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5 Lost in Translation? The Need for 10 ‘Upstream Engagement’ with Nanotechnology on Trial

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20 ABSTRACT Nowadays, the criticism of the so-called ‘deficit model’ and the need for ‘upstream
engagement’ in science and technology are becoming part of the master narratives of public
policies in many countries, especially concerning nanotechnology. This may be considered as a
major success for STS scholars, whose research results have largely contributed to this change,
especially those concerning the GMO controversies. Some STS scholars thus move from a
position of distant and critical observers to the role of experts in social engineering or advisers
of policy-makers. However, in their enthusiasm concerning the expected benefits of upstream
engagement, institutions, TA practitioners and social scientists seem to ignore some important
25 limitations as well as the implicit framing assumptions of the concept. Based on an experience
made by a group of social scientists in the Grenoble area—one of the major ‘nanodistricts’ in
Europe—our paper shows that the ‘upstream engagement’ concept is still embedded in a linear
model of innovation and is not very useful to anyone pursuing the co-production of innovations.
It is especially true when socio-technical networks are already aligned by powerful actors and a
worldwide agenda as in the case of nanotechnology. In order to give an opportunity for public
engagement to have a larger impact on decision-making, we propose an alternative approach,
30 which combines Actor–Network Theory (ANT), as an analytical tool, with the reflexive and
ongoing implementation of public participation. Public engagement is probably one of the critical
loci where STS scholars must reflect on the articulation between the knowledge they produce and
public policies in action.

35 KEY WORDS: Upstream engagement, public participation, technology assessment (TA),
co-production, nanotechnology, Actor–Network Theory (ANT), local government, science and
technology studies (STS)

40 Introduction

Nowadays, the criticism of the so-called ‘public understanding of science’ (PUS) model
and the need for public engagement in science and technology are becoming part of the

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master narratives of public policies in many countries. The PUS programme, launched in 1985 by the British Royal Society, addressed a quite undifferentiated entity called ‘the public’, which was to be educated and informed in order to secure support for innovation and reduce social resistance to technology. The more thoughtful critiques of this asymmetrical vision of the relationship between science and society have been developed in the UK at the ‘Lancaster School’ (Wynne, 1992; Irwin & Wynne, 1996). PUS is now characterized as a ‘deficit model’, in which lay people are conceived as passive and empty recipients of information to whom the institutions—be they universities, research centres, mass media, museums or schools—are supposed to provide education.

By contrast, ‘upstream engagement’ is now claimed to be a basic component of nanotechnology policies in various countries. ‘Public engagement’ is generally defined as a form of two-way communication between the public and those who have knowledge of, or power over, the particular issues at stake. Thus, ‘public engagement’ has the same meaning as ‘public participation’ which it tends to replace in some countries like the UK. In France, the term ‘public engagement’ is uncommon and ‘public participation’ is generally used. In this paper, we will use ‘public engagement’ and ‘public participation’ interchangeably. ‘Upstream engagement’ means that two-way communication has to take place in the early stages of technological development and not only downstream, in the adoption phase.

The UK is at the forefront. The 2004 report by the Royal Society and Royal Academy of Engineering *Nanoscience and Nanotechnologies: Opportunities and Uncertainties* provides key arguments for upstream engagement on nanotechnology (Royal Society & Royal Academy of Engineering, 2004). The UK government explicitly endorsed these views in its recent 10-year strategy for science and innovation, which includes a commitment

to enable [public] debate to take place ‘upstream’ in the scientific and technological development process, and not ‘downstream’ where technologies are waiting to be exploited but may be held back by public scepticism brought about through poor engagement and dialogue on issues of concern (HM Treasury, 2004).

The same spirit also inspires the *21st Century Nanotechnology Act* adopted by the US Congress in 2003. The Act requires public input and outreach activities to be integrated into the nanotechnology research programme ‘by the convening of regular and ongoing public discussions, through mechanisms such as citizens’ panels, consensus conferences, and educational events, as appropriate’.

Even in France, despite a strong technocratic tradition, public authorities are joining the bandwagon: former Prime Minister de Villepin has called for a public debate on nanotechnology in his address to the ‘Etats Généraux des Entreprises et du Développement Durable’ (National Debates on Firms and Sustainable Development, 31 May 2006). In January 2007 the local government of Ile-de-France organized a citizens conference (the French label for the Danish consensus conference)—to mention just two examples.

Contemporary interest in public engagement in science and technology may be considered as a major success of STS scholars, whose research results have largely contributed to this change. However we would like to raise two types of questions related to this change. First, we wonder whether this announces a genuine paradigmatic shift or if it is just a rhetorical change, a new way of educating ‘lay people’. Second, the call for

‘public engagement’—whatever this may actually mean—creates a new situation for STS scholars, since they move from the periphery to centre stage, as they are collectively the main source of this master narrative. Some STS scholars thus move from a position of distant critical observers to the role of experts in social engineering or advisers of policy-makers, which is a matter of debate within the STS community.¹

As often claimed—by STS scholars as well—the need for public engagement in nanotechnology is one of the major lessons of the GM debate. To quote Arie Rip, the GM case contributed to a ‘nanophobia-phobia’—the phobia that there is a public phobia (Rip, 2006, p. 358). Thus, in many countries there is a wide agreement on the following assessment:

- the GM crops saga is considered as a failure in the way a new technology has been introduced in society—especially in Europe, but also in the US, despite their widespread use;
- this failure is partly attributed to the deficit model, since the lack of upstream debate fed the severe backlash which occurred in most countries in the late 1990s;
- thus, if one wants to prevent a similar backlash for nanotechnology, it is necessary to foster upstream public engagement.

Although quite crude, such a formulation allows us to push reflection a step forward. Let us consider the GM crops saga and imagine a counter-factual history including upstream public engagement. For the purpose of this reflection, ‘upstream engagement’ may be equated to the organization of public debates, such as ‘GM Nation!’ in the UK, consensus conferences, etc., at an early stage of a technology’s trajectory.

Thus in our counter-factual history, public debates on GM crops would have been organized in the 1980s and—let us be optimistic—this would probably have resulted in recommendations on the right to be informed and to choose (labelling, traceability, co-existence, etc.), on risk regulation (including issues such as independence of expertise, a precautionary approach, etc.), and eventually on the need to prevent appropriation of life forms through patenting. We might also have registered a demand to target biological research to comply with small farmers’ needs and to protect biodiversity. But then, how would the outcomes of these debates have been translated into action? Would that have changed the policy-making process of any of the research institutions or any of the private companies’ strategies? Would such a change have been mediated by transformations in the public sphere and/or a more active role of media and civil society?

