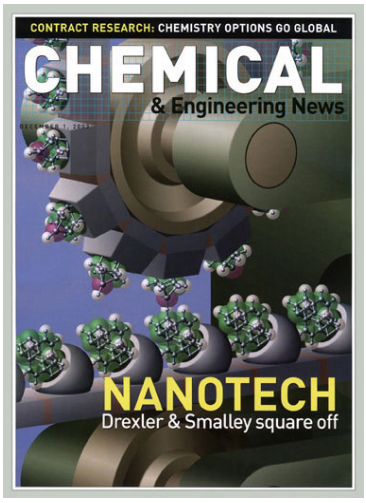
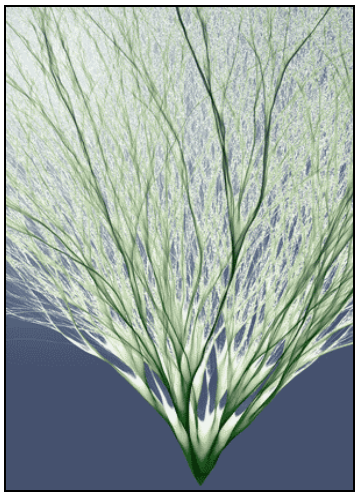
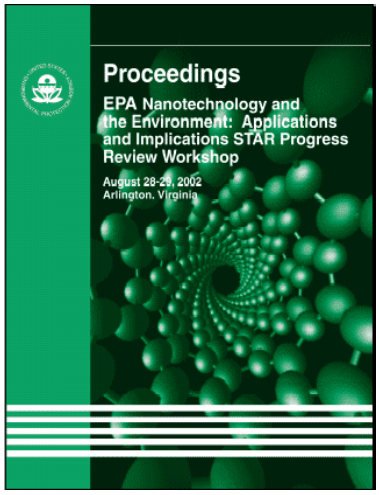
Making Small Talk:

Discourses of Environment in the Formation of the U.S. 21st Century National Nanotechnology Research and Development Act







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ABSTRACT

Environmentalist views of science and technology have always been complex. In the last 20 years, a set of theories and practices under the label of ecological modernization recasts the relationship between economic growth (usually associated with production and material growth) and the environment. Science and technology are recognized as tools for defining local and global problems and solutions, not simply as their cause. The purpose of this paper is to understand the framing of environmental concerns and definitions within the emerging field of nanotechnology in the context of ecological modernization theories of regulation. The approach, based on Maarten Hajer's (1995) work, is a discourse analysis of the practices of defining environment in nanotechnology through storylines and discourse-coalitions, using interviews and the transcription of the hearings on societal implications of nanotechnology in the U.S. House of Representatives during the formation of the 21st Century Nanotechnology Act (2003a). One storyline stresses the competitive benefits to the U.S. and the resulting applications that in turn will improve the environment. The main environmentalist storyline focuses on the handling of potential toxicity and calls for a moratorium on research and development. Though a storyline stressing potential environmental applications exists, it is equated with 'business as usual' and calls for the continuation of research. The paper addresses how problem closure in policy-making is achieved, and how storylines could bring about "reflexive" institutional arrangements.

TABLE OF CONTENTS

1 Introduction

"Giving humanity a profound technological advance is like giving a revolver to a baby." (Bell, 2004)

People accept a sense of helpless trust in innovation despite unknown consequences, especially when the potential benefits are great. Nanotechnology is one such example. Defined as the manipulation of matter at the nanoscale, nanotechnology spans disciplines of physics, biology, chemistry, engineering and medicine. Materials at the 1-100 nanometer scale begin to exhibit quantum effects. Understanding this behavior is the task of basic nanoscience research. Much about the properties of nanomaterials and techniques for control at the nanoscale is unknown. However, transformations are predicted in areas of health diagnostics, environment, electronics, energy and manufacturing. Policy-makers, scientists, government agencies, industry and finance are all involved in the balance between research and precaution. How do regulatory regimes that are tasked with solving existing environmental problems face a technology that has immense promise and as yet unknown risks? Is there a way to tackle those risks and still realize the potential? Do we have the systems in place to handle such a task?

These questions set the scene for more targeted inquiries throughout the paper, which is divided into three main sections. First, background on nanotechnology, policy and media sets the scene. Second, the literature review outlines and critically discusses the theoretical argumentative approach of storylines and discourse-coalitions based on

Maarten Hajer's (1995) *The Politics of Environmental Discourse*. This section includes a critical discussion of risk society, views on science studies and ecological modernization. Third is the findings and discourse analysis itself. How did the definition of nanotechnology come to be what it is today? How was science understood and used? Who is responsible for defining and regulating nanotech? The discourse analysis aims to reveal how meaning is given to physical phenomena such that a common understanding, or truth, emerges, and subsequently problems of policy can be defined and solved. To identify the storylines and discourse-coalitions, we follow their emergence in the process of writing and approving the 21st Century National Nanotechnology Research and Development Act, signed into law on December 3, 2003.

2 Background

2.1 Nanoscience and Nanotechnology

Possible applications of nanoscience research are purportedly endless, and include catalysts, superconductors, composites, nanowires, and quantum dots for cancer diagnosis. The promise of drastic changes to many of our current energy-intensive or pollution-creating production processes drives multi-agency research. Environmental sensors, pollution prevention through 'green' manufacturing and improved energy efficiency, conduction and storage are all of particular interest to the EPA and DOE (Interviews #7,14).

Nanomaterials are used today in stain-resistant trousers ("nanopants"), coatings for self-cleaning windows (photocatalysis) and in sunscreens and cosmetics. Replacing organic solvents with CO2 in industrial processes is one EPA success (Interview #14). Energy-related short-term applications include separator plates in batteries, hydrogen storage, fuel cells and solar cells (Nanoscience Research for Energy Needs, 2004, Bennett, 2004). Future environmental applications include fuel additives and catalysts to clean up waste streams, green chemistry to eliminate toxins at source, and nano-information systems to monitor life-cycles and manage disposal (Karn, 2002, EPA, 2004, Masciangioli, 2003).

Important nanoscale substances currently under research are carbon nanotubes (CNT) and 'buckyballs.' Discovered in 1991 by Sumio Iijima, CNT are only a few nanometers across

but are as strong as diamond. Buckyballs, carbon 60, or fullerenes – named in the mid-1980s for Buckminster Fuller– are 3 dimensional sphere-shaped structures potentially for use in electric circuits or drug delivery. Growing these consistently, or manufacturing them with precision, will be the most important hurdle to overcome in developing applications. How nanomaterials react in humans and the environment throughout their life cycle, and how to name and categorize them, is important for regulation. For example, graphite is already regulated in the U.S. under TSCA, but displays different properties in its CNT form.

2.2 Policy Background

In January 2000, The National Nanotechnology Initiative (NNI) was announced by former President Clinton, who made it a research priority for the administration. Led by Dr. Mihail Roco of NSF, also Editor-in-Chief of the *Journal of Nanoparticle Research*, staff members of interested agencies had been meeting regularly to discuss nanotechnology since 1996. In 1998, Roco was officially appointed head of an Interagency Working Group on Nanotechnology (IWGN). The IWGN published a worldwide study of the competitive nanotechnology climate and the research vision for the next decade (Roco, 2004). After establishing the NNI in 2000, the IWGN was reformed as NSET (Nanoscale Science, Engineering and Technology), now an official subcommittee of the National Science and Technology Council (NSTC) Committee on Technology (CT). 20 agencies now participate in monthly NSET meetings. According to the National Nanotechnology Coordination Office (NNCO), this is very much an agency-led initiative (interview #1).

The 21st Century National Nanotechnology Research and Development Act (Public Law 108-153) was signed on December 3, 2003. The house version of the bill, H.R.766 was introduced in February 2003 and was referred to the House Committee on Science. The Senate version, S.189, was referred to the Senate Committee on Commerce, Science and Transportation. Referrals to multiple committees usually extends the time it takes for a bill to pass, therefore other committees such as Energy and Natural Resources or Environment and Public Works were not involved.

Before mark-up of H.R.766, a full committee hearing on societal implications of nanotechnology took place on April 9, 2003. On May 1, 2003, the Senate Commerce Committee hearing focused on the progress of NNI and on issues of transferring of basic nanotechnology research to government and commercial applications.

