# Scenarios as Patterns of Orientation in Technology Development and Technology Assessment – Outline of a Research Program

unpublished manuscript, April 2012

Ingo Schulz-Schaeffer, schulz-schaeffer@uni-due.de, Institute for Sociology, University of Duisburg-Essen

## 1. Introduction

"Sal awakens; she smells coffee. A few minutes ago her alarm clock, alerted by her restless rolling before waking, had quietly asked, 'Coffee?' and she had mumbled, 'Yes.' 'Yes' and 'no' are the only words it knows. […] At breakfast Sal reads the news. She still prefers the paper form, as do most people. She spots an interesting quote from a columnist in the business section. She wipes her pen over the newspaper's name, date, section and page number and then circles the quote. The pen sends a message to the paper, which transmits the quote to her office. Electronic mail arrives from the company that made her garage door opener. She had lost the instruction manual and asked them for help. They have sent her a new manual and also something unexpected – a way to find the old one. According to the note, she can press a code into the opener and the missing manual will find itself. In the garage, she tracks a beeping noise to where the oil-stained manual had fallen behind some boxes. Sure enough, there is the tiny tab the manufacturer had affixed in the cover to try to avoid Email requests like her own. On the way to work Sal glances in the foreview mirror to check the traffic. […] Once Sal arrives at work, the foreview helps her find a parking spot quickly. As she walks into the building, the machines in her office prepare to log her in but do not complete the sequence until she actually enters her office. […] Sal picks up a tab and 'waves' it to her friend Jo in the design group, with whom she has a joint assignment. They are sharing a virtual office for a few weeks. The sharing can take many forms – in this case, the two have given each other access to their location detectors and to each other's screen contents and location. […] A blank tab on Sal's desk beeps and displays the word 'Joe' on it. She picks it up and gestures with it toward her live board. Joe wants to discuss a document with her; and now it shows up on the wall as she hears Joe's voice: 'I've been wrestling with this third paragraph all morning; and it still has the wrong tone. Would you mind reading it?' Sitting back and reading the paragraph, Sal wants to point to a word. She gestures again with the 'Joe' tab onto a nearby pad and then uses the stylus to circle the word she wants: 'I think it's this term 'ubiquitous.' It's just not in common enough use and makes the whole passage sound a little formal. Can we rephrase the sentence to get rid of it?'" (Weiser 1991: 74f.)

The preceding paragraph is neither part of a science fiction novel nor is its author a writer. In fact, it stems from a scientific article published in a major popular science magazine and its author is a scientist: Mark Weiser, at that time head of the Computer Science Laboratory at the Xerox Palo Alto Research Center, presenting his research group's ideas about a new and revolutionary way of computing. Additionally, it is a rather significant article. It has become to be considered as the foundational paper of a key future technology, called "ubiquitous computing", which has attracted a large amount of research money and research activities within the last decade.

Imaginations of the future are essential for all future-directed activities. Without people thinking about how the future might or should differ from the present innovations would never or only incidentally occur. The importance of technological future concepts for technology development and prospective technology assessment has become widely recognized in the relevant literature. However, there is a lack of secure knowledge about how technological future concepts influence innovation processes. This paper outlines a research program with the objective to fill this research gap. The following considerations rely on three distinctions: Previous research on technological future concepts in innovation processes has been preoccupied with studying visions. My suggestion is also to look at more specific forms of technological future concepts, especially on situational scenarios (as the Sal scenario presented above). The underlying assumption is that general and specific technological future concepts have different effects and uses in innovation processes and that the distinction between visions and scenarios helps to better understand the dynamics of future concepts in innovation processes. Secondly, I will distinguish between the social and the epistemic dynamics of technological future concepts. This distinction is accompanied by the assumption that the relevance of visions primarily lies in the social dimension whereas scenarios are relevant with respect to the factual dimension of innovation processes. Thirdly, one should take into account that future concepts may and will have different effects and uses in different innovation-related contexts. For this reason I distinguish between the research and technology policy context, the context of research and development, and the context of prospective technology assessment. For purposes of illustration, the following considerations refer occasionally to the contrasting use of future concepts in the fields of ubiquitous computing and nanotechnology.

## 2. Visions: the future concepts of radical innovations

Processes of technological innovation strive to bring about a reality, which for now exists only in imagination: the reality of future technology. Hence, innovation efforts rely on conceptions of the future. The future concepts of radical innovations are different from those that govern incremental innovations. The different character of the respective conceptions of future technology distinguishes incremental from radical innovation. Incremental innovations are efforts to improve and advance existing technology. Thus, in the case of incremental innovation the characteristics and features of the envisioned future technology are to a large part derived from the past: as solutions for the shortcomings and weaknesses existing technology has shown (cf. Rosenberg 1976: 125; Nelson/Winter 1977: 57; Dosi 1982: 152; Hughes 1987: 73f.). In this way, it is possible to formulate detailed and highly concrete conceptions of the technological future. At the same time, to extrapolate future technology from past developments has the effect to narrow down possible paths of technology development (cf. David 1986; Arthur 1989).[1]

In contrast to incremental innovation, radical innovation is characterized by discontinuity (cf. Freeman/Perez 1988: 46; Van de Ven et al. 1999: 63). Processes of radical innovation aim at future technology (and/or future uses) for which the past and the present do not provide technical (and/or cultural) precursors that may serve as example. For this reason, the conceptions of the technological future, radical innovative activities try to realize, cannot or only slightly be extrapolated from existing knowledge. Consequently, these future concepts typically are vague in their specifications of the technical features and the forms of use of the envisioned

[1] The orientation of the semiconductor development at Moore's law and related past development trends exemplifies this point. From these past developments the semiconductor industry derives detailed roadmaps for future research and development. Cf. in particular the ITRS roadmaps (International Technology Roadmap for Semiconductors; www.itrs.net.

technology. Additionally, considerable uncertainty exists with respect to the appropriate goal-attainment strategy and the time and effort required. Processes of radical innovation rely on imaginations about a technological future that is believed to be promising and, at least in principle, technically feasible. Yet, only future will tell whether these expectations will come true. It has become common use in technology-related discourses to call future concepts of this kind “visions”.[2] Especially the fields of technology, which currently are (or in the near past have been) considered as key future technologies, are highly affected by visions. Often, the names of these technologies are already “vision statements”: Artificial intelligence, genetic engineering, nanotechnology, ubiquitous computing etc.