There are currently no answers to such questions. And this is one of the blind spots of the upstream engagement discourse, which does not provide many hints on the relations between public deliberation, power structures, policy-making, and innovation processes. Including such relations in the scope of STS analysis is a major challenge.

STS scholars are well aware of the dangers of misusing the need for upstream engagement. Institutions may just employ it as a more sophisticated way of promoting public acceptance of new technologies, as noted by Brian Wynne. Accordingly, he observes that policy-makers are ‘hitting the notes but missing the music’, failing to acknowledge the deeper challenges of opening up their institutions and assumptions to critical debate (Wynne, 2006b). He also raises the question as to how STS scholars can better handle **Q1** the translation of public engagement into practice:

In the very process of taking on influence, we are interpreted in ways that of course we don’t control, and may not accept nor even understand. The next question hovers:

can STS influence its own ‘influence’, to limit its transformation into alien goods? (Wynne, 2007).

140 This paper deals with such an issue: when the knowledge produced by STS scholars is implemented in practice, how is it possible to prevent the knowledge from being lost in translation?

145 This paper is based on an advice on ‘Public debate and nanotechnologies’ produced in 2005 on behalf of the local government of Grenoble, also known as *La Métro* (Joly, 2005). The working group was coordinated by Pierre-Benoit Joly and comprised STS scholars (Michel Callon, Jean-Michel Fourniau, Claude Gilbert, Marie-Angèle Hermitte, Claude Joseph, Alain Kaufmann, Raphaël Larrère), members of Fondation Sciences Citoyennes, a think tank involved in science policy (Laurent Dianoux, Claudia Neubauer) and Roland Schaer (Cité des Sciences et de l’Industrie). Our paper is based on information collected for the advice. Within a six-month period, we conducted a series of hearings and inter-
150 views of policy-makers, NGOs and scientists involved in nanotechnology projects in the Grenoble area (13 hearings and four interviews). We also analyzed all available information on local nanotechnology projects, using institutional as well as activist sources, and all the decisions taken by local governments. Finally, we acted as participant observers in various public conferences organized in Grenoble.

155 Taking a reflexive stance on this experience, we examine the conditions under which STS scholars can help in preventing mistranslation and provide some guidance for genuine public engagement, while accepting the role of policy advice.

160 **‘Would You Help Us Organize Public Debate on Nanotechnology in Grenoble?’**

In October of 2004, Jean Caune, Vice-President in charge of research and new technologies at the local government of Grenoble, called *La Métro*, and also Professor of Communication Sciences at the University Stendhal at Grenoble, asked a group of social scientists to help his institution prepare a public debate on nanotechnology. *La Métro* is the name of the community of cities in the Grenoble area. Its council is constituted of
165 elected representatives of these cities. *La Métro* is the key local institution dealing mainly with territorial planning, but also with research and innovation policies.

Caune’s motivations for developing this initiative, as discussed in the first meetings, were rather ambivalent. On the one hand, he considered public debate to be instrumental in fostering ‘démocratie technicienne’ at the local level. Grenoble is one of the major
170 European nanodistricts, and local institutions, including *La Métro*, have actively contributed to this achievement through public funding. Indeed, nanotechnology is emerging as a mainstay of development in the Grenoble area, with a lot of promises but also with heavy investments which affect scientific and industrial policy. According to Jean Caune, the important stakes involved require public debate. He expected public debate to also help
175 elected representatives better grasp this issue, in light of the, in his view, unsatisfactory deliberation on nanotechnology at the Council of *La Métro*—although he himself was at the core of the policy process. On the other hand, this initiative was also triggered by the local campaigning of an activist group, *Pièces et Main d’Oeuvre* (PMO) (www.piecesetmaindoeuvre.com).
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Members of PMO define themselves as ‘ordinary citizens’ (Simples Citoyens). They raised public attention through a mix of confrontations and radical criticism of the logic

of development. For instance, they blocked the construction of the Minatec Centre for nanotechnology for several weeks. Minatec stands for Micro and Nano Technology. It is described by its promoters as ‘Europe’s top centre for innovation and expertise in micro- and nanotechnology’ (www.minatec.com). PMO activists struggle against the ‘Techno-gratin’ which develops ‘necrotechnologies’. Linguistic invention is one of their strengths. ‘Techno-gratin’ stands for techno-elites or technocrats, since ‘gratin’ is the slang word for elite; also, there is a specific gastronomic reference since ‘Gratin Dauphinois’ is the local traditional course made with potatoes and cheese. The term ‘necrotechnologies’ (from the Greek *Nekros*) was coined by Jean-Pierre Berlan, economist at INRA and anti-GM activist, to pinpoint what he considers to be the true identity of ‘biotechnologies’ (from the Greek *Bios*). French activists have then taken up this neologism to name a set of new technologies including bio- and nanotechnologies. Thus political representatives saw PMO as a threat.

Within the Council of *La Métro* there was also a tension between the willingness to open up decisions and find a way to foster public participation, on one hand, and the feeling that it was necessary to organize communication and educate the local population in order for lay people to get a better understanding of the key stakes involved in nanotechnology, on the other hand. Both positions are not totally opposed, since it is fair to say that the social appropriation of such a new technology requires a minimal collective understanding of relevant knowledge, that is, that we are collectively ‘scientifically literate’ (Jamison & Hard, 2003).

Both positions gave rise to two different projects: first, a two-day public conference called ‘Sciences and Democracy Forum’ in June 2005. It took a traditional form: roundtables of four or five prestigious speakers (scientists, policy-makers, stakeholders, etc.); the discussion was facilitated by a journalist, and the audience (about 300 people) could hardly interact. This project fit the culture of local political elites and the public relations department of *La Métro*. It was ambitious and well managed but to some extent ‘business as usual’.

We were asked to contribute to a project that was more innovative. There was a willingness to promote more participatory types of debate, possibly in order to feed the policy-making process. For this second project, there was no ready-to-use model. We could have helped organize a consensus conference—and to some extent this was what *La Métro* expected—but we were convinced that this would require a preparatory phase in order to provide an understanding of the local context and to better define the objectives of public deliberation on nanotechnology.

This is basically the way we defined the mandate of our working group: prepare a diagnosis of the local configuration of nanotechnology projects; present the various options available for participatory exercises; and make some recommendations about the road to follow in order to move towards a more participatory culture.

