Participation in Nanotechnology: Methods and Challenges

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Abstract. *There are increasing calls for better public participation in responding to the social and ethical issues expected to arise with nanotechnology research and development. Using a framework of different levels of participation, this paper discusses relevant methods for improving participation. Key challenges concern risk communication, dealing with disruptive technologies, and the possibilities for participatory governance in research and development communities.*

Keywords: public involvement, participatory planning, technology regulation, nanotechnology

INTRODUCTION

There are increasing calls for more public discussion about nanoscale science and technology. A February article in the scientific journal *Nanotechnology* argued that there was a growing gap between rapidly rising investment in nanoscience and industry, and very limited study and debate about the social and ethical implications of new nanotechnologies.[1] The ETC group, earlier involved in critiquing genetic engineering for agricultural biotechnology, has called for a moratorium on research and development of nanoparticulates until safety issues can be thoroughly assessed.[2] The popular British press has reported on Prince Charles' concern about the potential destructive impacts of "gray goo" nanomachines proliferating out of control.[3] Michel Crichton's recent novel "Prey" centers on struggle against escaped swarms of nanobots.[4] While earlier debates about the promise and peril of nanotechnology were largely confined to narrower circles of technology aficionados, science fiction fans, and speculative futurists, debate about nanotechnology is now moving more clearly into the public eye.

Even though nanotechnology may have even bigger social impacts than information technology or biotechnology, the social and ethical issues involved have so far received much less attention and discussion, particularly in comparison to the billions of dollars already being invested in nanotechnology research and development. The special properties that have already led nanomaterials to be used in sunscreens, tennis rackets, clothing treatments and other uses may pose new risks that deserve special regulatory attention. Future applications of nanotechnologies are expected to have much more dramatic impacts. The public is involved as current, and, more importantly, possible future users of products employing nanotechnology, as well as citizens of countries that are investing heavily in nanotechnology research and development.

Emerging technologies such as nanotechnology offer new opportunities and new dangers, posing questions for researchers, ordinary citizens, government officials, and others about what roles they may play in promoting safe and socially beneficial development and application of new technological capabilities. Nanotechnology, the precision control of materials at the scale of individual atoms, represents a set of technologies that could have profound impacts on all aspects of life. This paper discusses public participation processes that might contribute to the governance of these emerging technologies.

The first section briefly introduces nanotechnology and some potential implications. The following sections review relevant methods and challenges for public participation in the development of nanotechnology, particularly concerns about abuse of new technological capabilities, initiatives to promote informed and effective self-governance by researchers and other stakeholders, and the challenges for society in dealing with unpredictable and potentially highly disruptive technologies. A table summarizing key ideas is provided at the end of the paper.

The discussion is organized in terms of levels of participation:[5]

- No participation
- Information
- Consultation
- Involvement and collaboration
- Empowerment

NANOTECHNOLOGY

Atomic force microscopes, such as those used to place individual xenon atoms spelling out the IBM logo, are part of a growing capability to observe and manipulate individual atoms and molecules at the nanoscale of billionths of a meter. Nanotechnology products currently on the market have just begun to enter a few specialized applications, but large investments, already in the billions of dollars per year, are being made in nanotechnology research and development.

Advances from microelectronics to nanoelectronics hold the prospect of further shrinking and accelerating computers and other information technologies, as well as offering much more efficient ways to trap and hold solar energy. Nanotechnology is expected to enhance and complement biotechnology, developing sensors, precision drug delivery systems and nanomedical devices to make repairs within cells, improving health and extending life.[6] Nanotechnology should offer greatly enhanced capacity to prevent and clean up environmental pollution, for example filters to purify water and extract pollutants. Nanotechnology is expected to yield better materials and products, fashioned more precisely, less wastefully, and at much lower cost.

