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Publication Date

2008-06-30

Muddling-Through on the Cutting-Edge: How California and the European Union are Coping with the Risks of Nanotechnology

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California - European Union Regulatory Cooperation Project
Workshop Paper
February 22, 2008

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Introduction

Environmental economics justifies government's role in the environmental policy arena by the existence of the market failure of negative externalities. For illustration purposes, think of a company that manufactures and sells widgets of great utility to consumers. Said widget could have a number of negative externalities. As part of the manufacturing process, air and water could be polluted, with potential ecosystem risks, and workers could be exposed to health hazards. The consumer of the widget, as well as her friends and pets, could similarly be exposed to incidental hazards related to the widget. And at the end of the life of the widget, soil and water could be polluted and ecosystems could suffer damage. Ideally, the evolution of economic and scientific tools allows us to "internalize" these externalities, through the mechanism of environmental policy, to affect the bottom line of the firm that profits from the widget.

But what if there's no widget yet? What if there is instead a set of scientific and technical discoveries that hold great promise for the commercialization of a set of widgets of tremendous transformative utility to multiple industries? What if early scientific research into the prototype widgets shows that they behave quite differently than any previous widgets in both environmental and biological processes? What if government is already working to combat market failures related to insufficient incentives for private research and development (R&D) by spending hundreds of millions of dollars each year to support the basic and applied science underlying these prototype widgets? How does government internalize the externalities of non-existent products with no Standard Industrial Classifications (SIC), especially when it is internally committed to promote the development of these products, albeit at an upstream level?

This "hypothetical" situation is what actually confronts environmental policy-makers in the area of nanotechnology. The complexities of the problem make it a particularly rich area in which to explore experiments and cooperation in environmental policy, starting with California and the European Union (EU). Both jurisdictions are environmental policy leaders on many fronts, although their institutions and cultures are quite different. Both jurisdictions have nascent nanotechnology industries, with California representing probably the largest concentration of nanotechnology companies in the U.S. And both jurisdictions have "technology policy" institutions of a sort; California's technology policy – centered on the California Council of

Science and Technology – is a poor relation to the federal government’s, however, while the EU’s is probably best thought of as complementing those of its economically strongest members.

In confronting nanotechnology, there is currently no “first-best” policy solution like internalizing the externalities. Instead, policy is caught in a “second-best” world of “muddling through,” with existing institutions attempting to govern this new environmental policy challenge by tracking (and creating) new environmental knowledge regarding nanotechnologies and calling on admittedly imperfect analogies.

This Working Paper documents the muddling-through efforts of California and the EU as they confront this cutting-edge environmental policy challenge. The next section of the paper provides more background about nanotechnology, including its promise and some of its known problems. The following section lays out some of the muddling-through efforts of California and the EU with respect to worker and consumer safety. The final section involves a discussion of preliminary conclusions and next steps.

Nanotechnology: Hero and Villain

According to the National Nanotechnology Initiative (2008), “nanotechnology is the understanding and control of matter at dimensions of roughly 1 to 100 nanometers, where unique phenomena enable novel applications.” At this one-billionth-of-a-meter scale, the “physical, chemical, and biological properties of materials differ in fundamental and valuable ways from the properties of individual atoms and molecules or bulk matter” (ibid.). For example, “greater catalytic efficiency, increased electrical conductivity, and improved hardness and strength, are a result of nanomaterials’ larger surface area per unit of volume and quantum effects that occur at the nanometer scale”(EPA, 2007).

Nanotechnology is considered “pre-competitive” and, as Figure 1 illustrates, hundreds of millions of U.S. dollars are being spent to support it by governments around the world. Nanoparticles are currently in use in a number of commercial applications, including “electronic, magnetic and optoelectronic, biomedical, pharmaceutical, cosmetic, energy, catalytic and materials,” with the greatest revenue-generating applications reportedly “chemical-mechanical polishing, magnetic recording tapes, sunscreens, automotive catalyst supports, biolabeling, electroconductive coatings and optical fibers”(NNI, 2008). Many of the applications under development are in such “public good” areas as environmental protection, defense, and health care. For example, in the area of environmental protection, examples include use as a vehicle combustion additive to reduce diesel emissions, improved seawater desalination, superior techniques for reducing soil and groundwater contamination, renewable energy technologies such as advanced photovoltaic cells, and sensors that “hold promise for improved detection and tracking of contaminants” (EPA, 2007).

