innovation might be better served to agree on the term ‘issues’ rather than ‘implications’, which are, he states, neither determined nor determinable at this present time. Part of our argument here is that issues themselves are not yet determined either until there is more public awareness and public engagement.

The experiences of the current authors are brought to bear on what nanotechnology means in difference contexts. This is an interdisciplinary chapter, written by experts in specific fields of nanosciences, political sciences, and communications. The chapter maps the state of knowledge in the many related and unrelated fields of research. In the fields of nanoscale research, these areas of research connect back to seminal citations in the scientific literature that include, but are not limited to, surfaces, thin films and multilayers, materials, nanowires and catalysts, quantum dots (QDs), carbon nanotubes (CNTs), titanium dioxide, optics and photonics, and electron and atomic force microscopes. Today we also have scientific literature that cover fullerenes, nanotoxicology, nanosensors, molecular genetics, self –assembled mono-layers, nanophotonics, and nanoelectronics, among other fields (Kostoff *et al*, 2006).

Because of nanotechnology's interdisciplinary nature, terms are often contested; the rationale for using 'nanotechnology' as a catch-all frame of reference here is because the term has condensed in the public imagination, at least for those who have heard of, or have an understanding of, the term. Outside of specialist fields, however, the term is largely still unknown, as the public awareness research we present here shows. There have been many problems in the consistency of definitions. Can there be a standard definition of nanoscience, nanoscale or nanotechnology across disciplines? There are variances based on technology or discipline. 'Bottom up' is a concept wherein molecular tools are assembled from molecular processes, for example 'growing' nanoparticles through atomic and molecular crystals, whereas 'top-down' is a materials science perspective wherein smaller and smaller scales are created from larger-scale tools such as milling or etching. There can also be regional variances. Munshi *et al* (2007) refer to the distinctions between US and UK definitions (1 and 100 nanometres (nm) for the former, between 0.2 and 100 nm for the latter). The 'A to Z' of nanotechnology (2009) from Australia, sourced from the National Nanotechnology Institute, claims US and UK definitions to be analogous, with the Japanese at variance with the 50 to 100nm range classified as 'ultrafines'. There is tension among some nanotechnologists in various industries over terms which denote nanoscience rather than nanotechnology, and vice versa (The European Parliament has settled for 'nanomaterials' (European Parliament Committee on the Environment, Public Health and Food Safety, 2009). Although many scientists wish to differentiate between terms, a recent OECD statement to public engagement specialists and outreach managers states that ''nanotechnology' has to be understood as covering both nanosciences and nanotechnologies'. From the outset then we use the term 'nanotechnology' to mean the plural 'nanotechnologies' and also 'nanosciences', 'nanomaterials' and 'nanoscale research'.

Sociological and science communication research focuses heavily on how various people from a multitude of backgrounds can approach unknown spaces like this hi-tech arena and construct meaning. Anyone working on any field of nanotechnology must acknowledge the unknown quality about it, the mystique. It may not even matter, of course, that there is a lack of 'nano' awareness, at least not in the diffuse and amorphous terms in which we define it here. At the rate of current development in the scientific literature, the prefix 'nano' may be obsolete within a generation anyway, such is the widespread use of the various strands of technologies across the disciplines. Nanotechnology becomes a 'thing', whether a thing constructed by specialists or by non-specialists, a thing that may be hard to define precisely, but nonetheless which has enough currency at the moment for everyone to, at the moment, talk about.

We also report here on some scientific agreement on the hazards and risks of nanoparticles, although here there is still widespread disagreement. Since 2000, the National Science Foundation has identified social and environmental implications of manufactured nanoparticles such as quantum dots (QDs), carbon nanotubules (CNTs) and titanium dioxide particles (Albrecht *et al*, 2006).

Outside of scientific disciplines, nanotechnology has become an exciting area of discussion in the social sciences within the last five years, particularly in science and technology studies (STS) and the sub-discipline of science communication. Nanotechnology is considered a new terrain in some respects—being such a newly emerging technology affords it the opportunity to be a 'blank canvas' for public communication, thereby avoiding some of the pitfalls, it is hoped by many, that characterized other types of new technologies regarding public acceptance and media controversy such as stem cell research and genetically modified organisms (GMOs). There has been a turn in risk literature to more qualitative methods of defining risk constructions (Wynne, 1992; Smith *et al*, 2006) and nanotechnology may be seen as an excellent test case for this development (Macnaghten *et al* 2005a).

While much has been written in both risk assessment and risk communication literature, there has also been increasing interest in nanotechnology as a social and cultural phenomenon from mass media analysts and writers of sociology and social theory. Interests here include: how nanotechnology is understood, visualized and talked about across networks that include mediated communication between scientists, scientific instruments and imagery; fictional dystopian/utopian scenarios; how science and technology is represented by social movements; technology and critical theory and poststructural analysis of texts.

There is a new understanding in this era often defined as 'late modernity' where the relationships and boundaries between humanity, technology and nature have been called into question, on a scale as never before in history. The multidisciplinary nature of nanotechnology, and the implications of this much-talked-about technology for the materials and environmental sciences as well as the IT and health sectors is now rapidly unfolding.

We begin this chapter by outlining our common theoretical context for how a transformative technology like nanotechnology might, to paraphrase Bruno Latour (1987), move into society. While we concentrate here on those texts that either describe or comment on nanotechnology, we place them in a wider context using concepts from social theory in late modernity and the 'risk society' of sociologists Ulrich Beck and Anthony Giddens. In this risk society that has emerged in the 20th century, risk and its management 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.

Then, in turn, we look at various areas where nanotechnology is perceived to have an impact on society in terms of sustainability and visions of progress. We specifically focus on:

- how the various fields are described in terms of their economic potential; how innovation and new products on the market may (or may not) transform society and how military and business interests have nanotechnology high on the agenda;
- the dichotomized narratives of nanotechnology's role in relation to ecology, perceived within many technoscientific systems, on the one hand, as a key to green energy – and even a tool employed for the cooling down of global warming – and on the other hand as an environmental threat particularly by nanoparticle exposure;
- the similar promise/threat dichotomy often presented for nanotechnology for healthcare, through future-oriented narratives of nanobots and nanoparticle delivery through the body, seen as either (or both) a form of human enhancement or as toxic;
- the implications for global equity, in terms of rights and equality for persons, systems and developing countries; where a predicted cheap technology first becomes excessively expensive, then (again potentially) becomes omnipresent and invades private spaces and the realm of 'identities';
- the implications for the governance of nanotechnology, how society itself deals with it, as it currently appears to have an elitist business-academic ownership, and how can it (or should it) truly be transformative if there is limited public engagement; and
- how all of the foregoing are being imagined as a myriad of futures through science fiction scenario-building, that although rejected by those scientists within their intrinsic works, cannot escape the sci-fi legacies of Drexler and Joy in creating nano-nightmares and nano-dreams by inventing, through fictional tropes, everything from nano-assemblers to elevators to space (Center for Responsible Nanotechnology, 2009).

New collaborative efforts have emerged to steer the course of nanotechnology with combined society, ethics, understandings of nature, and sustainability dimensions. Approaches have been used with terms such as 'upstream public engagement' 'midstream modulation' (Fisher *et al*, 2006), 'accountable' nano labs (Doubleday, 2007), see-through science (Wilsdon and Willis, 2005) or constructive or real-time technology assessments (Schot and Rip, 1997 and Gaston and Sarewitz, 2002, respectively). These terms all describe different social worlds, from lab to media, where distinct knowledge and power practices around what nanotechnology might mean come into play. We look at these terms later in the chapter, and indeed critique whether or not the development of disparate technologies can be seen as a linear 'stream' in any real sense. But first let us examine our social-theoretical context for nanotechnology, environment and society.

6.145.2 21st Century Relationships between Science, Technology, Society and the Environment

Although often ridiculed in other contexts, Donald Rumsfeld's famous quote about there being 'known unknowns and unknown unknowns' is used to describe how we might currently think about the risks associated with nanotechnology. The category to which unknowns attributable to nanotechnology exist perhaps, is that of the unknown unknowns, those which are unpredictable and which cannot be accounted for using current scientific models and risk assessment (Wilsdon and Willis, 2005; Farber *et al*. 2008).

Recent studies on awareness of, and attitudes to, nanotechnology in various locales across the world suggests that little is known among publics about nanotechnology, as discussed further in Section 6.145.7.3 (Bainbridge, 2002; Cobb and Macoubrie, 2004; Hornig Priest, 2005; Lewenstein, 2005; Macoubrie , 2005; Scheufele and Lewenstein, 2005). The more answers nanotechnology appears to provide, the more questions are generated. There are many uncertainties.

Uncertainty has an increasingly prominent role on the social and the personal spheres within society. Ulrich Beck describes how Western society deals with new and emerging technologies in this period of late modernity as the 'risk society'. In this society, the old institutions and rules of early modernity, such as those belonging to religion, party politics, economics and science, are being challenged, in seeming paradox with increased technological advance and education across the Western world. There is greater individualism in social affairs, but also paradoxically, global networks are increasing by information and communications systems are improving through nanotechnological innovation. World events and ideas form a greater part of individual decision-making. Beck has referred to the phenomenon of reflexive modernization, a confrontation of society with itself. The notion of self, as Giddens (1991) has also noted, has created a reflexivity among both individuals and social structures. People and institutions are more self-aware. We might also tie these concepts to the notions of the 'knowledge society'.

Not without controversy, risk has been termed a construction, or a set of constructions, that are contested in 'relations of risk-definition' (Adam and van Loon, 2000, p2). Klaus Eder's (1996b) important book on the framing of ecology and environmentalism also describes concepts of nature as a construction. What he means is that there is a binary notion society has of itself as separate from the world of scientific knowledge and the 'wilderness', culture versus nature. According to Eder, both are inseparably linked. Societies in modernity have differentiated the way we look at nature into three spheres - the social, the factual and the subjective. Many social science studies of late modernity have shown, however, that the boundaries between these spheres have become more blurred. A construction does not mean that there is an epistemological constraint of 'fabricated risk' being 'imagined.' Risks are manufactured but are ultimately real. However, risks are constructed in that they are defined by various interest groups and stakeholders in a spaghetti junction of discourses.

We have defined here a view of the concept of discourse. Following Foucault, we look at discourse as a set of rules that govern bodies of text and utterances or as in the Hajer definition used by Munshi *et al*, discourse may also be considered

> a specific ensemble of ideas, concepts, and categorizations that are produced, reproduced, and transformed in a particular set of practices and through which meaning is given to physical and social realities (Munshi *et al*, 2007, citing Hajer, 1995b, p146).

Fischer has also stated that

> [d]iscourses reflect the links between a particular ideology, how it is constructed, and how it can function to establish a group's political power (Munshi *et al*, 2007 citing Fischer 1995).

As scholars in the communication of risk, it is important that we look closely then at the phenomenon of uncertainty and how it can be engaged with and communicated between science and other communities, and between various publics, and its dimensions of power. For Beck and Giddens, institutions of modernity, such as strategic technoscientific facilities of nanotechnology actively create, engage with and manage concepts of risk.

To address this risk society, we must acknowledge the triangular relationship between risks, technologies and futures (Adam and Van Loon, 2000). For Beck (1992), those in a position to legitimate risk—the mass media, scientists, politicians, the legal system—have key social positions. Much has been written about the politicizing of the narrative of risk and nature through green social movements. In the reflexive modernization sociology of Beck, Giddens and others, technology, politics and the environment will become, or are becoming, part of a new politics. Running alongside these green initiatives are the narratives of technological progress, full of promise and technology utopias. Beck speaks of a sub-politicization, a politics 'no longer [about the] interests that dominate the political horizon but [about] claims about the legitimacy of particular forms of knowledge' (ibid., p4) As a new industrial revolution is now predicted, we must then consider what consequences this might have for human and environmental safety in new ways.