There are technical debates about the feasibility of specific forms of nanotechnology, particularly the "molecular nanotechnology" of self-replicating assemblers proposed by Eric Drexler in the 1980s.[7] Drexler, and the Foresight Institute he helped establish, have been concerned with the possible benefits of nanotechnology, and even more concerned about the dangers it might pose, and the need to prepare society for powerful new technologies. However even leading scientists who disagree with bold visions of nanobots, global abundance of ultra-cheap manufactures, and rejuvenation, still argue that nanotechnology can be expected to have dramatic consequences for energy (e.g. cheap solar power), health, manufacturing, information technology, space travel, and augmentation of the physical and mental capacities of human beings.

Most discussion about the potential dangers of nanotechnology has focused on the dangers of accidents with self-replicating nanomachines, "gray goo"[8] or use of nanotechnology in warfare, [9] but there has been much less discussion of the broader social and economic impacts.[10] Apocalyptic threats, of accidents and abuse have attracted much attention. However, the most important risks and opportunities are likely to come from more prosaic applications that drastically reduce costs and increase capabilities, a disruptive general purpose technology with profound consequences for economies and societies.

Risks of Non-Participation

One possibility is that the public is ignored and excluded from discussions about research and development. Technical complexity makes it convenient to confine discussion to suitably qualified experts. However, experience from other fields indicates that this could lead to major problems downstream.

The story of nuclear power in the United States is the most conspicuous example of how overconfidence in the efficacy of safety measures, secrecy, and exclusion of the public ultimately bred distrust and polarization, creating "technological gridlock."[11] Simplistic discussion focusing only on the upside of nanotechnologies would be similarly likely to breed suspicion, comparable to earlier advocacy of nuclear power "too cheap to meter" from "the friendly atom." Ignoring the public may be an easy option in the short term, but creates the risk of criticism and major adverse impacts on reputation and business prospects later on. In Britain and other parts of Europe, controversies about "mad cow disease" are another example of the loss of public trust in regulatory agencies dealing with complex scientific problems.

Blanket claims that nanotechnology products are "substantially equivalent" to existing products, and so do not deserve any special labeling or regulatory attention risk running into the kind of controversies which have surrounded genetically modified foods. In the U.S., the theory of substantial equivalence permitted introduction of GM foods with relatively little public discussion for a period of time, but was later followed by alarms about "Frankenfoods" and vigorous opposition to GM foods.

Secrecy, silence, and overconfidence in the potential for containment and accident prevention may breed later problems. Experience suggests that all organizations involved in nanotechnology research and development, including government agencies, research institutes, and businesses, would be wise to undertake a pro-active approach to engaging the public.

Information

The first step on a ladder or spectrum of participation is sharing information. Nanotechnology is now receiving increasing coverage in newspapers and magazines, expanding beyond more specialized technical communities and science fiction stories. Most research has been conducted through science and its largely open procedures, and published in scholarly journals, through now patents and trade secrets are beginning to play a larger role. A growing number of websites report on nanotechnology science, investment, and other topics.

Nevertheless discussion is complicated by technical complexity. Aside from gray goo of swarming nanobots, there are still few easily digested sound bites for media. For most people, rejuvenation through nanomedicine, use of structural diamond as a commonplace building material, or household nanofabricators making products to order as easily as photocopies are currently printed, are still visions far too speculative to be taken seriously.

Many existing institutions already promote availability of information about some nanotechnology research and development. Government agencies, such as those funding nanotechnology research, are generally required to share information with the public about their activities. Interested citizens, journalists and others can also request more detailed disclosure of official records. Private companies have fewer obligations to share information, but are still required to file certain kinds of information with regulatory bodies such as the Securities and Exchange Commission and patent offices. To the extent that products, such as titanium nanoparticles in sunscreens and "Nanocare" antistain treatments on clothing, explicitly advertise their presence, such labeling may reduce worries about invisible and involuntary exposure.

Public and private organizations can also employ the usual range of public relations techniques to distribute information through press releases, briefings, interviews, tours, e-mail lists, webpages with Frequently Asked Questions (FAQs), advertising and other methods. They may also produce technical reports, journal articles and other documents aimed at more specialized audiences. Growing public concerns, such as those mentioned at the beginning of this paper, suggest that companies, research institutions and other organizations involved in nanotechnology research and development may wish to do more to make information available, and to engage in additional measures to improve understanding and discussion about how nanotechnology can be wisely developed.