## 3. Effects and uses of visions in the innovation process

Social research on innovation indicates that visions may have specific effects in innovation processes and specific uses in processes of technology assessment. Research on technology development analyses visions with respect to their empirically observable impact on innovative efforts. Research on technology assessment, rather, is interested in possible uses of visions as tools for assessing and shaping technologies of the future. Above all, the literature highlights the following three aspects:

### 3.1 Mobilizing and coordinating actors, interests, and resources

Many studies confirm that visions act as a means of mobilizing and coordinating innovation-related actors, interests, and resources (cf. Dierkes et al. 1992: 100ff.; van Lente 1993: 93ff., 125ff.; van Lente/Rip 1998b; Van de Ven et al. 1999: 30ff., 82f., 203; Bender 2005: 178ff.). Visions seem to have a specific “appeal” (Dierkes/Marz 1992: 52) and rhetorical power (Rammert 1994: 16f.; Schulz-Schaeffer 1996: 118). Being “expectations of potential” (van Lente/Rip 1998b: 222) they attract and thereby mobilize actors to invest time, money and career chances in efforts to realize them.

According to well known considerations from the Constructive Technology Assessment approach, the mobilizing and coordinating effect relies on the “performative role” (Geels/Smit 2000: 867. 882) of technological visions. These authors argue that the promise of a “promising technology” (van Lente 1993) at first is not much more than rhetorics (cf. van Lente/Rip 1998b: 224, 246). But it may give rise to a social dynamic “from rhetorics to social reality” (van Lente/Rip 1998b: 221): Scientists, research funding institutions, and enterprises become attracted by the vision’s promises. They bring their interests, competences, and preferences into play, and, on this ground, articulate their particular expectations with respect to the envisioned technology. In this way the vision as a rhetorical entity triggers a social process of “mutual positioning” (ibid.: 224), a process in which “actors take up positions and make linkages” (ibid.: 235). Mutual positioning necessarily implies that the expectations become more specific, allowing to derive more specific requirements for the development of the new technology (followed by again more specific expectations, and so on). This leads to a process of agenda building, and what has been mainly rhetorics at first, more and more becomes social reality (cf. van Lente/Rip 1998a; van Lente/Rip 1998b).

Some authors hold that not only rhetorics is responsible for the mobilizing and coordinating effect of visions but that additionally an epistemic dimension should be taken into account.

[2] There are some similar terms in use in innovation research like „guiding vision“ („Leitbild“), expectation structure“ or „promising technology“ which – including additional conceptual connotations – also denote future concepts of radical innovations.

Especially the guiding vision ("Leitbild") approach (cf. Dierkes et al. 1992) has stressed this aspect. The approach claims to explain the mobilizing and coordinating effect by the visions' character as patterns of orientation. The argument goes as follows: by serving as commonly shared vanishing points of thought and action visions shape the perceptions and assessments of the involved actors (cf. ibid.: 45ff., 100ff.). By influencing the actors in such a way, the visions have the effect of coordinating actors and guiding innovation-related decisions (cf. Marz/Dierkes 1992: 36f.). According to this strand of argument, decisions to pursue and to fund projects of technology development are influenced the more by visions, the less the result of the innovative activities can be anticipated. Thus, visions are of major influence especially in the case of radical innovations (cf. Dierkes 1993: 269).

### 3.2 Guiding research and development activities

As discussed in the previous section, there is little doubt that visions do have an impact on initiating programs and projects of technology development. A different question is whether visions act as patterns of orientation for the ongoing research and development activities of innovation processes. This is a controversial matter. The guiding vision approach argues in favor of this assumption (cf. e.g. Dierkes 1993: 268ff.). Referring to own historical reconstructive case studies, its proponents claim to have shown that visions influence the actual research and development activities of innovators and thus do have an impact on the features of new technologies and on the paths of their development (cf. Marz/Dierkes 1994: 42ff.; Dierkes et al. 1992: 59ff.). However, it is to be suspected that this finding is an artifact of retrospective analysis (cf. Grunwald 2004: 56), especially since other studies do not confirm such an immediate effect of visions on technology development (cf. Rammert et al. 1998; Berkhout et al. 2003: 12; Hellige 1996a: 25f.).

Yet, one should not easily dismiss the assumption that the content of technological future concepts exerts an influence on technological research and development. Social dynamics are not enough to explain how technological future concepts are transformed into research agendas. For the dynamic from rhetoric to social reality to occur, actors' need clues to evaluate whether or not it is of interest to them to engage in the development of the proposed technology. At least to some extent they need to know which competencies and resources might be useful for realizing the vision, which academic or economic aims and ambitions thereby might be pursued, etc. Otherwise, there is little reason why (and how) actors' should position themselves within such an endeavor. Since these questions refer to the imagined reality of technological future concepts the clues for answering them are not to be found anywhere else than in these future concepts. Consequently, the factual content of technological future concepts should play a part in the process of mutual positioning and agenda building. In line with this argument, van Lente and Rip agree that visions are not purely rhetorical: „expectation statements contain a ‚script', indicating promising lines of research and technical development to be undertaken by the enunciator of the statement and/or by others. Thus they mobilize support in specific ways." (van Lente/Rip 1998a: 218) It thus seems plausible to assume that future concepts provide orientation in innovation processes. Yet, this does not imply that visions have the capability to directly guide specific research and development activities (cf. Rammert 1994; Rammert et al. 1998).

### 3.3 Prospective technology assessment

Without sufficiently reliable assessments of the societal (i.e. economic, political, legal, social, and cultural) and ecological risks and benefits of future technologies there is little chance of influencing innovative activities with the objective to advance desirable technological developments and to discourage undesirable ones. In the case of radical innovations, the present knowledge about the future reality of the envisioned technology is more or less restricted to what can be derived from the future concepts. Thus, technology assessment in this case has little options but to refer to these concepts. Some authors take account of this fact by suggesting to develop methods for “guiding vision assessment” ("Leitbild-Assessment", cf. Dierkes 1991; Hellige 1996b) or “vision assessment” (Grunwald 2004; Grin/Grunwald 2000). The basic idea is to assess the technological future as envisioned by these future concepts, that is to assess the risks and benefits to be expected if the visions’ future would come true.

The idea to employ visions as tool of prospective technology assessment plays an important part in the guiding vision approach (cf. Dierkes 1991; Dierkes 1993; Marz/Dierkes 1994). As mentioned before, the authors of this approach hold the view that visions are effective in guiding research and development activities. Accordingly, they assume that the future the researchers and engineers are about to realize will be not too different from the future as pictured by these visions. Consequently, it makes sense to use the visions employed in innovative activities for assessing these activities’ future outcomes. Additionally, it becomes a promising idea to try to prospectively shape technological change by shaping the visions to which the researchers and engineers refer to in their innovative activities.