There is an emerging technological landscape, however, where there is increased economic and political competitiveness. There is a global battleground in future markets where the EU competes with the US and the rest of the world completes with Asia. We must then ask: where does the consumer fit into this theoretical frame? Consumers (current or future) are the publics; they are 'stakeholders', whether specialists or not. It is against this theoretical background that this discussion on nanotechnology, environment and society is further shaped, reflecting on the many discussions about impacts and implications. The complexity is increased by the variety of disciplines working within nanotechnology, and to a certain extent, commenting on the practices and processes that are often labeled in the nanotechnology domain. Munshi *et al* (2007) draw attention to the inconsistent definitions and scales not only between those based in the US and the UK but also between different groups of professionals such as technoscientists and chemists. Oberdorster *et al* (2007) and

Roco (2003) also refer to the fact that particles less than 100nm in linear size are considered nanoparticles by material scientists and toxicologists, while atmospheric scientists look for the nucleation mode of the atmospheric multimodal size distribution which less than 10nm. We cannot look for strict definitional agreement across the disciplines of nanotechnology but we can identify certain boundaries within which the catch-all term is applied.

There is a multitude of ways of describing and engaging with nanotechnology that extend beyond the physical, chemical and biological sciences. These discourses of nanotechnology are studied by a range of multidisciplinary methods of social science analysis. In previous work, the present authors have mapped out the intersections of these discourses between scientific, sociological, cultural and policy worlds. We believe that the entire bounded area of nanotechnology can now be divided into distinct areas of discourse. For Munshi *et al* (2007), there are nodes of discourse, where particular groups of people are central to demarcating boundaries of power associated with nanotechnology. These nodes are: (1) technoscientists, (2) business and industry leaders, (3) quasi-official bodies, (4) social science and humanities researchers, (5) fiction writers, (6) political activists, (7) journalists and popular science writers, and (8) publics excluded from all of the above. These distinctions are an important way for social science researchers in particular, but perhaps for all within these nodes, to look at the separation of powers within, and interactions between, these multiple enterprises, rather than expecting the existence of one type of discourse.

Murphy (2009) uses a ‘theory of practice’ approach that also demarcates discourse on nanotechnology, but focuses on practices, cultural habits and ways of doing things, that incorporate methods and materials as well as people. These are sites of discourse, a grounding of these discourses at particular points that can only be analyzed as distinct areas of practice, but which have relationships with other sites, and have particular resonances for public engagement. They are similar, and in many cases, analogous to Munshi *et al*’s (2007) categories: (1) business/ industrial and technoscience, (2) policy, (3) public affairs media, (4) science education (5) civil society organizations, (6) fictive and Web 2.0 forums, (7) the social sciences and the humanities and (8) local community. This reading of nanotechnology discourses draws from Ted Schatzki’s work on social sites and site ontology, where sites are a highly defined set of practices and orders, or arrangements of activities and things (Schatzki, 2002). The concept of ‘things’ are important in this analysis, as nanotechnology – in all its abstraction – depends on objects for visualization and understanding, something tangible to relate it to, some ‘thing’ from the real world of objects. Although nanotechnology may appear a strange concept to the novice, it is forced into discourses from what Nordmann (2005) calls the ‘nuomenal’ otherness that is alien to the world of objects. Thus, talk in sites is around harder materials and wearable technologies - even nanobots are acceptably alien devices. Sites also have specific ‘locations’ for grounding a discourse. The discourse and practices appear to be centralized, around a site of particular practices that are only meaningful at that site.

These sites also ground nanotechnology discourses outside the nanoscale communities. According to Murphy (2009), nanoscale lab practices, while containing distinct discourses, have not been grounded as sites of the social in terms of our public–inclined definition of nanotechnology, focusing rather on the multitude of specific technical processes unique to specialist fields (for many scientific and technological processes, the concept of nanotechnology has no real 'thingness' about it; also the 'nano' word may never even be explicitly mentioned. However, see Doubleday (2007) for his work on social organization within laboratories and implications for public engagement). Discourse sites are explanations of how nanotechnology operates within the social rules of multiple contexts, drawn from the philosophy of Heidegger on being and Wittgenstein on language-games (Reckwitz, 2002). These sites also require the use of media in the everyday.

It is interesting then, in this context, to see how public affairs media cover nanotechnology, or to track how nanotechnology becomes a 'thing' in mediated discourses.[1] Each of these methods of slicing off discourses for analysis is useful for researchers to see patterns, connections and difference when talking about nanotechnology in a new imagined future of the 21st century. There are other methods of analyzing media coverage and public engagement which strengthen this approach, as described later (see Hornig Priest, 2005, Lewenstein, 2005, and Scheufele and Lewenstein, 2005); however, the methodologies just described are integral to how the authors have looked at the different large-scale areas across discourses and registers. In the following sections, we look at the main themes that emerge across these nodes and sites of discourse regarding nanotechnology.

6.145.3 Economy

It is worthwhile to look now at the main source of what has reasonably been referred to as 'nanohype' centred on economy and innovation. In Section 6.145.7.3 we briefly discuss the 'frames' that emerge in nanotechnology discourses, ie the constructions that limit discourse. Arguably, there are no larger themes running through nanotechnology discourses than those of economic promise.

[cross refs to other chapters in the volume series?]

It was estimated before the global financial crisis of late 2008 that nanotechnology would be worth US $2.6 trillion to the US economy by 2014 (Lux Research, 2004), predicting the same global economy 'spiking' effects as caused historically by, electricity, automobiles and integrated circuitry before it (Hullman, 2006). There is speculation that nanotechnology will greatly surpass these revolutions because of the predicted transformative effect and multiple industries involved. As with the previous hi-tech waves, nanotechnology enjoys high levels of political support in many countries (Allen, 2005; Lane and Kalil, 2005) so much so that its spiking effect may be bigger. Nanotechnology has been considered a contributor 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 OECD predicts 2 million new jobs could be created (OECD, 2009) .

[1] Murphy (2009) uses discourse analysis such as that used by Fairclough (2003) and frame analysis (Scheufele, 1999; Gamson, 1992) to do this.

Economy and policy interests often frame the industry in terms of global nano-superpowers (such as US, EU, Russia, China, Korea and India) in competition with each other (Hullman, 2006). A report in the Asian Times 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 (ibid.)

Let us now examine some areas of nanotechnology that have economic implications, but also with ethical consequences: the tying up of Big Science with Big Business, unregulated product development, patenting, and military applications.

6.145.3.1 Technoscience and Business

Although nanotechnology products have begun to leak into the marketplace, as we see in the following section, the great predictions that were made early in the millennium have not come to pass. Product development is modest compared to the hugely central role that was once conceived for business at this stage, from vast improvements to existing products to creation of entirely new, almost unimaginable, product ranges (Munshi *et al*, 2007; Ulrich and Newberry, 2003).

While hi-tech companies and venture capitalists may still be attracted to the prestige of nanotechnology, there comes a time when demands are made for tangible objects. But talk about the contribution of nanotechnology to the economy still dominates. During a period of dramatic downturn in the world's economy, nanotechnology can bring optimism. EuroNanoForum 2009 in Prague focused on how nanotechnology would build a sustainable economy for the future by exploiting the growing need for sustainable development in European industry and society generally, such as the need for reduction in carbon emissions and the dependence on fossil fuels as well as the increase in energy demand, pollution control and clean water management (EuroNanoForum, 2009). According to a Woodrow Wilson Center report on green nanotech, nanotechnology combined with green chemistry represents the first stage of a 'proactive', rather than 'reactive', approach to solving environmental problems (Schmidt, 2007).

The business potential for nanotechnology has strong links with science policy and the rhetoric of technology used for society's gains, reinforcing the view of science being driven by technology and caught up in social and political realities. Emerging technology innovation is seen as a kick-starter for economies around the world and in many cases S&T funds are the sole survivors in budget cuts. Start-up companies with intellectual property in nanotechnology typically have one or two key patents (Munshi *et al* 2007).

According to Munshi *et al* (2007), it was Uldrich and Newberry (2003) who set the tone for nano-optimism with their book The Next Big Thing is Really Small where they envisaged nanotechnology to be at the core of manufacturing, both new products and old relationships between knowledge economy interests and nanotechnology facility developments in shared networks of practices. As an indicator of the cultural resonance of the economic story of nanotechnology, several media analysis studies have shown the excessive framing of nanotechnology in economic terms, particularly in the US media (Gorss and Lewenstein, 2005 ; Schütz and Wiedemann, 2008; Stephens, 2005; Gaskell *et al*, 2005) (see Section 5.145.7.3). In this highly strategic focus, there is a consensus on economic benefit, but scant coverage on any kind of risk, whether financial, environmental, health or otherwise. The rationale for investing in nanotechnology, and thus communication about the technologies, becomes top-down in its approach, although, in contrast, Macoubrie (2005) found that public opinion reflected the employment cost of this approach – a nanotech-rich future would cost jobs.

However, as the 2007 edition of Consumer Reports (Anon. 2007) shows, the business nodes of discourse are beginning to ask questions about nanotechnology risk. That same year, Business Week also had a significant advertising section about nanotechnology which acknowledged that there are risks (McCarthy, 2007).

6.145.3.2 Nanoproducts and Society

In Section 6.145.7.4 we look at the area of public engagement with nanotechnology and how new efforts are being made by nanoscale and higher education institutions in this regard. This public engagement includes, at its fullest application, public participation in decision-making processes about how and what nanoscale products are developed. But there is one fact that is contrarian: nanoproducts are already here.

So while we also draw attention later in this chapter to the abstractions of nanotechnology discourses, there is a tangibility here as more and more products incorporating nanoscale materials are released into the market (to the value of US $1.1 trillion in 2007 according to Lux Research (2008), which also estimated that there will be US $2.6 trillion dollars of nanotech-enabled manufactured products worldwide by 2014).

The National Nanotechnology Initiative (NNI) website lists several existing products which it claims are in the ‘pre-competitive’ stages including:

- Step assists on vans
- Bumpers on cars
- Paints and coatings to protect against corrosion, scratches and radiation
- Protective and glare-reducing coatings for eyeglasses and cars
- Metal-cutting tools
- Sunscreens and cosmetics
- Longer-lasting tennis balls
- Light-weight, stronger tennis racquets
- Stain-free clothing and mattresses
- Dental-bonding agent

- Burn and wound dressings
- Ink
- Automobile catalytic converters

Parenthetically, let us note that many of the products currently on the market containing nanoparticles do not contain the word ‘nano’ on their labels, for instance zinc oxide or titanium dioxide in sunscreens and fullerenes in anti-aging creams. With labeling not yet a prerequisite, there are claims that this leaves consumers in the dark.

Erickson (2008) however claims that it is incorrect to say that any artifacts have been created yet as products of nanotechnology; rather they are products of nanoscale research, which has a different set of practical elements and meanings depending on the discipline, from material sciences, to electrical or chemical engineering, to the computer sciences. But perhaps this is an over-simplified, essentialized distinction that denies the power of language and the evolution of popular science and scientific communication to the public. For the purposes of this chapter then, nanotechnology is nanoscale research, and is presented as a constructed term that has both scientific and (albeit limited) public currency.

6.145.3.3 Patenting Nanoproducts

Intellectual property will become more of a minefield in nanotechnoscientific fields with the passage of time. The idea for patenting has traditionally been to reward invention by controlling disclosure to stimulate innovation within a finite period of time. Previously, it had also created a particular relationship between governments and the ‘inventor’. However such an individual, and indeed such a relationship, rarely exists in today’s nano networks of expertise and innovation, because research typically attracts large investment, often from private ventures, and so the stakes are higher.

Patent law is strongly challenged by nanotechnology. It forces scientists to set boundaries to their work in a lattice of R&D fields that is hard to delineate. Bleeker *et al* (2004) also draws attention to the fact that the ‘nano’ term may boost an applicant’s patentability. A patent however must be adequately specialised. According to Bleeker (ibid.), a patentable development in the US must ‘meet certain standards of utility, novelty, and nonobviousness (p45)’. The issue of size, under this ruling, is ‘obvious’. Nanotechnology also presents a range of patenting problems owing to its interdisciplinarity. However, as with regulatory issues, how can there be patents where there is no knowledge of direct future use? Foundational nanotechnologies may come to have numerous applications.