Struggling with Key Analytical Points to Produce Advice

Reflection on this case allows anchoring general questions about public participation in a specific situation. Despite the contingencies and our own subjectivity, this experiment is thus instrumental to analyzing the relations between public participation, decision-making and innovation processes.

The negotiation of our mandate and our approach to the advice was much influenced by our own perception of the interaction between science, technology and society. And indeed, this perception is influenced by our research activities as STS scholars. Thus, it is necessary to begin with a brief clarification of our own understanding of how STS knowledge articulates the claim for ‘upstream engagement’.

According to most STS scholars, it is necessary to think of forms of deliberation which go beyond debating ‘downstream’ socio-political impacts of technological choices. As a main lesson of STS, there is no clear-cut separation between science and politics or between facts and values. On the one hand, the scientific enterprise incorporates hidden value judgements on what is necessary or good for society; on the other hand, agency is delegated to technical objects (Latour, 2005). Thus for STS scholars, technology is a structure of power which may—or should—be negotiated.

Accordingly, some STS scholars have highlighted situations of co-production of knowledge in which researchers enter into symmetrical collaboration with concerned people. In the literature, we find numerous cases related to patients’ organizations (Epstein, 1996; Callon *et al.*, 2001; Kaufmann, 2004) or distributed innovation (Von Hippel, 2004), and some propose devices (constructive TA, interactive TA, etc.) which aim at opening up the innovation process through public participation (Grin, 1997; Rip *et al.*, 1997). Throughout this paper, we use co-production in this narrow sense and not in the sense of simultaneous production of technological and political order, as also proposed by some STS scholars (Jasanoff, 2004).

Also, STS scholars are not at ease with the use of the term ‘public’. After all, belonging to a constructivist tradition, they consider that the ‘public’—or ‘society’—does not simply exist out there (Latour, 2005); controversies and innovations are dynamic processes which favour the ‘proliferation of the social’ and the constitution of collective identities (Strathern, 1999; Callon *et al.*, 2001).

To be fair, the call for public engagement (whether upstream or not) is much discussed, in the STS community as well. For instance, Pestre points out that public participation is closely associated with the shift from government to governance, which occurred in the 1980s and that it has to be analyzed as a new form of governmentality—and not only as an ideal of democracy. More basically, Pestre questions the possibility for public participation to really influence the direction of techno-scientific knowledge and products since ‘these are regulated mainly by other (competing or parallel) institutions that lie outside the dialogic order: markets, administrations, courts of justice, etc.’ (Pestre, 2008). Levidow follows the same line of argument while analyzing the impact of public participation on the governance of agricultural biotechnology in Europe (Levidow, 2007).

These questions lead to a focus on the complex interactions between public participation and the wider world. Translation of the outcomes of such deliberations into decisions—or wider impacts—cannot be taken for granted. We have claimed elsewhere that this translation process has to be considered as the cornerstone of research on public participation (Marris *et al.*, 2008).

Against this background, our experience in Grenoble is a good opportunity for testing upstream engagement and working on this translation process. Dealing with such an issue in a concrete situation, Actor–Network Theory (ANT) provides useful resources.² As suggested by the motto ‘Follow the actors’, we have to deal with power as an interactive property to be analyzed at the actor–network level. Thus another slogan of ANT: ‘Be sober with power’. Regulations of techno-sciences have to be examined within the framework of micro-interactions.

In this paper, our reference to ANT has both an instrumental—or methodological—and a normative dimension.

When considering nanotechnologies in Grenoble, one cannot stick to the traditional divide between what is social and what is not. The dynamics of nanotechnology cannot be understood if we stick to an analysis of social networks and human arrangements. We also have to consider the role of technical objects in creating socio-technical order. Integrating the ability of chips to connect different fields (for instance electronics and biotechnology), which were once separated, is instrumental, and therefore, it is necessary to document the socio-technical networks supporting those links. In this perspective, nanotechnologies are defined by local actors and the phenomenon of technological convergence is performed locally. Hence, following socio-technical networks forces paying attention to the concrete human/non-human arrangements and the way they make possible the exploration of new possibilities—including the promises of convergence.

Note that ANT, being attentive to local arrangements, can provide the analytical tools and instruments by which co-production may be enhanced. In this perspective, the construction of nanotechnology is not given in advance—it does not have a substantive essence—but it depends on the contingent dynamics of socio-technical networks. This is why the reference to ANT also leads to adopting a normative perspective on public participation. As stated by Callon, public participation may serve various objectives (Callon, 1999).

First, it may be directed towards education of the public, thus fostering the acceptance of technologies or already made decisions. Second, it may aim at organizing debates on the way society as a whole can better direct and control the path of technological evolution. Accordingly, public participation is linked to issues of regulation or governance of technologies. Third, public participation may consist in the involvement of concerned groups in the negotiation and construction of socio-technological options. In this perspective, public participation amounts to co-production. In ANT terms, this means making new translations and/or intervening on the integration of new entities in the socio-technical network. This third type of public participation is the one that can really benefit from ANT.

What does it Mean to be 'Upstream' of a Technology Wave?

The first problem with the expression 'upstream engagement' is that it implicitly refers to a linear model of innovation as a one-way flow from basic research to the users. This traditional representation has been widely criticized by innovation studies—see for instance Kline and Rosenberg (1986). If we consider the interactive model of innovation, one is never either upstream or downstream, but always at some specific point—let us say mid-stream (?)—in the production of knowledge. The key question is whether the decision-making process is characterized by a high degree of irreversibility (and thus a reduced number of available options) or whether the path for alternative choices is still open. As shown by Collingridge (1980), who pointed out the 'control dilemma', there is a trade-off between knowledge and control. This control dilemma can be solved only by ongoing, step-by-step evaluation, as we shall argue.

In the Grenoble case, various actors state that the debate was organized too late, after major decisions had been taken without public deliberation. When *La Métro* announced that it would organize a public debate, for example, the PMO reacted as follows:

It is now time, when everything has been made irreversible, to get involved in choices that have been made without us, for example by implanting into our minds this ‘culture of risk’ which is so specific to Grenoble. And to make us into co-managers of the catastrophe, within the context of this ‘démocratie technicienne’ that Jean Caune, vice-president of *La Métro*, is calling for, thus reinterpreting the oxymoron of the contract made between La Métro and INRA (www.piecesetmaindoeuvre.com; our translation).