CONSULTATION

Consultation involves a shift from one-way communication to two-way interaction, from education to dialogue. Typical consultation methods include public hearings, focus groups, suggestion boxes, open houses, and question and answer sessions. Broader discussion in the media, policy studies and other forums can also be considered a form of consultation that offers input into societal decisions about nanotechnology.

Legislative hearings on nanotechnology have provided some opportunities for comment from invited experts.[12] However until recently public discussion has largely been confined to relatively small groups of aficionados,[13] and a few early warnings from groups concerned about negative impacts of technology.[14]

Despite some relevant precedents in the human genome initiative, relatively little attention has been paid so far to social and ethical implications of nanotechnology. Resources are now becoming available, for example funding from the U.S. National Nanotechnology Initiative, for research on social and ethical issues. These could be employed to improve public participation in nanotechnology research and development.

Since the 1980s, the Foresight Institute, founded by Eric Drexler, has sought to promote discussion of how to deal with both the promise and perils of molecular nanotechnology.[15] Foresight has produced newsletters, papers, books, and a website to share information. It has organized conferences that have concentrated on technical issues but also included some papers dealing with issues of safety, international security and other broader implications Foresight has tried to engage in dialogue, both with those questioning the feasibility of nanotechnology and others alarmed by the dangers it might bring.

Another recent attempt to promote better informed public discussion comes from the Center for Responsible Nanotechnology, which is preparing a series of papers on various issues. For example, their analysis of how interpretations of precautionary principles might be applied in nanotechnology argues strongly for weighing the benefits that might be foregone if new technological capabilities are not developed.[16]

Risk communication issues pose a major challenge for public discussion about nanotechnology. Several "outrage" factors likely to elicit concerns about risk[17] are present, including:

- Novelty
- Invisibility
- Involuntary exposure
- Dread of catastrophe

Public concerns about risks of GM foods were exacerbated by the possible invisible and involuntary nature of exposure, issues which will also be present with nanotechnologies. Assertions about the feasibility of containing the spread of genetically modified organisms were undermined by controversies about dissemination of pollen from genetically engineered corn into nearby fields, and by the appearance of Starlink™ corn, intended only for animal consumption, in tortillas. Arguably, GM foods offered few clear benefits to consumers, aside from possibly lower prices, even though they did offer benefits for producers in reduced costs for pesticides, which might also bring positive environmental benefits.

The scale of nanotechnology makes it "invisible," and increases the likelihood that exposure may be involuntary. Scenarios of runaway self-replicating nanomachines generate dread of catastrophic outcomes. Some of these risk concerns can be addressed by ensuring control and containment, and voluntary, informed use of the technology, issues which are already being addressed in fields such as regulation of toxic substances, protocols for genetic therapy and safety measures in medicine using radioisotopes. Nevertheless these characteristics are likely to generate continuing concern about risks. Alarms about apocalyptic scenarios of accidents and abuse may also divert attention from the broader implications of emerging nanotechnologies. Drexler and others concerned about nanotechnology have sought to point out potential benefits such as improved medical care, environmental protection, and poverty alleviation, making the positive benefits for ordinary people much clearer.

Consultation tends to mostly involve those already interested in public policy issues. While discussion in mass media often highlights dangers, and concentrates on simple sound bites, some of the issues involved in nanotechnology research and development deserve deeper and more balanced consideration.

INVOLVEMENT AND COLLABORATION

Public involvement programs go beyond information and consultation to systematically engage stakeholders in identifying their concerns and ensuring they are addressed in the final decision. Workshops and other forums can offer opportunities for more intensive dialogue, the results of which can then be used by those making the decision. A good process should provide the public with feedback on how their inputs affected decisions.