Another public concern about nanotechnology patenting is the potential for the over-commercialization of nature. Patent law for emerging technologies has been in the docket before on this matter. For example, in the case of biotechnology, the United States Supreme Court decided in 1980 that ‘anything under the sun that is made by man' to be patentable, including genetically altered microorganisms (Diamond v Chakrabarty, 447 U.S. 303; Nelkin and Lindee, 2004). Since then rice genomes have been patented as well as their 'promoters', that is, genetic sequences that cause expression. Critics of this patenting system have raised concerns over the patenting of what would appear to be processes that occur in nature. Although there is subtle modification required in the organism or natural process under Diamond v Chakrabarty, 'discovery' is enough for genetic technologies under the European Patent Convention (EPC), Art 52(2), albeit a 'naturally-occurring' substance needs to be replicated by isolation and synthesis for general or specific use, thus a process of extraction is the novel part (Zech, 2009). Nanotechnology researchers also pride themselves on replicating natural processes in their work (as we mention later when discussing framing nanotechnology). Nanotechnologists often say that nanomachines occur in nature. It may be inappropriate, though, to utilize macroscale patents for nanoscale processes or phenomena selected from an earlier macroscale part of the process. What makes it patentable, potentially, are the 'new and surprising effects of the substance' (ibid. p151). Greener, more sustainable ways of implementing nano processes has become another patentable area. For example, a process developed in the University of Oregon could assist the synthesis of gold particles at room temperature (A to Z of Nanotechnology, 2005; Hutchison, 2005).

Within systems of nanotechnoscience there has emerged the possibility 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). The combined geographic, conceptual and commercial concept map thus visualized is one of many examples that show how the area has taken on a dynamic essence of it own. Among the many questions green nanotech patenting raises are fundamental ones about society's relationship to nature, how ownership has become more closely tied to the conservationist urges for stewardship. However, history has shown us that patenting systems adapt easily to emerging technologies (Bleeker *et al*, 2004). The rapid evolution of technological processes forces legislative and bureaucratic processes. Let us now explore how nanoproducts are being used in the burgeoning industrial-military complex.

6.145.3.4 Military Applications

The US Department of Defense has invested heavily into military uses of nanotechnology. The US Department of Defense is the largest investor in the NNI, with over 25% of the $1.6 billion total agency investment for 2010 (National Nanotechnology Initiative, 2009). Nanotechnological development in other countries is not synonymous with military application of course, but a superpower such as the US has to be wary of the conflation of nanotechnology and defense in other countries (Army Environmental Policy Institute, 2005a). Indeed, while the nanoscale may be part of the production process or conventional weaponry and outfits engineered for combat, there is also the possibility for the exploitation of the nanoscale for a new type of warfare (ibid., Army Environmental Policy Institute, 2005b).

It has become almost inevitable, however, to draw on sci-fi imagery of future war when discussing military applications of nanotechnology. Among the uses that have been put forward include combat suits and implants that give superhuman capabilities to combatants. A dystopian progression of this sci-fi theme of course is the possibility of full-scale global war that triggers the grey-goo scenario, a conceptual link to nuclear war.

There has long been a fascination in science fiction with military themes – e.g., *Flash Gordon*, *Buck Rodgers*, *Star Wars*, *Star Trek*. The militarization of space, it has been argued, came about through these links. Future war and weaponry have a strong cultural resonance with the publics who enjoy Hollywood blockbuster movies. As we also discuss in Section 6.145.8.1, the relationships between 'real' war and 'fiction' are complex but ultimately traceable.[2] While certain movies may have anti-war themes on the surface, often military personnel are drafted in as advisors, as was the case for the nanotech superhero *Iron Man* (2008).

The cultural theorist Colin Milburn noticed a very close relationship between the world of graphic novel sci-fi and real R&D. In his paper in *Intertexts*, 'Nanowarriors: Military Nanotechnology and Comic Books', Milburn (2005b) noted the striking similarities between an image that was doing the rounds from the MIT Institute for Soldier Nanotechnologies depicting a female 'soldier of the future' 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 (ibid.). The image became well publicized, appearing on websites, press releases and magazines.[3]

Section Section 6.145.8.1 provides detail on the Hollywood representations of nanotechnology. There is, however, one movie worth mentioning here: GI Joe: Rise of the Cobra, in production in early 2009 and widely anticipated by bloggers (slashfilm.com, 2008; generalsjoes.com, 2009; firstshowing.net, 2009). An article called 'Five Reasons Why GI Joe Could Actually Be Cool' has been circulated widely over a year before release among discussion forums (slashfilm.com, 2008). The five reasons involve a range of smart features on future soldier uniforms such as accelerator suits, nano bombs and 'nanite' masks. There are power implications in how the military prestige becomes translated to the screen. What Milburn describes is the blurring of fictional narratives and technological advance.

Both of these examples, GI Joe and Radix, show the shared military – industrial imaginaries of nanotechnology for a future hero. The current trend in Hollywood

[2] For a poststructuralist view of how technology, fiction and war have become intertwined, see Jean Baudrillard's (1995) *The Gulf War Did Not Take Place*.

[3] An interesting epilogue is that MIT had to remove the image following a lawsuit threatened by the creators of the *Radix* character. Milburn (2005b) demonstrates the complex discourse that took place between lawyers about what constitutes fact and what constitutes fiction in nanotechnology as well as how MIT's use might negate the fantasy of a comic book.

for futurized comic book heroes aligns itself well with the mythic qualities of a nation-state superhero from our ‘real’ projected futures. [4]

Whatever the cultural intricacies of ‘fact’ and ‘fiction’, as explored in the penultimate section, it is the recurring public concerns over transparency and trust that keep emerging in these discourses. There are compelling cases being made to consider, perhaps more carefully than other technologies, corporate responsibility for nanotechnology.

6.145.4 Ecology

The relationships between nanotechnology and ecology are complex, but there are two main opposing views, two loci of discourse:

a) Nanotechnology will help the environment, and in more optimistic readings, it has even been expected to reverse climate change.

b) Nanotechnology is harmful to the environment because of its unpredictability, specifically the relatively manageable threat of nanoparticles but also on a more fundamental scale, the threat to all life through perceived ‘nano-goo’ theories etc.

These two views are over-simplifications, but they are representative of the polarized utopian/dystopian worldviews. Let us first consider the implications of nanotechnology for the environment.

6.145.4.1 Nanotechnology and the Environment

Many chapters in this volume series have either outlined or shown in some detail the environmental potential for nanotechnology, regarding monitoring and treatment. **[cross refs to other chapters in the volume series?]**. 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, fertilizer sprays, watering, and harvesting (Joseph and Morrison, 2006);
- photovoltaics and other compact energy sources for expected cheaper more efficient fuel production;

[4] British political scientist Sean Howard (2002) has proposed an “Inner Space Treaty” in 2002 to limit military uses of nanotechnology, similar to the 1967 Outer Space Treaty.

- more controversial geo-engineering projects where, through nanotechnological processes, large scale ‘terra-forming’ of the planet reduces sunlight and /or carbon emission to combat global warming;
- cerium oxide nanomaterials which can combat diesel emissions, while iron materials have been used to remove contaminants from soils and groundwater (Environmental Protection Agency (U.S.), 2007).

These applications all reinforce the ‘green growth’ narrative. In contrast, the number of studies on the potential negative environmental impact of nanomaterials remains quite low (Anderson *et al*, 2009), although it has increased in the last five years. In fact much of today’s nanotechnology R&D requires environmental impact analysis, which began to come about in the mid-2000s when public concerns became more prominent about the safety of nanotechnology.

There is general scientific consensus that one unique feature of working on the nanoscale, where atoms and atomic clusters are put together, is that the physical properties of objects behave differently than on the microscale or larger. However, the degree of uncertainties about health and environmental impact has caused some concern. Not only do these uncertainties apply to public expectation, but they also apply 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, particularly where there is potentially high surface area per unit mass and surface reactivity, have potential environmental and health implications.

If the types of technology under discussion here are as prevalent as mooted, then there can be certain assurances that the future will see a large amount of nanoparticles of one type or another released in the environment, through waste seepage, leachates, waste water and air. Environmental treatment currently using nanomaterials, such as groundwater remediation, demonstrate that such nanoparticles do not safely agglomerate (Oberdorster *et al*, 2007; Tratnyek and Johnson, 2006). It is necessary then to track and record the transport and likely fate of such particles, which organisms are most at risk and the patterns of biotic accumulation. The behavior and fate of colloids, which are stable suspensions of organic and inorganic particles of 1 and 1000 nm diameter, appear commonly in the literature because of their role as effective transport vehicles for contaminant treatment in subsurface environments (Oberdorster *et al*, 2007, citing McCarthy and Zachara, 1989). The full complexity of soil and water science regarding colloids is only now being registered, much of it centering around particle and soil mobility (Oberdorster *et al*, 2007). The only part-consensus that can be formed for colloids is that they are poorly understood (ibid.) (See also Sealy (2006) for a starting point on the converging studies of the environmental health risk of amyloidal proteins.)

There have been many international strategies and initiatives to determine health and environmental risks and hazards associated with nanoscale materials as well as with other related concerns based on scientific evidence. The National

Nanotechnology Initiative (NNI), discussed more in Section 6.145.7.1, received $1.6 billion from the 2010 US Budget, and has its own EHS oversight program. The Woodrow Wilson International Center for Scholars and the Pew Charitable Trusts began the Project on Emerging Nanotechnologies (PEN) (Sandler, 2009) while UNESCO (2006) issued a report from its Social and Human Sciences program. Also on the research side, a report of the Royal Society and the Royal Academy of Engineering (UK) from 2004 is one of the most cited documents, but there is also the 2008 report of the Royal Commission on Environmental Pollution (UK). There are various international groups including the International Risk Governance Council (IRGC) (2005) and the International Council on Nanotechnology (ICON) (2009).

The International Risk Governance Council (IRGC) (2006, 2007) set up an independent Working Group on Nanotechnology in response to the need for a cross-disciplinary approach to nanotechnology risks and hazards. This body has also conducted a series of international surveys with stakeholders on the implications of the technologies. The Council has defined two frames of reference for the four generations of nanostructures that impact on how toxicity levels are examined. Frame One, or the 'passive' frame concerns those components of existing products that do not constitute excessive risk due to their stable behavior. Passive nanostructures are mainly first generation. Frame Two, or the 'active' frame, consists of second generation (active nanostructures), third generation (complex nanosystems), and fourth generation (molecular nanosystems) structures that also change the design and development of the existing ones and so their behavior becomes less easy to predict (ibid.).

There have been a number of major EU reports setting the agenda for detecting health and environmental risk (European Commission, 2004a, 2007) as well as the references in the EU Nanotechnology Action Plan (European Commission, 2005) and several special committee reports on emerging health risks from new chemical exposure and product safety. Nanotechnology is also mentioned in the EU Strategy for Environment and Health (European Commission, 2003), although not in the subsequent Environment and Health Action plan (European Commission, 2004b). On the highest level, the European Parliament (European Parliament Committee on the Environment, Public Health and Food Safety, 2009) and European Council (European Group on Ethics in Science and New Technologies to the European Commission, 2007) are seeking regulation, and environmental concerns have risen to the fore.

Much of the generalized scientific discourses about the environmental and health implications of nanotechnology are focused on both risks and benefits. Scholars at the Woodrow Wilson Center are trying to come to terms with the complexities: according to Davies (2009), current health and environmental agencies are unable to assess the risks of nanoparticles within the standard oversight models of risk assessment. The Center recommends that laws be changed to account for future unknowable technologies, as well as a new governmental body be created to not only look after 'environmental protection' in the old sense but also integrate technology assessment, forecasting, and health and safety monitoring.

Now let us consider the larger scale threat that is the Drexlerian vision of nanotechnological geoengineering, or terra-forming, where the smallest technology is proposed to be employed to effect large-scale planetary changes. The Center for Responsible Nanotechnology (2008) in particular proposes a role for molecular manufacturing in combating climate change, techniques such as controlling the sun's rays by increasing nano-emissions. In Section 6.145.7.3 we take a look at the social theoretical and media analysis reading of such projections— the framing linguistic devices used in emphasizing the need for greater mastery of nature. Such predictions and 'imagineering' opens up a whole set of ethical questions about what societies intend to do with new and emerging technologies, who governs science and how, and to what ends, making it a worthwhile exercise to map out the tropes of technology as servant, leader or peer.