Indeed, many decisions had been made long before the term nanotechnology was even publicly known. Key projects designed to move from microelectronics to nano-electronics were developed by the Commissariat à l’Energie Atomique (CEA) and its industrial development subsidiary, LETI, since the late 1990s. At the outset, the challenge was to bring together university, research and industry in order to prepare Grenoble for the next step of the roadmap of chip production (2007–2010), which would almost reach the nanoscale (20–30 nanometres).

From 2000 onwards, the board of *La Métro* took about 30 decisions related to nanotechnology (Joly, 2005). The first decision to set up the Minatec pole was taken in 2000. Then in 2002 three leaders of the chip industry decided to set up Alliance, a major R&D facility near Grenoble. This location was strongly supported by the local government. In 2003, together with the university and the hospital, the CEA launched the Nanobio project, with the aim to develop biological applications for the new chips (labs-on-chips, etc.); the CEA then took the lead of the European Nano2Life project. In 2005, academics and companies of the software industry prepared the Minalogic project. This helped Grenoble to successfully apply for becoming the French ‘*Pole de compétitivité à dimension mondiale*’, i.e. a world-level centre for competitiveness (*Le Monde*, 13 July 2005).

This brief account allows us to specify the decision-making process at stake.

- There is not a single isolated decision, but rather a sequence of cumulative choices. These network dynamics, which generate new links and create new entities, exhibit classical features of technological innovation, namely: increasing returns on investment, path dependency and lock-ins (Arthur, 1989).
- As illustrated by the images used by CEA managers to present the Minatec project, microchips play a key role in the dynamics of the nanotechnology network. First, the reference to the ‘Moore Law’ and to the ‘Roadmap of the Electronics Industry’ makes them appear as natural as biological evolution. Apparently there is no room for political choice. Second, the chips operate as connectors (or boundary objects) between heterogeneous worlds: they create links between disciplines, institutions, and practices.

Considering these features, modelling the Grenoble case using Actor–Network Theory and thereby analyzing the dynamics of the nanotechnology socio-technical network must be considered as a relevant endeavour. In this frame, technologies and actors evolve together, and the list of entities which comprise the network evolves as well. As Callon states, the network designs itself as much as it designs technologies (Callon, 1995). This dynamic is a non-linear one and may result in quite different states: a change in the list of actors authorized to negotiate, or in the order of their intervention, or in the morphology of the interactions, which, in consequence, will produce other technological

devices. The degree of irreversibility of the trajectory of such networks is strongly linked to two elements.

- 365 ● The degree of similarity of the actors recruited (Callon, 1995, p. 321): if recruitment takes place in similar networks, the new members are quasi-substitutable for the earlier ones. Internal links reinforce one another to the detriment of external links. The probability of opening up to other networks is low, because each actor has become more and more like the others; the boundaries between the network and its 'environment' are reinforced and the network becomes autonomous from its context. 370 The trajectory is highly irreversible.
- The shape of the co-ordination mechanisms: if the actors involved are strongly connected through strong links associated with sunk costs or dense social relations, the degree of irreversibility is high.

375 A first look at the local situation leads to a rather ambiguous assessment. On the one hand, the degree of similarity is very low, and still decreasing, while the chips allow connections with new worlds. In terms of economic development, nanotechnology can help the Grenoble economy to overcome its strong dependency on electronics. For instance, thanks to the development of 'labs-on-chips' and biomedical applications, various 380 companies—including Biomérieux—have decided to settle in Grenoble. However, despite this technological diversity, 'coordination mechanisms' frame rather narrowly the design and implementation of new projects. The cult of high-tech, as the only way to promote socio-economic development, is part of the master narrative which forms the local cultural cement. We will come back to this in the next section.

385 Nevertheless, this development allows us to propose a more rigorous definition as a substitute to the 'upstream metaphor'. It also leads to identifying a basic and preliminary condition for successful public participation. Public participation should be based on a close examination of the socio-technical network, since detailed information on its knowledge and dynamics is necessary to act on it (namely to propose the recruitment 390 of new entities, foster new associations, etc.). This may involve activities of socio-technological mapping and scenario building.

This is close to the constructive technology assessment (cTA) approach which had been developed in the 1980s and 1990s in the Netherlands (Rip *et al.*, 1997; Schot & Rip, 1996). cTA aims at broadening the design of new technologies through the feedback of TA activities 395 into the actual construction of technology. There are, however, three main differences to our own approach.

- 400 ● First, cTA is designed to *improve* the innovation process, and it is assumed that including the social into the process of technology creation is sufficient. Here, it is necessary to include the possibility of questioning the innovation process and to assess its economic, social and political implications, taking into account the position of actors who are opposed to it.
- 405 ● Second, cTA is designed for *technological innovations*. Here, what is at stake is a complex process of local development, which has some institutional implications for higher education, for research organizations, for territorial planning, etc.
- Third, cTA is designed for *single* technological innovations. Here, in the case of nano-technology projects, we are facing a technological trajectory that includes many diverse

technological innovations. This trajectory is characterized by radical uncertainty about the possible outputs and associated risks. This uncertainty, which includes many ‘unknown unknowns’, cannot be reduced overnight. Therefore, it is necessary to design a process of on-going, step-by-step evaluation.

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Thus we have the following statements:

Statement 1: The ‘upstream’ metaphor is revealed to be misleading. Instead of using it, we suggest that we consider the degree of irreversibility of trajectories—which can be measured according to the state of the socio-technological network (Callon, 1995). Public participation has to be equipped with tools, such as socio-technological mapping or scenario building, which allow for measuring the degree of irreversibility and identifying possibilities for opening up technological trajectories through changes in the socio-technological network.

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Statement 2: ‘Public participation comes (either too early or) too late’: it is necessary to go beyond such rhetorical statements and to consider the conditions under which new associations may influence the dynamics of the network. This leads to recommending on-going, step-by-step evaluation (see also Rip, 2000; Dupuy & Grinbaum, 2004).

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Public Participation in Nanotechnology and Local Policy-Making Processes

Analyzing the dynamics of the nanotechnology network makes it possible to go further and suggests creating new links and cutting some others. For instance, as proposed by some activists, the link between nanotech research and the military deserves closer attention; some research agreements might be re-examined. It should also be possible to promote environmental applications of nanotechnology and to request devoting a significant part of the budget to the social sciences or to counter-expertise in order to reinforce critical stances, etc.