H.R.766 passed the house as a science bill, therefore with more focus on societal implications. S.189 was dominated more by commerce interests, and it was this version that became the final bill. Various amendments proposed in the House that did not make it into the final language were as follows: to put 5% of funding toward societal and ethical implications; to ensure public oversight through citizen advisory groups; to ensure public participation through citizen panels; and to specific programs to provide sustained support for research toward inexpensive and clean energy production.

Some of these proposed amendments were the direct result of the National Academy of Sciences review of NNI and the resulting recommendations reported in *Small Wonders, Endless Frontiers* (NAS, 2002). These included that OSTP create an independent advisory board, properly balance short and long term funding as part of strategic goals, and restructure funding to ensure societal implications become a "vital" part of NNI. A desire to abide by the spirit of these recommendations is apparent from those interviewed, but proposals especially by the House to target %5 of funding to societal research and ensure an independent advisory board were left out of the law.

Differences between House and Senate bills are either worked out in conference – when a set of conferees from each side make formal statements to agree on final language – or in 'pre-conference,' during a set of meetings between staffers. In this case, differences were discussed in pre-conference and agreement was reached on a substitute amendment for H.R.766 that would then go back and pass the House. Pre-conference is common for science-related bills that are not controversial.

Public law 108-153 (2003a) created provisions for an interagency National Nanotechnology Program (NNP) with specified activities and a coordination role for the NNCO. NNP is designed to enable nanoscience basic research through user center facilities and laboratories mainly handled by the DOE. The aim is to understand basic properties at the nanoscale, improve metrology, advance U.S. competitiveness and accelerate nanotechnology application transfer to the private sector. A research program to identify "ethical, legal, environmental, and other appropriate societal concerns" should

be "widely disseminated" (2003a). Environmental affects are understood here in a number of ways, including health and safety in laboratories, positive environmental applications that can be marketed, and as negative 'environmental implications.'

Progress is to be monitored by an advisory panel. Representative Mike Honda in fact proposed an Advisory panel in a separate bill, but it was agreed in pre-conference that the President's Counsel of Advisors on Science and Technology (PCAST) would take on the role. Additionally, a National Nanotechnology Preparedness Center is meant to guide responsible development.

Though allocations of funding for nanotechnology will increase only slightly with the new law, the bill gives structure, focus and legitimacy to the existing funding. NNI is an exception in a year when the president's R&D funding requests increase Homeland Security and defense budgets, but decrease funding to most other agencies. As one of three interagency research initiatives currently funded by the administration (along with Information Technology and Climate Change), the NNI has seen double-digit increases in annual funding over the last 4 years (Davey, 2004). Within the U.S, funding is authorized at over 3 billion dollars in the next 5 years. Outside the U.S., many countries including Japan, Germany, China, India and Israel have nanotechnology programs. Market size estimates are in the billions to trillions of U.S. dollars by 2010.

Funding is broken down into 5 modes. The first includes broad and basic science research. The second focuses on "Nine Grand Challenges" with a quick return on

investment and includes specifically nanostructured materials, nanoscale manufacturing, bio-explosive detection, nano-electronics, metrology, health care, energy conversion & storage, robotics, and environmental improvement processes. The third research mode involves conducting multidisciplinary research focusing on educating a new workforce, a fourth funds infrastructure, and a fifth provides funding for societal implications research (Merzbacher, 2004, Davey, 2004).

2.3 Media Background

Media coverage and exchange is a sub-political process that not only informs the public, it informs the actors in the nanotech world, enabling their virtual interaction. Mainstream news sources tend to focus on industry news, scientific studies and environmental and health effects. Prophesies of a nanotech revolution make good headlines, and so do studies of risks. Buckyballs causing damage in fish, nanoparticles passing the blood barrier and studies on rats dying from CNT inhalation were all covered. These studies are not of huge concern to scientists given that risk is determined not only by toxicity, but also by levels of exposure, which as yet is very minimal. In the last 6 months, about 20% of coverage in major news stories mention "risk" which could also be financial risk. "Safety" and "ecology" are mentioned in fewer than 1% of stories (see Appendix II). The most recent coverage concerned The Royal Society Report on Nanotechnology (2004), which called for some nanoparticles to be treated as unique substances by policy-makers.

Forbes/Wolfe provides a good combination of the hype and the cautionary language used in finance. The message is that nanotech is precipitating an industrial revolution, and that you too can be a Rockefeller. "…I predict in this next era with precision molecular and atomic control we will live through exponential economic growth and technological progress" (Wolfe, 2003).

Small Times (online) reports on nanotechnology, particularly on industry, but is not averse to including critical commentary. In a 2004 opinion piece, Howard Lovy wrote that "for now, it is commerce that is driving the nanotech vision, redefining "real" nanotechnology to suit what is best for nano business." (Lovy, 2004b)

Howard Lovy has recently left Small Times to concentrate full time on freelance projects and his blog, Nanobot. According to statistics covering the July 19-August 7 time period, Howard Lovy's blog received over 150,000 page views, and top visitors included technology companies in the United States, NIH offices, U.S. House of Representatives Office, the U.S. Air Force, and the European Union Office in Luxembourg. (Lovy, 2004a).

Nanotechnology is recognized internationally and in the U.S. as the "next small thing" (Rejeski, 2004) though Rejeski sheds doubt on how revolutionary this technology really will be. It is still unclear exactly how its responsible use will be ensured. Both the benefits from applications and the risks are potentially very great.

2.4 Methodology

Almost every news article, website, publicly available conference report or congressional proceeding contains valuable material for understanding storylines and reified meanings. Because discourse-coalitions are not only based on actual meetings between actors, but are reinforced and produced within sub-political processes and feedback to belief systems, I did not want to ignore the information actors rely on. I focused on the media mentioned in section 2.3, as well as on personal communications and un-structured interviews (see Interviews). Interview questions were tailored for the subject, and were designed to get the views of the participant on what was the "correct" definition of nanotechnology, its potential and its risks, as well as the best approaches for regulating it. In introducing myself I necessarily spoke of environmental policy, and this may have influenced the responses.

The transcript of April 9, 2003 Full Science Committee Hearing on The Societal Implications of Nanotechnology became the focus for understanding storylines and discourse-coalitions. (I relied on http://thomas.loc.gov for all Congressional documents, including the transcript). Four speakers were involved; Ray Kurzweil is an inventor and businessman; Christine Peterson is the president and co-founder of the Foresight Institute; Dr. Vicki Colvin heads the Center for Biological and Environmental Nanotechnology (CBEN) at Rice University, which is taking on risk assessment studies of nanomaterials; and Dr. Langdon Winner is a political science professor in the Department of Science and Technology Studies at Rensselaer Polytechnic Institute, Troy,

New York (Committee-on-Science, 2003). (For more biographical information, see Appendix I). Those who questioned the speakers included Chairman Sherwood Boehlert (R-NY), Dana Rohrabacher (R-Calif.), Michael Honda (D-Calif.), David Wu (D-Oregon).

I traced the storylines according to Hajer's (1995) method (overview p. 164). My own summary of the environment-in-nanotechnology discursive space was influenced also by Dryzek's (1997) outlines of discourses of environment by their ontology, relationships between agents, and key metaphors.

3 Theoretical Approach and Literature Review

Environmental problems challenge the efficacy of existing political processes, which in turn challenges us to find new approaches for understanding policy-making. When environmental problems are potential byproducts of the development of converging or emerging technologies, it is worth asking strategic questions about science funding and technology development, and larger questions about policy-making. Why do policy makers write one piece of legislation and not another? Allocate funding to some agencies and not others? And in this case, which definitions of nanoscience and nanotechnology will be used or rejected by those formulating policy?

One way to answer these is to draw on a pluralist framework whereby organizations and interested actors are understood as competitively using the resources available to them to wield influence. Of Weale's (1992) four idioms of policy analysis, this falls into the institutional vein. The institutional idiom is a middle-range analysis between rational choice and systems approaches, and contains some elements of each. It is familiar because it is a kind of systematized common sense (Weale, 1992 p.54), where actors are bombarded with information as they make choices within bounded rationality.