Questions are often raised about the public awareness and use of scientific and technological knowledge regarding environmental risk. As Wynne and many other sociologists and science communication experts point out, of public concerns cannot merely be considered to be borne out of irrational fears or ignorance (see especially Wynne, 1992) Cultural understanding of the publics' reaction to nanoparticles and safety is required, looking at existing fears of the unknown and unseen as well as general consumer behavior in response to toxicity risk.

Yet current research from the sociological end of science and risk communication would suggest that the blurring of the lines between risk and hazard is a very human part of the cognitive process, and must be accepted on its own terms for effective communications. Peter Sandman (1993) suggests that risk should be considered a sum of objective hazard assessment and subjective 'outrage' factors, many of which are emotive and need to be understood in these terms.

Strange as it may seem, it was the case of Brian Wynne's famous Cumbrian sheep farmers that informs much of contemporary sociological studies of risk communication. In an influential paper published in the late 1990s, considered a landmark in science communication and STS research, Wynne presents the case for how publics can construct active and sophisticated responses to scientific risk information, responses that are often lost to scientific and authoritarian reasoning Wynne (1992) Following the Chernobyl nuclear incident in Kiev in 1986, sheep farmers near the Sellafield (formerly Windscale) nuclear fuels plant in the Lake District of Cumbria, Northern England, were informed by Government-appointed experts not to use the land for pasture, despite earlier reports that there was no radioactive contamination in the area. Sellafield, of course, has its own history of conflict between nearby Ireland and other regions of the UK beyond Cumbria. What Wynne builds up in his ethnographic analysis is a story of powerful social networks where there is much to be contested: scientists' testimonies against farmers, 'lay knowledge' of science, radioactive measurement methods (proven later to be inaccurate), and the relationships between the local community and a major institutional employer such as the Sellafield nuclear fuels plant. There was a multitude of channels of information flow entirely dependent on the context of this particular controversy, and all with implications associated with the inequity of power and authority. Informed by contemporary science and technology studies of public reception, the publication of Wynne's paper was one of the seminal moments for understanding the power of context and social identities, or representations of identity in debate, for controversial scientific information and the environment.

Within scientific discourses, characterizations of exposure, hazard and risk to nanoparticles tend to focus on the monitoring of intentional release. For instance zero-valent iron—iron particles purposefully released for groundwater contaminant remediation—can be tracked and exposure concentrations determined (Center for Groundwater Research, 2009). However, there is a large bulk of unidentified domestic and industrial nanoparticles from sources than cannot be easily identified. Scientific risk assessment therefore depends upon identification of the different types of nanoparticles most prevalent in the environment (Oberdorster *et al*, 2007).

Scientific disagreements about the breadth and scope of nanotoxicology studies exist. There is a view that current definitions of nanomaterials may be too narrow for food toxicology, given that there is such a variety, as presented to the UK Parliament in June 2009 by expert witnesses (www.parliament.uk, 2009). In fact, the European Parliament's (European Parliament Committee on the Environment, Public Health and Food Safety, 2009) communication on nanotechnology explicitly contradicts the earlier findings of the European Commission report (European Group on Ethics in Science and New Technologies to the European Commission, 2007), stating the report is 'misleading' in its representation of a possible market without adequate data on implications. This would appear to be a significant shift at the higher levels of European politics towards addressing EHS issues. While the 2004 report of the Royal Society and the Royal Academy of Engineering had similar misgivings about approving of nanotechnology carte blanche, both reports suggest a multidisciplinary approach to risk assessment. This approach, it has been acknowledged, includes a perspective from humanities and social sciences. The next section looks at the broad sociological landscape, particular from critical theory, of public discourse on ecology and risk.

6.145.4.2 Nature, Technology and Public Discourse

The discussion so far has focused primarily on the expert discourses of ecological risk from scientific communities. By invoking the sociological writings of Beck, Wynne and Giddens in the discussion however, we recognize, as do scientific discourses, that other forms of expertise are required to contribute to the knowledge systems of nanotechnology (Royal Society and the Royal Academy of Engineering, 2004; Toumey, 2007). There has been much written within the 'late modernity' literature about how society responds to ideas of science and nature outside of scientific practices (Giddens, 1991; MacNaghten *et al*, 2005a, 2005b; Nowotny *et al* 2002; Wynne, 1992). There are key concepts about where publics—humans—see themselves in relation to science, technology and nature; conquering, preserving or submitting to nature. There are future-orientated tropes mapping humanity's place in ecology, future health and human longevity/ enhancement in modern cultures of therapy.

Ecological politics was born out of the 1960s countercultural resistance to Big Science and industrial modernity, symbolized by Rachel Carson's (1987) *Silent Spring*. However, where once mobilization of ecology social movements was counter-cultural, now, in addition to political action by Civil Society Organizations (CSOs), green thinking has become mainstream and institutional (Eder, 1996a). Hajer (1995a), Eder (1996a, 1996b) and many others have looked at this politicization of ecology. We are seeing an embedding of ecology into social processes, in politics (as political ecology), in business and aspects of everyday life. Eder (1996b) has called it a 'masterframe' of ecologism within society.

The framing of nanotechnology as nature is a recent manifestation of the ecology masterframe. There is a common phrase throughout nanoscience text books that nanotechnology is 'replicating nature'; often, there is a more optimistic claim that it may well better nature. This is the storyline that adds to the power of nanotechnology – humans in control of nature beyond imagination. Such is its power that it is difficult to construct a theory of how technology and society will exist, particularly given the challenges such expected transformations pose for traditional social theory and the fact that future imagineering is happening in small communities removed from most publics (Dunkley, 2004). Such divinations of nanotechnology in society are tied up with other emerging technosciences, such as biotechnology. In the framing studies of Eder and Hajer, we can draw historical parallels with other facets of ecological modernization, such as advocates and resistances to nuclear energy and genetically modified organisms. STS studies inform us too that public input into institutional science is inevitable at some level in late modernity. We can also learn from Habermas' critical theory of how discourse of technology is represented in the public sphere or the technological ethics of Hans Jonas. Jonas was not speaking directly about nanotechnology in the following 1984 passage, but the new emerging technologies surely prove his point more than ever before:

> Modern technology, informed by an ever deeper penetration of nature and propelled by the forces of market and politics, has enhanced human power beyond anything known or even dreamed of before. It is a power over matter, over life on earth, and over man himself; and it keeps growing at an accelerating pace (Jonas, 1984 p.ix).

Response and resistance to socioscientific strategies tend to have social movements as actors, specifically community-based responses, as we look at in Section 6.145.4.3. In Section 6.145.7.4 we explore the political dimension further for nanotechnology by asking questions about the role of deliberative and aggregate democracy in the use of, and in policy-making around, this new and emerging technology.

6.145.4.3 NGOs and Local Communities

Non-governmental Organizations (NGOs) have begun to emerge in opposition to nanotechnology, although perhaps not (yet) with the same intensity as for other emerging technologies such as genetic modification of crops and animals. The Big Down report from the Action Group on Erosion, Technology, and Concentration (ETC Group, 2003) was a direct source for Prince Charles' famous negative assessment of nanotechnology in 2003. A group calling itself 'THONG' (Topless Humans Organized for Natural Genetics) staged semi-nude demonstrations at large nanotechnology events in the mid-2000s. Friends of the Earth has produced briefing papers about the potential risk of nanotechnology, while Nanotechnology Citizen Engagement Organization (NanoCEO, 2009), a US-based group, has organized a series of 'Nano Cafes'. Greenpeace was an active participant in a series of workshops with nano industry panelists in 2007, organized by Demos, a UK-based think tank on democracy (Demos, 2009).

What emerges strongly from these representations, particularly those in the recent past which have taken on board public value issues that writers such as Alan Irwin (2006) and Brian Wynne (1992, 2005) describe, is a need to address other forms of risk and varying perspectives of the public good in an era of responsible innovation, whether it be for healthcare, materials production, electronics or other commercial venture (see in particular Sandler, 2009 and Rip, 2006).

Despite the existence of some valuable resistance and commentary from NGOs about nanomaterials, it might be argued that there have not been, as yet, grounded discourses at community level about nanotechnology. It is not yet an environmental health issue on large scale public consciousness level. Nano talk may well be driven at this stage by natural and social sciences, with some NGOs, and with commercial imperatives underpinning all efforts.

6.145.5 Health

6.145.5.1 Nanotechnology and Health

As with the effects of nanotechnology on the environment, the impact of this new technology on healthcare is polarized. On the one hand, nanomedicine offers opportunities to advance treatments for a range of disorders including cardiovascular and neurodegenerative diseases, cancers, diabetes, and musculoskeletal disorders among others (European Technology Platform, 2006); on the other, there is increasing scientific evidence of some degree of health risk associated with nanostructures. There are many factors that are either difficult or impossible to measure regarding nanoparticle concentration levels and exposure rates; however some toxicology studies show potential risk for respiratory and immune systems, and some carcinogenic effects (Anderson *et al*, 2009 citing Handy and Shaw, 2007 and Hannah and Thompson, 2008).

Let us first deal with the positive narratives of the emerging field of nanomedicine and nanobiotechnology. While the extrinsic discourse of news media and fiction often refers to nanobots, the intrinsic discourse downplays this supposed sci-fi aspect. There is some research on nanomaterials' ability to enter cells, which has therapeutic potential—for example, to manage pathogens using silver nanoparticles (Baker *et al*. 2005), to treat tumor cells using hematite (Ito *et al*. 2004), and to use polymers to reduce the side effects of chemotherapies (Vicent & Duncan 2006). The European Technology Platform on Nanomedicine (2006) is a strategic alliance between the European Commission and industry which coordinates research and clinical efforts towards (i) targeted drug delivery, which includes nanobiomolecular processes such as impalefection or the use of nanoparticles for gene delivery; (ii) biodiagnostics, the identification of disease at the very early stages; and (iii) regenerative medicine to overcome organ or tissue failure.

There has, however, also been a significant increase in scientific publications on negative implications on health, as we discuss next.

6.145.5.2 Nanotoxicity

Donaldson *et al* (2004) coined the term ‘nanotoxicology’ in 2004. It has since become a sub-field in itself looking at the science of nanoparticle toxicity, with a dedicated scientific journal, Nanotoxicology, published since 2007. Fadeel *et al* (2007) state in their overview in the first edition:

> The very same properties that make engineered nanomaterials so promising from a technological perspective, such as their high degree of reactivity and the ability to cross biological barriers, could also make these novel materials harmful to human health and the environment (ibid., p73)

A recent NATO workshop has summarized what it called the ‘wide-scale’ risk/ benefit issues associated with nanoparticles as well as the societal dimensions of such issues (Linkov *et al* 2008). As we broaden out the discussion further, we want to emphasize here how these ‘societal dimensions’ are not necessarily secondary to the issues, but integral to public construction of risk. But let us first focus on scientific health risk.