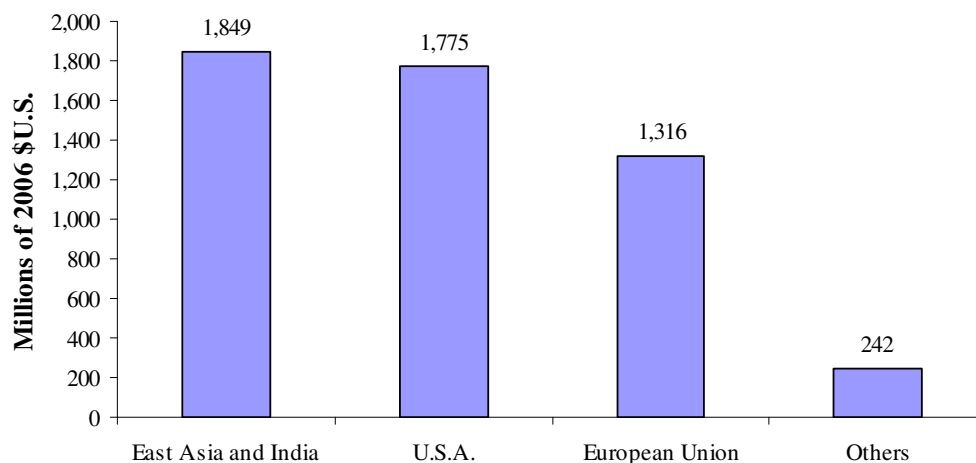


Figure 1: Government funding for nanotechnology (2006 U.S.\$ millions). Note that EU numbers are based solely on the funding attributed to France, Germany, and the United Kingdom. Adapted from Lux Research (2007).

Figure 2 provides a stylized representation of the life-cycle of a nanomaterial in one of three application areas – consumer products, medicine, and environmental remediation – and where in that life cycle the material might enter organisms and the wider environment.

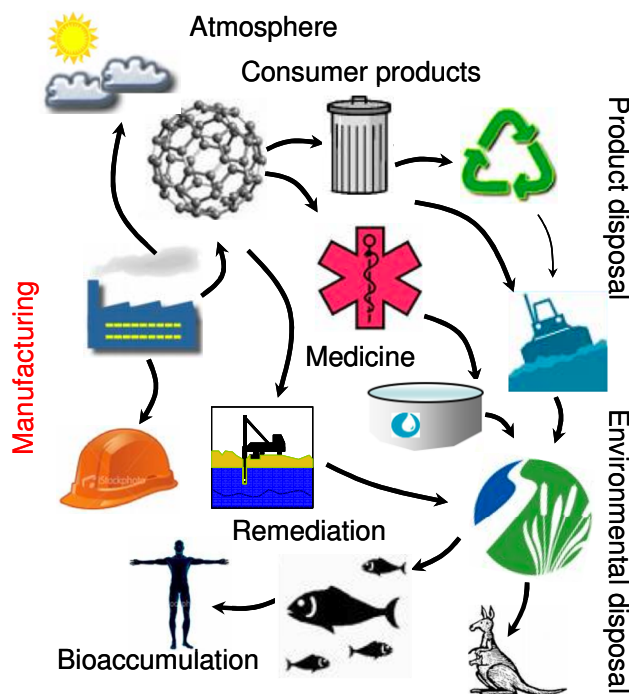


Figure 2: A stylized representation of the life-cycle of a nanomaterial. Source: Banfield (2007).

Nanoparticles pose a number of difficult challenges for risk assessment because of their small size, their similarity to naturally occurring and incidental nanoparticles, and because of their unique properties. EPA (2007) presents what is known and can be inferred about the challenges nanoparticles pose to risk assessment, ranging from identification and characterization to environmental fate to detection and monitoring to human health and ecological effects. For the purposes of this paper, it is enough to mention a few illustrative challenges. For example, inhaled nanoparticles can penetrate the skin, pass through cell membranes, cross the blood-brain barrier, be absorbed into lymphatic channels, and reach bone marrow, lymph nodes, the heart and lungs, and the central nervous system (EPA, 2007; Oberdorster, 2005). In another example, nanoparticles behave differently in water and biological fluids than their bulk materials. An additional challenge is posed by the toxicity and durability of the surface coatings that are often applied to underlying nanoparticles for various functional and toxicological reasons. Finally, “bacteria and living cells can take up nanosized particles, providing the basis for potential bioaccumulation in the food chain” (EPA, 2007).

Muddling Through

Although California and the EU, like other jurisdictions around the world, are far from being able to internalize the externalities associated with nanotechnology, they are attempting to muddle through by funding research to help resolve some of the scientific uncertainties involved in nanomaterial risk and by proactively governing this challenging problem through existing institutions. This section characterizes the institutions and efforts of California and the EU with regard to environmental research funding and governance of nanotechnology. The material in this section is based on a review of documents as well as a number of informant interviews conducted with California government personnel; going forward, we plan to interview similar informants in the EU. Material derived from the interviews is the text is referenced by the subject’s initials and the year of the interview.

Environmental Research Funding

Institutions. Environmental research, like other public research, operates under very different institutions in California, the U.S., and the EU. In the U.S., the federal government takes primacy in research funding over the states, through such institutions as the National Science Foundation (NSF) and the National Institutes of Health. States like California do fund research, however, sometimes through dedicated institutions, such as the California Energy Commission, and sometimes simply through the state university system. In the EU, there is a long-standing debate about the need for an NSF at the level of the European Commission (EC).¹ Instead, most of the nanotechnology research is funded through the successive Framework Programmes for Research and Development, of which the seventh is currently operating (see . In addition, individual EU member states fund research into the environmental, health, and safety (EHS) implications nanotechnology. For example, the United Kingdom operates the Nanotechnology Research Coordination Group (NRCG), which oversees a cross-government EHS research program, as well as the Environmental Nanoscience Initiative, which studies the environmental effects of manufactured nanomaterials.

