Chapter 2
Technology Assessment and Approaches to Early Engagement

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Abstract Technology Assessment (TA) emerged in the 1970s as a research-based policy-advising activity. During the 1980s, TA discovered technology development at the lab level as a subject of interest, reflection, and intervention. Since that time, TA as orientation for shaping new technology and innovation has been part of the overall TA portfolio. TA concepts and approaches to early engagement have been developed in different frameworks, e.g. as Constructive TA. In the last 10 years, a new wave of early engagement in TA occurred mainly in the field of new and emerging technologies such as nanotechnology, enhancement technologies, and synthetic biology. This wave led to many activities involving TA in early stages of development. In this chapter, we describe the most relevant approaches in TA aiming at early engagement. A deeper look will be presented into conceptual backgrounds that are specifically relevant to early engagement, such as concepts of technology determinism, social constructivism, and co-evolution. As a case study, we discuss an ongoing activity at the Karlsruhe Institute of Technology (KIT) where a major technological development in the field of new cement is accompanied by systems analysis and innovation research from its very beginning. This case allows specifically for discussing chances and opportunities of early engagement but also pitfalls and obstacles.

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2.1 Introduction and Overview

Technology Assessment (TA) emerged in the 1970s as a research-based policy-advising activity. In the first period of TA, technology was regarded to follow its own dynamics (technology determinism) with the consequence that the main task of TA was seen in functions of early-warning of risks and early recognition of opportunities. The objective was to enable political actors to undertake measures to, for example, compensate or prevent anticipated negative impacts of technology. The spheres of technology development at the lab and the issue of shaping technology at the level of products and systems were not addressed at all because of the deterministic attitude concerning technology and the focus on policy advice.

This situation changed in the 1980s. Following the emerging social constructivist paradigm, slogans such as "social shaping of technology" were coined and the approach of Constructive Technology Assessment (CTA) was developed (Rip and Robinson; Chap. 3). TA discovered technology development at the lab level as a subject of interest, reflection, and intervention. Since that time, TA as orientation for shaping new technology and innovation has been part of the overall TA portfolio. This portfolio covers the whole spectrum from the political (e.g. parliamentarian) level far away from the lab up to concrete intervention in engineering, design and development at the level of R&D programmes and concrete projects at the lab (Grunwald 2009a).

An early observation was that, in order to be able to contribute to shaping technology *ex ante* instead of only analysing impacts and consequences of its use *ex post*, TA should be involved *in early stages* of technology development. The concern that TA might be too late in order to do its job has accompanied the development of TA from its beginnings. This has motivated concepts and approaches to early engagement – however, the possibility of early engagement seems to be threatened by the so-called Control Dilemma (Collingridge 1980; see Sect. 2.3 of this chapter) stating that shaping technology will fail anyway: in early stages of development because of lack of knowledge, and in later stages because then there will be no more room for shaping.

In the last 10 years, a new wave of early engagement (sometimes called "upstream engagement") has been observed in TA. It occurred mainly in the field of new and emerging technologies (NEST) such as nanotechnology, nanobiotechnology, enhancement technologies, and synthetic biology. These fields of science and technology development show a strong "enabling character", probably allowing for manifold applications in different areas which are extremely difficult to anticipate. This situation makes it necessary – from a TA perspective – to perform an *accompanying TA process* reflecting on the ethical, social, legal, and economic issues at stake (Rip and Swierstra 2007; Grunwald 2010a).

In this chapter, we describe the most relevant approaches in TA and in neighbouring research activities aiming at early engagement. To this end, we start with a general introduction to TA by mentioning some issues of its history, objectives, and recent developments (Sect. 2.2). Then we present a deeper look into conceptual backgrounds that are specifically relevant to early engagement, referring to the debates around technology determinism, social constructivism, and co-evolution (Sect. 2.3). This look prepares the ground for presenting TA approaches aimed at early engagement such as accompanying systems analysis, the approach of the German Association of Engineers, and the Vision Assessment (Sect. 2.4). As a case study, we discuss an ongoing activity at the Karlsruhe Institute of Technology (KIT) where a major technological development in the field of new cement is accompanied by systems analysis and innovation research from its very beginning (Sect. 2.5). The last section includes some reflections on challenges, limits, and obstacles of the TA approaches developed so far.

2.2 Technology Assessment[1]

TA arose from specific historical circumstances in the 1960s and 1970s far away from any lab context. Activities and concerns in the US political system, in particular in the US Congress, culminated in the creation of the Office of Technology Assessment (OTA) in 1972 (Bimber 1996). The concrete background consisted in the asymmetrical access to technically and politically relevant information between the legislative and executive bodies of the United States. From this point of view, the aim of legislative TA serving the Parliament was to restore parity. This very specific origin of TA found a lot of successors in Europe which succeeded in establishing a lively network (European Parliamentary Technology Assessment EPTA).