In collaboration, through citizen panels, task forces, advisory committees and other methods, stakeholders have a "seat at the table" enabling them to participate actively in developing alternatives and identifying preferred solutions. For public participation at the level of involvement or collaboration, the final decision still lies in the hands of a regulatory agency, private company, or other ultimate decisionmaker. Typically, such a decisionmaker (or series of decisionmakers in a government or business hierarchy), acts on the recommendations formulated by a collaborative group in which stakeholders have a major role. However it is worth noting that stakeholders have not only voice in the process, but power in the extent to which they retain the option of resorting to other channels, such as criticism in the media, political lobbying, and litigation in court, if they are not satisfied with the direction or the results of the process.

So far for nanotechnology, little use has been made of more systematic methods for promoting discussion, such as stakeholder panels or citizen juries.[18] In dealing with technically complex issues, these methods have the key advantage of allowing a representative group of people time to learn about and consider new, technically complex issues, moving beyond first impressions to deeper examination. Citizen juries and similar methods have been used to examine questions in biotechnology as well as other social policy issues. Stakeholder panels have been employed for activities such as deciding the location of new facilities and developing emergency plans for chemical plants. In the case of nanotechnology, such public involvement methods could help to overcome some of the barriers posed by technical complexity. They might also help direct attention to the broader implications of nanotechnology for everyday lives, redressing the bias toward attention to catastrophic scenarios of accident and abuse that are more attractive for media coverage.

A prominent example of collaboration is negotiated rulemaking, where regulatory agencies involve representatives from potentially affected businesses, concerned civic organizations, specialist experts, and others to take part in drafting regulations. Such methods can draw on knowledge of the participants and formulate regulations that are likely to be more feasible to implement, and less likely to result in objections and legal challenges, than regulations formulated by an agency unilaterally. Negotiated rulemaking could play an important role in the development of regulations concerning nanotechnology, particularly given the technical complexity of many of the issues.

Regulatory attention to nanotechnology is in an

AVOIDING CATASTROPHE

The most apocalyptic scenarios for nanotechnology concern "gray goo," the specter of swarms of self-replicating nanobots consuming the biosphere. Subsequent analysis has shown the potential for safe design to prevent accidental development of runaway replicators by a variety of means, such as building in dependence on artificial "vitamins," and requiring external information and authorization for reproduction. As weapons, gray goo nanobots would be extremely inefficient compared to alternative technologies, particularly bioengineered viruses, suggesting their use is unlikely. Although nanotechnology is likely to be employed in other weapons, those would not pose such catastrophic risks.

Catastrophic technological risk is not new and there are ways to deal with such risks. Based on earlier regulatory experience in areas such as industrial safety, toxic chemicals, recombinant DNA, and nuclear power, Morone and Woodhoouse (1986) identified a set of strategies for averting potentially catastrophic risks. Protection against potential hazards can be pursued through *containment* (as done with research on hazardous biological substances and nuclear power), *prohibitions or limitations on use*, *siting* and other measures to reduce or mitigate adverse impacts by intervening in the chain of events that could led to catastrophic impacts. *Cautious research and development* can seek to control and incrementally examine risks. *Testing* can be carried out to assess specific risks. Pro-active measures can be taken to *learn from experience*, as occurs for example after aircraft accidents, and as occurred in the progressive relaxation of restrictions on rDNA research as it became clear that risks could be controlled and were much lower than initially suggested. *Setting priorities* among risks can play a crucial role.

Strong technical arguments have been made as to why apocalyptic scenarios for accident or abuse of nanotechnology are unlikely. The broader economic and social opportunities and threats affected by nanotechnology are likely to be more important topics for debate. Discussion of ways to deal with catastrophic risks can be expected to be a continuing part of public debate about nanotechnology. However methods are needed that help keep from becoming obsessed with catastrophic dangers, and ensure adequate attention to other possible implications, negative and positive, for society, economy and environment.

early stage. However, much research is already guided by existing safety procedures, and products would come under existing regulatory regimes. A key question thus concerns the extent to which new or special measures are needed to deal with nanotechnology. Recently raised concerns about research and applications involving carbon nanotubes and other nanoparticulates, and advocacy of a moratorium until consensus is developed on suitable safety precautions in nanotech R&D,[19] is likely to be only one of many debates about the extent to which nanotechnology deserves special regulatory attention.