¹ The EC is the government of the European Union (EU), responsible for proposing and implementing policies and for the day-to-day working of the EU. Each member country has one commissioner at the EC.

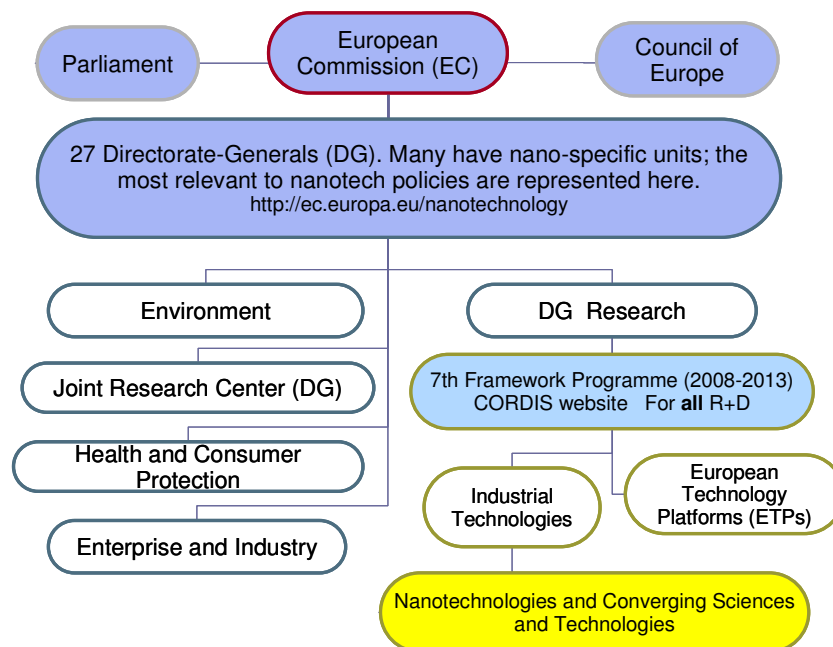


Figure 3: Organization chart of the EC with respect to nanotechnology research

EU. Although critical to someday being able to characterize and assess the externalities associated with nanotechnology, environmental research is not being funded either in the U.S. or in the EC at levels even proximate to those in support of advancing nanotechnology itself. Our analysis of data from EC (2008) concludes that the combined effort of ten years (1998-2006) of “environmental implications” research by the EC and EU member states adds up to only about 6% of what the three EU member nations depicted in Figure 1 spent in support of nanotechnology in 2006.

U.S. and California. The U.S. funds proportionately more EHS research, although it is still only a tiny amount of overall federal R&D funding related to nanotechnology. Our analysis of multi-agency funds for EHS research, which is coordinated through the National Nanotechnology Initiative (NNI) with all other federal R&D in nanoscale science, engineering, and technology, shows that EHS comprises only about 3-5% of the total funds. Figure 4 displays the comparison between EHS and total nanotechnology R&D spending (and approved budgets) by the NNI between 2006 and 2009, which reflects considerable improvement over the 2000 to 2004 period (Dunphy-Guzman, 2006 provides a close examination of NNI EHS funding in this earlier period). Note that although California is a large recipient of federal Environmental Protection Agency (EPA) funds for nanotechnology EHS, the state does not appear to provide much in the way of independent EHS R&D, as far as we have been able to determine. The major efforts include a University of California (UC) five-year “lead campus” program in nanotoxicology at UC Los Angeles and a recently signed research partnership between California’s EPA (Cal/EPA), through the Office of Environmental Health Hazard Assessment (OEHHA), and the UC San Francisco “program on reproductive health and the environment to put together the policy framework for nano products,” the details of which are not yet public (RK, 2007).

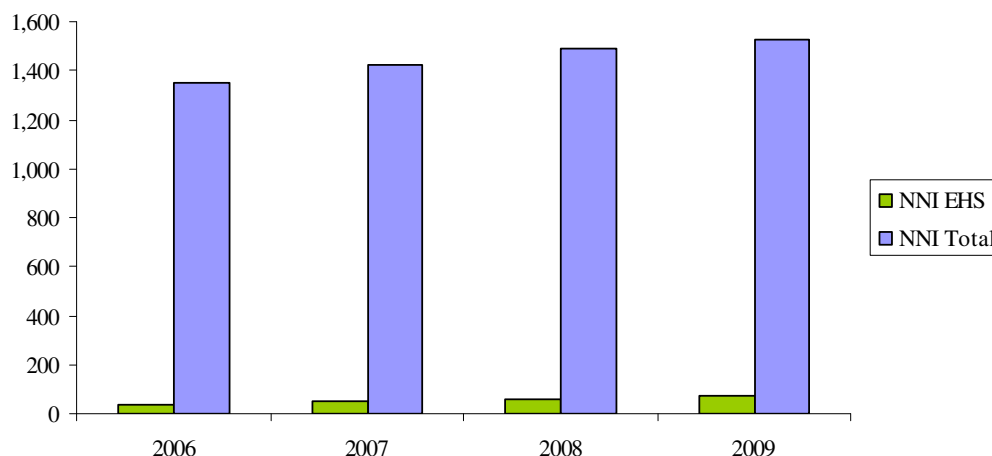


Figure 4: Total versus Environmental Health and Safety spending under the U.S. National Nanotechnology Initiative. Source: NNI (2008).