Parallel to this specific development in the political system, radical intellectual changes were taking place. The optimistic belief in scientific and technical progress, which had predominated in the post-Second World War period, came under pressure. Broad segments of Western society were deeply unsettled by the "Limits of Growth" which addressed the limitedness of natural resources. Furthermore, problems with unintended side effects, in particular with respect to the natural environment, and new ethical questions led to societal conflicts on the legitimacy of technology. A fundamental dispute on how to deal with science and technology emerged. Far beyond supporting parity between executive and legislative forces in democracy, TA was then expected to contribute to new forms of societal orientation and legitimisation of science and technology. This constellation led to a complex and multi-dimensional set of objectives and rationales of TA.

Nowadays, the term "Technology Assessment" is a widely used designation of the systematic approaches and methods to investigate the conditions for and the consequences of technology and to denote their societal evaluation. According to an existing definition, TA is a scientific, interactive, and communicative process which aims to contribute to the formation of public and political opinion on societal aspects of science and technology (Decker and Ladikas 2004). TA thus provides knowledge,

[1] This Section builds on earlier and more comprehensive descriptions of Technology Assessment given by one of the authors (Grunwald 2009a, 2010a).

orientation, and procedures on how to cope with challenges at the interface between technology and society on both directions: TA explores and assesses possible impacts and consequences of technology in a prospective manner on the one hand, and helps to introduce society's expectations and needs concerning new technology into the relevant decision-making processes, on the other.

The focus of TA dwells on the perspective of *unintended side effects* like accidents, negative environmental impacts, ethical problems, and unintended social consequences (Bechmann et al. 2007) and on assessing these in relation to expected benefits and innovation potential. TA has been set up to enable assessment procedures making use of scientific knowledge, ethical orientation, and participatory processes as well (Grunwald 2009a). The mission of TA is, thus, to contribute to "a better technology in a better society" (Rip et al. 1995) in various dimensions and following various objectives in detail.

The first objective of TA was, as indicated above, to support political decision-making mainly in the fields of regulation and research funding. The classical institutions and procedures of democracy should be provided with knowledge and orientation in order to make "better decisions". Reflexivity should be added to political bodies and their decision-making processes. This type of TA is still active and expanding in the fields of parliamentary technology assessment (Cruz-Castro and Sanz-Menendez 2004) and in many forms of advising governmental bodies and authorities.

A second objective is directly related to democracy or, in a more radical sense, aims to prevent a possibly emerging technocracy. From the 1960s on there have been concerns that the scientific and technological advance could threaten the functioning of democracy because only few experts were capable of really understanding the complex technologies (Habermas 1970). The technocracy hypothesis was born painting a picture of a future society where experts would make the decisions with respect to their own value systems by coming up with the "one best solution" for any situation of choice, and with politics restricted to implementing the results. Against this background, one of the many origins of TA is to counteract and to enable and empower society to take active roles in democratic deliberation on science and technology (Schomberg 1999).

A third objective of TA is related to the ways in which society deals with conflicts over new technology. Experiences of severe technology conflicts and of legitimacy deficits have accompanied many Western countries in the past decades. There was (and partially still is) little acceptance of particular political decisions on technology such as on nuclear power and nuclear waste disposal sites in some countries. Also doubts about their legitimacy combined with suspicions of technocratic decision-making, fuelled the emergence of severe conflicts. These developments motivated TA to think about procedures of conflict prevention and resolution, in particular including participatory approaches (Joss and Belucci 2002).

The fourth and in the context of this paper most relevant objective concerns the level of technology itself rather than the ways society deals with technology issues. The idea of shaping technology according to social values was born in the framework of Social Constructivism (Sect. 2.3). If this would succeed, so the hope, problems of rejection or non-acceptance would no longer occur at all, and a better technology, serving the demands of people and of society in a better way, could be reached. This is the very intention of Constructive Technology Assessment (Rip and Robinson; Chap. 3).

An international community established itself around the concept of TA and its various dimensions and diverse objectives, using different concepts and methodologies. Part of this community works in institutions explicitly devoted to TA (e.g., to provide advice to Parliaments, cf., for instance, the EPTA network, www.eptanetwork.org), part of it is organised in networks (cf. Netzwerk Technikfolgenabschätzung, www.netzwerk-ta.net), part is describing its work as systems analysis, in particular in the fields of material flow analysis, energy balancing, and life cycle assessment LCA, and another part converges on the fringes of disciplinary organisations and conferences, such as in sections of sociological or philosophical organisations, or in the STS Community, e.g., under the auspices of EASST (the European Association for the Study of Science and Technology), and of many IEEE (Institute of Electrical and Electronics Engineers) activities relating to the social implications of technology.

2.3 Technology Determinism, Social Constructivism, and Co-evolution

TA needs models of technology development and of the processes of governance influencing research and development in order to be able to fulfil its tasks in the ways intended. These models then influence the way how TA is to be conceptualised, how it is embedded in governance, how it is actually performed, and to which addressees its results shall be customised. To give a hypothetical illustration: if one believed in a technology development model ascribing all power to industry and international companies, TA as policy advice would simply be nonsense.