However, it has soon been criticized to be an exaggerated claim that by analyzing visions it would be possible to recognize the consequences of technologies while they are still under development (cf. Hellige 1993: 196; 1996a: 29). Such a concept of prospective technology assessment underestimates the fact that innovation, and especially radical innovation, “involves uncertainty in a essential way” (Nelson/Winter 1977: 47), so that the “outcomes of innovative efforts can hardly be known ex ante” (Dosi 1988: 222). Additionally, given the current state of research there is little reason to believe that visions exert an immediate influence on research and developmental activities. As Grunwald states, „their promised use for shaping technology in a prospective sense […] has not been realised“ (Grunwald 2004: 56; cf. Grunwald 2002: 149f.). This opinion is shared by many other researchers (cf. e.g. Schot/Rip 1997: 260; Rammert 1994: 16f.).

Nevertheless, even the above-mentioned critics do not entirely dismiss the idea of using future concepts as means for prospective technology assessment. Hellige suggests an attenuated version of vision assessment (cf. Hellige 1996a: 29). Following his line of argument, Grunwald proposes an elaborated concept of vision assessment. The cornerstone of his argument is that technological future concepts because of their mobilizing effects actually influence innovative efforts (vgl. Grunwald 2006: 69ff.; Grunwald 2004: 57). For visions to play a part in innovative efforts, it is not necessary that they are blueprints of future technologies, which they are not. It is enough that visions are affecting decisions concerning the establishment and funding of innovative efforts. Vision assessment, then, is the task to analyze the visions’ actual influence on innovation-related decisions and to evaluate whether this influence leads to decisions that are desirable from the point of view of society.

The idea to prospectively shape future technology by establishing visions of desirable techno-social futures remains highly attractive as well – in spite of the above-mentioned objections. The technology policy approach of transition management may serve as an example. According to this approach, sustainability visions should be employed to formulate desirable objectives of technology development, such as “cleaner cars” or “clean coal”, from which policies to attain the visions’ goals systematically should be derived. „The long-term visions of sustainability should be used as a guide to formulate programmes and policies and the setting of short-term and long-term objectives.“ (Kemp/Rotmans 2004: 147; cf. Kemp/Loorbach 2005).

Here again it is implied that visions may not only rhetorically but also factually structure technology development.

## 4. Integrative capacity and lack of concreteness

Several well-known concepts of technology assessment in one or another way adhere to the idea of employing visions as means of prospective technology assessment and of prospective shaping of technology. This is remarkable, given the rather discouraging performance, visions according to many researchers have shown in this respect. The reason for it is that if visions could be used in this way, a crucial problem of technology assessment could be solved: the problem of overcoming the „dichotomy between promotion and control of new technology“ (Rip 2002: 14; vgl. Schot/Rip 1997: 264). Most distinctly, the guiding vision approach embodies this hope. According to this approach, the visions on the one hand significantly structure technology development efforts (“Leitbildprägung”, i.e. visions governing technology development). On the other hand these visions can be used to prospectively control technology development processes with respect to their outcomes (“Leitbildgestaltung”, i.e. shaping the visions which are governing technology development) (cf. Marz/Dierkes 1994: 35).

The main obstacle for using this integrative potential of visions lies in the fact that, though visions undoubtedly affect public and private decisions to engage in technology development, they do not provide pictures of the future detailed enough to guide specific research and development activities. Visions are rough sketches rather than detailed drawings of the technological future they focus on. They do not elaborate on the complexity of the future reality in sufficient detail to determine definite steps for realizing this future. For the same reason they do not provide a sound basis for evaluating the risks and benefits of the envisioned technological future. Thus, shaping technology by shaping visions does maybe work in the context of research and technology policy but not in the context of actual research and development activities. The question, then, is whether there are forms to express concepts of technological future, which may compensate for the visions’ lack of concreteness.

## 5. Scenarios: specified conceptions of technological future

The scenario as a tool for future research, from the outset, has been a means of concretizing and specifying future concepts. Scenarios created for this purpose try to take into account a plurality of factors and circumstances, which might affect the reality of the future technology and its forms of use, in order to describe this possible future as a complex of specified cause-effect-relationships. Scenarios put visions into concrete terms by focusing on the interdependences that are (or might be) constitutive for the actual reality of the envisioned future. This does not mean that scenarios are or claim to be forecasts. Just as visions, they are not. Scenarios no more than visions provide a solution to the problem of fundamental uncertainty of innovative activities. Like visions, scenarios rely on assumptions about the future, which result at best from informed guess. In a different respect, scenarios put visions in concrete terms: they are spelling out the implications of the visions’ assumptions. As Steinmüller states, scenarios act out fictional realities by elaborating coherent chains of cause and effect, which include aims and consequences of human action and constraints exposed by circumstances (Steinmüller 2003: 3)

For scenarios to become useful tools for describing hypothetic future realities in a most realistic and plausible way, the scholarly literature stresses the importance of the following quality criteria: First, scenarios should be credible (cf. Wilson 1978) and consistent (cf. Godet 1986: 135). They should provide a coherent and consistent picture and derive it plausibly from the underlying assumptions about the imagined future. Second, the scenarios should be exhaustive (cf. Steinmüller 2003: 15f.) or holistic (cf. ibid.: 7; Steinmüller 1997: 52), meaning that they should include all the aspects of the imagined future reality that might be of importance. And third, the underlying assumptions from which the scenarios are derived should be made explicit (cf. Amara 1991).

Descriptions of this kind that have been employed in strategic military studies carried out in the 1950s by RAND Corporation for the U.S. Army are the first that have been referred to as scenarios. These studies used hypothetical battlefield situations to elaborate, which own or enemy's options might exist under certain conditions (cf. Steinmüller 2003: 3). Since the 1970s the use of scenarios has found its way into the business world, where it, according to Minx and Böhlke, more and more turns into a standard tool for strategic planning (cf. Minx/Böhlke 2006: 17). Several studies support the view that scenarios have become one of the main tools of future research (cf. Steinmüller 2003: 3; Weber 1990; Gausemeier et al. 1997: 203f.; Albert et al. 2002).

In the context of strategic planning, an important role of scenarios is to support decision-making under the condition of uncertainty by providing descriptions of possible cause-effect-relationships from which criteria for decision-making can be derived. Herman Kahn and Anthony J. Wiener, the pioneers of scenario research, stress this point as follows: "Scenarios are hypothetical sequences of events constructed for the purpose of focusing attention to causal processes and decision points" (Kahn/Wiener 1967: 6). In a more encompassing sense they consider the scenario to be an "aid to thinking" (ibid.: 262) because the scenario is a means to go ahead from the visions' overall pictures of the future to descriptions of the specific reality of possible futures.