Many articles on the toxicity of nanoparticles have been published in the Journal of Nanoparticle Research. Other environmental health journals have published reports of toxicological research on colloids (Oberdorster *et al*, 2007; McCarthy and Zachara, 1989) and amyloids (Sealy, 2006). Health risks associated with nanoparticles have historically been investigated by conventional particulate toxicology on the nanoscale. Certainly there are naturally occurring nanoparticles, such as volcanic dust or certain bacterial or mineral composites, in the environment. The sources of contamination have also been identified as consequences 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 G. Oberdorster, *et al* 2005). There are other materials labeled high-risk such as asbestos or silica (Oberdorster *et al*, 2007). There are also particulate behavior studies contributing to overall knowledge from virology, and from the toxicology of air pollution particles below 10 µm in size (ibid.), termed invariably by research communities as ‘ultrafines’ or ‘incidental’ nanoparticles, by-products of macro processes of production. Early studies showed 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 preposition 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 of what is known about engineered nanoparticles has been learned form 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)

These days, researchers look at how nanoparticles represent hazards to human and other mammalian tissue. For example, Shvedova *et al* (2008) have found that single walled carbon nanotubes can impact adversely on mice lungs when inhaled. Many scientific studies show that nanoparticles have the propensity to cross cell barriers and interact with cellular structures. This phenomenon can produce many potential benefits for therapeutic and diagnostic procedures in biomedicine. However, in addition to other factors, the significantly small size and its relation to surface area have implications for mammalian tissue (ibid.). There is a particular concern for crossing the blood/brain barrier. This appears to be the case for a large range of nanomaterials including carbon nanotubes, metal nanoparticles, fullerenes and quantum dots. Oberdorster *et al* (2007) have indicated that many of the toxicology studies in rodents and cell lines have used agglomerated and aggregated rather than mono-dispersed particles, and such studies indicate that even in the agglomerated forms the smaller particles are more potent than previously expected. There are many questions raised by the occupational aspects of nanotechnology (National Institute for Occupational Safety and Health, 2009), the primary one being as follows: if there is to be a large nano-industry and little current regulation (Section 6.145.7), how are those nano-researchers being protected (Maynard, 2007)? Where some broad consensus seems to have emerged is not on nanoparticle dosage—where a ‘no observed adverse effect level’ system , or NOAEL, is applied by regulatory agencies such as the US Environmental Protection Agency, which assumes that everything at a certain dosage level is harmful—but on observing particle surface area (Environmental Protection Agency, 2007). However, as Maynard stresses, ‘we can no longer rely on hazard evaluations, risk assessments or regulations that are based on our understanding of chemicals alone’ (p3).

6.145.6 Equity

Having briefly addressed scientific risk concerns, let us now turn to issues of nanotechnology that are closely related to health, environmental and personal well-being. A central concern around new and emerging technologies is the extent to which they serve and reinforce ideological, political, social, cultural and gendered interests. 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. In addition, the control of intellectual property of nanotechnology applications, devices and manufacturing processes is being driven by large corporations and laboratories based primarily in the First World, which has significant economic implications for the developing world. Who gets access to nanoscale technologies and at what price is an issue of fundamental importance for equity considerations of nanotechnology. There has been very little substantive attention given to these issues, although these concerns are now gaining some visibility in the scholarship and in the reports written by environmental and other NGOs.

6.145.6.1 Global Equity and Rights : Implications for Developing Countries

The concern about a nano-divide between First and Third World countries, marking a growing gap between those with advanced nanotechnologies and those without, has been voiced by development agencies and activists. Such a gap could be widened if resources are poured into profit generating consumer products rather than into technologies and applications that could alleviate poverty and promote development in Third World countries (see Association for Women's Rights in Development (AWID), 2004). Indeed, it is precisely such imperatives that drive the global pharmaceutical industry resulting in a focus on producing innumerable over-the-counter products for wealthier nations rather than ensuring access to essential, life-saving drugs for poorer ones. Recognizing the potential for nanotechnology to create winners and losers in both national and international contexts, scholars such as Baird and Vogt (2004) ask whether nanotechnology

> will address the most urgent problems of developing countries (energy, clean water, food) or just accept a 'global nanodivide' as we have come to live with a 'digital and genetic divide' (p393).

The concerns about the negative impacts of nanotechnology on marginalized communities, voiced most cogently by the ETC Group (2003), are countered by others who point out that nanotechnology applications can become the means to achieve the United Nations Millennium Development Goals (see, for example, Salamanca-Buentello *et al*., 2005; United Nations Millennium Project, 2005). Thus, the United Nations Millennium Project report (ibid.) states that nanotechnology and biotechnology will combine for such diverse applications as environmental and health technologies as water treatment and remediation, energy storage, production, and conversion; disease diagnosis and screening; drug delivery systems; health monitoring; air pollution and remediation; food processing and storage; vector and pest detection and control; and agricultural productivity enhancement.

Although the same report cautions that, given their potential for causing environmental and other harms, such technologies need to be developed with care, there is an overwhelmingly techno-utopian edge to the discussion of the development possibilities—such as, wealth, health, and other improvements—that nanotechnology appears to open up. The ETC Group (2006) addresses in detail the significant negative implications of nanotechnology for the most marginalized communities. It points out that nanotechnology can radically transform the manufacturing process, with the creation from scratch of smaller, cheaper products that require fewer raw materials. Nanotechnology's new designer materials could topple commodity markets, disrupt trade and eliminate jobs. Worker-displacement brought on by commodity obsolescence will hurt the poorest and most vulnerable, particularly those workers in the developing world who do not have the economic flexibility to respond to sudden demands for new skills or different raw materials (ibid, p. viii). There are clearly major contributions that nanotechnology can make to address current inequities. The provision of clean drinking water, cheap energy, health benefits, and a cleaner environment are all desirable and important goals that deserve support. Yet it is important to note that in the face of the privatization of science, the concentration of resources in the hands of a few powerful actors, and a context where governments align too easily with the corporate sector, the desire for profit at the expense of human needs is likely to prevail. There is little evidence to indicate either the ability or the desire of governments to regulate nanotechnology in a way that ensures democratic control for the public good.

6.145.6.2 Power

As has been described in the last section, what has been particularly forceful about nanotechnology is its global reach. The framing of nanotechnology makes it truly international as well as systems and strategy-oriented. There are global threats, not just in the acute sense that there may be 'ecophagy' (Foresight Institute, 2000) or assemblers running amok, but regarding the politics of science and technology governance. The structures of democratic and/or participative processes are being examined in relation to nanotechnology. Nanotechnology has been considered a test case for public engagement and involvement in science policy and the narratives of science. Many see this as learning from the mistakes leading to miscommunication and mistrust that followed the genetic modification debates (Gaskell, 2003).

But there are other questions for the legitimization of nanoscientific research . In charting a map of the nanoworld, Munshi *et al* (2007) show how

> power plays out in the core struggles to not only define what constitutes nanotechnology but also around the ways in which the field should be developed and regulated (p446).

Dominant power rests with the nanoscientists/engineers, industry and the state. The decisions on the definitional aspects of nanotechnology rests with technoscientists and the decisions by states and the private sector to secure millions of dollars for nanotechnoscientific research and applications are aligned with the strategic influence that comes with definitional power. This strategic alliance is hardly power neutral as is revealed by the little more than superficial concern for ethical, social and equity issues in the dominant discourses around nanotechnology.

The need to increase the visibility of nanotechnological concepts in education has been identified by several scholars (Lakhtakia, 2005; Lightfeather, 2006; Madhavan *et al*., 2006; Swinney and Seal, 2008). Mass education may not eliminate the power inequities inherent in a situation where research and funding decisions are transforming societies without any active involvement of multiple publics, including and especially the most marginalized voices and communities. However, in time education may lessen the impacts of power inequities, particularly if these inequities are made explicit as part of the teaching.

6.145.6.3 Identity

For many environmental activists, inequities around new technologies are not just about human survival but also about, as McKibben (2003) puts it, ‘our identity’. As the subtitle of McKibben’s (2003) book indicates, the challenge of our times is ‘staying human in an engineered age’. The claims of technoscientists about nanotechnology’s capacity to alter every aspect of existence has opened up the potential for what Fukuyama (2002) and many others have called a posthuman future—a future that goes beyond that of cyborgs but that with a potential to radically alter conceptions of what it is to be human. If we are at the advent of a posthuman age, nanotechnology is beginning to usher this in, affecting issues of identity and privacy. Writers such as Hayles (2004) and Milburn (2002, 2005a, 2005b) feel the future is here in our collective cultural gaze. From postructuralist readings and the social theory of Foucault, the scope of ‘nanotechnology and identity’ can be described as seeing and feeling a nanoworld through media, cultural imagery of marketing and advertising, and Hollywood. Identity becomes caught in the biopolitics of things, networks and places, and while it may seem a threat to many, identity is in a constant state of ‘becoming’, as the power of constant nano-gaze forces normative action, a change in practices and behaviors. Donna Haraway (1988) also paints this technoscientific landscape, a space where the emergent practices of information, communication technologies, nanotechnology and genetic engineering always has gendered implications.

6.145.6.4 Gender

> Technology is more than a set of physical objects or artifacts. It also fundamentally embodies a culture or set of social relations made up of certain sorts of

> knowledge, beliefs, desires and practices (Wajcman, 1991, p. 149).

Feminist perspectives on technology have been driven by a recognition that both technology and gender are socially constructed, and are embedded in ideologies, worldviews, and configurations of power that have implications for the material worlds we live in. Feminists have long argued that the transformative power of technology can reinforce traditional gender patterns of power and authority or re-envision how gender is played out on numerous social, political, economic and other fronts (see, for example, Cockburn, 1983, 1985; Wajcman, 1991; Balsamo, 1996; Ong and Collier, 2005). In theorizing the link between gender and technology, feminist technology studies (FTS) scholars have argued, first, that gender and technology mutually influence each other, whereby technology 'is both a source and consequence of gender relations and vice versa' (Faulkner, 2001, p81). Second, FTS scholars have drawn on the triad proposed by Harding (1986) and Scott (1988) to analyze gender-technology relations, namely

> of gender structures (e.g., occupations, education), gender symbolism (e.g., cultural associations between masculinity and technology), and gender identity (how people see themselves as women and men) (Faulkner, 2000, p90).

Although each node of this triad has relevance for a specific examination of the gender implications of nanotechnology, little scholarly attention has been paid to this issue. For example, the extraordinary range of nanotechnology developments hold significant gender implications, from gold nanoshells that identify cancer cells for destruction to targeted delivery of drugs to specific parts of the body, to the possibilities for human performance enhancement technologies, and all of which remain to be explored in their specificities in feminist scholarship.

The Association of Women's Rights in Development (2004) has called for the consideration of gender equality and women's human rights early in the process of nanotechnology development by asking the following questions:

- What are the effects of these nanotechnologies on women's bodies and reproduction?
- What are their effects on women's work?
- How can women's rights be supported by these technologies, if at all?
- What do we need to know about these technologies to guarantee women's rights are not undermined? (AWID, 2004, p. 4)

Although answers to these critical questions remain to be addressed, NGOs and women's health advocates have focused attention on some new nano applications being developed that are of special significance for women. The Global Campaign for Microbicides, for example, advocates the development and use of microbicides—a new type of product that aims to prevent or reduce the transmission of HIV/AIDS and other sexually transmitted diseases through topical application—because it could 'put safe, affordable and accessible protection into the hands of women' (ETC Group, 2006, p32; Global Campaign for Microbicides, 2009). In a cogent discussion of the implications of the vaginal microbicide 'Vivagel', which uses nanoscale molecules and is currently going through human trials, the ETC Group points out that the 'development of a microbicide, which is replicable, sustains a good shelf life and is attractive to users, will require an estimated US $600 million over the next 10 years' (ibid., p. 34). This must be seen in the context of a cheap, simple technology of AIDS prevention—the condom—which is easy to store and distribute, but remains in short supply because of funding shortfalls from OECD countries. Reports from the World Health Organization (WHO), the World Bank, and the major public-private-partnerships involving the Gates Foundation and other wealthy corporate sources, indicate the extent of failure in the fight against malaria, tuberculosis and other preventable diseases. The case of the global program to fight malaria, where the technology involved is cheap—that is, treated mosquito netting, insecticides, and medicines—is particularly striking for its failure to deliver on its promises. Hence, it is important to caution that blind faith in the ability of nanomedicines to cure the diseases rampant in the Third World, is unlikely to materialize unless fundamental structural issues of equity and justice are addressed.

In the context of gender, new technologies and development, Darling (2006) argues that

> progress on social justice and the social norms which are embedded in a public domain is increasingly being sacrificed to legal- and market-based norms in the new genomics-based consumerism that defines the current new and emerging technologies (p).

Indeed, from the perspective of women, a fundamental issue in the access and use of new technologies such as microbicides is that of gender power and inequality. The Global Campaign for Microbicides (2009) argues that unlike with the condom, the microbicide can be used by women directly and thus can empower them to protect themselves from unsafe sex and have greater control over their sexual health and fertility. Others, however, raise questions around safety issues of microbicides which could result in using vulnerable women as guinea pigs in clinical trials, while diverting attention and resources from other areas of women's empowerment that could give them greater economic independence and enhance their ability to negotiate control over their lives. The tension between the desire for a silver bullet of nanotechnology to address what are ultimately deep-rooted structural problems of inequity and injustice thus remains to be resolved.