There are two grand and mutually contradicting narratives underlying different forms of TA: the *Technology Determinism* paradigm, on the one hand, claims that technology cannot be influenced by but determines society. The *Social Constructivism* paradigm, on the other, states that technology can be "constructed' according to social values. Over the past decade, a third and intermediary paradigm has become the dominant narrative: the model of a *co-evolution* of technology and society. These lines of thought will be described briefly to allow for a better understanding of the options of choice and their implications at the conceptual level.

Scientific progress and technological advance have been the most powerful driving forces of and in society for decades. It is plausible to raise the question whether the dynamics of science and technology has purely internal roots and origins, whether this dynamics could be influenced from an external perspective, e.g. by politics, or not, and in which way society should act according to the answers given to the first two questions. Technology Determinism assumes a strong inherent dynamics of science and technology at place and gives a negative answer to the question whether technology is designable and controllable by society. The course of technology development over time is regarded as a result of that internal and inherent dynamics. Society and policy-makers should, therefore, not aim at steering or shaping technology because this would not be possible in principle. They only could, following this line of thought, prepare themselves for the new technologies that would inevitably come, and try to deal with their impacts and consequences in a most socially compatible way. Technology itself is, in this perspective, no subject for societal and political influence at all – only the way society deals with the impacts of technology could be subject to political measures.

This paradigm was dominant in the 1970s and the beginning of the 1980s. It had decisive impact on the early concepts of TA. If, according to Technology Determinism, technology could not be influenced by society but society had to prepare itself for coming technologies and their impacts (opportunities as well as risks), TA was mainly seen as a means of forecasting and predicting impacts and consequences of technology in order to enhance the opportunities of early societal action and adaptation. In particular, the idea of the "early warning" function of TA was coined against this background. The lab level and the development processes of technology were no serious subjects of interest of TA, simply because of the dominating paradigm mentioned (Grunwald 2009a, 2010a).

Social sciences' research on technology, however, proved naïve technology determinism false and motivated, fuelled by Social Constructivism (Bijker et al. 1987), approaches of social shaping of technology (SST) (Yoshinaka et al. 2003). It was shown that technology is really being "made" and influenced by many groups and institutions in society. The development of technology should, following these ideas, be perceived as the result of societal processes of meaning giving, negotiation, and decision-making. Theories of technology development were established which highlighted the importance of decision-making processes involving many actors at all stages of development and which showed that the resulting decisions depend on values and interests of those actors (Bijker and Law 1994).

The idea of "shaping technology" became, based on this particular paradigm, dominant in the 1990s (Bijker and Law 1994) and motivated new TA concepts, in particular the emergence of Constructive TA (Rip et al. 1995). CTA has lobbied for the early and broad participation of societal actors, including key economic players, and for the establishment of a learning society experimenting with technology. In the normative respect, CTA builds on a basis of deliberative democracy in which a liberal picture of the state highlights self-organising processes in the marketplace.

Social Constructivism has in the meantime been criticised for being too optimistic with regard to the malleability of technology. Critics pointed to path dependencies, to economic forces, and to irreversibilities in technology development setting limitations to shaping approaches. The idea of a co-evolution of technology and society takes this criticism into account and considers both sides as mutually influencing each other and as being closely interlinked with each other (Rip 2007). Following this idea, neither naïve shaping of technology according to social values is possible, nor is society helplessly damned to adapt itself to a self-dynamic technology.

Instead, the situation is complex, and though possibilities for society influencing technology development are seen, it is considered ambitious to realise them.

This development refers in a specific sense to the "Control Dilemma" (Collingridge 1980) which was already briefly mentioned in the introduction. Collingridge looked at technologies in an early stage of development and at mature technologies as well. Regarding the latter, he stated that there could only be a minimal societal influence. For economic reasons it would not be possible to change or modify mature and market-ready technological products or systems to a significant extent. In the best case, minor adaptations might be expected in case of societal pressure. Referring to technologies in an early stage of development, Collingridge problematised the feasibility of targeted societal influence on technology according to societal values, expectations of benefits and the avoidance of risk, due to a severe lack of knowledge about future products and their impacts. The dilemma therefore reads: shaping technologies with regard to societal expectations in an early stage of development must fail because of lack of knowledge, and, shaping technologies in a mature state is not possible because of economic forces. Once the impacts of a technology are relatively well-known, the chances of influencing this technology will significantly decrease. Thus, shaping technology with regard to societal expectations and values would not be possible at all.

The dichotomy expressed in the Control Dilemma is, however, artificial if understood in an extreme way. The question of whether TA should start early and should be prospective or only start when reliable statements about consequences are available poses a false dilemma. The issue here is not an either-or one but the differentiation of TA in line with the problem at hand and with the validity of the available knowledge of the consequences. TA differs conceptually and methodologically depending on whether it is concerned with measurable consequences of technology or with more prospective ones. That means TA should be conceptualised as research and assessment *accompanying* the technology development and using concepts and methods appropriate to the stage of development of the technology under consideration. What "appropriate" means here refers to the governance of the respective field to which TA is to contribute.