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However, the feasibility of such proposals depends greatly on the autonomy of local policy-makers vis-à-vis the nanotechnology network they partly belong to and of the position of public participation in this context. According to ANT, policy-making is conditioned by the state of the socio-technical network. We analyzed this by examining decisions on nanotechnology projects taken at the Council of *La Métro*. This revealed that: (i) elected representatives are poorly equipped to assess technological projects, and thus (ii) following the logic of voting in political parties, most of them delegate their assessment to those of their peers who have the expertise and who are strongly aligned in the nanotech network. Decisions are presented as ‘best—and only—possible choice’, as if there is no room for political choice. To use a classic wording, decision-making is rather technocratic.

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Alignment of policy-makers in the nanotechnology network is further reinforced by the local technological culture. Common narratives state that for a long time Grenoble has had no other option than to develop through high-tech. Michel Destot, Mayor of Grenoble, expresses this position forcefully:

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I like to describe our Grésivaudan Valley [where Grenoble is located], this alpine ‘trough’ which ranges from the Grenoble synchrotron to CERN, near Geneva, as

the ‘Valley of the Intellect’ (in *Le Dauphiné Libéré*, ‘Grenoble, symbole du débat public et de la confiance dans le progrès scientifique’, 1 June 2006, our translation).

455 Adopting the model of Silicon Valley will bring wealth and employment. In this macro-frame, nanotechnology is conceived as the major opportunity for fulfilling many a promise. But there is great urgency: as technological progress is cumulative, it is ‘now or never’. The adjunct to the Mayor of Grenoble in charge of economic development highlighted this state of urgency in the hearings we performed for this advice:
460 ‘We cannot lose time with ethical issues since we have to compete with countries like South Korea which do not care about them!’ (our translation). This frame—which involves a number of value judgements on the organization of the social and the role of technological development—serves to coordinate action and to align actors. Such a frame is deeply rooted in local collective history; that is why it is both ideological
465 and cultural.

In this context, in order to render the nanotech issue an object of debate and political decision, it is necessary to find ways to intervene in network dynamics from the outside. This requires opportunities to act within the network without being aligned with it. This means that it should be possible to discuss technical matters while questioning
470 the master frame of the Grenoble culture. Decisions taken at the Council of *La Métro* could have provided an occasion to find such an opportunity. However, as already mentioned, this was not the case.

The lack of a specific space for technology assessment (TA) is quite a common situation. Designing instruments or institutions that might allow politicians to get a grasp
475 on technological choices has long been attempted—without finding an ideal solution. Some 30 years ago, technology assessment had been designed in order to provide policy-makers with their own means of analyzing socio-economic and ethical implications of technological change. This was felt as necessary in order to make technological options a matter of public discussion, thus preventing the spread of a technocratic mode of government (Mironesco, 1997). At the local level, the lack of TA capacity is really a problem,
480 since policy-makers do not have the opportunity to gain a grasp of technological problems; they have no other choice than to trust the experts who tend to have strong interests in the same technological development.

However, international experience also shows that TA has not fulfilled these expectations when designed as a place of close interaction between technologists and policy-makers. In some European countries, TA has been conceived as participatory and this has fostered deliberation on technological choices in the public sphere (Joss, 2002; Barthe, 2006). Q2

490 These observations bring us back to a key argument of the literature on upstream engagement. It is necessary to open spaces for public deliberation concerning technological choices. Such spaces should not only give voice to experts and counter-experts, but they should give ‘ordinary citizens’ the opportunity to participate in the debate, discuss with experts and form their own opinions. However, so far the literature on upstream engagement has not defined the conditions necessary for participatory technology assessment to be translated in the techno-policy process.
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It is necessary to create a *dialogic space* which would allow debate on nanotechnology developments. Such a space has to be independent from the nanotech network—and also

from *La Métro*, since this institution is very much involved in the network. This may be possible by three complementary means:

- 500 ● first, the choice of a model of public participation based on transparent procedures which ensure equity, fairness and competence in public dialogue (for instance the consensus conference) (Renn *et al.*, 1995). In the nanotech case in Grenoble, principle of equity requires that weak actors may be offered the possibility to strengthen their arguments through the funding of counter-expertise;
- 505 ● second, it is necessary to delegate the responsibility for the public dialogue to an independent body; and
- 510 ● third, an independent evaluation of the participatory initiative has to be implemented. Evaluation has to take into account both the process and the impacts (e.g. Horlick-Jones *et al.*, 2007). However, any attempt to evaluate an impact using a simple criterion, for instance, a direct consequence of any participatory procedure on decision-making, would fail to grasp the complexity of ways impact should be assessed in a specific context. Far more attention should be paid to designing processes which allow a real measurement of impact using a sophisticated framework like the one proposed by TAMI (Decker & Ladikas, 2004). A linear appraisal of impact of TA neglects important dimensions: the effect of the process itself on the various actors involved and the fact that a given TA method will have very different effects, depending on the specific context, be it scientific, political or cultural.

520 Note that emphasising procedure does not mean—as stated by Dupuy in his criticism of Callon on technological democracy—that we collectively renounce thinking about the substance of the problem and that we delegate our collective choices to uncertain procedures (Dupuy, 2002). On the contrary, fair procedures ought to guarantee that the robustness of any kind of statement can be tested through public discussion. The obligation to consider and discuss all the statements and all the arguments (Latour, 1999) is the best guarantee for the independence of dialogical space.

525 Creation of a dialogic space also requires promoting a culture of debating socio-technological options. Beyond isolated engagements in specific technological choices, dialogic space should emerge as the consequence of various initiatives such as: frequent organization of public dialogues such as science cafés (Cafés des sciences), research grants designed to enhance the capacities of civil society organizations, social sciences research on local developments in nanotechnology, etc.

530 Dialogic space does not equal political decision. Decisions are not delegated to participatory processes, but they remain in the remit of elected councils. However, by taking up the initiative of public participation, such councils should take the outcome into account and publicly explain how this informs their decision or not. Indeed, such a space is necessary for policy-makers to engage in the debate and deal with nanotech as a matter of concern—and not as a matter of fact (Latour, 1999). The goal is to improve the interaction between political representatives and technologists, allowing the former to ‘speak outside’ of the network, and to some extent exercise control on behalf of their constituencies.

540 These developments allow us to formulate two more statements:

Statement 3: The creation of a dialogic space—within which public engagement may take place—is especially important in situations where the socio-technological

network includes policy-makers, since it may allow re-politicizing the issues at stake.