Governance Efforts

California. In 2004, the California State Controller and U.S. Congressman Michael Honda sponsored a “Blue Ribbon Task Force on Nanotechnology” (Task Force) to identify what California needed to do to successfully develop the economic opportunities of nanotechnologies. The report called for the establishment of a bureau to centralize and coordinate California’s nanotechnology policy, but to date, there do not appear to have been any steps in this direction. The interviews conducted for this paper indicate that climate change is crowding out the consideration of other aspects of science and technology policy from California’s current agenda (DJ, 2007; HS, 2007). Similarly, although some of the conclusions of the Task Force report called on Cal/EPA to promote environmentally beneficial applications of nanotechnology, develop responsible stewardship of nanotechnology products in partnership with manufacturers, and implement information tracking systems, no mandate from the California Assembly has asked any agency to explore nanomaterials or make policy recommendations (BRTF, 2005)

Instead, actions regarding nanomaterials are being pursued at the initiative and from the perspective of each agency: OEHHA focuses on risk assessment; the Department of Toxic Substances Control (DTSC, another branch of Cal/EPA) focuses on pollution control; and the newly created California Department of Public Health (DPH) concentrates on environmental and occupational disease control. Note that DPH works through five divisions, two of which are likely to be interested in nanomaterials: the Center for Environmental Health (CEH) and the Center for Chronic Disease Prevention (CCDP). The Division of Occupational Safety and Health (better known as Cal/OSHA), which is the branch of the California Department of Industrial Relations that sets and enforces occupational health and safety standards, has been relatively inactive with regards to nanomaterials (BG, 2007; DJ, 2007). Organization charts for these agencies with respect to nanotechnology are presented in Figure 5 and Figure 6.