TA carried out in early stages of development may look different in the cases of NEST (new and emerging science and technology), where ethical and philosophical questions are in the centre of interest (e.g. Grunwald 2010b), in the field of transforming large infrastructures such as the energy supply system where something like "transition management" in the framework of reflexive governance (Voss et al. 2006) is needed, and in the field of developing new materials and processes where early systems analysis including Life Cycle Assessment is required to help shaping the development towards sustainable development (see the case study in Sect. 2.5). In all of these fields, TA adds specific prospective knowledge and reflexivity to the perspectives of natural scientists, managers, developers, and engineers involved.

Opening up the lab in this context means bringing additional perspectives and TA knowledge to the lab, aiming at supporting decision-making there. This could include, for instance, increasing the awareness of lab researchers with respect to possibly involved ethical issues, organising debates on the responsibilities of researchers in the overall governance of science, bringing knowledge about innovation and diffusion processes to the lab level, and enhancing the consciousness of lab researchers with regard to possible societal implications and consequences of their work. The resulting increase of knowledge and reflexivity could have an influence on ongoing design decisions concerning experiments and development processes but also on the agenda setting processes at the lab level.

2.4 TA Approaches to Early Engagement

The first and still most frequently cited TA approach to early engagement is the already mentioned CTA approach (Rip et al. 1995) initially based on Social Constructivism and later on following the co-evolution picture. In this section, we will not introduce CTA because the Chapter by Rip and Robinson (Chap. 3) is dedicated to it. Instead, we will present the accompanying systems analysis approach (4.1) which is frequently used and mostly not subsumed under the TA label, the concept proposed and implemented by the Association of German Engineers (4.2), the Responsible Innovation approach as a recent development (4.3), and the Vision Assessment looking at visionary communication in the context of NEST (4.4).

2.4.1 Accompanying Systems Analysis

Basic task of an accompanying systems analysis is to assess opportunities, potentials and risks of a new technology in an early stage of development despite existing uncertainties in order to provide decision-makers in politics, science and economy with first information. Such an analysis is not restricted to aspects of engineering and natural science, e.g. estimating conditions for a large-scale technical realisation and possible ecological impacts, but also considers the political, societal and economic framework requirements of the innovation. Besides the opportunities and potentials, the (economic and societal) benefit of the invention is assessed.

The systems analysis starts with a description and analysis of the existing “landscape” (the added value chain and its societal context) where the innovation will be implemented and used in future. Besides an analysis of the current political, economic and technical conditions, this includes a characterisation of the pertaining industry, in particular of its structure and the regulatory framework conditions. Furthermore, stakeholders and lobbies have to be identified which would be affected by including the innovation in the industrial and societal metabolism.

Moreover, technological questions on the conditions for a large-scale technical realisation have to be answered. This comprises the (cumulative) energy expenditure and material flows, taking into account the entire process chain (including the upstream chain) from cradle to grave as well as the availability of raw materials, the cost of their supply, and associated possible ecological effects which have to be identified and assessed. These issues are studied using methods like material flow analysis and energy balancing based on thermodynamic and thermochemical approaches including realistic efficiency estimations. In some cases, the Life Cycle Analysis (LCA) tool can be used (cp. Schepelmann et al. 2009).

Results can be used to advance the development of the technology, focusing on its large-scale technical realisation, and for giving early insights into sustainability effects. The work is an iterative process depending on the current level of the development and new findings. In addition, to foster technical development, the results of the systems analysis are used for a comprehensive assessment of the complete production process, including sustainability aspects.

At the forefront of economic considerations are first estimates of the anticipated capital and operating costs of the new technology. A systems analysis can also include extended economic investigations taking into account issues such as the determination of CO_2 mitigation costs, “hidden extras”, “societal extras”, and problems of discounting. The sustainability assessment usually relies on adequate indicators covering economic, ecological and social aspects to evaluate the technological development.

Positive material properties of a new “socially wanted” product do not automatically guarantee a successful launch. Therefore, also the innovation process has to be investigated with a special focus on fostering development and disclosure of inhibitory factors. Marketing strategies for a product launch, however, are not in the focus of the TA investigation. Instead, the results of the analyses are used to provide the actors involved with supportive knowledge for implementation.

As shown above, a relatively tight involvement of systems analytical investigations in technology development at the lab is, on the one hand, necessary for the systems analytical part, in particular because this constellation allows direct access to relevant data and an in-depth analysis of the innovation process. Close cooperation with systems analysis should, on the other, also be of great benefit for the development project because the results of systems analysis could be used to directly inform developers about possible obstacles and could give hints how to meet sustainability objectives by optimising the design (Poel 2009). Nevertheless, awareness must be raised of possible unwanted effects such as decreasing independence of systems analytical TA (see Sect. 2.5).

2.4.2 Technology Evaluation

The Association of German Engineers (VDI, Verein Deutscher Ingenieure) has been dealing with challenges of technology to society since the 1960s. Many VDI publications address issues such as technology and society, responsibility of engineers and a code of conduct.