Instead I will use a discourse approach (Weale's fourth idiom). The purpose is twofold. First, discourses help reveal how belief systems and institutions interact such that problems come to be meaningfully understood and action by policy makers legitimized. Policy is not created without sub-political processes – local agitation, media, international influence or innovation – influencing what policies are adopted. Though environmental policy decisions may lay claims to rationality through which its legitimacy is secured (Rydin, 2003), within the discourse idiom, claims to rationality can be deconstructed and far-reaching movements of power (see Foucault's disciplines, Foucault, 1984) – are distinguishable. Therefore understanding socio-cognitive construction of problems is the main focus. The second benefit of a discursive approach is that it allows us to examine whether discursive practices lead to 'reflexive' ecological modernization, or the creation of new institutional arrangements in environmental regulation.

This section will first look at Hajer's (1995) *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process*. His argumentative approach through

identifying storylines and discourse-coalitions will be explored. His discourse definition combines Foucault's more structural elucidations of the workings of power with a more instrumental social science approach concerned with actors and their interests. Hajer draws on Ulrich Beck's Risk Society (1992) and technocratic and reflexive ecological modernization. I will explore definitions of environmental crisis in the risk society further by bringing in science studies, particularly views of co-production of scientific and technical knowledge. Ecological Modernization Theory (EMT) will be discussed to situate 'reflexive' ecological modernization within the current literature.

3.1 Argumentative Approach

Regulation requires that problems be defined through practices of discursive closure that rely on social accommodation and conflict resolution, both of which are necessary for problem closure (Hajer, 1995 pp.22-23). "…Policy-making can be analyzed as a set of practices that are meant to process fragmented and contradictory statements to be able to create the sort of problems institutions can handle and for which solutions can be found…Hence policies are not only devised to solve problems, problems also have to be devised to be able to create politics" (Hajer, 1995 p.15 ,see also Weale, 1992).

Social constructivist approaches interrogate the process by which some topics are discussed out of or into politics. Hajer takes the social constructivist approach as one starting point to develop an argumentative analytical framework for the study of political processes. He proposes to analyze the ways in which certain problems are presented,

differences played out, and social coalitions form around specific meanings. He also holds onto a clear institutional dimension to understand how meanings are produced in context. Practices of drawing on ideas and categorizations are what give meaning to physical and social realities (Weale, 1992 p.44).

Hajer's approach draws on the work of Foucault, who shifts the emphasis from institutions to 'disciplines' where knowledge and power join (Dreyfus and Rabinow, 1982). Thus discourses are not defined as passive language used by actors. Within Foucault's approach the role of the discoursing subject is set within constraining and enabling forces that have the effect of prohibiting or allowing certain framings and actions (see also Giddens, 1984). Hajer categorizes Foucault's 'discursive order' as structuralist, where the agency of an actor comes from the interaction of the agent with the structure. The extent of the subject's agency is ambiguous.

At the other extreme is a view of discourse on the level of interpersonal communication, or social-interactive discourse theory. It corrects Foucault's theory in two ways. First, it sees actors as "active, selecting and adapting thoughts, mutating and creating them, in the continued struggle for argumentative victory against rival thinkers" (Billig, 1989 quoted in Hajer, 1995 p. 54). It recognizes that speakers can argue a persuasive case (logos), rely on a reputation (ethos) and can play on the emotions of the speaker (pathos).

The second correction has to do with the perspective on social change and permanence. This 'immanentist' view is that rules and legitimate modes of expression have to be

constantly "reproduced and reconfirmed in actual speech situations" (Hajer, 1995 p.55). The focus on the text would be too instrumental for Foucault, but for Hajer these corrections help reveal how actors do navigate actively through institutions, and how they routinize cognitive commitments to reinforce permanent meaning (Hajer, 1995 p.56).

Are Hajer's meso-concepts workable? They are combining structuralist approaches with exactly the rational choice elements within an institutional approach that Foucault seeks to move away from. Foucault does not accept that meaning or belief is separate from the structures within which agents practice. (Dreyfus and Rabinow, 1982 p.xxvii). By using Harre's social-interactive approaches (Harre et al., 1999 see especially ch.3), Hajer does accept that actors can manipulate language and thus find something meaningful. Can the approaches readily be combined?

Recognizing the merits of both the structural aspects and textual analysis may contribute to theoretical fuzziness, but in a practical case study, it is difficult to not recognize some actively discoursing subjects who push on institutions even as those institutions pull on them. Foucault's Panopticon (Rabinow, 1984), the diabolical web of power, surveillance and oppression, is useful conceptually. But Hajer's creation of middle-range concepts allows us a method to identify actor agency as well.

Storylines: In order to construct the storylines, we look at sub-political processes, recurring tropes, and the creation of symbols, images and metaphors that are evoked by actors. Agency is not only result of institutional power, nor is discourse the manipulation

of discussion or rhetoric. Language is "constitutive" of subjects (Hajer 1995, p. 51); when actors draw on storylines, they reinforce the discourse and they are in turn subject to it, thereby limiting the problems that are defined and the choices for solving them. Storylines are thus narratives that are regenerated as actors draw on discourses to give unifying meaning to social interactions and natural occurrences. A storyline becomes a form of agency.

Discourse-Coalitions: Moving beyond Sabatier's "advocacy coalitions" (Sabatier and Jenkins-Smith, 1993) and an individualist focus, discourse-coalitions refers to the way that individual agency and structural contexts interact to create meaningful definitions. Language is not a passive tool, but integral to the creation of preferences or ideas of reality in the first place. New discourses may therefore change what is considered possible. Moreover, belief systems are not something external to the discourse, but cognitive shifts occur though interaction that feed back to those systems. The argumentative approach to discourse is important to politics because the definitions arrived at through such a process create political change. Hajer does not specify here the difference between core and peripheral beliefs, as does Sabatier, therefore leaving open the degree of institutional change that is possible, perhaps beyond Heclo's policy learning (see Sabatier, 1986).

Storylines and discourse-coalitions allow fragmented discourses to resolve into common understanding. Where storylines interact, one generally dominates so that discursive closure is possible. "Discursive dominance or hegemony is thus seen as an essentially

socio-cognitive product" (Hajer, 1995 p.60) Plausibility, a necessary element to discursive power, is therefore not objective, but relies on credibility and accessibility. In order to assess discursive hegemony, we look for actors drawing on elements of a discourse to make a case, and shifts in concrete policies due to the discussions (Hajer, 1995 pp.59-61).

3.2 Risk Society and Science Studies

Risk society (Beck, 1992) frames ecological problems as crises that are the consequences of industrial society itself. It thus questions the ability of the institutions that supported industrial society to solve the resulting problems, and casts doubt on science that legitimized past ineffective solutions. Reflection and uncertainty are both characteristics of 'reflexive modernization' theory.

In his 1999 "World Risk Society", Beck elaborates two interpretations of reflexive modernization. In the first, emphasis is on knowledge reflec*tion* of the consequences of modernization, and the second is tied up with unintended consequences of it, or *unawareness* (reflex*ive*) (Beck, 1999 p.109). He identifies aspects of unawareness as selective knowledge, uncertainty, mistakes or errors, inability and unwillingness to know (Beck, 1999 p.122). He believes reflexive modernization can be limited to modern societies exclusively, whereas the knowledge reflection type could also describe any pre-modern society that amasses knowledge and learns from its mistakes.

Reflexive ecological modernization is characterized by "a deliberate social choice out of alternative scenarios" (Hajer, 1995 p.280), which seems to draw more on reflec*tion*. However, Beck associates lack of knowledge leading to "decision-making in uncertainty on all sides" (Beck, 1999 p.122) with the reflexive unawareness phase of modernity. The fact that Hajer examines how sub-political processes edit knowledge or hide contested knowledge claims means that Hajer's approach is also reflexive in this sense.

But if the knowledge is as uncertain as Beck claims, how could he also claim that we have environmental problems? The sociology of scientific knowledge is critical of empirical facts and sees science processes as being inevitably effected by the social: individuals' experiences, the institutions that financially support science, the peer-review structure, and a reductionist methodology (see Wynne, 1996, Irwin, 1995). Science is often seen as overwhelming other kinds of specific knowledge not because of its inherent truth, but because of its claims to universality. Social constructivist approaches are often criticized for saying that physical problems are entirely politically constructed. Radical post-modern critiques of ecological modernization deny the objective existence of universally relevant ecological problems (Mol and Sonnenfeld, 2000b). As for those who create the knowledge we rely on to define problems or solutions, for Foucault, the 'specific intellectual' (scientists and experts) are "given authority because their work and our fate are intertwined, not because they have any special claim to represent reason" (Rabinow, 1984 p.23). Yet Beck's reflexive modernity is grounded in a certainty that problems, backed up by scientific claims, do in fact exist.