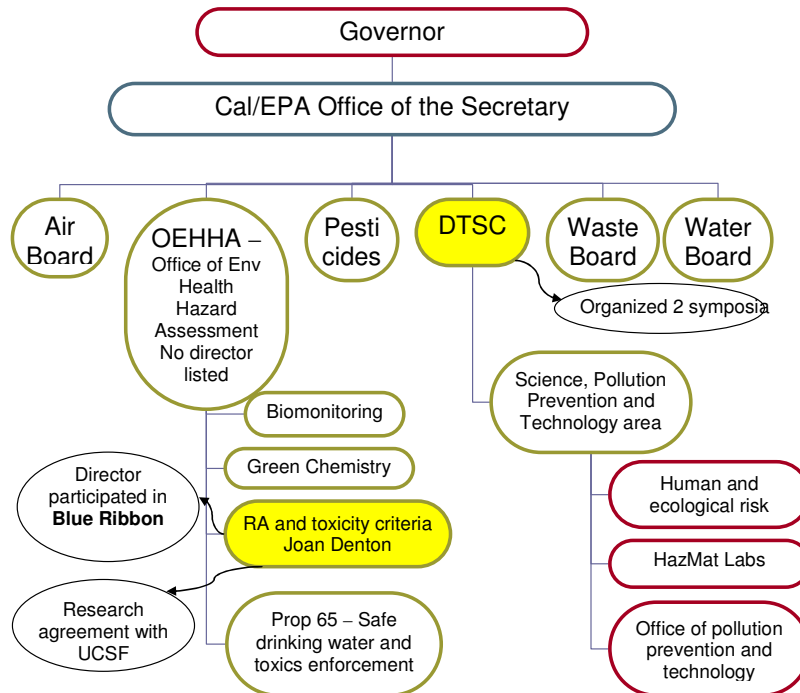


Figure 5: Organization chart for Cal/EPA with respect to nanotechnology

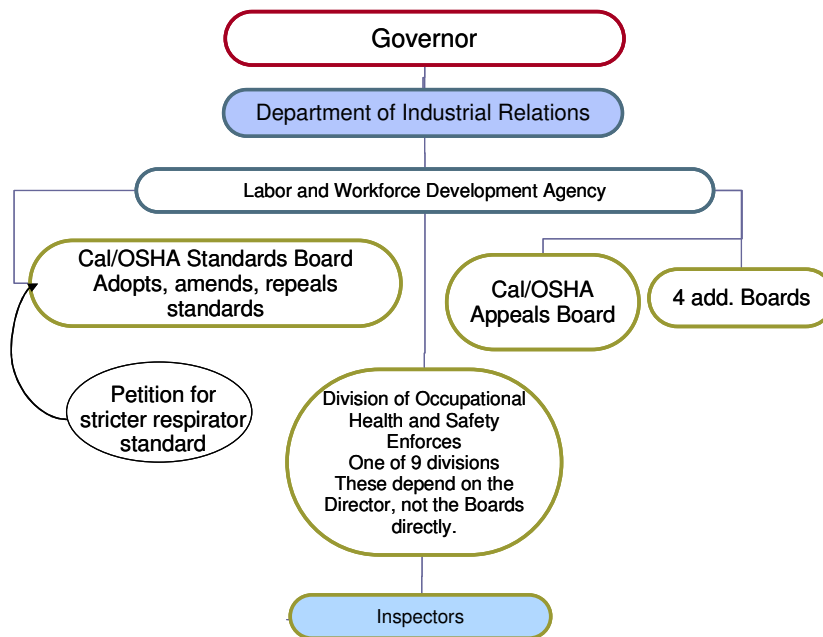


Figure 6: Organization chart of Cal/OSHA with respect to nanotechnology

In general, interviewees believe that the commitment to pursue the governance of nanomaterials (both from outside and within the agencies) is variable, and there is an awareness that economic interests in favor of nanomaterials are strong. While some prefer a precautionary approach, there is a realization that this is unlikely. Most of the independent work of the agencies listed above

emerged from informal conversations between OEHHA, DTSC, and DPH that were held some years ago, and grew from the realization that nanomaterials were “likely to fall between the cracks” of the regulatory system. For a while, regular meetings were held to facilitate sharing information on nanomaterials amongst the agencies. Although they have now been interrupted, each agency continues to collect information on nanomaterials and toxicity for internal purposes. The specific actions and perspectives of these three agencies are reviewed below.

- OEHHA sees nanomaterials as the new “plastic”, and expects it to become prevalent in consumer products and production processes. They are adopting the ‘green chemistry’ framework for thinking about nanomaterials, with an emphasis on case-by-case evaluation to assess safer alternatives and an emphasis on reducing the use of chemicals (DJ, 2007).² OEHHA aims to avert public fears and work with industry to develop a product stewardship approach based on industrial ecology principles. OEHHA claims to be more business oriented than other California agencies: one of their goals is to “explore the merits of pro-active industrial initiatives and traditional governmental regulatory approaches” (RK, 2007).
- DTSC organized two symposia in 2007 to bring together EHS professionals, business leaders and regulators in California to exchange information and begin to develop a shared understanding of the issues. These day-long sessions, which involved prominent people in the federal debate, addressed general issues – definitions of nanotechnology, review of toxicity research – and specific concerns like pesticides. In addition, DTSC has been compiling information, useful articles and links to quality organizations, and making this material available through its website.
- Like the other agencies, DPH has been compiling relevant data and articles for internal use and encourages staff to attend nanotechnology-related events. Unlike the other agencies, no framework – like green chemistry - is formally being used to think about nanomaterials. However, DPH is responsible for enforcing the Safe Cosmetic Act (SB 484), which could yield some lessons that are applicable to nanomaterials (DM, 2007).

Regarding worker safety, as mentioned above, Cal-OSHA, which sets and monitors worker safety standards, has been fairly inactive with regards to nanomaterials (BG, 2007), although a new development may change that. In February 2007, an industrial hygienist filed a petition to Cal-OSHA challenging current assigned protection factor (APF) standards for respirators on the grounds that they do not provide sufficient protection from nanomaterials (Cal-OSHA). The petition argues in favor of more stringent APF standards on the filtering facepiece, on the grounds that federal standards are not supported by scientific research because of the involvement of business interests in conducting this research (Cal-OSHA, 2007a).

It is interesting to consider this petition in California against the perspective of the U.S. federal government. Charles Geraci, chief of the Document Development Branch of the U.S. National Institute of Occupational Safety and Health (NIOSH), appears to take a very “un-precautionary”

² Green chemistry is a package of technologies, design principles and tools to reduce the toxicity, resource and energy use, and pollution of chemicals Iles, A., 2005. Shifting to Green Chemistry: The Need for Innovations in Sustainability Marketing. Business Strategy and the Environment (in press)..

position that workers are safe until further research is conducted. He is quoted as saying that NIOSH only has data on about six of the thousands of nanoparticles that are being created and that NIOSH has not yet tested respiratory efficacy. Nonetheless, he claims that “HEPA filters are efficient for nanoparticles and N-95 respirators ‘should provide protection,’ as well as that ‘a risk management approach and current control approaches should work’.” (Cal-OSHA, 2007b).

EU. The EC oversees several Directorate-Generals (DGs) that are directly involved in promoting nanotechnologies research and governance. These DGs are depicted in the organization chart for the EC with respect to nanotechnology governance, which is presented in Figure 7 below.