Statement 4: The creation of a dialogic space requires a set of conditions:

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- a long term engagement of policy-makers in public participation;
- procedures—including independent evaluation—which guarantee fairness, equity and competence in the dialogue;
- launching a set of initiatives aimed at creating a culture of debate on scientific and technological issues; and

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- clarifying the relation between dialogic space and political decision, rather than equate them.

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Participation for What? Education, Regulation of Nanotech or Co-production?

Most critics of public participation point to the absence of any real impact of participatory procedures in the public sphere or at the level of decision-making. This kind of criticism is often short-sighted, failing to adequately take into account the complex and multi-faceted nature of the issue. Technology assessment representatives sometimes try to underscore or refine this issue by replacing the rather linear term of ‘impact’ by the one of ‘resonance’. According to Hennen *et al.*, ‘resonance in this sense describes any kind of observable reaction to a TA process in its societal environment’ (Hennen *et al.*, 2004, p. 58). And, ‘impact of TA is defined as any change with regard to the state of knowledge, opinion held, and action taken by relevant actors in the process of societal debate on technological issues’ (Hennen *et al.*, 2004, p. 61). According to the European project ‘Technology Assessment—Method and Impacts’ (TAMI) (Decker & Ladikas, 2004), at least three different kinds of impact must be considered:

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- raising knowledge;
- forming attitudes and opinions; and
- initiating actions.

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Although we deduce from ANT a strong normative position on the role of public engagement (engagement as a means for co-production), in real-life situations, specific initiatives often have mixed and ambiguous objectives (Irwin, 2006). This is probably why TA practitioners adopt a pragmatic stance on impact evaluation.

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We can draw on a number of public engagement experiences that have already taken place in various countries (refer to www.cipast.org for a comprehensive list). So far, most experiences may be characterized as aiming at educating the public and improving the regulation of nanotechnology. The 2005 Madison Consensus Conference (www.lafollette.wisc.edu/research/Nano/nanoreport42805.pdf), the UK Nanojury (www.nanojury.org), or the various initiatives analyzed by the Nanotechnology Engagement Group (NEG) (Gavelin *et al.*, 2007) are cases in point. Participation is confined to the area of technology regulation and hardly deals with new frames for action and knowledge co-production. This is consistent with what we have learned from consensus conferences or focus groups dedicated to GMOs (Marris & Joly, 1999). Indeed, as argued by

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Arnall and Parr (2005), these kinds of participatory procedures result in a common set of questions.

- Who is in control?
- 590 ● Where can I get information that I trust?
- On what terms is the technology being introduced?
- What risks apply, with what certainty, and to whom?
- Where do the benefits fall?
- 595 ● Do the risks and benefits fall to the same people? (E.g. mobile phones are popular while mobile phone masts are not).
- Who takes responsibility for resulting problems?

These experiences show that public participation on nanotechnology can probably help policy-makers design and implement regulatory frameworks that are more relevant. However, we may wonder whether the productivity of such debates will be as high as expected. On the one hand, if the hypotheses underlying a common set of questions are confirmed, the danger is for outputs of participatory exercises to be quite predictable and redundant. On the other hand, although interesting at the national or international level, such outputs lie beyond the scope of local actors like the Grenoble ones. Global issues may lie within the frame of the nanotechnology problem as defined by local actors, but it is necessary to find ways to articulate public participation within local decision-making processes.

Our investigation in Grenoble showed that the issue is locally framed in view of specific global and local problems. These are:

- 610 ● generic questions concerning nanotechnology: known and unknown risks, opportunities and threats related to technological convergence, societal implications related to RFID and the possibilities of generalized surveillance;
- 615 ● questions related to the high-tech-based strategy of development for the Grenoble area: impact of nanotechnology on local development (infrastructure, employment, job structure, housing market, etc.); long term risks linked to industrial overspecialization; impact of the focus on nanotech and effects of hybridization between research and industry on the university structure (including patenting and secrecy, military research, etc.).

620 Given the range and the diversity of those issues, we can expect a public engagement initiative to be very fruitful. Accordingly, we suggested starting with a procedure which allows a wide framing of the issue in question and promotes interactions between the various publics and experts. Such initiative has to be considered as a starting point for the creation of a dialogic space rather than a one-shot event. In the perspective of on-going assessment and co-production of socio-technological options, it is also necessary to design participatory procedures which allow actors to intervene within the nanotech network and to influence its dynamics—as opposed to regulation which acts from outside.

630 As a starter, it would be necessary to discuss how far the mode of production of knowledge at stake may be open to public intervention. For instance, nano-electronics is usually considered as a matter of big money and big players who coordinate through long-term roadmaps at the international level; the aim is to develop enabling and dual technologies

that may be used in any type of application (environmental, medical, as well as military). Accordingly, public engagement is unlikely to influence the trajectory of nano-electronics.

One of the first necessary steps is probably to discuss such statements and so to question the metaphysical programme which lies behind nanotechnology research (Dupuy & Roure, 2004) or to discuss whether nanotechnology inevitably concentrates power and lowers individual autonomy (Sclove, 1995). Therefore, as far as nanotechnology is concerned, the objective of ‘interaction for co-production’ leads to positing two challenges.

- Adapt the mode of production of knowledge in order to make it more interactive and open to public intervention (Stirling, 2006). But is open-nanotech possible? See the previous questions on the ‘essence’ of nanotechnology?
- Design tools for continuous interactions conducive to engaging nanotechnologists and institutions in reflexive activities in the course of their research. This requires fostering interactions between nanotechnologists, social sciences and the various publics. To this respect, initiatives like those taken by Arie Rip in the Nanoned programme (www.nanoned.nl), the Nanotechnology Engagement Group (www.involve.org) in the UK or STS projects funded by NSF in the USA (Barben *et al.*, 2007) are of key interest.

This being said, it appears clear that ‘upstream engagement’ is not a ready-to-use solution. Hence our final statements:

Statement 5: Public participation is not a ‘one-shot’ endeavour but has to be a long-term and continuous engagement. Various tools, including those suited to foster reflexivity on the part of nanotechnologists and to reinforce the capacities of ‘counter-expertise’, should be used.

Statement 6: We need to create platforms for designing and experimenting with participatory processes in order to improve and adapt them to specific issues and contexts.

The Advice and its Fate

Let us now revert to our own involvement in Grenoble. Preparation of this advice did not occur in an empty space. On the contrary, we entered a polarized field. Indeed, when dealing with the objectives of public participation, we may first look at the positions of the actors involved.