Beck's apparent contradiction is examined further in science studies. Murdoch and Clark (1994) describe the alternative as "hybridity, where the "divide" of social and nature is overcome. Latour (1993 p.4) would rather call the realm of human and nonhuman interaction the "collective" and describes the word "social" as that which social scientists have decided to label the human side of this collective. Hannigan's (1995) description of social constructivism recognizes the existence of competing certainties, rather than one definition of the ecological crisis.

Nanotechnology itself has not been identified as an "ecological crisis" or problem, but it is understood as an enabling technology that could potentially follow in the risky footsteps of nuclear or GMO debates that led to the mistrust of entire industries. It is understood as a solution to other ecological crises currently defined in society, especially climate change. Therefore, for our purposes, ecological problems do exist, and we do not discount findings of science as irrelevant. Rather, a more nuanced is a view is taken, that knowledge is co-produced through the interactions of nature and society, which are not clearly separable.

Two main points are important here. The first is that science legitimizes certain kinds of power and expertise, but marginalizes equally legitimate, culturally-based knowledges. Jasonoff (2004) explores how "…co-production offers new ways of thinking about power, highlighting the often invisible role of knowledges, expertise, technical practices and material objects in shaping, sustaining, subverting or transforming relations of authority" (Jasanoff, 2004 p.4). Co-production is distinguished as constitutive or

interactional. The former looks at creating permanence, especially where emerging knowledge is solidified either in the laboratory or outside it, and the latter is concerned with accommodation through interaction between social and scientific practices (Jasanoff, 2004 pp.18-19). Relating this back to Hajer's two functions of problem closure, discursive closure and social accommodation, we see that co-production of knowledge is concerned with similar practices whereby credibility and trust evolve, which in turn legitimize a certain problem-solving course. Important to note for the case of nanotechnology, risk assessment techniques that are understood as an objective fact-finding process should be recognized as part of social and political processes (White et al., 2004).

The second point is that whether ecological problems are the result of scientific or social processes (or co-produced, as is contended here), controversies will increase rather than decrease over a process of defining 'truth'. Therefore, at the beginning of defining a new 'problem' we should not discount the absence of overt conflict (Latour, 1985). What happens when conflict and ecological crisis are not immediately apparent, but are emerging along with the development of the technology itself? One major assumption of risk society theories is that if we don't see vocal protest, then no problem exists (Wynne, 1996). Wynne shows that there may be an underlying mistrust and impotence in the face of what government and industry are doing. Silence comes from the fact that the public knows that they have no choice but to rely on the industry and government decisions that shape their lives.

Public surveys on nanotechnology by the University of North Carolina show that 80% of respondents don't even know yet that this technology exists. This would refute Wynne's observation because clearly in this case no protest is equivalent to no knowledge. However, if the public has heard of nanotech, though generally optimistic about the science, 65% do not trust business leaders to adequately protect public health (Austin, 2004). Though there is not yet an overt conflict, the seeds for that conflict lie in mistrust.

The misunderstandings stemming from a knowledge divide can be illustrated using Latour's (1999) analogy that scientists and the public or the "mob" are at opposite ends of a bridge, with social scientists interpreting in between. However, science is influenced by opinions, choices of where to allocate funding, potential market applications, and many other social concerns. The public is not unreasonable and mob-like unless they are confronted with a science that pretends to ignore its social foundations. Thus adding realism to science (Latour, 1999) should not undermine its claims to truth.

3.3 Ecological Modernization Theory

Within two main directions of ecological modernization theory, descriptive and prescriptive, Mol and Sonnenfeld (2000) situate Hajer in the first category because of his interest in social and institutional transformations. EMT in the prescriptive sense is more normative and involved with outlining physical change in production processes toward integrated economic and environmental win-win scenarios. Early EMT was criticized for its technological optimism. Later it has become tempered by a more nuanced view of

science and technology, and it is this latter phase that engages with the risk society dilemma (Mol and Sonnenfeld, 2000b).

Both of these "phases" or understandings are apparent in the nanotechnology case, and they are not incompatible. Hajer terms these the techno-corporatist and reflexive ecological modernization. The first puts experts in charge of finding universal approaches and solutions. The second stresses finding reflexive institutional arrangements that recognize "the socio-cognitive basis of discourse-coalitions" (Hajer, 1995 p.287).

I call the first "accidental" or "passive" ecological modernization, which can be difficult to distinguish from traditional or pragmatist environmental policy approaches. Though some have criticized this more passive type as misunderstanding of the definition of ecological modernization (Murphy, 2000), it is in line with the transformations described in ecological modernization. For example, science and technology are seen as solutions not just causes of the problem, and there is an increasing importance of markets (Mol and Sonnenfeld, 2000a). What is also apparent even in the passive sense is that it is no longer credible for environment and economy to work against each other. Dryzek (1997 pp.147-149) cites Christoff's (1996) definitions of weak and strong EMT to show the range of interpretations ; the former is a way of securing competitive advantage, while the latter includes open-ended possibilities for institutional change.

Eco-modernist discourse relies primarily on scientific and economic rationality (Rydin, 2003). Even when facts are only acceptable, as Wynne (1996) suggests, because they are

based on a powerful lack of other options, facts must still be used to legitimate action. How to reconcile this with the view that later phases of ecological modernization take on the risk-society skepticism of science? By drawing on passive and reflexive understandings of ecological modernization, I will show how actors perceive the use of science by institutions. The actors involved do not need to consciously perceive the nature/culture co-production of science as has been outlined above.

We are looking for reflexivity in institutions, which relies on an analysis of sub-politics and trajectories of technologies. We are not advocating prescriptive work so much as making explicit the activities that produce knowledge, and understanding patterns there. *"The idea of "endogenous future" is midway between attempts at prediction (which are always precarious) and the suggestion that everything is still possible (and it is just a matter of actors deciding on what they want to work towards). Actors will always take enabling and constraining factors in the situation into account, but Constructive TA assumes that it can add to this because of a broader & deeper understanding of sociotechnical dynamics." (Rip, 2004)*

3.4 Summary

Hajer's approach looks for problem closure through discursive closure and social acceptability. He looks for how environmental problems can be framed so that they may fit within existing institutions or necessitate institutional change, and if they are interpreted as a process of structural change that is beyond human control. In the

development of storylines, the use of scientific knowledge and the definition of the ecological problem or crisis can be one of the major sources of conflict and disagreement. Discursive dominance allows actors to avoid confrontation through the emergence of acceptable meanings. Storylines can be eco-modernist in the passive or reflexive sense. In the passive sense, a need to pay attention to environmental issues is recognized. In the reflexive sense, discursive practices make new institutional arrangements possible.

4 Findings and Analysis

Throughout the defining stages of nanotechnology, there have been competing ideas of which is the appropriate direction for research and development (R&D), and some became the "right" paths. Overt controversy was rare in the political process of formulating the Nanotechnology Act. Discourse analysis can reveal the workings of power where no outright conflict has taken place. Our aim is to understand not just what the environmental issues of nanotechnology are, but how those came to be meaningfully understood by actors who will in turn use these definitions to define "environmental" concerns of nanotechnology. I will first outline basic idealized storylines. Then I turn to how credibility coalesces as actors draw on discourses to form storylines and discourse-coalitions, bringing one definition to a hegemonic position whereby problems are identified and solutions proposed. Specifically, this is aided by looking at the historically significant conflicts around science, powerful actors, the role of science in the hearings,

and institutional changes. Finally, I address reflexive eco-modernist potential and arrangements.

4.1 Long-Term Preparatory Storyline

The practice of defining nanotechnology began with Richard Feynman's 1959 presentation "There's plenty of room at the bottom" when he enticed a new generation of scientists to enter the field. "We can arrange atoms the way we want, the very *atoms*, all the way down!" he said provocatively (Feynman, 1959).