- The DG for Research coordinates research efforts across the EU, including nanotoxicology. It includes the DG Research for Industrial Technologies, which houses the Nanotechnologies and Converging Sciences and Technologies Unit.
- The DG for Enterprise and Industry oversees chemicals policy. It is responsible for the implementation of the new Registration, Evaluation, Authorization and Restriction of Chemicals (REACH) program. REACH unifies European chemicals regulation, and requires the registration of chemical substances. The objective is to close information gaps on hazards and identify appropriate risk management measures. In REACH, industry is responsible for generating whatever data is required to make risk management decisions and for demonstrating that a chemical is safe. The European Chemicals Agency (ECHA) will evaluate particularly suspect chemical substances, recommend safer substitutes, analyze alternatives and implement total or partial bans when a risk is considered unacceptable. REACH is supposed to impose the same procedures on all chemicals, eliminating any distinction between new and existing chemicals.
- The DG for Health and Consumer Protection oversees different committees involved in assessing risk assessment methodologies and regulation. The Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR), which functions under this DG, is particularly relevant to nanotechnology.
- The DG for Environment applies to environmental issues actions that are similar to those of the DG for Health and Consumer Protection.
- The Joint Research Center oversees risk assessment and reference materials.

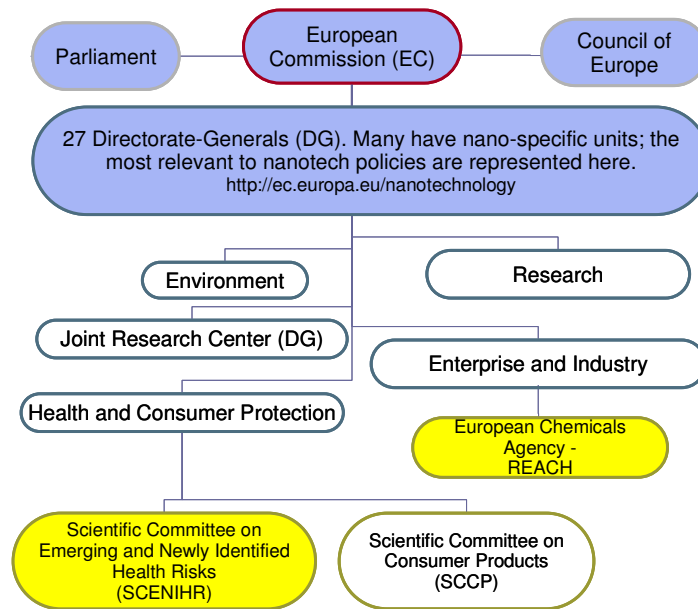


Figure 7: Organization chart of the EC with respect to nanotechnology

With regard to worker safety, the OSH-ERA project was launched in April 2006 to coordinate member states' research efforts and exchange information regarding occupational health and safety. This new forum began a public consultation process to develop a possible code of conduct for responsibly developing nanotechnologies. Although the consultation process has closed, no report about the results is currently available (OSH-ERA, 2007).

In addition to the EC's efforts, several member states are acting independently to govern nanotechnologies. Many of these efforts appear to focus on evaluating how REACH will impact the regulation of potentially toxic substances. Two states stand out for the extent to which they have pursued EHS issues. In Germany, the Federal Environment Agency, Federal Institute for Occupational Safety and Health, and the Federal Institute for Risk Assessment are working with industry to identify exposure risks for workers and risk management at the workplace. In the UK, the Department for Environment, Food and Rural Affairs (DEFRA) launched a voluntary reporting scheme for nanomaterial hazards that was the closest any jurisdiction had come at that time to regulating nanotechnology. It received nine submissions between September 2006 and December 2007 (DEFRA, 2007).

Consumer Safety - California and the EU. Most governance efforts in California and the EU are aimed at improving consumer safety by regulating the commercial use of toxic substances. From the legal point of view, it is unclear whether or not nanomaterials are new chemicals or indistinct from their bulk counterparts, which are already regulated by such existing regulations as the U.S. federal Toxic Substances Control Act (TSCA, administered by the U.S. EPA) and REACH in Europe. A lot is at stake in this distinction, since considering nanomaterials to be 'new' would significantly raise the safety bar for their commercialization. Another challenge nanomaterials pose to TSCA and REACH is based on the characteristics of their toxicity, which appears to be more a function of their physical and chemical properties than of the quantity being handled (Davies, 2006; EC, 2004; EPA, 2007; Roco, 2005). In this context, some in the U.S. have

questioned the suitability of TSCA to adequately address the hazards of nanomaterials (note that this questioning is part of the current debate about the suitability of TSCA to all chemicals).

California, however, has its own regulatory tools for dealing with toxic substances. These include Proposition 65, a 1986 ballot initiative that became the Safe Drinking Water and Toxic Enforcement Act of 1986. Proposition 65 requires California (through OEHHA) to publish an annual list of chemicals known to cause cancer or birth defects or other reproductive harm; the current list stands at about 775 chemicals. Proposition 65 also requires businesses to disclose whether significant amounts of these chemicals are in products for purchase, are present in workplaces, or are released into the environment. In addition, California has a new regulatory tool – the Safe Cosmetics Act, which went into effect in January 2007 and places the burden on manufacturers to demonstrate product safety and report ingredients that cause cancer or reproductive harm – that interview subjects at DPH believe holds promise in governing nanotechnology. The thought is that this act could provide a framework for thinking about nanomaterials by contributing to discussions on how to measure exposure, identify acceptable standards of exposure, and best report toxicity information (DM, 2007).