The nature of public involvement will depend on the kind of regulation that may be pursued. For the case of self-replicating assemblers, molecular nanotechnology, there are special challenges. It seems likely that prohibition is unworkable, and military monopolization of nanotechnology research and development undesirable.[20] If so, then civilian research and development might be guided by an approach similar to that used for recombinant DNA technology. This could rely primarily on self-regulation and responsible professional practice, backed by a modest level of government regulation. If such an approach were able to forestall accidents and develop the capabilities needed to defend against abuse, then the other major issues would concern the impacts of molecular nanotechnology as a new general-purpose technology with major impacts.

A broader issue concerns the allocation of effort between attempting to define and anticipate risks in advance and developing capacity to resiliently respond to risks over time, particularly in cases where there is a large degree of uncertainty about how new technologies will actually be applied. Rather than only devoting resources to planning and anticipation to prevent problems, it may be more productive to balance anticipation with resilient strategies for learning from and responding to problems as they actually appear.[21]

Typically in the discussion that occurs as part of consultation or public involvement activities, participants bring their own broader agendas, for example proponents seeking to profit from a technology, politicians pursuing publicity and support, and nongovernment groups with their own particular missions. The recent calls for a temporary moratorium on nanotech development come from a group that has been active in debates about genetically modified organisms (GMO), particularly new biotech crops. They are extremely concerned about international inequities in access to new technologies and the dangers of corporate monopolies exploiting and abusing intellectual property rights.

Regulations focus on decisions made through government procedures. A strong government role may be advocated as a way of promoting democratic participation in decisions about development of technologies with major implications for societal welfare. A key issue concerns the extent to which decisions are made through a centralized regulatory process, versus being left up to more decentralized actions of individuals, corporations and others acting on their own, though still possibly constrained by broader regulatory restraints and guidelines.

EMPOWERMENT

The next level of participation is often discussed in terms of empowerment. Empowerment offers participants greater ability to determine their own futures, in contrast to just being informed, listened to, engaged in participatory processes or carrying out joint decision-making. Participation need not be restricted to citizens taking part in government actions to legislate, plan or regulate, or working in partnership with government, but includes the space for individuals, groups and communities to act autonomously and independently. Empowerment is a broad category that can be further subdivided into several different levels:

- Partnership (co-management)
- Delegated authority
- Regulated autonomy
- Responsible independence[22]

Under public involvement and collaboration, the final authority remains with one party, such as a government agency or private company, even if that decisionmaker informs, listens to, and involves others in the decision process. By contrast partnership means all parties take part in determining decisions, so that authority and responsibility are genuinely shared. Decision rules might require unanimity, where all parties have a veto; consensus, where everyone agrees to support, or at least not oppose, an outcome; or be based on a majority vote or other procedure. When an agency of government is involved in such joint decision-making the power relationship is inherently asymmetric, but is still significantly different from a situation where government retains final decision-making authority.

In some cases the pursuit of consensus in negotiated rulemaking may approach a partnership or collaborative approach. Other participants willing to engage in legal challenges to rules with which they are unhappy have a strong weapon to bring into play, even if the immediate authority to issue regulations lies with government. Where government agencies enter into cooperative arrangements with communities, private sector groups, or other entities, with both sides having a strong say in framing the terms of cooperating and deciding whether or not to act together, then the arrangement can be seen as one of partnership.

One area where public-private partnership arrangements might play a significant role in nanotechnology lies in establishing relevant standards, e.g. for software and communication interfaces in nanotechnology, as an alternative to proprietary standards controlled by a single company, or standards unilaterally established by government.