"Engines of Creation" (Drexler, 1986) also envisioned stacking atoms from the bottom-up, tapping into nature's ability for self-replication. Replicators would be able to make copies of themselves, growing into machines just as ribosomes and proteins work to build molecules and cells from DNA blueprints. The positive implications of this are extending human life or transforming manufacturing, and the dangerous side of this is out-of control self-replication, now known as the "grey goo" scenario. In contrast, the processes of manufacturing known as "top-down" that have been with us since early humans chipped rock to make tools (Economist, 2004) are polluting and harmful to human health.

Nobel Prize winner Richard Smalley and Eric Drexler have been engaged in a scientific debate over the possibility of replicators and the validity of the science behind Drexler's vision. Recently Drexler published a paper defining the difference between replicators and bottom-up "assemblers" which would be easier to build and not prone to grow into grey goo (Drexler and Phoenix, 2004). Though not an admission that replication is

scientifically impossible, just that they would be overly expensive and complex, the grey goo scenario, popularized by Michael Crighton's *Prey*, has been rendered science fiction. Instead, like a miniature factory, nanoassemblers would build parts in a more controlled way. This is molecular manufacturing or molecular nanotechnology (MNT).

The long-term view needs the vision but cannot afford the science fiction. Discoursers use "visionaries" to positively motivate new scientists to enter a field, such as in Feynman's speech, but "science fiction" when it predicts something horrific like grey goo. Co-founder of Sun Microsystems, Bill Joy, wrote a now widely cited article in Wired on "Why The Future Doesn't Need Us" (Joy, 2000). He reflects on who is in control; the technology and science or the humans who use it. This sits uneasily with Drexlerian optimists who call for more research.

Storyline summary: Potential uses and abuses are great, so our research must focus on responsible management of the most imaginative, long-term possible applications, and we should prepare (militarily if necessary) for these. This touches on what it is to be human, and on our moral position vis-à-vis science and technology.

4.2 Passive Ecological Modernization Storyline

Drexler's shift in focus comes at a time when members of U.S. agencies are also fascinated by the "revolutionizing" capabilities and commercial opportunities of nanotechnology (Siegel et al., 1999). Roco, nanotechnology senior advisor at the NSF

since 1995, explains: "We move the whole foundation of industry and medicine and environment from macro and micro, where the properties cannot be changed, to nano, where all these properties functions can be changed easily if you know how to do it. Basically this is the reason we call it the foundation for a new industrial revolution…" Roco distinguishes his definition from Drexler's by saying "we have a definition that defines the field in such a way that the work that was done 20 years ago is not part of nanotechnology"(Interview #10).

Bottom-up manufacturing from the long-term storyline is kept here, but only in its most positive twist. Scientific American's "Understanding Nanotechnology" calls the "grand vision…assembling complex machines and circuits atom by atom" (Roukes, 2002 p.19) but asserts that nanoscience is still in its infancy and therefore is not unsafe. The definition of nanotechnology should stress the under-evaluated good impacts rather than the over-evaluated grey goo science fiction scenario (Roco, 2003 p.182).

This storyline began incorporating the environment and health applications as well as the commercial benefits. In a 1995 presentation "Nanotechnology and the next 50 years", Richard Smalley described in detail the problems of global warming and increasing populations demanding more and more energy, and asserted that "the answer to many of our most pressing problems, to the extent these answers are possible in this universe, will some way or another be found… on this nanometer length scale" (Smalley, 1995).

The first paragraph of the Supplement to the President's budget published by the NSET and the Nanotechnology Coordination Office (NNCO) draws on the excitement:

> *Imagine a single area of scientific discovery with the potential to enable a wealth of innovative new technologies across a vast array of fields including healthcare, information technology, energy production and utilization, homeland security and national defense, biotechnology, food and agriculture, aerospace, manufacturing, and environmental improvement. Nanoscience…has this potential.* (NSET, 2004)

The term 'societal implications' has evolved to include environmental implications in addition to ethical, business, legal, and equity issues. MNT definitions evolve out, while environmental and health evolves into this definition. Led again by Roco, a conference on Societal and Ethical Implications of Nanotechnology resulted in a 272 page report which did not address MNT (Interview #2) but referred to environmental sustainability as one of the positive societal implications (NSET, 2001). Toxicity studies were also not included. At the DOE conference in June of 2004, Clayton Teague, director of the NNCO, presented ethical, societal and environmental considerations of nanotech, stating that 2004 funding for health and safety including environmental study is estimated at 14% of total NNI allocations (Teague, 2004). This presentation highlights education and environmental research centers, outlines 6 meetings that have taken place on societal and ethical (including environmental) implications since June 2002, and mentions the NIH/NIEHS National Toxicology Program whose goal is to move toxicology from a reactive to predictive science (NIEHS, 2004). Roco continually reinforced the message that "the main reason for developing nanotechnology is to advance broad societal goals such as improved comprehension of nature, increased productivity, better healthcare, and extending the limits of sustainable development and of human potential" (Roco, 2003

p.181). When Sean Murdock of the Nanobusiness alliance was asked whether his environmental concern would conflict with his role as a business advocate, he responded, "I think they're actually aligned" (Lovy, 2003).

Storyline summary: The evolution described above in the definition of nanotechnology brings us to the most dominant storyline: ecological modernization combined with a business-as-usual pragmatic discourse. The structure of the argument is as follows: Nanotechnology is the next industrial revolution, good for commercial interests, environment and human health. We have societal obligations to pursue potentially beneficial technologies with a balanced assessment of risk. After all, we use risky substances like gasoline everyday. We are only at the beginning of understanding enough about nanoscale properties, and while the possibilities *are* revolutionary, grey goo is science fiction. This is not like GMOs: Through partnerships between open research institutions and business and international collaboration, the basic science and applications will advance quickly. NSET will continue to regularly and monitor research with the administrative regulatory capabilities that already exist: FDA for food, EPA (TSCA) for new materials, NIOSH for worker safety, NIST for standards creation, DOE for energy and environment, DOD for military safety and applications. Research should continue so we know what we are regulating for. The benefits of nanotechnology far outweigh any known risks.

4.3 Short-Term Precautionary Storyline

A challenge to the evolving eco-modernist storyline is a fairly traditional environmentalist critique by Canada-based ETC, a group which also spoke out against GMOs. They created a series of reports calling for a global moratorium (ETC, 2003a) and an International Convention for Evaluation of New Technologies (ICENT) (ETC, 2003b) until more is known about the environmental and health effects of nanotechnology. Findings from Brussels also call for a precautionary, incremental approach, somewhat supportive of a partial moratorium on some specific products (EC, 2004). In April, ETC outlined 10 risk warnings, citing a series of toxicology studies including a 1997 study showing that titanium dioxide nanoparticles cause free-radicals in skin cells, Dupont's Haskell laboratory studies in rats showing lung toxicity, Dr. Gunter Oberdorster's study on the movement of nanoparticles from nasal passages into the brain, and finally Dr. Eva Oberdorster's finding that buckyballs cause damage to fish brains (ETC, 2004a). The headlines after ETC's July 8, 2004 report (ETC, 2004b) outlining toxic threats and again calling for a moratorium referred to "Green Goo: the New Nano Threat" (hAnluain, 2004). However, in an international dialogue in June with representatives from 25 countries and the EU, none of the 25 countries present was considering a moratorium (NSF, 2004).

Storyline summary: We have some 80,000 existing chemicals and regulation only on about 20,000. Toxicity has not been handled well in the past. It will be handled no better now: nanotechnology products have already been on the market for 10 years or more

without sufficient toxicity study. "The train has left the station" and the only solution is a global moratorium that gives us time to research each of these materials and their effects on humans and ecosystems.

Can this be dismissed as Luddite hype when the positive societal implications sound like "the Christmas Wish List of our civilization"? (Smalley, 1995) Though the administration relies on TSCA as the method for regulating existing chemicals and new permutations of those under Significant New Use (SNUR) provisions, a case study suggested by the Wilson Center on the use of TSCA points to weaknesses. It states that "with real nanoproducts already on the market, and a deluge to follow, an urgent set of issues resolve around the adequacy of our *existing* regulatory system to provide the necessary safeguards and early warnings" (Wardak, 2003 pp.3-4).

This storyline also has the effect of defying the unified Roco definition of nanotechnology as manipulation of matter at the nanoscale. At the international dialogue mentioned above, it was noted that some applications may proceed slowly in line with current regulatory techniques, such as the electronics industry, and others will have potentially more hazardous outcomes, such as the bio-nano interface (NSF, 2004), for example drug delivery systems or biomimetics. The storyline acknowledges a degree of complexity in the science and therefore invites a variety of responses.