Although a number of participants in the U.S. TSCA debate see the EU's REACH as an example the U.S. should follow, nanomaterials are posing challenges to REACH as well. On the one hand, the European Chemicals Agency makes it clear that:

“[nanomaterials fall under the scope of REACH], and their health and environment properties must be assessed following the provisions of the REACH Regulation. Potential registrants should first consider whether they have obligations under REACH, irrespective of the size of the substances. Once it is established that the substance falls within the scope of REACH, further investigation of the detailed provisions of REACH may indicate that different provisions apply according to the hazard properties associated with the size of the substances. The evolving science of nanotechnology may necessitate further requirements in the future to reflect the particular properties of nano particles.” (ECHA, 2007)

On the other hand, non-governmental organizations (NGO's) like Greenpeace claim that TSCA and REACH will have similar problems with respect to nanotechnology. Under REACH's current provisions, Greenpeace (2007) claims that only a small number of nanomaterials will actually fall within the scope of REACH because most of these materials will be considered equivalent to their bulk cousins, despite different toxicological properties.

The EC is clearly not just relying on REACH to cope with the environmental problems potentially related to nanotechnology. Two examples are illustrative. The Scientific Committee on Consumer Products (SCCP) was asked to make recommendations on the use of nanomaterials in cosmetics, including sunscreens, although these would presumably be regulated through REACH. In addition, the EC asked the Scientific Committee on Emerging and Newly Identified Health Risks (SCENIHR) to review the adequacy of existing risk assessment methodologies for nanotechnologies. The SCENIHR report concludes that although “existing toxicological and ecotoxicological methods are appropriate to assess many of the hazards associated with nanoparticles, they may not be sufficient to address all the hazards” (EC, 2007). In particular, they signal out a series of knowledge gaps, for example in areas such as “nanoparticle characterisation, detection and measurement; their fate and persistence in humans and the environment; and all aspects of the associated toxicology and ecotoxicology” (EC, 2007). A

more detailed follow-up report recommends improvement in methodologies and technical guidance and proposes a staged risk assessment strategy.

The EU is also conducting an inventory of other existing regulation regarding nanotechnology and working to develop a voluntary code of conduct for businesses (EurActiv, 2007). The justification for this review is the EC's recognition that "the particular nature of nanotechnologies requires the re-examination [of regulation] and possible revision," and particular concern that the relevance of thresholds for production that define exemption categories "...should be revisited and, when appropriate, changed" (EC, 2004). Until this review is complete, the EC is postponing any further regulatory actions on nanotechnology. In the meantime, the EC recommends continuing to apply existing regulation on a case by case basis (EC, 2007).

Finally, the EC is also turning to the private sector for additional input into a variety of issues related to nanotechnology governance, via the institution of the European Technology Platforms (ETPs). The Sustainable Chemistry European Technology Platform, with the participation of several industry stakeholders like BASF, Bayer, or Dow Europe, have produced a voluntary code of conduct on nanotechnology, a guide on safe manufacturing and activities involving nanoparticles at workplaces, and detailed information on nanomaterial characterization.³ In addition, the Industrial Safety ETP hosted a workshop on workplace and environmental safety related to nanomaterials.

Conclusion

Governments around the world are far from being able to internalize the externalities related to nanotechnology. The actions of two of the world's most environmentally progressive jurisdictions, California and the EU, are indicative of the way jurisdictions are muddling through with regard to the implications of this cutting-edge technology.

In California, there is no federal or state mandate to even consider the risks of nanotechnology, although agencies are acting out of their own initiative to experiment with such frameworks as green chemistry and REACH-like regulation. They are also beginning to fund research into the environmental implications of nanotechnologies.

Meanwhile, the EU has more formal hierarchical pressure to cope with nanomaterial risk, but is engaged in multiple approaches to governing these risks. These include: wrestling with the implications of REACH for nanotechnology governance, which is occurring at the levels of the EC, EU member states, and NGO's; conducting regulatory reviews and soliciting new regulation and risk assessment strategies; and working with industry on voluntary practices. It also spends money on research into the EHS issues of nanotechnologies, but, as in the U.S., funding levels are far below the amounts spent in support of the development of nanotechnologies for commercial and public good purposes.

Other than research funding, there seems to be very little consensus that clear leadership is occurring on the part of either jurisdiction regarding the "best practices" of environmental

³ <http://www.suschem.org/>

governance of nanotechnology. Public opinion does not give a good sense on whether either jurisdiction will take up the cause of nanotechnology with great urgency in the coming years.

A number of studies have specifically looked at the attitudes towards nanotechnology.⁴ The results of this research emphasize the low public salience of nanotechnology, with low levels of knowledge or awareness in both the U.S. and Europe. In the U.S., Kahan et. al. (2007) find that a majority have heard little or nothing about nanotechnology (see Table 1) but most think the benefits will outweigh the risks (see Table 2). Likewise, Gaskell et. al. (2005) find that 50% of U.S. respondents believe nanotechnology will improve our way of life in the next 20 years. In contrast, on average, 29% of Europeans feel this way and a majority (53%) respond “don’t know” to this question (see Table 3).