## 6. Types of scenarios

The scholarly literature refers to the following three dimensions to distinguish between different forms of scenarios. I will use these three dimensions as basis of a typology to characterize the specific type of scenario most appropriate to act as means of concretizing visions.

***Projective vs. normative scenarios:*** This distinction goes back to Kahn's and Wiener's distintion between "'surprise-free' projection" and "canonical variations" (Kahn/Wiener 1967: 8f.). If the conceptions of the future are obtained by extrapolating the future from the past and the present, the resulting scenarios are called projective or explorative scenarios. Normative scenarios, in contrast, are based on assumptions, which are not derived from current trends. Normative scenarios focus on change and not on continuation. They are conceptions of desirable or undesirable future states. Normative scenarios include best-case scenarios as well as worst-case scenarios (cf. Steinmüller 1997: 53f.; Steinmüller 2003: 9f.). These are features normative scenarios share with technological visions (visions, however, due to their function as mobilizing devices, mostly are imaginations of desirable future states). For this reason, the scenarios that are concretizing technological visions basically are normative scenarios. However, it should not be neglected that even radical innovations are discontinuous developments only in certain respects and in other respects (as in the case of incremental innovation) recombinations of already existing elements (cf. Edquist 1997: 1; Van de Ven et al. 1999: 9). This means that visions – and the corresponding scenarios – include projective components (cf. Steinmüller 1997: 53f.; Steinmüller 2003: 9f.).

***Situational vs. developmental scenarios:*** A scenario's description of the interdependencies between components and relations may either address a possible future state of affairs (situational scenario) or a possible future development (developmental scenario) (cf. Steinmüller 2003: 11). Technological visions are conceptions of desirable (or undesirable) future states of affairs. The scenarios putting these visions into concrete thus are situational scenarios. However, developmental scenarios also may come into play since both types of scenarios refer to each other. On the one hand, in a kind of forecasting, it is possible to derive situational scenarios from developmental scenarios. In this case, the developmental scenario serves as a basis for extrapolating the future reality that will result from the development as represented by the developmental scenario. On the other hand, in a kind of backcasting, it is possible to derive developmental scenarios from situational scenarios. This can be done by asking which steps of development are necessary to realize (or to prevent) the future reality as described by a situational scenario (cf. Steinmüller 1997: 55). The pictures-of-the-future process as developed by Siemens AG calls this strategy "retropolation" (cf. Eberl 2001: 5). Both ways of deriving scenarios from each other serve different purposes. According to Steinmüller, deriving steps of development from situational scenarios helps to learn about what it would require to achieve at the future reality as described by the respective situational scenario. It thus is a way to identify options for shaping the future. Deriving future situations from developmental scenarios on the other hand helps to identify the implications of possible innovation strategies and thus can be used as a means of technology assessment (cf. Steinmüller 1997: 55).

***Quantitative vs. qualitative scenarios:*** To describe in quantitative terms the elements and relations to be taken into account within a scenario, it is necessary to derive the assumed figures from actual trends, which already have been measured quantitatively. The best-known example of a predominantly quantitative scenario is the Club of Rome's study "The Limits to Growth" (Meadows et al. 1972). As this study clearly demonstrates, quantitative scenarios tend to blur the boundaries between scenario and mere extrapolation. To a certain degree all assumptions about technological future states are affected by uncertainty and the possible ways there are characterized by discontinuity. To deal with such complexities, scenario construction has to rely on qualitative processes of reasoning about more or less probable, feasible and desirable (or undesirable) future developments and future states and on verbal descriptions thereof (cf. Schwartz 1993: 34; Steinmüller 2003: 45f.). For this reason, scenarios differ from forecasts by a certain amount of qualitative argumentation. As Ropohl puts it, the general character of scenarios is a qualitative one (cf. Ropohl 1997: 193). Looked at more closely, it is the proportion of projective or normative components that gives a scenario a more quantitative or a more qualitative character. Scenarios with a predominantly qualitative orientation usually take the form of narratives, in most cases in textual form but sometimes as cartoons or film sequences. A way to further increase the concreteness and the realism of qualitative scenarios is the so-called narrative scenario, a form of narration that introduces fictional persons as the story's protagonists (cf. Steinmüller 2003: 36).

Considering all three dimensions, it can be theorized that the qualitative normative situational scenario should be empirically observable as the most appropriate type of scenarios for concretizing and specifying the technological visions of radical innovations. Furthermore, it is to expect that qualitative normative situational scenarios that take the form of narrative episodes should serve this purpose especially well. In the field of ubiquitous computing this type of scenarios is very common – often in the form of narrative scenarios. Even the paper in which Mark Weiser proposes the vision of ubiquitous computing for the first time, includes a scenario of this kind – the above quoted Sal scenario (cf. Weiser 1991: 74f.).

## 7. Visions und Scenarios in Ubiquitous Computing and Nanotechnology

In his foundational paper Weiser envisions a technological future in which computers no longer constitute a world of their own, “approachable only through complex jargon that has nothing to do with the tasks for which people actually use computers” (Weiser 1991: 66), but rather become “an integral, invisible part of people’s lives” (cf. ebd.). According to this vision, a myriad of interconnected computing units embedded within the users’ everyday environment will constitute a constant background presence, a ubiquitous informational infrastructure that is intuitively usable based on everyday knowledge. In this paper, Weiser also coins the term “ubiquitous computing” to denote this vision.

As of the turn of the millennium, this vision has had a considerable impact on research policy. In 2001, the U.S. National Academy of Sciences publishes a research policy paper, which proposes the vision of embedded computer-networks. It states the aim “to develop a research agenda that could guide federal programs related to computing research and inform the research community (in industry, universities, and government) about the challenging needs of this emerging research area“ (National Academy of Sciences 2001: VIII). At the same time, the Nomura Research Institute, that is influential in the Japanese research policy, publishes a series of research reports proclaiming “Ubiquitous Networking” as the new paradigm of information technology (cf. Murakami/Fujinuma 2000; Murakami 2001; 2003). The Japanese national research policy soon adopted this idea. In a White Paper of the Ministry of Telecommunications a strategy for realizing a „Ubiquitous Network Society“ (cf. MPMHAPT 2004) is suggested. Similar research policy activities are taking place in Europe. Already in 1999, the Information Society Technologies Advisory Group (ISTAG) – a panel of experts providing advice for the European research policy in the field of information technology – proposes the vision of ambient intelligence (cf. ISTAG 1999: 2), thus creating an own label for research policy in the emerging field of ubiquitous computing. In a subsequent report this vision is characterized as follows: „People are surrounded by intelligent intuitive interfaces that are embedded in all kinds of objects and an environment that is capable of recognising and responding to the presence of different individuals in a seamless, unobtrusive and often invisible way.“ (ISTAG 2001: 1).