4.4 Chart of the discursive space (external document)

4.5 Discourse-coalitions

Discourses are by definition fragmented. The storylines above bring some actors together who are not even in agreement, but who pose some similar questions, such as Bill Joy and Eric Drexler. A degree of cohesion must be achieved for policy. The following section focuses on the House hearings on societal implications to show how storylines and coalitions were acted out, the role of science, and how it became legitimate to research first and regulate later.

In the beginning, there was science… The word "science" or "scientific knowledge" in terms of the nanotechnology debate is often associated with the word "research". The distinction made by Latour (1999) is that research is allowed to be open-ended, uncertain, experimental and collective, while science is not. The NNI is an R&D initiative. Research is perhaps allowed to be more interactive than Latour's bridge image, where science on the one end gets *decided*, then is handed to social scientists for *interpretation* and then is *used* by the public on the other.

But the divided view is precisely what comes across in this exchange:

> Mr. Rohrabacher: *…this sounds like to me you are putting all of the sociology and literature majors in charge of defining the goals of engineering and… science majors…*
>
> Dr. Colvin: *I think that we [all] believe that only an economist…or an anthropologist could really figure out how, if you give…palm pilots to…third world countries how that might disrupt their culture. That is not something I can do… consequences research can't be done by nanotechnologists.*

> Mr. Rohrabacher: *I think what we are talking about here is injecting bureaucracy into the sciences.*
>
> Mr. Kurzweil: *…If you look at how things have gone with GMOs that has not gone well, and it is not apparently a scientific issue. It is a political and cultural issue.* (2003b pp.135-136)

Kurzweil has evoked the GMO debate to show the dangers of not being sensitive to public opinion from the outset. The best way of safeguarding the industry and maintaining the trust of the public is understood as not allowing public or social aspects to contaminate the infallible scientific processes of discovering truth. Similarly, when citizen panels are suggested for overcoming divisive issues, Mr. Rohrabacher responds: "Are we assuming the nuts aren't going to be the ones on the panel?" (2003b p.137) Where Latour advocates for science that is less "certain" but more trustworthy in that it makes the "collective" influence explicit, here a much less reflexive view dominates.

Later, a compromise is reached that could be interpreted as a call for more "upstream" (White et al., 2004) inclusion of public deliberation:

> Mr. Sherman: *I want to respond to the distinguished chair of the Space Subcommittee that long before his Subcommittee authorized the programs that took us into space, the poets made us want to go there. And it is good to have the societal elements, or as he would abbreviate the term "nuts", talking to the scientists at an early stage in this process rather than wait until toward the end.* (2003b p.140)

Vision: A reference to the utopic visions in culture that precede scientific discovery appears in the first sentence of Mr. Sherman's statement above. The promise of

nanotechnology comes in its ability to transform our future by re-engineering the way we manufacture and use materials today. The passive eco-modernist construction allows actors to draw on images of the future that are utopic, but not those that are dystopic. Scientists are allowed to blur fact and fiction (Gimzewski and Vesna, 2003) in a positive way, but not to predict scary scenarios. Mr. Sherman asked the panelists to predict when they thought nanotechnology would give us posthuman intelligence, and Ms. Peterson responded with surprise that, her work on MNT, normally "labeled science fiction" (2003b, p.144) or grey goo, would be discussed in a Senate hearing. Senator Boehlert characterizes the risks as short-term, and discounts the long-term: "While some concerns have already been raised that seem more…in the realm of science fiction, there are also very real issues with the potential health and environmental effects of nanosized particles"(2003b, p.24). However, MNT-based visions are incorporated by Dr. Colvin as nano-manufacturing from the bottom up, and she comfortably considers this part of the grand vision of nanotechnology. These are both long-term possibilities and yet one is considered by most to be impossible "science fiction" and the other a possible vision.

Inevitability: Moreover, there is no hope for relinquishment of nanotechnology. "We have no choice but to confront the challenge of guiding nanotechnology in a constructive direction" (Kurzweil, 2003 p.1). Where more precautionary technologist Bill Joy advocates "verifying relinquishment" (Joy, 2000), the consensus here becomes that it is beyond our control to stop, but not beyond our control to use it responsibly.

Complexity as a Non-Issue: When the scientific discussion strays into areas of complexity that are not accompanied by a familiar discourse, the goals of technological optimists are impaired. Mr. Wu asks if self-replicating machines are imminently possible, and a discussion of protein folding ensues that is very abbreviated here:

> Mr. Kurzweil: …*The goal is not to have self-replication of non-biological entities happen naturally…We have ribosomes that actually assemble protein machines*…
>
> Mr. Wu: …*we understand some things about ribosomes, but there are certain proteins…where we don't understand how they fold into a form that works…so are we really on the verge of nanotechnology that is self-replicating?*
>
> Mr. Kurzweil: *I think I have commented that that is a number of generations away. We haven't solved the protein-folding problem yet.*
>
> Ms. Peterson: …*It turns out we don't need to solve the protein folding problem before we make these nanoscale machines…*
>
> Mr. Wu: *I didn't mean to imply that we need to solve the protein issue*…(2003b pp.153-155)

Mr. Wu continues questioning, trying to close in on an understanding of the issue, until his time is up. The fact that this is an issue that cannot easily be defined means that the R&D act hardly addresses it. A one-time study of "self-assemblers" remains as compromise language that no longer makes sense: It combines the visionary bottom-up manufacturing with science fiction grey goo self-replication to create the word "self-assemblers" – which are neither one. Though Mr. Kurzweil tries to clarify by saying that we only have two nanotechnology definitions, "near-term and a long-term [that] are really two different fields" (p. 123), the discussion of assemblers shows that the long-

term is still discursively too incoherent for problem closure to arise, and therefore it is left out of the funding act almost entirely.

Discursive Closure: A definition for everyone: According to the Foresight institute, Roco has narrowed the nanodefinition by not supporting replicators or even assembler research, and according to some staffers he has widened the definition to include nanoparticles that should be studied in addition to assemblers (Interviews #2,3, and 11). The definition of nanoscience and nanotechnology as manipulation of matter on the nanoscale is vague enough that it is acceptable to many groups. Ambiguity can lead to political credibility because it allows for discursive closure, where each group can identify with a particular aspect of a storyline (Rydin, 1999). Discursive closure here was aided by this broad definition.

Problem Closure: More Research: All three storylines view science as the process of discovery of existing patterns and laws describing natural phenomena that, once understood, can be utilized for anything imaginable. The view that the meaning attributed to physical phenomena results from a practice of socio-cognitive construction remains in the realm of social science theorists. The solution is therefore that more research is needed. Roco's (2003) assertion that nanotechnology's success is determined by a "complex architecture of factors" such as science, public acceptance and technology transfer capability means that research funding is disseminated widely. It could also be interpreted as planting the seeds for reflexive institutional arrangements.

4.6 Signs of Reflexive Ecological Modernization?

Where do we see the impact of discursive constructions on institutions? Changes are apparent at the laboratory level, where scientists from different disciplines are using the same scientific instruments (Interview #13). Interdisciplinary study is encouraged and open research centers available for both academic and industry research. Exploring lab-level interdisciplinarity further will be left to another research paper.

On the policy level, three changes are particularly apparent. First, monthly NSET meetings involving over 35 agencies encourage multidisciplinary, bipartisan information exchange. Headed by Roco, the more passive eco-modernist storyline has dominated in the past, and might continue to shape the future.

Second, the PCAST advisory body, established in 1991 to advise the president on science issues, also now advises on nanotechnology. Though controversial because it is not independent, PCAST now seems to have appointed and consulted a variety of familiar specialists in nanotechnology, and speakers have included Dr. Vicki Colvin and Sean Murdock. Could the fact that one panel is advising on many topics including nanotech lead to integration with other science research projects, such as climate change?

Third, the Nanotechnology Preparedness Center specified in the law is yet to be formed. It will conduct research into "societal, ethical, environmental, educational, legal and

workforce implications of the technology" as well as identifying "responsible research, development, and application of nanotechnology" (Section 9). The center goals seem to open to a degree of interpretation. Apparently it was originally conceived much more as a way to bridge the gap between basic research and the market rather than to address environmental or ethical implications (Interview #13). Roco's NSF volunteered to solicit applications for funding (Interview #12).