6.145.6.5 Privacy

In this section we follow a common view on the ethics of surveillance, which could potentially see the panoptic side of nanotechnology, following the poststructuralist theorist Michel Foucault (Foresight Institute, 2009). The panopticon was an extreme Big Brother vision by Jeremy Bentham for prisoners—a central observation space connecting up to glass walls on every surrounding cell within a prison where all prisoners could be visible to a single guard, thus increasing surveillance and decreasing both labor costs and privacy; fear of and future surveillance by the state have been captured in Orwell's 1984 and more recently, *The Manchurian Candidate* (2004).

Several strands of nanotechnology may interlink to provide a point of maximum surveillance with the development of smaller and smaller sensor devices leading to the possibility of 'smart dust' (sensor-active nanoparticles) covering the built and natural environment (Heller and Peterson, 2009). Computer chips will have exponentially greater power in smaller spaces beyond lithographic techniques, which many hardware companies are already attempting to do. Heller and Peterson (ibid.) report that researchers at Hiroshima University and Nippon Hoso Kyokai have developed a photoconductive silicon nanocrystal film with potential for use in miniature cameras. A more subtle but nonetheless effective technique of surveillance may be biomedical nano-sensors. A growing area of healthcare and bioethics now concerns itself with the implications of self-diagnostic devices such as the cardiovascular-disease-risk biochip or toxin sensors.

Such ubiquitous monitoring devices bring into question how micro-surveillance can track consumption and behavioral patterns. Many civil liberties groups have expressed concern about such invasions into privacy as well as the ethics of self-control versus external-agency control. The agencies external to one's own personal health management include a local doctor's surgery, insurance firms, or even local government. How far can current global security concerns go in order to 'keep us safe'? Some STS scholars do not focus on the ethics of a society where publics are tied in to surveillance systems —rather it is seen as an inevitable 'actor network' where institutions, humans and non-human concepts and devices are intertwined and inseparable in a mesh of social actions (Latour, 2005). However, CSOs representing human interests are not convinced that this network of information and objects is always beneficial. The norms of privacy are beginning to change, with citizens accustomed to increased surveillance using more sophisticated and integrated ways, such as smart cameras, GPS and radiofrequency identification (RFID). Many scenarios are presented when publics are offered glimpses of the future, for instance integration of chips, smart materials, and the so-called 'Internet of Things' where physical objects and cyberspace are more tightly enmeshed. As computing power increases— again through nanotechnology— larger and larger databases are used for the storing, management and retrieval of information from assemblages of people and objects in ever-sprouting rhizomes within these networks, all at less and less cost, or so the narrative goes.

6.145.7 Governance

Section 6.145.6 introduced the inequities of power politically that leads to social concerns about how nanotechnology might be used for (or against) society and the environment . However, there is much also to be said about the control of science and technology itself: science politics more than public politics.

For nanotechnology, much has been made of the problems regarding legislation and insurance for platform technologies which have no direct applications yet and whose impact on environment and health even at their foundational stages is still unclear. As a result, there are global structures of oversight—although to what ends and for whose main benefit may still be debated. Investments are made to the NNI in the US by many agencies including the National Science Foundation (NSF) to look at the responsible use of nanotechnology (described in Section 6.145.7.1). Agencies such as National Institute for Occupational Safety and Health (NIOSH) in USA, the US Food and Drugs Administration (FDA) and the European Food Safety Authority (EFSA) are looking at the safety of nanotechnology. The International Risk Governance Council (2007) and the Responsible NanoCode (2008) are looking for broader strategies, concentrating on food and cosmetics in the former. Although regulation is difficult, there are early attempts: nanoscale substances come under the EPA Toxic Substance Control Act; there is the EC Code of Conduct; and NIOSH currently disseminates alerts on occupational risk. Although these are attempts at regulation and governance under existing structures in most cases, there is as yet no direct environmental legislation. Despite the transformative talk of nanotechnology discourses, regulatory and legislative agencies are still looking at this technology through old lenses.

According to Munshi *et al* (2007), serious attention to governance matters had been slow to appear in any of the major nanotechnology discourse nodes, with the most significant literatures developing first in law, scientometrics, and humanistic analysis of ideology. By 2009, however, a small amount of literature has emerged on nanotechnology governance, although much of it is a rather superficial acknowledgment of the potential political implications of nanotechnology and the occasional applications of well-established political theories, concepts, and methods to nanotechnology policies and expected consequences. Most governance research falls into three categories: (i) analysis of government promotion of nanotechnology development from the mid 1990s through the present by way of massive public funding of research initiatives; (ii) analysis of governmental capacities for regulating nanotechnology in the present and in the more predictable future of the next decade or so; and (iii) ‘public engagement’ with, and democratic control of, nanotechnology issues and policies.

6.145.7.1 Science and Technology Policy: Funding Nanotechnology R&D

In the 21st century, governments have become sponsors and promoters of nanotechnology research, development, and deployment. In the United States, for example, something close to consensus among science policy elites under the Clinton Administration in the 1990s produced the NNI, an interagency program for establishing a major R&D program for realizing the full potential of nanotechnology, facilitating technology transfer to fuel the national economy, and educating the public to produce a nanotechnology skilled workforce. The initiative eventually led to passage, under the Bush Administration, of the Twenty-First Century Nanotechnology Research and Development Act of 2003, which authorized expenditure of almost level amounts of approximately one billion dollars per year for several years. The NNI is a comprehensive program involving twenty-three government agencies, eleven of which receive R&D funding. Other wealthy countries, such as Japan and the United Kingdom, also have identified nanotechnology as an emerging technology to be subsidized and have established programs to promote and develop it.

This kind of governmental embrace of nanotechnology, backed by allocation of substantial resources, creates winners and losers in political processes that can readily be analyzed by traditional social science theories and methodologies. This follows the politics, as famously defined by Harold Lasswell in the 1930s, of ‘who gets what, when, how’. Bosso and Rodrigues, for example, analyze how nanotechnology fits the pattern of a new policy that creates ‘new stakeholders who then organize themselves . . . to maintain and even extend that policy’ (Bosso and Rodrigues 2007, p369). And so now we have the NNI and EU Action Plan. Nanotechnology has been described as a driver for economic recovery and sustainability, by the so-called ‘green growth’ movement. What has emerged from a decade of virtually unconstrained political enthusiasm for nanotechnology globally is a new, politically potent, policy advocacy community. Stronger public-oriented policy measures are required; recently, the OECD Working Party on Public Engagement developed ‘points for consideration’ for a nano public-engagement policy.

6.145.7.2 Nanotechnology Regulatory Capacity

In the early days of nanoscale research, there was a near-consensus among all of the nanotechnology discourses on the eventual need for some kind of regulatory oversight of nanotechnology applications if not of research and development. Where there was fundamental disagreement, it was on whether such regulation would likely need to be draconian or needed any time soon.

But it appears to be difficult to have a single regulatory framework suitable for the range of applications on which nanotechnology will have an impact (International Risk Governance Council, 2007). A 2008 conference held in Rovigo, Italy, Managing the Uncertainty of Nanotechnologies: Challenges to Law, Ethics and Policy Making, highlighted the legislative and regulatory difficulties associated with nanotechnology. It is a fraught and uncertain area, as described by the conference announcement, when it referred to ‘the heuristic effort’ required to deal with regulating and attempting to guide the transformative and uncertain nature of nanotechnology (CIGA, 2008). Several international reports have either called for, or attempted to, sketch out a regulatory framework including the EU Action Plan, the White Paper on Nanotechnology Risk Governance (International Risk Governance Council Working Group on Nanotechnology, 2006), reports from the ESSA and the FDA, the EPA (2007) White Paper on nanotechnology, an OECD Working Party (OECD Environment Directorate, 2006), several US reports from the Woodrow Wilson Foundation on risk concepts and oversight (see especially Macoubrie (2005) and Greenwood (2007), EU opinion reports on ethical and social issues (European Commission, 2000, 2003, 2004a; European Group on Ethics in Science and New Technologies to the European Commission, 2007) and a Code of Conduct (European Commission, 2007). The precautionary principle has been adopted by the EC as a possible regulatory way forward—that is, protection of human, environmental, animal and plant health where only preliminary scientific evidence of risk exists (European Commission, 2000). However there is opposition to this idea also, as voiced at the Rovigo conference, on the grounds that legally the principle is 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.

Nanotechnology enthusiasts continue to be concerned that regulatory processes and frameworks will impede innovation and commercialization (Kurzweil 2005), while concerned writers and political activists issue warning tales and call for caution and moratoriums. With regard to governmental capacity to regulate effectively,

> relatively little attention has been paid to understanding the current capacity and expected needs of the agencies and officials that researches, firms, investors, and citizens expect to make critical decisions on a wide range of emerging nanotechnology applications (Bosso *et al*. 2006, 378).

Most recently, some attention has come from regulatory analysts and technology policy scholars on the question of how existing systems of regulation ought to be modified to address that have already arisen or seem likely to arise soon (Davies 2005; Wardak and Regeski 2003; Wardak and Gorman 2006; Marchant and Sylvester 2006). Nearly all such analyses assume that all that is needed for nanotechnology will be incremental modifications to existing regulatory systems, including possibly even some modifications to deregulate commercialization. In part because the likely EHS effects of nanotechnology are still poorly understood, and in part because of an unwillingness to confront politically a general (and mistaken) belief that technological progress means social good (Sandler and Kay, 2006), only minor, incremental adaptations are expected to be required, in this view.

These biases notwithstanding, little systematic, proactive thinking has been done about the regulatory challenges for policy design likely to be posed by nanoscale innovations, whether in terms of policy scale, institutions, or tools. For example, most of those who write on the subject assume that the most appropriate locus for nanotechnology regulation and governance is, and will continue to be, at the national level, yet a strong case can be made that for a technology with such transboundary risks and benefits, much of its regulation must inevitably have a transnational component, or even be predominantly transnational (Marchant and Sylvester, 2006) It is not clear that current national regulatory systems can ever be adapted adequately to address the most important of the environmental and social issues likely to posed by a set of technologies with such potentially revolutionary characteristics. Even if current policy systems can be sufficiently adapted, nanotechnology, like other emergent technologies such as genetic engineering, raises troubling questions about what might constitute appropriate democratic ‘engagement’ and control—questions that are even more troubling when considered in a transnational context (Baber and Bartlett 2009).

In 2001, the case of Kyllo versus United States (Cornell University Law School, 2009) might at least provide a precedent for protecting privacy and civil liberties. This case found police guilty of using intrusive devices on a woman suspected of growing large quantities of marijuana. Heat-seeking technology was used to spot lamps used to promote photosynthesis in the plants, and such devices were deemed to be 'not in general public use…[but used] to explore details of a private home that would previously have been unknowable without physical intrusion' (Heller and Peterson, 2009). The Court decided that the Fourth Amendment—protection against 'unreasonable searches and seizures'— could be invoked in such a case.

6.145.7.3 Public Attitudes and Media Coverage

Coverage by the mass media has been used as a key barometer for ideas, opinions and ideological biases towards the concept of nanotechnology (Anderson *et al* 2005; Cobb, 2005; Cobb and Macoubrie, 2004; Hornig Priest, 2006; Stephens, 2005; Scheufele and Lewenstein, 2005; Schütz and Wiedemann, 2008). While news media will cover nanoparticle risks from time-to-time, coverage is scant across the world and, not surprisingly, awareness is limited (Anderson *et al,* 2005). This is confirmed by surveys of individuals. Cobb and Macoubrie (2004) have also found, using what they claim is the first national telephone survey on the issue, that initial US reaction to nanotechnology is quite positive, with respondents referring to treatment of disease as the best possible outcome and the most potential risk associated with surveillance devices and privacy issues, as discussed in Section 6.145.6.5. The issue of trust arose quite prominently in this survey, particularly in matters of healthcare where business leaders are involved. Often, recognized figures enter debates to play with the public notion of trust. Anderson *et al* (2005) 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.