The most prominent outcome of these activities is the VDI Guideline No. 3780 (VDI 1991, also available in English), which has become quite well-known, at least in the German-speaking countries. It is intended to provide a "Guide to Technology Assessment According to Individual and Social Ethical Aspects". For engineers and in industry, assessments are to a certain extent part of their daily work. Evaluations play a central role, for instance whenever a line of technology is judged to be promising or to lead to a dead end; whenever the chances for future products are assessed; whenever a choice between competing materials is made; or whenever a new production method is introduced to a company. Though evaluation may be commonplace in engineering practice, the new thing about this guideline for societal technological evaluation is its scope, which also includes the societally relevant dimensions of impacts as well as technical and economic factors. Technological evaluation should be conducted in line with socially acknowledged values. Eight central values forming the VDI "Value Octagon" have been identified: functional reliability, economic efficiency, prosperity, safety, health, environmental quality, personality development, and social quality (VDI 1991). These values are thought to influence technical action and fall under the premise that it "should be the objective of all technical action […] to secure and to improve human possibilities in life" (VDI 1991, p. 7).

According to the VDI Guideline, the identified values shall be considered in processes of technology development, in particular in technology design (see Poel 2009). They shall virtually be *built into* the technology. Engineers or scientists should, on the basis of their knowledge and abilities, push the development of technology in the "right" direction by observing these values and avoiding undesirable developments. If this exceeds their authority or competence, engineers should take part in the corresponding procedures of technology evaluation. This mode of operation is rather close to Value Sensitive Design (see Chap. 4 in this volume). However, VDI did not pay much attention to how to make this approach work. Although the approach is well integrated in the education of engineers at many technical universities in Germany, it did not have much impact on practical development yet.

As the Guideline addresses directly the actions and decisions of engineers, it is relevant to research and development also in the lab, in publicly funded science as well as in industry. "Opening up the lab" would not be necessary as an extra effort because, following the Guideline, engineers and researchers at the lab level should act according to the values mentioned in the Guideline. However, theory and practice seem to differ considerably in this respect.

2.4.3 Responsible Research and Innovation (RRI)

The ideas of "responsible research" in scientific and technological advance and of "responsible innovation" in the field of new products, services and systems have been discussed for some years now with increasing intensity (Siune et al. 2009). The postulate of Responsible Research and Innovation (RRI) adds explicit ethical reflection to Technology Assessment (TA) and Science, Technology and Society (STS) studies and includes all of them into integrative approaches to shaping technology and innovation (Schomberg 2012). Responsible innovation brings together TA with its experience in assessment procedures, actor involvement, foresight and ethical evaluation, in particular under the framework of responsibility, and also builds on the body of knowledge about R&D and innovation processes provided by STS studies and STIS studies (Science, Technology, Innovation and Society) (Grunwald 2012).

Science institutions, including research funding agencies, have started taking a pro-active role in promoting integrative research and development (see the Responsible Innovation programme of the Dutch National Science Foundation NWO as an example). Thus, the governance of science and of R&D processes is changing, opening up new possibilities and opportunities for involving new actors and new types of reflection. In particular, RRI aims at intervening R&D processes in early stages of development:

> Responsible development of nanotechnology can be characterized as the balancing of efforts to maximize the technology's positive contributions and minimize its negative consequences. Thus, responsible development involves an examination both of applications and of potential implications. It implies a commitment to develop and use technology to help meet the most pressing human and societal needs, while making every reasonable effort to anticipate and mitigate adverse implications or unintended consequences. (National Research Council 2006, p. 73)

The emergence of RRI reflects the diagnosis that available approaches to shaping science and technology still do not meet all of the far-ranging expectations towards technology governance and achieving a "better technology in a better society" (Rip et al. 1995). The hope behind the RRI movement is that new – or further developed – approaches could add considerably to existing approaches such as TA and engineering ethics. Indeed, compared to earlier approaches such as SST or CTA there are shifts of accentuation and new focuses of emphasis (Schomberg 2012; Grunwald 2012):

- "Shaping innovation" complements or even replaces the former slogan "shaping technology" which characterised the social constructivist approach to technology. This shift reflects the insight that it is not technology *as such* which influences society and therefore should be shaped according to society's needs, expectation and values, but it is *innovation* by which technology and society interact as has been pointed out by many STS studies.
- There is a closer look on societal contexts of new technology and science. RRI can be regarded as a further step towards taking the demand-pull perspective and social values in shaping technology and innovation more serious.
- Instead of distant *observation* following classical paradigms of science there is now a clear indication for *intervention* into the development and innovation process: RRI projects shall "make a difference" not only in terms of research but also as interventions into the "real world".

- The spectrum of stakeholders to be involved in participatory processes and dialogue is to be broadened further because of new forms of science and technology governance (Siune et al. 2009; Schomberg 2012).
- Following the above-mentioned issues, RRI can be regarded as a radicalisation of the well-known post-normal science (Funtowicz and Ravetz 1993), being even closer to social practice and being prepared for intervention and for taking responsibility for this intervention.