It is noticeable that these “vision statements” nearly always are accompanied by scenarios, which in more or less detail spell out for a variety of domains of application how the future reality of ubiquitous computing[3] possibly will look like. Weiser’s Sal scenario describes the use of ubicomp technologies at home, during commuting, and at work in the bureau. The ISTAG report „Scenarios for Ambient Intelligence in 2010“ provides four narrative scenarios covering the domains of shopping, traveling, health care, mobile communication, recreational activities, and education (cf. ISTAG 2001: 4ff., 26ff.). The respective Japanese research policy papers include scenarios with similar topics. They are often presented as cartoons (cf. Mobile IT Forum 2003: 1ff.; MPMHAPT 2004: 19). The U.S. research agenda “Embedded, everywhere” also provides scenarios, though with a different thematic focus: mobility, warfare, and agriculture (cf. National Academy of Sciences 2001: 16ff.)

[3] The different terms „ubiquitous computing“, ubiquitous networking“, „embedded systems“, „ambient intelligence“, or „pervasive computing“ are basically referring to the same technological vision. They differ from each other only slightly. To simplify matters I am using only the term ubiquitous computing and it’s often used abbreviation “ubicomp”.

Technology assessment studies of ubiquitous computing also rely heavily on scenarios. The EU project "SWAMI – Safeguards in a World of Ambient Intelligence" has set standards for the use of scenarios for assessing ubicomp technology. Here, four so-called "dark scenarios" build the basis for assessing the new technology – narrative worst-case scenarios devised to shed light on social and societal risks of future ubiquitous technology applications (cf. Punie et al. 2006).

With respect to the visions of nanotechnology, it is useful to distinguish between so-called futuristic or utopian visions and so-called realistic visions. K. Eric Drexler, to whom the authorship of the term "nanotechnology" usually is credited,[4] is the most outstanding proponent of the futuristic-utopian discourse. His pivotal vision is the future existence of molecular assemblers: nanoscale machines able to assemble designated structures from individual molecules or atoms. Thus being able to assemble the structure they themselves consist of, molecular assemblers additionally are self-replicative machines. Drexler affiliates far-reaching expectations for the future to this basic vision, which are quite futuristic visions as well: the colonization of the universe; the prolongation of the human life span, even up to immortality; a revolution of industrial production resulting in an extremely cost-efficient and resource-saving mode of production (cf. Drexler 1986; Drexler/Peterson 1991). However, Drexler does not conceal a possible threat to humankind connected with nanotechnology, the so-called grey goo scenario: an uncontrolled self-replication of molecular assemblers could suffocate any life in the world under a coat of these machines.

Futuristic visions play an important part in the public debate on nanotechnology, as for example the Bill Joy debate[5] has shown (cf. Schirrmacher 2001). Within the scientific discourse, however, the prevailing opinion is that popular visions of this kind are mere science fiction while it should be the task of serious scientific endeavor to elaborate more realistic and less fanciful future conceptions. An expression of this rejection of futuristic visions is that within the scientific discourse the origin of nanotechnology usually is traced back not to Drexler but to Richard Feynman. Though it was Drexler who introduced nanotechnology as a term and as a conception of future technology to the scientific world, instead, Feynmans talk „There's plenty of room at the bottom" (cf. Feynman 1960) is commonly considered to be the foundational document of nanotechnology (cf. Salin 2007: 203; Schaper-Rinkel 2006: 476; Fogelberg/Glimell 2003: 73). The research policy papers concerned with nanotechnology largely express a very similar view towards nanotechnological visions (cf. National Science and Technology Council 1999: 8; Royal Society 2004: 5). Nevertheless, the expectations regarding nanotechnology are not necessarily more modest within this discourse and the conceptions that count as realistic visions are not always less far-reaching than those within the futuristic discourse.

Most influential for nanotechnology to be set on the agenda of research funding agencies and policymakers are the research policy papers that have been worked out in the context of the emerging U.S. National Nanotechnology Initiative. According to an expectation prominent in these papers, "nanotechnology will have a major impact on the health, wealth and security of the world's people that will be at least as significant in this century [the 21st century; ISS] as antibiotics, the integrated circuit, and manmade polymers" (National Science and Technology

---

[4] However, he was not the first to use this term to describe nanoscale production technology (cf. Schaper-Rinkel 2006: 475).

[5] Cf. http://www.wired.com/wired/archive/8.04/joy.html (last access: 2011/11/01).

Council 1999: 2) have been for the 20th century. The overall vision of the National Nanotechnology Initiative pictures a future, „in which the ability to understand and control matter on the nanoscale leads to a revolution in technology and industry“ (National Science and Technology Council 2004: 1). This overall vision includes a multitude of visions for different domains of application: lighter and more durable materials, which will make production and transportation more energy-efficient; improved healthcare that will prolong life and improve its quality; dramatic reduction of waste and pollution through nanotechnological means, to name only a few of them (cf. National Science Foundation 2001: 3-10).

In contrast to ubiquitous computing, the use of normative situational scenarios is rather seldom in nanotechnology. While there is a constant and systematic use of scenarios as means to substantiate visions in research policy as well as in technology assessment activities concerned with ubiquitous computing, a similar use of scenarios in nanotechnology occurs only occasional and if so mostly in a less elaborated manner (cf. Aschenbrenner 2003; Bundesministerium für Bildung und Forschung 2006: 28). Some nanotechnology studies employ developmental scenarios for purposes of prospective technology assessment, but the parameter structuring these scenarios often remain rather abstract (cf. High Level Expert Group "Foresighting the New Technology Wave" 2004; Nanologue 2006; 11ff.; Renn/Roco 2006: 52ff.). Overall, in the field of nanotechnology neither the research policy papers nor the technology assessment systematically uses normative situational scenarios or scenarios at all. Most times, when the term "scenario" is used, it is used to designate visions (cf. Roco/Bainbridge 2002: 4-6; Brune et al. 2006: 382ff.; Grunwald 2006: 51ff.)