Anderson *et al* (2005), Cobb and Macoubrie (2004), Cobb (2005), and Scheufele and Lewenstein (2005) are well-cited studies of framing of nanotechnology in the media. Cobb (ibid.), in particular, highlights the effects this may have on public opinion. For the discourse analyst, frames are a means of organizing discourse that, according to Fisher (1997), create 'common sense' patterns of images or concepts. They emphasize and omit information and, within the framing theories of Gamson (1992) and Benford and Snow (2000), there are conscious or unconscious attempts by actors to add credence to these patterns by drawing on what others may believe, thereby constructing a collective identity for or against a concept. There are perhaps some common observations that can be made about nanotechnology in the media and of audience/reader responses: first, there is little public knowledge of the subject; second, economic and global issue frames are prominent (see also Hornig Priest (2006), Stephens (2005) and Anderson *et al*

(2005) for the identification of these types of frames[5]); and third, nanotechnology peaked in coverage between 2003 and 2005. Many of these studies examine audience perceptions from pre-selected newspaper frames (Cobb, 2005; Schütz and Wiedemann, 2008). Cobb uses what he calls a 'thoughtful receiver' hypothesis, which places the citizen into an active agency, yet the model of communication still suggests a linear mechanism. However, 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. Scheufele and Lewenstein (2005) argue to move beyond framing effects, to look for elements from social theory studies of ideologies (a closely related concept).[6] While Hackett (1984) encourages media analysts to look for ideology rather than the older tradition of the 'objectivity and bias paradigm' (ibid., p96), there is a strong argument from current 'culturalist' audience research to consider both audience 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.

While there are still many high-profile projects in the social sciences focused on 'opinions' about nanotechnology, more recent methods are sophisticated and combine efforts to find out about 'knowledge' and 'attitudes' with immanent and contextual types of public engagement activities. .In fact, within science communication and STS fields in general, there has been a noteworthy convergence of what would have traditionally have been seen as 'public understanding of science' methods and more sociologically-inclined work on public, civic and community engagement.

6.145.7.4 Nanotechnology Public Engagement and Democracy

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 was one thing—public perspectives on the enterprise of science was quite another. The fifth report of the House of Lords has strong references to nanotechnology (House of Lords Select Committee on Science and Technology, 2004). Rob Doubleday (2007) has noted three historical phases of public engagement with nanotechnology by the House of Lords, at least as far as public debate is concerned. In the first phase, nanotechnology appears on the policy stage. In the second phase, more public voices emerge with diverse views on, and even opposition to, nanotechnology. Doubleday notes an institutionalization of

[5] Anderson *et al* (2005) use the concept of frame relatively loosely in the coding process eg the 'science fiction and popular culture' frame, the 'business story' frame. We advocate a refined and defined boundary for frames, following Gamson (1992) and Gamson and Modigliani (1989).
[6] As has been mentioned in Section 6.145.5, in defining the 'four generations' of nanostructures, the International Risk Governance Council Report (2007) even suggests two 'frames' of reference around which technological discourses coalesce, the 'passive' frame and the 'active' frame.

public engagement by the third stage, which , we would argue, sets strategic agendas for nanotechnology discourse, even from NGOs taking the talk beyond legitimized public concerns. The debate in the UK on active national espousal of genetically modified foodstuffs can only serve to demonstrate further what happens when public consultation remains within its instrumental remit. In a recent report of the Woodrow Wilson Center on future oversight, Davis states that the ‘technology of public-participation mechanisms lags behind the science-based technologies of the 21st century’ (Davis, 2009, p17).

First-generation contributions to technoscientific, business, governmental official, and journalistic discourses about nanotechnology are all permeated with analogies to the controversies of the 1980s and 1990s on genetically modified organisms; in the UK, there is an equally popular analogy to the bovine-spongiform-encephalitis or ‘mad cow’ crisis of the 1990s. As already stated, consensus exists that something went wrong with the way genetically modified organisms were introduced and explained to the public that led to widespread public resistance. Nanotechnology is assumed to have the same potential; consequently, from early on promoters of nanotechnology have advocated learning from this experience and paying greater attention to the possible social and ethical implications of nanotechnology and the need for better communication with the public (Sandler and Kay, 2006). In part because of substantial funding from the National Science Foundation in the USA and attention focused in the UK by an inquiry of Royal Society and Royal Academy of Engineering (2004), there has been a considerable amount of research about public attitudes and knowledge, risk communication, and dialogue involving nanotechnology.

One of the first and easiest research tools in technology assessment exercises and consultations to look at the social dimensions of nanotechnology is opinion surveys. Such surveys consistently show that the public is generally not aware of nanotechnology, with less than a third aware of the term and an even smaller fraction able to demonstrate minimal understanding (Royal Society and the Royal Academy of Engineering. 2004; Gaskell *et al*. 2005; Cobb and Macoubrie, 2004). These and other similar findings underpin the standard ‘understanding deficit model,’ which postulates that publics distrust new technologies because it is ignorant of them; the failures of the publics to accept and adapt to the introduction of new technologies stems primarily from lack of knowledge. The appropriate response in this view, and certainly what has been the main response to date, is education and exploratory reassurance, or investment in public outreach while simultaneously funding assessment of social and ethical implications of the new technology. The NNI in the US, for example, provides substantial funding for this kind of one-way risk research and communication, which has been criticized because it ‘is focused on education and acceptance, not productive discourse’ (Sandler and Kay 2006b, p676).

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? However, the loudest debate over public engagement seems not to be over any kind of public or democratic control over research or technology, but rather the most appropriate timing of public engagement processes. Rather than 'downstream' retrospective engagement, when the technology has been launched or even after opinions are already formed, some call for 'upstream' engagement, or involving citizens prospectively, early in R&D phases before major controversies have emerged and opinions have polarized (Macnaghten *et al*, 2005a, 2005b; Rogers-Hayden *et al* 2007; Rogers-Hayden and Pidgeon 2007; Wilsdon and Willis, 2005). Although the term 'upstream' may over-simplify how innovations occur in science and technology, this level of engagement is expected to have several benefits, including making possible technological decisions that 'are sensitive to the ethical and value concerns of directly affected groups or populations' (Rogers-Hayden and Pidgeon 2007, p192), thereby increasing trust in decision processes and producing more widely accepted outcomes. Some advocates of upstream engagement emphasize that the point of engagement or dialogue is more than education about and acceptance of nanotechnology, or the promotion of it as a public good. Rather, it is to give 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, Mohr, and Pidgeon 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).

Actual democratic governance of nanotechnology is rarely broached, and when it is, the arguments rarely draw on either a rich development of democratic theory (Baber and Bartlett, 2005) or the equally rich accumulated experience of democratic experimentalism of recent decades (Gastil and Levine, 2005). This is true of both the politically active naysayers (McKibben, 2003) and the nano-enthusiasts. There is some acknowledgment that public engagement can serve to improve the legitimacy of nanotechnology decisions, thus enhancing public confidence and trust to the extent of perhaps avoiding the negative outcomes that characterized the debate on genetically modified organisms and, in Britain, the bovine-spongiform-encephalitis disaster (Rogers-Hayden, Mohr, and Pidgeon 2007; Sandler and Kay 2006). But there is little appreciation that modern crises of legitimacy can only be addressed by public participation in actual decisions about the allocation and amelioration of risk, as has been argued by critical theorists such as Beck (1992) and science studies scholars. The default public envisioned for nanotechnology is the 'global public', yet the environment for nanotechnology is an infinite number of complex and heterogeneous local conditions, with policy made by irreducibly heterogeneous human communities based on contextually grounded systems of tacit knowledge and mainly place-based sciences (Baber and Bartlett, 2009). Small wonder, then, that the proponents of nanotechnology prefer not to think beyond minimally democratic policy systems that are based on interest aggregation and representation voting only but leave real power over the development and deployment of nanotechnology in the hands of market forces and those with direct vested interests.

Social action from CSOs, combined with the sociological approaches of STS and its ilk described previously, have arguably changed the landscape for strategic public engagement of nanotechnology. Suddenly a more ground-up approach has evolved and involved more depth of engagement. Types of activities used include (i) the constitution of citizen juries, whereby controversial public issues are discussed among a ‘jury’ of 12-20 people, who listen to experts or ‘witnesses,’ and make recommendations based on what they have heard; (ii) consensus conferences, also containing a small sample of non-experts who have greater access to expert processes, held over 2-3 days; and (iii) deliberative polling or mapping where a larger sample, democratically representative and multi-panels of stakeholders, exchange commonalities and variances

Other initiatives at the upstream level have included (i) ‘NanoDialogues’, a UK process framed around risk and organised by ScienceWise (2008); (ii) Small Talk (2008), organised by a UK government public understanding of science group; and (iii) Nanologue (2009), a Germany-UK-Switzerland joint project holding workshops on future scenarios. Upstream models that have gained popularity for nanotechnology are consensus conferences, deliberative polling and convergence seminars, such as the NanoBio-RAISE event in the Netherlands in 2007 where non-experts and experts made recommendations. Recently, the OECD Working Party on Public Engagement developed ‘points for consideration’ for nano public engagement policy.

Increasing developments on the internet such as Web 2.0 forums and scientists’ blogs have opened up new public spaces for science communication (see . 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 (2003), 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 of public opinion 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? In the next section, a different perspective of understanding and engaging with nanotechnology is presented, one that is recognizable for all discourses – the representations that seem to owe more to science fiction than popular perceptions of lab science.

6.145.8 Imagined Futures

6.145.8.1 ‘Fact’ and ‘Fiction’: Social and Cultural Influences

As has already been mentioned in Section 6.145.3.4 when discussing military applications of nanotechnology, science and science fiction have a symbiotic relationship. The creative possibilities of science have not only inspired science fiction writers to imagine the future in utopian terms but have also provoked them to manage risk by projecting dystopian scenarios. Concurrently, scientists have followed the imagination of science fiction to relentlessly pursue the dreams of 'advances' that promise to improve the world and at the same time work on preventing possible catastrophes. It is hardly surprising therefore that some of the words now commonly used in scientific discourse were used by science fiction writers decades ago: words such as 'robotics' in Isaac Asimov's Liar or 'genetic engineering' in Jack Williamson's Dragon Island (Prucher, 2007).

Yet never before has the discourse of science and technology been so lured by the seductive power of science fiction as has the discourse of nanotechnology. The narrative of this emerging field about which even scientists do not know enough about is strikingly similar to that of science fiction. It is about being a 'portal opening on a new world' (Rita Colwell, cited in Ratner and Ratner, 2003, p1) where 'our ability to work at the 'molecular level, atom by atom, to create something new, something we can manufacture from the 'bottom up' opens huge vistas' (David Swain, cited in Ratner and Ratner, 2003, cover).

That the car in the new incarnation of the popular television series Knight Rider can not only converse intelligently with humans but also take strategic decisions about changing color and size to adapt to rapidly changing situations is hardly unusual for a science fiction drama. What is significant, however, is that the makers of this television series advertise the fact that the car's fantastic abilities are achieved with the help of nanotechnology. The articulation of this 'fact' attempts to put nanotechnology on par with science fiction itself. In explaining How the New Knight Rider Car Works, Fuller (2009) points out that all the car's extraordinary abilities are actually captured for the digital screen by 'using computer-generated imagery (CGI)'. But the key point is that although 'the filmmakers haven't released many specifics' about the three modes within which the car works, 'we can assume the body of the car will change shape with the help of nanoscopic machines called assemblers' (Fuller, 2009).

This is where the blurring of the boundaries between science and science fiction is most noticeable. What is described in science fiction is no longer projected to be a fantasy. On the contrary, the discourse of nanotechnology appears to thrive on pushing the narrative of this emergent technoscience as one that is already in the realm of the fantastic. By doing so, it is accelerating the pace of an imagined future that is no longer a cyborg future of humans and non-humans in shared co-existence but a posthuman future where there is no tangible difference between perceptions of what is human and what is non-human.

The dissolution of boundaries between fact and fiction has characterized the construction of the dominant narrative of nanotechnology (Gimzewski & Vesna, 2003). Unlike many other domains of science and technology, the discourse of nanotechnology is soaked in claims about its limitless ability to design, engineer, and, more importantly, manipulate matter as we know it to turn fiction into reality:

> Can you imagine making yourself invisible like Harry Potter, or a Klingon battleship? Or riding into space on an elevator?