The concrete realisation within the Responsible Innovation programme of the Dutch Science Foundation makes clear that "opening up the lab" is part of the agenda. Ethicists, TA researchers and STS scholars shall cooperate with natural scientists, engineers, developers, and managers in order to come up with modified and, hopefully, more "responsible" products, systems and services. It is still too early to assess whether the ambitious goals have been reached, and what conditions should be fulfilled to support fulfilling the expectations.

2.4.4 Vision Assessment

Quite often visions and metaphors mark the revolutionary advance of science in general and act as an important factor in societal debates, in particular in NEST (Grunwald 2007 for the case of Human Enhancement). Available studies have shown that futuristic visions are ambivalent: they may cause fascination as well as concern and fear. The main argument for requiring early engagement of TA in the form of a vision assessment is the importance of visions in actual debates, that is, both in the debate on the opportunities afforded by scientific and technological progress and in ongoing risk debates (Grunwald 2007).

Vision assessment is a new TA tool that is not directed at the assessment of technologies but at the assessment of visions which are communicated across the many interfaces between technology and society (Grin and Grunwald 2000). Vision assessment can be analytically divided into (see Grunwald 2009b):

- vision *analysis* – which is itself subdivided into a *substantial* aspect (what is the content of the respective vision?) and a pragmatic aspect (how is it used in concrete communication?),
- vision *evaluation* (how could the content of the vision be evaluated and judged?), and
- vision *management* (how should the people and groups affected deal with the visions?).

The general aim is to provide transparent disclosure of the relationship between knowledge and values, knowledge and the lack of it, and the evaluation of these relationships and their implications. In particular, vision assessment should allow the various and partly divergent normative aspects of visions of the future to directly confront each other in order to improve transparency and clarity of their contents, premises, and meanings.

The lab level is indirectly addressed by vision assessment. Techno-visionary communication often has impacts on the agenda of science and research, it may attract young people to the respective research fields, it may influence research funding, and it may create public awareness and political support. Researchers at the lab can contribute to developing visions but also to scrutinising and assessing them. Accordingly, in spite of the fact that vision assessment mainly addresses public debates on new and emerging science and technology researchers operating at the lab must be involved in processes of vision management.

2.4.5 Real-Time Technology Assessment and New Approaches

Technology Assessment is a field of research and engagement which requires continuous adaptation to new developments and changing boundary conditions as well as learning procedures. The history of TA can be told as continued exploration of and experimentation with new approaches.

One of the most recent conceptual developments in TA is the so-called Real-time Technology Assessment (Guston and Sarewitz 2002), which is a social technology with the goal of redesigning knowledge production and application to make design and other choices in research and development more explicit, informed, transparent, accountable, and participatory. It combines problem-oriented empirical research and dynamics of technology with research on and engagement with values accompanying these developments. It was nanotechnology which gave rise to the development of this approach.

Another recent development in TA is related to the notion of a “third generation TA” (Yoshizawa 2012). This development identifies a first (expert-based, parliamentary-centred) and a second (involving selected citizens, parliamentary-related) generation of TA. Third generation TA is, in contrast, not necessarily based in an established organisation, “but rather in a flexible distribution network of existing intellectual and human resources, facilitating active engagement of lay public as well as intermediate actors between experts and technology end-users” (Yoshizawa 2012). There are some relations to the idea of Responsible Innovation (see above), but in this case everything is still ongoing.

2.5 Case Study: Systems Analysis for Developing New Cement

In this section, we describe the approaches of accompanying systems analysis and innovation research based on a case study in which we discuss an ongoing technology development at Karlsruhe Institute of Technology (KIT), a project which has become a beacon of the KIT.

Cement is a mass construction material with large world-wide growth rates, whose production is energy-intensive and connected with high CO_2 emissions. Cement, mostly Ordinary Portland Cement (OPC), is mainly used for concrete – next to water the most commonly used material worldwide. According to our assessments, the global cement production emitted in 2008 a total of about 2.5 billion tons CO_2 (Achternbosch et al. 2011a). This corresponds to 8 % of the global anthropogenic CO_2 emissions. The cement industry has adopted many measures to reduce these emissions, such as improving techniques or using secondary materials. However, it can be shown that these measures are not sufficient to stabilise or even lower the amount of future CO_2 emissions. Carbon Capture and Storage (CCS) is currently discussed controversially as a "tool" for reducing CO_2 emissions, but it is likely that this process is very energy-intensive, uneconomic, and possible risks are difficult to assess (Luhmann 2009). Instead of focusing on this end-of-pipe technology, which has not even been realised, the development of "low-CO_2 cements" that are produced with substantially lower CO_2 emissions would be a more sustainable course provided these innovative cements do have the potential to replace conventional cement.