## 8. Effects and uses of scenarios in the innovation process

### 8.1 Mobilizing and coordinating actors, interests, and resources

To understand the relevance of scenarios as means of mobilizing and coordinating actors, interests, and resources, the comparison with the respective relevance of visions is useful. This comparison reveals remarkable differences in how future conceptions are used in ubicomp and in nanotechnology research policy. As described above, there is considerable empirical evidence that the relevance of technological visions largely results from their rhetorical power. According to these findings, visions are especially well suited to attract the attention and to mobilize the support of research policy bodies, policy-makers, and organizational decision-makers, which is necessary to set up the respective research programs and research projects. The relevant literature largely agrees that technological visions may and do exercise this rhetorical power even when they are of no use as means of orienting and guiding the actual research and development of the envisioned technologies. The futuristic visions of nanotechnology confirm this. Quite a few of them propose ideas far away (if not principally distinct) from what will be technically feasible for decades to come, and thus are completely unsuitable for orienting specific research activities (cf. Lösch 2006). Nevertheless, many studies observe a considerable actual significance of futuristic visions at the interface between science on the one hand and politics and the public on the other hand (cf. Grunwald 2006: 70). This holds especially in the field of nanotechnology (cf. Deutscher Bundestag 2004: 145, 153; Coenen 2003: 8f.; Brune et al. 2006: 388f.). The visions that have been influential for establishing nanotechnology as a key future technology seem to differ from those of other new technologies in that they are only loosely coupled with the emerging scientific foundations of nanotechnology or with questions concerning the technical feasibility and usefulness of possible applications (cf. Woyke 2010: 53). It is in line with this observation that the use of situational scenarios – that is the use of more concrete and application-oriented future concepts – as means of attracting attention and mobilizing resources is rather seldom in the context of nanotechnology.

In the context of ubiquitous computing this is markedly different. As mentioned above, from the outset the visions of ubiquitous computing are accompanied by scenarios as a means of specifying the overall future conceptions of the new technology and its possible uses. In itself, this finding of course does not imply that these scenarios are employed as means of mobilizing resources and support for technology development. However, there is evidence that ubicomp scenarios indeed serve as rhetorical means to this end. Qualitative normative situational scenarios are prominently placed within the research policy papers, which are written to promote and to initiate ubicomp-related research programs. Additionally, it is obvious that these scenarios are deliberately designed to emphasize the benefits of a future reality of ubiquitous computing (cf. Friedewald et al. 2005: 23; Punie et al. 2006: 7). It is hard to imagine that this scenarios' rhetorical presentation is without the intention to win over the policy papers' addressees.

What are the factors influencing the different use and impact of scenarios as rhetorical means? The above considerations suggest that scenarios – due do their character as more application-oriented forms of future concepts – occur only in the context of sufficiently realistic visions while futuristic visions are unsuitable to deduce from them scenarios. Another idea is that the rhetorical use of scenarios in the context of research policy serves to mobilize actors more directly involved in technology development – and thus more application-oriented – than the visions' addressees. This hypothesis is supported by the fact that in the field of ubiquitous computing especially the industry-oriented strategic papers and the research policy of the European Union, which also is considerably application oriented, draw heavily on scenarios. Another observation fits into this picture: the debate on nanotechnology in which visions play a major part is mainly a public debate. It is a debate on the more fundamental issues concerning the promises and risks of nanotechnology. In this debate, the visions serve to attain public attention for the more fundamental research policy positions concerning nanotechnology rather than to promote specific research and development programs. However, these are only preliminary explanations, which remain to be substantiated empirically.

## 8.2 Guiding research and development activities

One of the position papers aimed at establishing and institutionalizing ubiquitous computing explicitly states that scenarios provide an opportunity to concretize ubicomp visions with respect to future technological applications. The Embedded Systems Roadmap 2002 (cf. Eggermont 2002) presents the following multistage development model: An overarching vision of a desirable technology constitutes the starting point of the process. From this vision, domain-specific scenarios of promising applications are derived. Subsequently, roadmaps are worked out, which define the steps of development necessary to realize the technological components of the arrangements described by the scenarios (cf. ibid.: Eggermont 2002f.). In a similar way, the Information Society Technologies Advisory Group (ISTAG) characterizes the ubicomp scenarios they employ as "ways to uncover the specific steps and challenges in technology […] that have to be taken into account when anticipating the future. To put it another way, scenario planning is a tool to help us invent our future." (ISTAG 2001: 1)

Statements of this kind suggest that scenarios may be effective as patterns of orientation in the process of transforming technological visions into research agendas (see also Friedewald et al. 2005: 8). This is a rather interesting point, especially since the Constructive Technology Assessment approach, which at present is the probably most well known concept for analyzing technological future concepts, considers the transformation process from visions to agendas to be mainly a social dynamic in which epistemic orientation plays a minor part (cf. above 3.1 and 3.2). There is some evidence that this view applies more to certain processes of agenda building in nanotechnology than to those in the field of ubiquitous computing. However, this question is also open to further research.

Whether or not scenarios provide patterns of orientation that are guiding actual research and development activities is another research question that to my knowledge has yet not been explored in much detail. Kornelia Konrad (2004: 10, 24, 33, 135, 147) assumes that scenarios are indeed effective in such a way. However, neither her own research nor the actor-network theory studies she refers to, really confirm this assumption. Nevertheless, actor-network theory is a useful reference with respect to the question since it provides a consideration from which it is highly plausible that scenarios should have such a capacity. According to this consideration, every successful innovation is a new arrangement of coordinated roles. The performance of the technical components, the behavior of the users, the technology-related services of providers etc. must fit together sufficiently well to make a useful and usable technology (cf. Akrich 1992a; 1992b; Callon 1986; 1993). Thus, the technical components – just as all the other components of an innovation – occupy specific roles within the network of complementary interrelated roles the innovation consists of. To envision and to define the possible roles a new technology may and should (or should not) adopt within future contexts of application is exactly what qualitative normative situational scenarios are about. Consequently, scenarios of this kind indeed should have the capacity to provide guidance for innovation-related research and development activities.

## 8.3 Prospective technology assessment

It is not very clear how important the use of scenarios for purposes of technology assessment (TA) really is. Some TA experts appraise scenarios to have become the main device for technology-related future assessment (cf. Grunwald 2002: 226). Half of the TA experts included in a survey from 1990 state to work with scenarios (cf. Bonnet 1994: 44f.). A guideline about technology assessment put up by the Association of German Engineers characterizes scenarios to be one of the most mentioned methods (cf. VDI 1991: 37). However, it is arguable that the empirical reality of technology assessment corresponds with these perceptions. A survey conducted by Karlheinz Steinmüller shows that only in one percent of about 200 TA projects included, scenarios are mentioned at all (cf. Steinmüller 1999: 670). A review of the TA reports regularly published in the journal "Technikfolgenabschätzung – Theorie und Praxis" (http://www.itas.fzk.de/deu/tatup/inhalt.htm) provides a similar result for the last years. Additionally, there is not much literature elaborating on scenarios as a method of technology assessment.[6] These are findings supporting the view that all in all scenarios are rather marginal in their use for purposes of technology assessment (cf. Konrad 2004: 20ff., 259ff.). In contrast to this overall picture, scenarios are the method of choice for prospective technology assessment in the field of ubiquitous computing, while in the field of nanotechnology the vision assessment approach has become rather prominent in the last years.