> Nanotechnology may bring these and many other extraordinary ideas out of the story book, off the movie screen, and into reality – one day (Challener, 2008).

Such claims, which clearly set the sky as the limit for nanotechnology, run parallel to science fiction depictions of the emerging field as is evident in Neal Stephenson's much publicized novel Diamond Age in which nanotechnology-driven 'matter compilers' work like magic wands that can create just about any object that can ever be imagined. As Munshi *et al* (2007) have pointed out,

> the imagined futures of nanotechnology conjured up by nanoscientists, which attract billions of dollars for R & D from government and industry, are in fact, coterminous with science fiction, embodying Baudrillard's notion of 'hyperreality' (p. 441).

The French philosopher, Jean Baudrillard (2002) conceptualizes hyperreality to be a state where the real world and the fictional world collapse into one another. In one of his seminal works Simulacra and Simulations, Baudrillard described the Disneyland of Los Angeles as a space that captures hyperreality: 'The Disneyland imaginary is neither true or false: it is a deterrence machine set up in order to rejuvenate in reverse the fiction of the real' (p. 166).

The 'fiction of the real' is a key aspect of the discourses around nanotechnology. As some commentators have pointed out, many technoscientists promoting the cause of nanotechnology actually draw on the narrative techniques of science fiction. For example, Lopez (2004) argues that 'the central metaphor in [nanoscience and technology] discourse – nanotechnoscientists as master builders – provides a semantic link to SF [science fiction] narrative elements'. This central metaphor that portrays 'nanostructures as the building blocks of matter and the nanotechnoscientist as the master builder' attempts to convey the 'radical transformative powers that [nanoscience and technology] not only denotes but also connotes' (Lopez, 2004).

The fiction of the real can be, of course, both utopian and dystopian. The proclaimed limitless capacities of nanotechnology to manipulate matter as we know it has also opened up fears about the destructive potential of a technology without harness. It is a 'technology that is hard to control' and 'like a virus, a nanomachine can develop its own agenda that is part of, or becomes part of, its program' (Melzer, 2006, p195). This aspect of the emerging field has been captured by Michael Crichton's (2002) bestselling novel Prey in which self-replicating micro-robots create a world of grey and grim chaos. This novel illustrates 'the devastating consequences that result when cutting-edge technoscience joins hands with corporate greed and human fallibility' (Munshi *et al*. 2007, p441).

Human fallibility is indeed the most vulnerable spot in the discourses around nanotechnology for this is a field which is driving the world into what writer such as Hayles, Milburn and Fukuyama call a 'posthuman future'. Fukuyama's (2002) scenario of a posthuman future is constructed on the basis of biotechnology's potential to alter human nature and yet it is clear that nanotechnology has far greater potential to remove the concept of human in a futuristic world than biotechnology. As Patricia Melzer (2006) states

> nanotechnology comes straight from the labs of bioengineers and holds the promising/threatening potential for exploding existing paradigms, not only within the sciences, but also in our understanding of social orders (pp. 179-180).

Richard Calder's novel *Dead Girls* brings out the stark face of a posthuman future. As Melzer (2006) describes:

> Dead Girls is about dolls. Life-size, animated dolls – some fully artificial, others half human; some with no consciousness, others with a machine consciousness. All of them female, all sexualized. It is in the figures of the dolls that the underlying theme of Dead Girls manifests itself, the obsession with imitations of the 'real': counterfeit versus original, mechanical versus human, machine consciousness versus human consciousness, and the resulting dissolution of the category 'real' in the wake of a terrifying, quantum-based nanotechnology. (Melzer, 2006, p191)

If indeed nanotechnology will drive the world towards a posthuman future—or if our world is already posthuman—what then will be the status of human rights or indeed of human notions of privacy and control over mind and body? The 2004 version of the movie *Manchurian Candidate* does bring such issues to the forefront as it demonstrates how 'nanotechnology is used to re-jig the central nervous system of a key player in a political tussle' (Munshi *et al*, 2007, p. 442). As McKie (2003) writes

> If the optimistic grand narrative of Western progress is underwritten by Science, then science fiction consistently reworks that utopic tall tale with pessimistic and/or catastrophic outcomes (p131).

In many ways, therefore, it is science fiction that is leading the movement to regulate nanotechnology and creating the space to explore the ethical dimensions of a technology that claims to radically alter the world.

6.145.8.2 The Construction of Utopias and Dystopias

The dichotomized 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 utilized to capture culture and 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).

Perhaps the most (in)famous risk-related written pieces were Bill Joy's (2000) references to 'grey goo' scenarios and out-of-control nanobots, which along with the ETC Group (2003) may have contributed to Prince Charles' popularizing the ideas through news media opinion pieces (Radford, 2003). 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 Ludwig Fleck's thought communities of science. 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.

There is a continuing debate within science communication between those who see popularization as a weakened form of scientific dissemination of 'formal science' (ibid.) and those who see it as part of the process of communication. This conflict becomes more acute when fictive-orientated discussions are involved, such as dramatization for film or documentary, or indeed discussing technologies that are speculative.

Future-oriented narratives are common in media representations of nanotechnology, fictional and otherwise (ibid, Erickson 2008). Placing the domain of future possibilities and visions into contemporary discourse opens up a different type of conversation. Writers such as Hayles (2004) and Milburn (2005) refer to the transcendent power of nanotechnology, rather than its more mundane practical applications, and these themes are seen in science-fiction blogs, film and advertising. However, increasingly, the transcendence of future scenarios are brought into formal science or science educational spaces (Brake and Thornton, 2003; Thurs, 2007).

Speculative narratives and concerns from science fiction, fan fiction and comic-book popular culture and other forms of cultural imagination are part of what might be called the media practices (Couldry, 2004) which engage with nanotechnology, using embedded popular cultural understandings of a concept. In fact, these fiction-orientated arenas may deal most prominently with some sense of risk or concern, such as the 'grey goo' scenario. Rather than considering such concerns as outlandish and outside the terms of debate, understanding media practices of the 'cultures of nanotechnology' might focus away from traditional 'risk assessment' and instrumentalist ideas of public concerns about technology and bring public participation closer to the sites of innovation where publics feel they have a voice in the eventual policy and regulatory outcome.

While, we may heed the words of Arie Rip and Alfred Nordmann (Nordmann and Rip, 2009) in focusing on the inequities and issues associated with practical nanotechnology now without getting too drawn into future, unknowable ethics, it also useful to note the hyperreality of nanotechnology discourses (esoteric and exoteric) are constructed and described as the future here and now, and thus have 'clear and present dangers'.

6.145.8.3 Scenario Planning

Whereas the construction of scenarios by science fiction writers can seem to be an exercise to be indulged in by a few, whose products may have mass readership or viewership, planning based on scenarios can be useful for both governments and corporations.

Scenario planning has its roots in systems analysis developed by various think tanks after the Second World War. Scenario planning is a way to describe the current state of an entity and its environs and develop several hypotheses about the future of that entity, thereby enabling discussions about how that entity ought to evolve. The entity can be a school, a town, a metropolitan area, a province, a country, a group of countries, or a corporation, an industry focus group, an industrial regulatory agency of a government, or even a national or transnational CSO. Scenario planning helps in identifying and learning 'about the social, economic and political factors that engender and influence sociotechnical systems, and thus affect[s] the adoption of new technologies and their subsequent diffusion' (Farber and Lakhtakia, 2009, S3). The complexity of the future is simplified for analysis, with the understanding that different outcomes are possible, all based on some common pre-determined elements as well as on elements that differ from scenario to scenario.

Let us examine the power of scenarios. Imagine having to write a poem in iambic pentameter on the encounter of a mortal such as Ulysses with an airborne mode of transportation. The pre-determined elements are the meter, an ancient Greek hero, and a flying object with at least one seat. Whether the flying object is a living being or a manufactured object, whether it can seat one or more people, how is it powered, how far it can transport, and so on, are elements that will differ from poem to poem. Thus, these poems are scenarios which are hypotheses or even simulations of the future of transportation.

As Herbert Kahn wrote,

> [O]ne must remember that the scenario is not used as a predictive device. The analyst is dealing with the unknown and to some degree unknowable future. . . . Imagination has always been one of the principal means for dealing in various ways with the future, and the scenario is simply one of many devices useful in stimulating and disciplining the imagination. To the extent that particular scenarios may be divorced from reality, the proper criticism would seem to be of particular scenarios rather than of the method. And of course unrealistic scenarios are often useful aids to discussion, if only to point out that the particular possibilities are unrealistic (Kahn, 1990).

Small wonder then that the use of scenario analysis for better understanding of the social and ethical implications of nanotechnology is acknowledged in the Strategic Plan of the NNI (National Science and Technology Council 2007, p 31).

6.145.9 Conclusion: Nature and Nanotechnology

There is optimism in the realization that the ways in which nanotechnology and society interact is a growing concern at a strategic level. Large scale academic institutions are tasked with this, such as the Center for Nanotechnology and Society and the Society for the Study of Nanoscience and Emerging Technologies (S-NET). The NNI, under a new Amendments Act passed early during the Presidency of Barack Obama in the US, will look closer at the EHS issues (Library of Congress, 2009). Framing documents such as the EU Action Plan (European Commission, 2005) openly acknowledge that a greater diversity of stakeholders are required to govern the many processes of nanotechnology, with terms such as 'expectations' and 'concerns' appearing frequently. Back in 2000, the House of Lords began a process of inclusive S&T policy which resulted in various British policy documents recommending public consultation and involvement. Green nanotechnology innovation has recently been trumpeted (EuroNanoForum, 2009), which paints a more contradictory picture of the relationships between sustainability, environmental damage and repair regarding nanotechnology. There is a change from the original top-down proclamations about nanotechnology. But we must now ensure that regulatory processes are adequate and public engagement meaningful.

In this chapter, we have mapped out the complex social domains where nanotechnology discourse occurs, centered around health and environment in intent, but primarily driven by economics in deed. The scientific understandings of the risks to environment and health by nanotechnology have been described, as have been their associated social transformative processes, particularly in the context of an ecological 'masterframe' within society. We have looked at the economic promise of nanotechnology, and the areas of economics affected, at product development and military applications. We have opened out the discussion further to look at the many political dimensions associated with nanotechnology governance, and the problems of public engagement. Finally, we have considered carefully the increasingly complex relationships between future narratives of fiction and comparative narratives of nanotechnology progress.

The central theme of our argument is that it is impossible and indeed unnecessary to separate cleanly the technoscientific aspects from the social aspects, particularly where public engagement towards a sustainable and responsible development of nanotechnology is required. The many nodes and sites of discourse we draw on show how many registers can be used when talking about nanotechnology. There are also common patterns in the concerns raised about nanotechnology's relationship with nature and the power implications of large scale governance of a small scale technology. There needs to be public input to strategic development; however the promise of upstream communication has been tempered by criticism, some of it coming from within the social action communities themselves, particularly of the challenge of meaningfully creating the space where upstream input might occur, unprotected by strategic framing of activity outputs by their designers and facilitators. The theoretical framework drawn on here, from Giddens, Beck and commentators on ecological modernization, would suggest that the new landscapes of science and technology very much depend on social networks, reflexivity of strategic framing processes, and both shared and conflicting understandings of risk. This is even more so the case in the liminal spaces that are created between the many disciplines involved in nanotechnology projects. But there can be many shared practices and goals between these spaces, for example the urgent need by both NGOs and green nanotechnologists to address climate change. However, true sustainability takes into account Northworld/Southworld dimensions as well as the publics marginalized locally. All communities, whether of knowledge or of habitation, are involved in this 'futurescaping' or 'imagineering', this constructing of multiple worlds of possibilities through scenarios; literally, 'telling stories about the future' (De Geus, 1997, p46). Although innovation is seen by many to be a concept detrimental to the process of knowledge construction around nanotechnology, caught up as it is with the corporate confines of technoscience, there are instruments available to us to at least see through a responsible innovation for nanotechnology that is sustainable, in all senses of the word, across networks, societies and our future personal lives.

The fields of nanotechnology promise so much that is exciting. If nanotechnology delivers on its promise within the social sciences as a space for innovative public realization and empowerment, that also applies the lessons learned from emerging technology debates of the past, then it truly will be revolutionary.

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