Where a concerned community takes substantial initiative in proposing rules, while inviting government to provide authoritative sanction for the final rules, then the relationship goes beyond collaboration to be more one of partnership. The process by which regulations for recombinant DNA were developed is a good example in which the scientific community took the initiative to develop rules for promoting safety in research and development of an emerging technology.

Scientists, engineers, and others concerned about preventing accidents and reducing the risks of abuse of technology need not wait for government regulation, but can also take initiative themselves. The Foresight Guidelines on Nanotechnology represent one such effort.[23] The guidelines are intended to ensure that any nanomachinery that might have the potential for self-replication is designed with appropriate safeguards, spelling out both broad principles and detailed suggestions such as making reproduction dependent on external information, authorization, and special materials. As with the guidelines on recombinant DNA research, guidelines such as those proposed by Foresight may become incorporated in a mix of mandatory government regulations and voluntary research standards. The development of the Foresight Guidelines represents an example of empowered action, initiated independently of government, looking ahead to deal with potential risks of a new technology. Recent draft legislation proposed to the U.S. Congress includes calls for development of suitable guidelines for self-replicating nanomachinery, incorporating several of the ideas laid out in the Foresight Guidelines.

A further level of empowerment allows stakeholders the freedom to make decisions themselves, within regulatory guidelines and reporting requirements. Beyond specific regulatory requirements, a community, business or other entity which is legally liable to harm created by its products will need suitable insurance, and so have incentives promoting responsible development of nanotechnology. The potential legal consequences for product liability would help to regulate behavior, promoting safe use and providing incentives to prevent accidents and abuse. To the extent that companies seek to obtain insurance to protect themselves against liabilities this could stimulate sophisticated assessment of risks and other problems, with a minimal government role.

In addition to specific worries about liability, individuals, corporations, and other institutions, such as universities, may also be motivated by concern to protect their reputation. Consequently, they have incentives as private actors to respond to social concerns. Liability and reputation offer a way of promoting responsibility in how individuals and corporations use their independence. They also offer a source of leverage for potential affected individuals and groups, and other activists, which may bypass or complement more conventional regulatory routes for dealing with risks and social impacts of new technologies. These dynamics have clearly been at play in debates about GMOs, evaporating the value of stocks in companies involved in agricultural biotechnology and discouraging further investment in the field. Reputational incentives may also play a significant role in nanotechnology.

Participation in nanotechnology also involves issues of who has access to knowledge and who has rights to develop the technology. Intellectual property law concerning patents, copyrights, trade secrets and related issues has begun to play a major role in affecting access to technology. This invokes issues about the extent to which patents offer suitable incentives for innovation and the extent to which they may needlessly promote monopoly, exploitation, excessive transactions costs, inequity, and other problems.

The application of "open source" approaches to software development, as exemplified by the Linux operating system and the development of hypertext markup language for the worldwide web illustrates one way of expanding participation. Application of such approaches to software and hardware for nanotechnology could make a major difference in who gains access to nanotechnology.[24] Such approaches may promote applications that empower individuals to use and develop the technology. Conversely, highly restrictive licensing could promote monopolies.

One of the challenges in promoting public discussion about empowerment and self-governance in nanotechnology R&D may lie in how to avoid polarization and simplified rhetorical stereotypes of total laissez-faire and extreme over-regulation, and instead engage in a more nuanced analysis of issues and alternatives for technology governance. While empowerment is unlikely to be the only strategy involved in the governance of nanotechnology, partnerships, delegated authority, regulated autonomy, and responsible independence may still supply an important complement to consultation, involvement, and collaboration in government regulation, as part of developing a suitable system of technological governance.

CONCLUSIONS

The scope of participation in nanotechnology research and development so far has been relatively narrow. Consultation methods, such as participatory planning, stakeholder panels, and citizen juries seem particularly promising as a means to improve public discussion.

Nanotechnology research and development, and related discussions about how to best regulate and utilize new technological capabilities will engage with larger societal debates about technology and social values. Some of this debate will focus on the relevance of and various interpretations of "precautionary principles," how to make decisions before solid scientific confirmation is available, who should bear the burden of showing that new technologies are safe or dangerous, and an appropriate balance between anticipatory planning and resilient learning responses. In the absence of consensus on underlying principles, specific arguments about nanotechnology issues are likely to be entangled with these more fundamental philosophical disputes.