Fourth, where R&D efforts are identified as international, there is the potential for a wide set of questions from different cultural contexts to be considered. The reflexive effects will depend on whether international interactions are set in context such that redefined problems feed back into political processes.

This list of changes is dwarfed by what did not change. Sub-politics largely defined nanotechnology and the response, evidenced by the reliance on science, the growing ethos of powerful science experts like Dr. Roco, and media attention to risk that led to attempts to give a "balanced" attention to positive societal (including environmental) implications and toxicity risks. Multiple committees in Congress were left out of the debate in the interest of swift passage. The main focus of this bill was basic research and commercialization, because even assigning regulatory responsibility beyond what each agency already handles was considered unnecessary or premature, for example, changes to TSCA were not deemed necessary at this time. Senator's staffers characterize Congress as the "tail of the dog", thus able to respond only in crisis, an apt description in the nanotechnology case as well. The mantra "we have learned from the mistakes of GMOs"

does not show the public specifically how the learning is being implemented, except to repeat that more research is being conducted.

At least two areas in the U.S. are understood as inevitable or beyond human control, thus leaving few avenues for reflexive change: technological advances, and a 'free' market. What remains encouraging is the openness and transparency of the U.S. system that does allow debate to occur within the political process. This has led to recognition that cross-disciplinary expertise and "complex architecture" will lead to successful nanotechnology development.

5 Conclusions

Discourse analysis illuminates the practices of constructing problems that can be dealt with by policy. If we had looked ahead in the early 1990s, we might have foreseen an MNT research act. Fast forward to 2001, and the beginning of the consensus on a definition of nanotech was framed that meant everything from particle toxicity to assemblers. The long-term visions and short-term precautions of two storylines were incorporated into the pragmatic approach to policy-making such that a passive eco-modernist storyline emerged and dominated the NNI. Previous dominant understandings of nanotechnology fell into the periphery. The problem thus became uncertainty and lack of knowledge, which needs no regulation, and a funding bill to add guidance to the existing operations of agencies was most desirable by agencies and industry.

Routinization of socio-cognitive constructions of nanotechnology that marginalized some of the available science, allowing many agencies to come together under one program, also opened the door to an environmentalist response in 2003 that focused on toxicity. Without public outcry or widespread support from other environmental groups, and because exciting environmental applications are easily espoused by the EPA and industry alike, the power of the passive eco-modernist storyline was easily reinforcable. TSCA's record is well-known, and discourse-coalitions formed around this environmentalist storyline such that those who oppose TSCA or consider it sufficient were able to harmlessly debate in familiar regulatory territory without slowing passage of 108-153.

The nanotechnology funding act is not specifically regulation, but it does represent a choice to research first and regulate later. If "new forms of interactions and reflection between scientists and others are necessary in the nano-era" (White et al., 2004) in order to ensure responsible technology development, do we see them addressed here? At least three areas that are weak in the dominant discourse deserve more attention. One is that tacit utopian visions underlie scientists predictions that need to be made explicit, the second is the need for "upstream" public deliberation, not only surveys, and thirdly, the way NGOs represent society needs to be better understood (see White et al., 2004). NGOs in the U.S. are distracted by an administration hostile to many existing environmental policies. Their absence is another reason for the discursive dominance of a passive eco-modernist storyline. What are their options for response? It seems they will

be forced to take up either the toxics precautionary approach, or align with a fragmented reflexive ecological modernization storyline.

Are the more traditional environmentalist/green goo scenarios and eco-modernist formulations that stress environmental applications incompatible? If nanotechnology has the capacity to solve many of the problems facing us today in areas of energy use and production processes, then the current focus on environmental toxicology research will not create arrangements that will creatively actualize preventative technology potential. Green goo and reflexive eco-modern storylines are both moral-technocratic constructions, but they critique existing political institutions differently. The former wants to recognize what has gone wrong in the past and fix it. The other is more interested in creating the space for future economic or political arrangements that will allow for the potential of the technology to be used. They do not have to be incompatible, however, they may at times work against each other. It could be threatening to environmental groups who are fighting to solve toxicity issues if the eco-modernist discursive line is dominated, as it is today, by the more pragmatic view of leaving this to market forces.

There is space for a stronger eco-modernist storyline stressing the interaction of nanotechnology with existing climate change or energy discourses to allow new problems in environment to be discussed and therefore 'solvable.' It allows us to ask different questions that research can then answer with policy. What regulatory systems make reflexivity possible? Are we putting in place preventative practices that allow us to avoid chasing after industry with reactionary admonishments to act responsibly? What are the

barriers to realizing the long-term potential of this technology responsibly? And what are the societal, economic and environmental costs if we do not?

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Cover Images

1. Cover of *Chemical & Engineering News,* December 1, 2003
2. Electron flow imaging, available from : http://www.ericjhellergallery.com/index.pl?page=category;catid=2
3. Cover from the Proceedings report from the EPA Nanotechnology and Environment: Applications and Implications STAR progress review workshop, 2002. Available from: http://es.epa.gov/ncer/publications/workshop/

REFERENCES

(2003a) 21st Century Nanotechnology Research and Development Act, Public Law no. S189.

(2003b) House of Representatives. House Committee on Science. *The Societal Implications of Nanotechnology*. Hearing, 9 April. 108-13. Available from: http://commdocs.house.gov/committees/science/hsy86340.000/hsy86340_0f.htm

Austin, C. (2004) "Study Shows Americans Encouraged by Prospects of Nanotechnology" *NC State University* [Internet] 14 July Available from: http://www.ncsu.edu/news/press_releases/04_07/211.htm [Accessed 16 July, 2004]

Beck, U. (1992) "From Industrial Society to Risk Society: Questions of Survival, Social Structure and Ecological Enlightenment" *Theory, Culture and Society,* **9,** 97-123.

Beck, U. (1999) *World Risk Society,* Polity Press, Cambridge, UK.

Bell, I. (2004) "Upgrading the Human Condition" Date, 2004 Available from: http://www.sundayherald.com/43701

Committee-on-Science (2003) "Hearing Charter: The Societal Implications of Nanotechnology" *U.S. House of Representatives* [Internet] Available from: http://www.house.gov/science/hearings/full03/apr09/charter.htm [Accessed June 22, 2004]

Davey, M. (2004) *Federal Research and Development Funding: FY2004,* Congressional Research Service, The Library of Congress.

Drexler, E. (1986) *Engines of Creation*.

Drexler, E. and Phoenix, C. (2004) "Safe Exponential Manufacturing" *Nanotechnology,* **15,** 869-872.

Dreyfus, H. L. and Rabinow, P. (1982) *Michel Foucault : beyond structuralism and hermeneutics,* The University of Chicago Press, Chicago.

Dryzek, J. (1997) *The Politics of the Earth,* Oxford University Press, Oxford.

EC (2004) *Nanotechnologies: A Preliminary Risk Analysis on the Basis of a Workshop Organized in Brussels on 1-2 March 2004 by the Health and Consumer Protection Directorate General of the European Commission,* European Commission, Brussels.

Economist (2004) "Nanotechnology's Unhappy Father" *Science Technology Quarterly, Economist.com* Date, 2004 Available from: http://www.economist.com/science/tq/displayStory.cfm?Story_id=2477051

EPA (2004) "Commercially Available Nanotechnology products" *ETC* [Internet] Available from: http://www.etcgroup.org/documents/nanoproducts_EPA.pdf

ETC (2003a) "No Small Matter II: The Case for a Global Moratorium, Size Matters!" *ETC: Occasional Paper Series,* **7**.

ETC (2003b) "Strategy for Converging Technologies: The Little Bang Theory" *ETC: Communique*.

ETC (2004a) "Nano's Troubled Waters" *etcgroup.org* [Internet] Available from: http://www.etcgroup.org/article.asp?newsid=445 [Accessed July 19, 2004]

ETC (2004b) "Nanotech News in Living Colour: An Update on White Papers, Red Flags, Green Goo (and Red Herrings)" *ETC: Communique*.