In Grenoble public participation is criticized from two opposite sides. On the one hand, most policy-makers involved in the nanotechnology socio-technical network consider that public participation should aim at educating lay people and fostering acceptance of the nanotechnology projects. Their vision is to contribute to the spread of a culture of innovation and high-tech. When asked about setting up ethical committees and/or submitting decisions to public participation, they emphasize the urgency arising from international competition.

A small minority of local policy-makers from the ranks of the Green Party seem ready to go further and accept that public participation may play a role in decision-making processes. Basically, they have the feeling that mediating the relations of experts and politicians through public participation may help re-politicize the issue. They do expect

public participation to contribute to a genuine change in technology governance. However, they are in a minority position, and they lack knowledge of public participation theories and practices.

680 On the other hand, public participation initiatives of *La Métro* are challenged by activists of PMO. In their view, democracy is an illusion, since power is captured by the ‘techno-société grenobloise’, which is keen on developing ‘necrotechnologies’ and transforming Grenoble into an ‘experimental laboratory’. Thus, they deny the legitimacy of elected representatives. According to PMO, public debate and public participation is no more than a strategic tool designed to overcome contestation. It is merely a way of reinforcing the power of
685 the ‘techno-gratin’ (techno-establishment) by controlling the mass media. PMO consider that there is no need to discuss with the other actors. They attend debates organized by public authorities and present their statements but will not accept any debate. They also organize more or less formal debates between ‘*Simplex Citoyens*’ and consider this to be the best way for citizens to form their own judgement on nanotechnologies.

690 Interestingly, they adhere to the same positivistic position as their opponents: they believe they know all there is to know about the economic, social and environmental implications of nanotechnology and see no need to debate with the ‘techno-gratin’, only to fight them. They praise an agonistic model of politics which rejects the ideal of public deliberation (Mouffe, 1999). Thus the political space for public engagement is quite limited. Given the importance of a radical opposition, public engagement initiatives
695 are at risk in the view of many actors, including those policy-makers who expect a genuine change in technology governance.

As a group of STS scholars, we were working on behalf of *La Métro*, so we were considered as ‘mercenaries’, taking part in manipulating the public. Thus, we faced tough criticism from PMO, and our assignment triggered additional discussion on top of the other
700 debates.

Indeed, while producing the advice, we had a deep perception of the difficulty of the task. Only a few actors shared the feeling that classical communication and organization of big conferences would not be enough. These actors were very keen on being innovative
705 by setting up a consensus conference. However, the risk of this initiative being instrumentalized appeared to be considerable, given the history of the projects and the polarization of the field. We thus felt that the intent to organize public engagement had to be part of a genuine move towards new relations between science, technology and society.

Our main message was that the leadership of Grenoble in the field of nanotechnology should be accompanied by a strong involvement of key players in opening up the innovation processes (‘a socialization of innovation’). In this perspective, it would be necessary to promote the institutionalization of public participation (frequent participatory exercises following the procedural rules defined above) to foster interactive public debate and to promote research on public participation. The first concrete recommendation was to
715 organize a consensus conference which would address a broad question such as:

Is the pursuit of the development of nanotechnology—with its civil and military applications—a good option for Grenoble? If not, what are the alternatives; if yes, under which conditions and in which directions?

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Our report was published and widely circulated. It was presented three times and discussed by more or less wide audiences in Grenoble.

Recommendations of the STS working group on nanotechnology and public participation in Grenoble

Local elected representatives must firmly and in the long-term commit to promoting a ‘socialization of innovation’. This commitment will stand on four pillars:

- participation of citizens in technology assessment and technological choices;
- capacity building of civil society;
- reform of institutions in charge of educating the public about scientific and technological matters;
- coordination of the actions undertaken in Grenoble with other decision levels (the region, the state, Europe) and collaboration with other European technological districts.

1. Participation of citizens in the choices concerning nanotechnology.

Recommendation 1.

Organize a citizen conference within one year.

The question asked to the panel could be the following: ‘Is the pursuit of the development of nanotechnology—with its civil and military applications—a good option for Grenoble? If not, what are the alternatives; if yes, under which conditions, and in which directions?’

Recommendation 2.

Fund studies demanded by local associations.

While preparing the citizen conference, 2% of the total budget that *La Métro* devotes to nanotechnology projects should be allotted to studies demanded by associations.

Recommendation 3.

Give a written and public answer to the citizen panel based on a careful reading of the report, stating the points of convergence and divergence, and be explicit about the decisions taken after the participatory exercise.

Recommendation 4.

Organize, on a regular basis, citizen conferences or other well-tried approaches for participatory assessment and forecasting—as citizens’ juries and scenario workshops—concerning the various decisions at stake in *La Métro*.

2. Capacity building of civil society.

Recommendation 5.

Encourage public access to the production of scientific knowledge by supporting partnership between public research laboratories and non-profit civil society organizations.

Recommendation 6.

Reinforce the research capacity of the social sciences in the field of participatory technology assessment.

3. *Toward a new age of scientific and technological culture.*

Recommendation 7.

Redefine the project known as ‘The City of Innovation’ by setting up a ‘Mission for public debate on science and technology’, with the objective of fostering the creation of public spaces for discussing scientific and technological choices; notably by sustaining initiatives undertaken by associations.

Local policy-makers never reacted directly to our proposals. At various occasions, they severely criticized Recommendation 1 on the ground that it was too radical. Actually, they did not accept the idea that Grenoble’s engagement in nanotechnology should be publicly discussed. They would have accepted a consensus conference aimed at discussing general issues or specific points—but not the basic decision as such, nor the way local nanotechnology policy is framed.

Instead, they funded a series of public debates co-organized by Vivagora (an NGO specialized in the organization of public debates on scientific issues) and the Grenoble CCSTI (the local Centre for Scientific and Technological Culture): ‘Nanoviv: projects, responsibilities, and finalities of nano-biotechnology’ (http://www.vivagora.org/article.php3?id_article=81). The objective of this series of debates was to ‘elaborate new recommendations which will aim to improve the practices of actors, to enhance their responsibility and to foster “démocratie technique”’. In the programme of Vivagora conferences, the final public debate included a round table on the theme: ‘Shall we pursue the development of nano-biotechnology? Why? How?’. Interestingly, this phrasing is very similar to the one we proposed. However, there is obviously a huge gap between a consensus conference and a one-hour ‘talk show’. Thus such an initiative is obviously very different from the recommendations we made, even though it has sometimes been presented as a follow-up by local policy-makers.