Similarly, concerns about potential inequities in access to benefits from new technologies and fears about corporate monopolization and exploitation of new technologies may be major issues for many participants in societal debates, as has occurred in the case of genetic engineering. Religious values and other moral beliefs will be challenged by the development of new ways to augment human capabilities by implanted machines, life extension therapies, and other new technological capabilities. Differing views about technical progress, environmental sustainability, individual liberty and other key values can lead to sharply different views about how to respond to the new opportunities created by nanotechnology.

Participation in nanotechnology need not be restricted to being informed or consulted about government action, but also includes ways in which researchers, engineers, and citizens in general may be empowered to take part in an open and responsible process of technological development. Participation in nanotechnology involves decisions not just about use of specific methods such as information sharing, consultation, partnership, and self-governance, but also broader questions about the roles of government, and the pursuit of individual and societal goals. Some key areas for discussions about nanotechnology through workshops, advisory panels, and other means include:

- Risk communication
- Intellectual property
- Impacts on global poverty and affluence
- Coping with economic transformations

Government agencies, businesses, civic organizations, and others concerned about research and development of nanotechnology can draw on the full range of public participation methods. Collectively these could help constitute a system of institutions for governance of nanotechnology. In the short term, the key opportunities for improving participation lie in application of citizen juries, stakeholder panels, participatory workshops, and related techniques for consultation and public involvement that bring together a broad range of concerned groups and networks, and allow them adequate time to learn about and deliberate aspects of the social choices involved in researching and developing nanotechnologies.

NOTES

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Levels of Participation for Public Involvement in Nanotechnology

LEVELS	EXAMPLES	ADVANTAGES/DISADVANTAGES
0. No participation	• Withhold information • Deny dangers, dismiss critics • Confine discussion to experts and technical issues • Disregard differences between new technologies and products and old ones, e.g. "substantial equivalence"	• Delay in discussion and analysis • Outrage and backlash if concealed problems show up later on • Risk of "technological gridlock," e.g. nuclear power • Risk of losing public and investor confidence, e.g. Monsanto, GM crops
1. Information	• Regulatory filings • Journal articles, technical publications • Public relations: press releases, FAQs, briefings, interviews, tours, websites, e-mail lists, advertisements, etc.	• Better understanding by public and decisionmakers • Concerns about bias, selective disclosure • One-way, lack of dialogue
2. Consultation	• Public hearings, public comment procedures, community open houses, focus groups • Online forums, addresses (postal and e-mail) for comments	• Facilitate diverse, well-informed public input into decision-making • Identify public concerns and ideas • Difficulty in understanding and discussing complex technical issues • Need for inclusive outreach
3. Involvement	• Participatory workshops	• Engage representative range of concerned people • More intensive interaction • Results are input to decisions
4. Collaboration	• Stakeholder panel input into plans • Citizen jury recommendations • Negotiated rulemaking by regulatory agencies together with stakeholders	• Stakeholders have a "seat at the table" in developing and ranking alternatives • Customized adaptation to technical and economic constraints and regulatory goals • Risk of process being captured by narrow interests
5. Empowerment partnership (co-management), delegated authority, regulated autonomy, responsible independence	• Joint decisions by concerned groups and government, e.g. in standards-setting • Self-regulation, e.g. Foresight Guidelines on MNT, corporate codes of conduct, environmental audits • Reputational consequences • Tort law, insurance • Open standards, open source software, non-exclusive licensing, etc. • Consumer choice in technologies and products, labeling	• Obtain advantages of both government authority and professional standards • Encourages voluntary initiative, flexible development of best practices • Focus on individual and corporate responsibility • Difficulties in determining liability • Facilitate collaboration, error detection, prevent monopoly abuse • Reduce concerns about invisible and involuntary risks