Feynman, R. P. (1959) "There's Plenty of Room at the Bottom" *Xyvex and Dr. Ralph Merkle* [Internet] Available from: http://www.zyvex.com/nanotech/feynman.html [Accessed June 15, 2004]

Foucault, M. (1984) *The History of Sexuality, Vol.1, An introduction,* Penguin, Harmondsworth.

Giddens, A. (1984) *The constitution of society : outline of the theory of structuration / Anthony Giddens.,* Polity Press, Cambridge.

Gimzewski, J. and Vesna, V. (2003) "The Nanomeme Syndrome: Blurring of fact and fiction in the construction of a new science" *Technoetic Arts journal*.

Hajer, M. A. (1995) *The Politics of Environmental Discourse: Ecological Modernization and the Policy Process,* Clarendon Press, Oxford.

hAnluain, D. Ó. (2004) "Green Goo: The New Nano-Threat" *Wired News*. July 19.

Hannigan, J. (1995) *Environmental Sociology: a social constructionist perspective,* Routledge, London.

Harre, R., Brockmeier, J. and Mulhausler, P. (1999) *Greenspeak: A study of Environmental Discourse,* Sage Publications, London.

Heclo, H. (1974) *Social Policy in Britain and Sweden,* Yale University Press, New Haven.

Irwin, A. (1995) *Citizen Science,* Routledge, London and New York.

Jasanoff, S. (2004) "The Idiom of Co-production" In *States of Knowledge: The Co-Production of Science and Social Order* (Ed, Jasanoff, S.) Routledge, London.

Joy, B. (2000) "Why The Future Doesn't Need Us" *Wired Magazine*, 8:4, April.

Karn, B. 2002. *EPA Nanotechnology and the Environment* Applications and Implications STAR Progress Review Workshop. Arlington, VA. August 28-29 2002.

Kurzweil, R. (2003) "Testimony of Ray Kurzweil on the Societal Implications of Nanotechnology" *House of Representatives* [Internet] Available from: http://www.house.gov/science/hearings/full03/kurzweil.pdf [Accessed 22 June, 2004]

Latour, B (1987) *Science in Action,* Harvard University Press, Cambridge, MA.

Latour, B. (1993) *We Have Never Been Modern*, (trans. Porter, C.) Harvester Wheatsheaf.

Latour, B. (1999) *Pandora's Hope: essays on the reality of science studies,* Harvard University Press, Cambridge, MA.

Lovy, H. (2003) "New Alliance Chief: Open Talk of Risk "Makes Business Sense"" *Small Times* Date, 2003 Available from: http://www.smalltimes.com/document_display.cfm?document_id=7937&keyword=%22Howard%20Lovy%22&summary=1&startsum=1

Lovy, H. (2004a) "Letter from Leelanau" *Howard Lovy's Nanobot Blogspot* [Internet] 6 August Available from: http://nanobot.blogspot.com/2004/08/letter-from-leelanau.html [Accessed 6 August, 2004]

Lovy, H. (2004b) "Nano Re-Created In Business's Image; Is This The Best Of All Futures?" *Small Times* [Internet] January 23, 2004 Available from: http://smalltimes.com/document_display.cfm?document_id=7279&keyword=sean%20and%20murdock&summary=1&startsum=1 [Accessed June 3, 2004]

Masciangioli, T. (2003) "Envrionmental Technologes at the Nanoscale" *Environmental Science and Technology,* **37,** 73-112.

Merzbacher, C. 2004, *National Nanotechnology Initiative: A Policy Perspective,* Natinoal Science and Technology Council Office of Science and Technology Policy.

Mol, A. P. J. and Sonnenfeld, D. A. (2000a) "Ecological Modernisation Around the World: An Introduction" In *Ecological Modernisation Around the World: Perspectives and Critical Debates* (Eds, Mol, A. P. J. and Sonnenfeld, D. A.) Frank Cass, London, Portland, OR.

Mol, A. P. J. and Sonnenfeld, D. A. (2000b) "Ecological Modernisation Theory in Debate" In *Ecological Modernisation Around the World: Perspectives and Critical Debates* (Eds, Mol, A. P. J. and Sonnenfeld, D. A.) Frank Cass, London, Portland, OR.

Murdoch, J. and Clark, J. (1994) "Sustainable Knowledge" *Geoforum,* **25,** 115-132.

Murphy, J. (2000) "Ecological Modernisation" *Geoforum,* **31,** 1-8.

NAS (2002) *Small Wonders, Endless Frontiers: A Review of the National Nanotechnology Initiative,* The National Academies.

NIEHS (2004) *Toxicology in the 21st Century: The Role of the National Toxicology Program,* National Institute of Environmental Health Sciences.

NSET (2001) *Societal Implications of Nanoscience and Nanotechnology,* National Science Foundation, Arlington, VA.

NSET (2004) *National Nanotechnology Initiative: Research and Development Supporting the Next Industrial Revolution,* Executive Office of the President, Washington, D.C.

NSF (2004) *Report: International Dialogue on Responsible Research and Development of Nanotechnology,* Meridian Insitute and the National Science Foundation, Alexandria, Virginia, U.S.

Rabinow, P. (1984) "Introduction" In *The Foucault Reader: An Introduction to Foucault's Thought* (Ed, Rabinow, P.) Penguin Group, London, New York.

Rip, A. (2004) *Constructive Technology Assessment of Nanotechnology* Available from: http://www.stage-research.net/STAGE/PAGES/Nano.html

Rejeski, D. (2004) "The Next Small Thing" *The Environmental Forum.*

Roco, M. C. (2003) "Broader Societal Issues of Nanotechnology" *Journal of Nanoparticle Research,* **5,** 181-189.

Roco, M. C. (2004) "The US National Nanotechnology Initiative after 3 years (2001-2003)" *Journal of Nanoparticle Research,* **6,** 1-10.

Roukes, M. L. (2002) "Plenty of Room, Indeed" In *Understanding Nanotechnology* Scientific American and Byron Preiss Visual Publications, Inc, New York.

Rydin, Y. (1999) "Can We Talk Ourselves into Sustainability? The Role of Discourse in the Environmental Policy Process" *Environmental Values,* **8,** 467-484.

Rydin, Y. (2003) *Conflict, Consensus and Rationality in Environmental Planning: An Institutional Discourse Approach,* Oxford University Press, Oxford.

Sabatier, P. (1986) "Top-Down and Bottom-Up Approaches to Implementation Research: A Critical Analysis and Suggested Synthesis" *Journal of Public Policy,* **6,** 21-48.

Sabatier, P. and Jenkins-Smith, H. C. (Eds.) (1993) *Policy Change and Learning : An Advocacy Coalition Approach,* Westview Press, Boulder, CO.

Siegel, R. W., Hu, E. and Roco, M. C. (Eds.) (1999) *Nanostructure Science and Technology: A Worldwide Study,* Kluwer Academic Publishers.

Smalley, R. (1995) "Nanotechnology and the Next Fifty Years" *Rice University* [Internet] December 7 Available from: http://smalley.rice.edu/Papers/dallas12-96.html [Accessed June 3, 2004]

Teague, E. C. 2004, *Ethical, Societal and Environmental Considerations in Realizing the Promise of Nanoscale Science and Technology,* National Science and Technology Council, Washington, D.C., (Powerpoint Presentation).

The Royal Society (2004) *Nanoscience and Nanotechnologies: Opportunities and Uncertainties,* The Royal Society, London.

Wardak, A. (2003) *Nanotechnology and Regulation: A Case Study using the Toxic Substances Control Act (TSCA),* Woodrow Wilson Center for Scholars, Washington, D.C.

Weale, A. (1992) *The New Politics of Pollution,* Manchester University Press, Manchester and New York.

White, R. G., Kearnes, M., Miller, P., Macnaghten, P., Wildson, J. and Wynne, B. (2004) *Bio-to-Nano? Learning the Lessons, Interrogating the Comparison,* Institute for Environment, Philosophy and Public Policy, Lancaster University and Demos.

Wolfe, J. (2003) "Forbes/Wolfe Nanotech Weekly Insider" *Forbes Wolfe* [Internet] 19 December Available from: http://www.forbesinc.com/newsletters/nanotech/public/insider/fwnwi_12192003.htm [Accessed 20 August, 2004]

Wynne, B. (1996) "May The Sheep Safely Graze?" In *Risk, Environment and Modernity* (Eds, Lash, S., Szerszynski, B. and Wynne, B.) Sage.