As discussed earlier, powerful local policy-makers were not ready to enter a genuine public engagement process. They were convinced that it was necessary to educate the public in order to promote a scientific culture and to create a context in favour of nanotechnology. This view does not contradict the idea of organizing debates on key problems related to the development of nanotechnology, but it does not allow discussion of local choices and how local publics might be involved either.

In this experience in Grenoble, it was not possible to get beyond a rather simplistic discussion, opposing the prerogative of representative democracy to the instrumentalization of participation. This is illustrative of the French debate on public participation, where the whole discussion usually turns around consensus conferences, their lack of impact and the (in-)ability of citizens to contribute to scientific and technological issues. Nothing is ever said regarding other participatory methods, much less the opportunities for knowledge co-production. In this situation, it is very difficult to have a productive discussion about the virtues and limitations of public participation and its specific place within democracy. This was particularly striking in the public arenas where our report had been mentioned. Even Jean Caune—who mandated us to do the job—kept criticizing our proposal for setting up a consensus conference. As a result, nothing was ever said about the other six recommendations.

Beyond the Naïve View: Can We Still Engage in Public Engagement?

The first conclusion drawn from this case study is that we should not be too optimistic about public engagement in nanotech. To be fair, we have to acknowledge that participation works in the sense that so far, the experiences have produced interesting results. Indeed, we agree with Rogers-Hayden and Pidgeon (2006): ‘Lay people are not seen as needing “education”, but they are seen instead as offering valuable insights into such things as ownership, control, social justice, and societal values that may aid in the consideration and development of new technology’. But does this mean—as often claimed—that we are experiencing a paradigm shift from public education to public participation? We challenge this stance, since the articulation between the microcosm of public participation and the wider world is not clear. **Q3**

Public participation may well be a way for local elites to overcome local contestation and keep acting as usual, thus finding a new source of legitimacy through public debate. As asserted by PMO, quoting Lampedusa in the movie *Il Gattopardo*, ‘It is necessary that everything changes in order for nothing to change!’ Thus, use participation but still stick to technocratic governance. On the other hand, local activists who mobilize against nanotech do not want to engage in participatory exercises initiated by the local government. In this case, everything is happening in a small world where direct interactions amplify the reactions, so the opening of a dialogic space is quite problematic.

It seems easier to organize public participation at a national level (as in France) or when it is initiated by private bodies (as in the UK). However, a quick glance at such endeavours does not lead to a more positive appraisal of the current dynamics. In both cases, the objectives of public participation are fuzzy and the relation to decision-making is not clearly defined. Current experiences may well contradict the expectations of the master narrative: public engagement may fail to improve democratic practices while influencing technological developments. Therefore, it is necessary to remain critical, since public engagement may easily get lost in institutional translations! This is one of the key messages of Wynne’s afterword to the Demos booklet, a plea for a ‘genuine dialogue’ on nanotech:

However, the more complex shift of focus, which the move ‘upstream’ was intended to introduce, has frequently been misunderstood. This can be noted, for example, in the otherwise admirable Royal Society/RAE report on nanotechnology. This describes the potential role of upstream engagement in anticipating sensitive issues, despite our emphasis that upstream forms of public engagement with science are emphatically not about earlier *prediction* (and subsequent management) of impacts (Wynne, 2006a).

The problem of translation is partly due to the way STS claims have been received. But it is also due to blind spots in the analysis of technology governance. Very few research papers have been devoted to investigating the conditions of a successful implementation of public participation; most of the literature is directed towards methodological issues or to the description—and criticism—of specific public engagement experiences. As claimed elsewhere, lack of analysis of the interactions between the microcosm of public participation and the wider world is one of the major shortcomings of studies of public participation (Marris *et al.*, 2008).

In this paper, we have shown that much more attention must be paid to how participatory technology assessment is translated within the dynamics of socio-technological networks. This is the only way to be in a good position to answer Wynne's question: 'how can STS influence its own influence?'

860 We have focused on ANT, which is probably one of the best tools for dealing with public engagement in a serious manner since it offers conceptual tools to question technology. We have shown that ANT helps to clarify the objectives and opportunities of public participation. Thinking about how to intervene in the nanotech network dynamics can help actors in concrete situations to collectively influence the development of the
865 technology. ANT may also help characterize the network dynamics by shedding light on some key features (similarity, type of coordination, etc.) and thus providing a better understanding of the degree of irreversibility of technological trajectories. This should definitely contribute to fostering knowledge co-production. An examination of the output of consensus conferences shows that this should allow a much higher productivity of public engagement.
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However, ANT is seriously limited. It does not provide any hint as to how to act on the dynamics of the network from outside and to reflect on the position of the polity outside the network. To deal with this problem, we have suggested that it is necessary to design a dialogic space which allows discussion of any statement made in terms of the promises, the choices and the dynamics of the network. However, up to this point, we lack theoretical
875 bases to articulate ANT and theories of the public sphere. We develop elsewhere a model of the public sphere as a mosaic of arenas. Our hunch is that we have to take into account the grammars of arenas within which socio-technical networks unfold. In this perspective, dialogic space ought to be considered as a new emerging public arena (Bonneuil *et al.*, 2008).
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Hence, we are short of knowledge on the link between decision-making and participation, and between participation and the public sphere. Such points have to be developed further in order to provide a robust basis for practitioners of public engagement. The credibility and potential of participatory procedures are greatly dependent on the collective
885 endeavour to critically assess the design and output of participatory exercises and their influence on the technologies' trajectories. All those issues have to be taken very seriously by TA practitioners and promoters as well as by STS scholars. Public engagement is probably one of the critical loci where STS must reflect on its impact on policy and on its political positioning.

890 The fate of public participation is not yet decided, but it will be determined through a process of creative implementation. This will obviously depend on pre-existing power relations, but also on the participation of STS scholars. Since this process is now starting, involvement of social sciences is a major opportunity to produce knowledge on the interactions between public participation, decision-making and innovation processes.
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Notes

¹See the on-going debate on engagement of STS scholars in the policy room: Webster (2007), Nowotny (2007) and Wynne (2007).

905 ²For an introduction to ANT, see the seminal paper by Callon (1986) and more recent contributions such as Law and Hassard (1999) and Latour (2005). A comprehensive bibliography can be found on the website ‘The Actor–Network Resource’ maintained by John Law at <http://www.lancs.ac.uk/fass/centres/css/ant/antres.htm>.

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