At the Karlsruhe Institute of Technology (KIT; www.kit.edu), cement and concrete have been topics of research for many years. Since 1997, the workgroup "Construction Materials" (BSG) of the Institute of Technical Chemistry (ITC) has been investigating the cement chemistry related to hardened cement stone (calcium silicate hydrates). A major impulse for the development of efficient and novel binders came with the analysis of material flows in cement production carried out by the Institute for Technology Assessment and Systems Analysis (ITAS) of KIT (Achternbosch et al. 2005) in cooperation with the BSG. The research was funded by the Federal Environment Agency from 2000 to 2003. In the year 2006, the activities of four BSG researchers resulted in the development of a new class of low-CO_2 binders, which form the basis of Celitement®.

In the same year, ITAS informed the Executive Board of Directors about this remarkable development and recommended its support and funding. High potential was seen in developing a new cementitious binder, whose production is probably associated with much lower CO_2 emissions than that of conventional cement. ITAS was convinced that the research results could be transformed to industrial scale and that the new cement, in addition to the cleaner production issues, could show improved structural properties – compared to OPC. In particular, due to current and forthcoming climate policy regulations these new binders could have a good chance to enter the market and to revolutionise the construction industry.

The Board followed these recommendations. Since that date, the cement project has received great attention and importance. According to a directive issued by the Board in 2006, the development was treated as strictly confidential for obvious reasons, and up to the issuance of related patents it was not allowed to publish anything, not even the fact that this development was already on the way. This statement was an excellent starting position to protect the interests of the KIT with regard to transferring this technology to industry.

Since 2007, several patents have been issued for Celitement®, concerning both the material composition and the principle of the production process. The (binder) system of Celitement® is similar to that of the conventional OPC. However, there are large differences in the manufacturing process, the potential of energy efficiency, and the amount of CO_2 emissions associated with the production. In order to promote the development of the binder and the process design for commercial use, the Celitement® GmbH was founded in 2009 as a spin-off of the Schwenk Group (industry), the Karlsruhe Institute of Technology KIT, and the originators of the invention.

In the last 5 years, the project "Celitement®" has become a beacon of KIT, and since that time it has been accompanied by systems analysis conducted at ITAS. In the case of a successful market introduction, the Celitement® invention would have great economic potential. Thus it is quite understandable that further research in this field need to be handled with great care by all persons involved: KIT (Executive Board), inventors (BSG), accompanying systems analysis (ITAS), and industry (Schwenk Group). Therefore, all project participants were sworn to secrecy; for ITAS this means that results of the work in the years 2007–2009 could be used only internally and were not allowed to be published. Even the fact that ITAS carries out research to evaluate this project was not revealed until February 2009, when the information was published by KIT Press Release 014/2009 and the website of the spin-off Celitement® GmbH (www.celitement.com).

The work of ITAS in the context of the innovative binder covers various areas. Studies on the energy consumption for the production of Celitement® and the associated CO_2 emissions for evaluating the CO_2 reduction potential of the process are included. The findings are made available to the inventors to foster the development process; on the other hand they are used by ITAS for a systems analytical assessment of the entire process chain. The results are compared with the corresponding data for the production of conventional cements.

Another task of ITAS is to examine the opportunities and potentials of products based on Celitement® for a successful market entry. Closely connected with this work is the analysis of the innovation process. This could be described as a "life analysis", because this time it is not an analysis "afterwards" but an analysis which can react immediately on changes in "parameters", changing basic and edge conditions. To what extent it will be possible to publish the results of this work is difficult to estimate because they are closely linked with the interests of the cement industry, especially Celitement's shareholders.

In the summer of 2011, on the premises of the KIT North Campus, a pilot plant went into operation, which will accelerate the process of developing Celitement® from laboratory scale to technical readiness for the industrial production process. With this pilot plant it is now possible to produce larger amounts of Celitement®, which must be available to evaluate its material properties in detail. The data provided by the pilot plant enable ITAS to make more reliable estimates of energy use and CO_2 savings resulting from the production of Celitement.

The work and resulting recommendations of ITAS are seen only as internal help in decision-making by the other project participants. The ITAS project group, however, has never been actively involved in any of these processes because of the strong economic orientation of this project. The shareholders of the Celitement® GmbH – the inventors, the Schwenk Group and the KIT Board – alone make strategic decisions and take care about their implementation. The pursuit of economic interests with the premise of a fast market launch requires development of strategies and their implementation, which are not ITAS tasks.

Since 2009, ITAS has focused on topics that offer greater academic freedom, but which are nevertheless of crucial importance for the overall project. Parts of this work focus on studies of current and possible future actions of the global cement industry to reduce CO_2 emissions. First results were already published in Achternbosch et al. (2011a) after being "signed off" by the other project participants (ensuring that the confidentiality obligation was complied with). The report focuses on issues of demand, production capacity, and the raw material situation, but also looks at the CO_2 emissions released in the manufacturing process and the changing framework requirements due to the international climate regime.

Another task is extensive research on the development of low-CO_2 cements that are currently discussed in the media as possible alternatives to conventional cement (e.g. Novacem, Calera). These are analysed for their potential as mass building materials and their possibilities for reducing CO_2 emissions. The results of this work can be published without prior consultation with the shareholders of the Celitement® GmbH. The very first publication focused on Novacem (Achternbosch et al. 2011b).