Technology assessment is no end in itself but a means to produce knowledge useful for taking advantage of the benefits of new technologies and avoiding the possible risks associated

[6] For example, in von Westphalen's Handbook of Technology Assessment (cf. von Westphalen 1997) there is an article that introduces into scenario technique without including any consideration how to use this technique as a method of technology assessment (cf. Gausemeier et al. 1997).

with them. Thus, technology assessment aims at shaping technology. However, this poses an anticipation and control dilemma. While it is easier adequately to anticipate the consequences of a new technology in later steps of their development than at the beginning, it is easier to influence the direction of the development process in the beginning than in later phases (cf. Collingridge 1980: 16ff.). If to shape technology, it is thus necessary to assess emerging technologies at an early time when it is hardly possible to acquire sound knowledge of the possible effects that might be associated with them. Some approaches like the Constructive Technology Assessment approach deal with this problem by redefining what technology assessment can and should accomplish. Accordingly, technology assessment should be viewed as a method to enhance reflexivity within the ongoing process of technology development rather than as an instrument of anticipation and forecasting. In this context, Arie Rip explicitely refers to scenarios: „if paths are created while walking (Garud/Karnøe 2001), emerging paths can be mapped, and the way they emerge can be analysed […]. Basically, what happens is that scenarios are created in which impacts can be (speculatively) identified and assessed […]. Actors always work with partial and diffuse versions of such scenarios to orient themselves – and others. A social-science supported TA might improve the quality of their scenarios." (Rip 2002: 38)

Thus, the scenarios used by innovating actors as tools to invent the future should be employed by TA actors to assess the future as envisioned by these scenarios. By deriving recommendations from their assessments, technology assessment then may contribute to the invention of the future. In the field of ubiquitous computing this is a realistic option because there is a considerable similarity between the scenarios to be found in the context of research policy and of research and development and those used in TA studies. In contrast, prospective technology assessment in the field of nanotechnology cannot rely on such a link. Instead, it is largely dependent on visions if to derive assessments from conceptions of the technological future. These visions, however, are primarily rhetorical means for policy processes and do not provide much factual guidance for technology development. For this reason, the analysis of visions as provided by the vision assessment approach is rather a method of analyzing and assessing policy processes than a way to concomitantly assess emerging ideas about emerging technologies.

## 9. Outline of a research program

Technological innovation processes aim at inventing a future that for now exists only in imagination. This constitutes – especially in the case of radical innovations – the relevance of technological future concepts. Previous research on the impact of technological future concepts on innovation processes mainly focuses on visions: (1) The Constructive Technology Assessment approach views visions as triggers of a social dynamic of mutual positioning of innovating actors. Through this social process, the ideas about the envisioned future technology successively become more and more specific. The approach highlights the rhetorical function of visions but is not very elaborate on epistemic aspects of technological future concepts. (2) The guiding vision approach as well assumes that visions possess a rhetorical power to mobilize actors and resources. Additionally, the proponents of this approach are strongly convinced that visions provide guidance for research and development activities. However, the prevailing opinion within the relevant literature is that the related studies do not give sufficient evidence to confirm this point. (3) According to the vision assessment approach, visions are important because of their impact on research and technology policy discourses. Thus, the task of vision assessment is to support the development of policies and public opinion by reflecting on what these visions say and imply. Previous research provides only few considerations on more specific forms of technological future concepts and there is little empirical work concerning the question if and how future concepts epistemically guide actors in innovation processes.

There is a research gap regarding this question. While former research dealt with it but could not answer it satisfactorily with respect to visions, the more recent research is primarily interested in the rhetorical and political use of visions and does not pay much attention to the epistemic dimension of future concepts. As I have argued above, there are reasons to believe that situational scenarios rather than visions include information about the components of the envisioned new technology, their features, performance, and interrelatedness, which all can be used to orient research and development activities. Against this background, the most promising way to close the research gap is to study the uses and effects of these (and other) more specific future concepts in innovation processes.

Exploring the epistemic dimension of future concepts in innovation processes is part of the more general objective of developing an approach that conceptually integrates technology and innovation studies with prospective technology assessment. From the descriptive analytical perspective of technology and innovation studies, technological future concepts are factors that do or may influence innovation processes. From the normative perspective of technology assessment, technological future concepts are tools for prospective technology assessment. If future concepts serve as a common point of reference for both perspectives this could be used to integrate both perspectives. This integration would require (a) that future concepts do indeed exert influence on technology development, (b) that the same future concepts are used as tools for prospective technology assessment, and (c) that the recommendations resulting from the assessment process find their way back into the domain of technology development – for example in form of future concepts with more desirable or less risk-laden features. As argued above, visions are unsuitable to bridge the gap between technology development and technology assessment but scenarios have this integrative capacity.

Both objectives – to explore the epistemic dimension of scenarios and to assess their potential for integrating technology development and technology assessment – require studying the respective uses and effects of scenarios in different innovation-related contexts: (a) in the research and technology policy context of mobilizing actors and resources, of mutual positioning of the actors involved, of the transformation of general ideas about the technological future into research agendas and research programs, and of establishing programs supporting research and development of the envisioned new technologies, (b) in the context of research and development of the new technologies, and (c) in the context of prospective technology assessment.

Where situational scenarios occur such as in the field of ubiquitous computing, they do not completely replace visions. Rather they complement them by spelling out the visions' overall ideas in specific ways. Thus, with the occurrence of scenarios visions do not become redundant. This implies that visions may remain to be relevant for innovation processes in certain respects even when there are more specific ways to express ideas about the technological future. Consequently, for each of the three contexts just mentioned the respective uses and effects of scenarios should be analyzed in comparison with corresponding uses and effects of visions. It should be added that the scenarios' and visions' uses and effects in question not necessarily are intentional ones. Obviously, an intentional use should be expected when visions are deliberately employed as rhetorical means or scenarios as technology assessment techniques. Yet the ways in which future concepts influence processes of research and development are less unambiguous and rhetorical effects do not necessarily presuppose corresponding intentions. Thus, research on these issues should take in mind that unintentional effects of future concepts on innovation processes might be as important as those resulting from their intentional use.