Table 1: How much have you hear about nanotechnology before today?									
Percentages N = 1862 Source: Adapted from Kahan et al. 2007									
Nothing at all	53								
Just a little	28								
Some	14								
A lot	5								
Table 2: Do you think...									
Percentages N = 1862 Source: Adapted from Kahan et al. 2007									
The benefits of nanotechnology will outweigh the risks	53								
The risks of nanotechnology will outweigh the benefits	36								
Not sure	11								
Table 3: Do you think nanotechnology will improve our way of life in the next 20 years, will it have no effect, or will it make things worse?									
Percentages N = 1000 per country Source: Adapted from Gaskell et. al. 2005									
	U.S.	Europe	Denmark	Luxembourg	Sweden	Norway	Spain	Finland	France
Will improve	50	29	46	45	43	40	39	34	33
Will have no effect	12	12	10	15	7	12	7	26	10
Will make things worse	4	6	6	10	2	15	3	4	5
Don't know	35	53	39	30	48	34	52	36	52
	Italy	Belgium	Germany	Austria	Netherlands	Greece	UK	Portugal	Ireland
Will improve	32	30	21	28	28	26	24	24	18
Will have no effect	8	14	22	17	9	5	10	6	6
Will make	7	7	7	9	5	14	5	7	8

⁴ Published results in the U.S. Bainbridge 2002, Cobb and Macoubrie 2004, Scheufele and Lewenstein 2005, Macoubrie 2006 and Kahan et. al, 2007. In Europe, the Eurobarometer has included some questions about nanotechnology in 2001 and 2005. These results are analyzed in Gaskell et. al, 2005. In addition, several efforts are currently under way to use consensus conference methods to explore attitudes towards nanotechnology in Germany and the U.S. In Germany these are being conducted by the Federal Institute for Risk Assessment and focus on consumer products. In the U.S., one project, based on in-depth interviews, is led by the Center for Nanotechnology and Society (CNS) at UC Santa Barbara and another, based on consensus conferences focused on human enhancement technologies, is led by the CNS at Arizona State University and North Carolina State University.

things worse									
Don't know	54	49	49	47	59	55	61	63	68

We caution that the distribution of responses in Europe does not necessarily mean pessimism. First, there is wide variation within Europe that is difficult to explain. Most Spaniards, for example, are either optimistic or uncertain (don't know) while a quarter of Finnish respondents think that nanotechnology "will have no effect" on our quality of life. Whether "no effect" reflects a neutral, pessimistic or indifferent attitude or if it is equivalent to a "don't know" response is open to interpretation. No quantitative survey we are aware of asks directly about concern for the health and environmental implications of nanomaterials.

In the absence of a clear public mandate, California and EU efforts to muddle through on nanotechnology governance are being complemented by the efforts of a host of voluntary and non-governmental institutions to develop and implement both formal and voluntary science and regulatory initiatives. Table 4 lays out the institutional players already discussed in this paper as well as some of these non-jurisdictional players.

Table 4. Institutional players in the global nanotechnology governance debate			
	Funded Science & Research	Voluntary Standards & Safety Practices	Regulatory/ Legal
Local			Berkeley, CA Cambridge, MA
California (sub-national)	"Nano-Centers" Cal/EPA-OEHHA partnership with UCSF	Blue Ribbon Task Force	Cal/EPA – DTSC Cal/EPA - OEHHA CA – DPH Cal/OSHA
National U.S.	NNI DHHS NIOSH	EPA Am. Chem. Council Env. Defense-Dupont	FDA
National Europe/EU	DG Research DG Health and Consumer Protection, DG Environment and the Joint Research Center	UK's DEFRA European Technology Platforms	ECHA
International Government	OECD	ISO	
International NGO/ Industry	ICON IGRC	ASTM-International	

Many professional associations have formed sub-groups on nanotechnologies to attempt to influence the shape of regulation. These include the chemical industry, legal associations, and business alliances in both the U.S. and Europe. In addition, several environmentally-minded NGOs have advocated in favor of strictly regulating nanotechnologies; these include the ETC Group, Tri-Tac in California (a technical advisory group for waste water facilities in California), Friends of the Earth, and Greenpeace, among others. One of the most innovative non-governmental efforts is a three-year collaboration between Environmental Defense and DuPont (ED-Dupont) to explore ways that nanomaterials users can identify and manage potential hazards of nanomaterials across the entire lifecycle (EDDP, 2007). In addition, the American Society for Testing and Materials-International (ASTM) and the International Standards Organization (ISO) are both developing nanomaterials nomenclatures with the collaboration of industry, government

agencies, universities and professional associations. The ISO's Technical Committee 229 on nanotechnologies has a working group on health, safety and the environment led by the United States, under the direction of the American National Standards Institute (ANSI).

As in California and the European Union, it is unclear whether any of these non-jurisdictional players will stumble onto what will become a dominant path for governing nanotechnology.

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