It is already apparent from this brief account that the ITAS project group operates in a field of tension:

- ITAS sees itself as an independent and neutral research and TA institution. This is an important condition of our work, especially in the context of our mandate for policy advice. From the outside, this is even an indispensable prerequisite for the credibility of an institute for technology assessment. It is quite understandable that, from the external view (outside), a very tight involvement in projects with economic interests would put the neutrality of ITAS in question. This is one reason that topics such as public relations, promotion and marketing are not in our responsibility when practising supporting research on technical developments. As a consequence, ITAS is rarely mentioned in press releases or media appearances of Celitement. On the other hand, a "tighter" integration has positive effects on our work, because this allows an in-depth analysis of the innovation process, which can react on actual experiences and information.
- The systems analytical work, particularly on alternative cements, has brought us a lot of attention in the "cement community". We are advisors for associations, the industry partner of the Celitement® GmbH and research institutions of universities and are in contact with the Federal Association of the cement industry.
- The position of the cement industry is often ambivalent towards our studies: If the results do not affect their business and their interests, our work is acknowledged with great appreciation. Sometimes the industry draws important lessons from our work (advisory role), because a lot of information that we provide are based on studies which cannot be carried out in that depth by one

of their own. And in addition, we often confront the cement industry with quite different perspectives.

- It is remarkable that the new low-CO_2 cements (Novacem, Calera, Celitement®) which have gained the attention of the media and the public were not developed in the research departments of the cement industry, but almost exclusively in the "non-industry-oriented" university environment or in corresponding major research institutions. The further development of these inventions is done by start-up companies. The studies ITAS is currently working on do not affect the interests of the cement industry, of university research institutes or major research centres connected with the building industry. From the perspective of the established industries, the results for low-CO_2 cements, which are not always favourable, confirm their strategy – namely their adherence to developments that closely lean on conventional cements.

The construction industry is rather a conservative branch where traditionally only incremental innovations can be implemented. The cement industry looks back to an era of 150 years of successful implementation of Portland cement, a cement system which up to now seems unchangeable in the minds of experts of the industry and institutes for Materials Research of the building industry. Editorial boards of professional journals of Materials Research in the building industry are mostly composed of these experts. These experts are often also authorities in political motivated committees. If systems analytical articles with another system view are submitted for publication in these journals, constraints for publication cannot be excluded due to this conservative view. If rejected, the desired recipients cannot be reached.

Our case study reveals that the systems analysis accompanying the Celitement® project in close relation with lab research is embedded in the field of conflict (technology determinism vs. social constructivism) elucidated in Chap. 3. This is particularly perceptible in respect to the aspect of governance. On the one hand, the attendance of TA is clearly wanted and promoted. On the other, however, the old distrust against TA scientists as technology laggards is ingrained, leading to sometimes complex processes of negotiation and to restrictions concerning publications.

2.6 Conclusion

Technology Assessment looks back on a history of now more than four decades. According to different and partially heterogeneous expectations of what TA should deliver, and because the expectations vary over time, TA has developed several approaches to meet different challenges and match different contexts. Besides the more policy-oriented approaches, several TA concepts deal with the challenge to support technology development in direct contact with developers at the lab level. The background theory of Social Constructivism gives rise to some optimism about the possibility of shaping technology.

However, there are also limitations and obstacles, as well as possible non-intended side-effects if TA works closely with lab research. It is important to point out that the model of TA research intimately linked with technical R&D also harbours problems. Its independence might be threatened, especially if the necessary distance to the technical developments and those working on them is lost. The case study (Sect. 2.5) is an illustrative example of this problem but also shows how to tackle them successfully and continue cooperation between lab development and TA in the case of conflict. To the same extent as TA would become part of the development process and identify itself with the technical success, the suspicion might emerge that possible positive results were "purchased" or that it was nothing but an accelerator in the process of innovation. The credibility of TA – which is essential for it to do its job – would be endangered.

A second critical issue is conflict and freedom of research. In innovation research and development, usually strong economic interests are part of the game. These could lead to conflicts as was also shown in the Celitement® case (Sect. 2.5). If TA came up with unexpected and unfavourable results for the innovation under consideration, e.g. concerning the competitiveness or sustainability indicators, voices might come up to suppress these results. Frequently, free publication is restricted by confidentiality agreements (see the case study in Sect. 2.5) which would allow preventing the publication of unwanted TA results. In this case, the task of TA would be to convince the partners that negative results for the innovation considered should not be suppressed, but taken seriously and used to re-design and improve it. Indeed, negative or unexpected results can often be interpreted as recommendation for change which could improve the chances of the innovation under development at the marketplace. Anyway, simultaneously sustaining the independence of TA and its relevance to R&D in concrete research and innovation processes requires balancing the distance of an observer to the neighbourhood of an involved person, which is an ambitious and delicate task.

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