The following hypotheses about the uses and effects of scenarios in comparison to visions within the different contexts of the innovation process are the main guidelines for the research program outlined here. The first and second hypotheses address the research and technology policy context:

H1: Like visions, scenarios are means of mobilizing actors and resources. In contrast to visions, scenarios attract the more application-oriented actors in innovation processes.

H2: Scenarios provide epistemic guidance for the transformation of visions into research agendas and research programs, while visions in this process act as triggers of social dynamics.

Recent innovation research tends to view the formation of research agendas and the establishment research programs mainly as a social, political, and rhetorical process while paying less attention to epistemic factors. However, the institutionalization of a new field of technology is an epistemic as well as a social process and thus it should be regarded as including a social and a factual dimension. Establishing a new field of technology, a new research agenda, or a new research program requires to define the subject of the research activities to be established. It requires to specify the characteristics, features, and problem-solving capacities of the new technology and to identify the respective requirements for research and development. This is the factual dimension. Mobilizing and mutual positioning of actors constitutes social dimension of the process. The presupposition of the first hypothesis is that visions are of major importance with respect to the social dynamics of establishing research agendas and research programs. Additionally, the hypothesis assumes that scenarios by mobilizing application-oriented actors also act on the social dimension of this process. The presupposition of second hypothesis is that visions possess little potential for epistemic guidance in the context of research policy. According to the second hypothesis, this is what should be expected from scenarios.

H3: In contrast to visions, scenarios provide epistemic guidance for actual research and development activities. Scenarios can be used as tools to invent the future.

The third hypothesis addresses the context of research and development. Gaining better knowledge about the connections between technological future concepts and actual research and development of new technologies would substantially advance innovation research. Van Lente and Rip characterize the process through which the promises of technological visions result in new technologies as a “promise-requirement spiral” (van Lente/Rip 1998a: 223). To realize a technological vision it is necessary to translate its promises into developmental requirements: Which technological problems have to be dealt with? Which competencies and resources are needed? Which actors with which competencies and resources are already aboard or have to be mobilized? etc. According to the authors, the promises of a technological vision become more specific through this translation process. For example, the actors involved will focus on certain domains of application and on certain strategies of research and development while other possible paths will be postponed or remain unnoticed. The more specific promises allow to define even more specific requirements which in turn lead to even more specific promises and so on.

With scenarios, it would be more appropriate to speak of an expectation-requirement spiral, because scenarios concretize visions by translating their overall promises into specific expectations about the technological future. If scenarios act as patterns of orientation for research and development activities, expectation-requirement spirals of the following kind should be observable: Requirements for research and development are derived from the scenarios' expectations about the new technology's performance within specific domains of application. The definition of these requirements allows to further specify the scenarios and in turn to define even more specific requirements, etc. The empirical existence of such expectation-requirement spirals would strongly support the assumption of the scenarios' capacity to guide actual research and development activities. Such a capacity is to be expected because scenarios are (if they are well-crafted) complexes of consistently specified cause-effect relationships thus providing a particularly good basis for translating ideas about the technological futures into instructions about how to reach there. The third hypothesis leaves it open whether the transformation of technological future concepts into actual research and development activities necessarily includes a epistemic dynamic. It is open to empirical research to which degree social and epistemic dynamics might substitute each other in this respect and different kinds and uses of future concepts such as those in ubiquitous computing in contrast to those in nanotechnology might provide different answers.

The fourth and fifth hypotheses address the context of prospective technology assessment:

H4: Scenarios are a way to spell out the possible future reality of a new technology coherently and in much detail for each domain of application that might be promising or that is expected or suspected to emerge. Scenarios are useful tools for prospective technology assessment because they provide realistic descriptions as a basis for assessing the future technology's possible risks and benefits.

H5: If scenarios have the capacity to orient research and development, they can become useful tools for shaping technology. This requires that the scenarios used for purposes of prospective technology assessment are sufficiently similar to the scenarios, which are influential in the context of research and development

When technological future concepts are the basis for assessing the risks and benefits of new technologies, the subject of such prospective technology assessment is not the future reality (which is unpredictable) but the present ideas and assumption about the future. In line with considerations of the vision assessment approach (see Ch. 3.3), it can be argued that there are circumstances under which these present ideas about the future nevertheless are important for innovation processes: If they influence the perceptions, thoughts, and actions of the actors involved. The fourth hypothesis presupposes that the scenarios' influence on innovative actors results from the realism of their descriptions of possible future realities and assumes that this realism makes them useful for prospective technology assessment. It sounds contradictory, at first, that realistic descriptions (plural!) of an unpredictable future could be given. Yet this is exactly what scenario design aims at. It becomes an attainable goal by starting with hypothetical basic assumptions about the future and limiting the task of giving realistic descriptions to the description of the consequences following from these assumptions. The above mentioned quality criteria for scenario design: credibility, consistency, coherence, completeness, and plausibility with reference to the underlying assumptions (see Ch. 5) all serve this purpose. Designed this way, scenarios are realistic only in relation to their underlying assumptions. Obviously, scenarios then can become the more realistic the more plausible these basic assumptions are.

Accordingly, with respect to the fourth hypothesis there are two main questions open for empirical research: The first question concerns the role of scenarios for generating realistic descriptions of the complexes of cause-effect relationships of which the alternate possible future realities of a new technology might consist. However, the scenarios' descriptions – even if they internally are highly realistic – might remain an intellectual game as long as their underlying assumptions are deemed unrealistic or unsubstantiated. Since scenarios by focusing on specific future technological applications are down-to-earth versions of future concepts this should be helpful for staying realistic also with respect to the scenarios' underlying assumptions. Thus, the second question concerns the suitability of scenario design for supporting the development of well-grounded basic assumptions.

In the case of prospective technology assessment, all recommendations for shaping technology have to be derived from the assessment of the new technologies as they are pictured by technological future concepts. Consequently, the quality of the recommendations depends on the quality of the future concepts used to develop them. Since scenarios allow for realistic and coherent descriptions, the fifth hypothesis assumes that this form of future concepts is especially suitable as a basis for arriving at well-founded recommendations on the shaping of future technology. However, actually to shape technology on the basis of scenarios is a demanding endeavor. It requires not only well-crafted scenarios for well-reasoned deliberation. Additionally, the relevance of the conclusions drawn from the scenario assessment depends on effectiveness of the underlying scenarios as patterns of orientation within the context of research and development. As argued above, only by influencing the thoughts and actions of the actors involved technological future concepts are of any relevance for innovation processes. Consequently, only the assessment of scenarios which are influential in this way allow to generate recommendations of relevance if the aim is to shape technology. Thus, a further prerequisite of assessing scenarios with the aim of shaping technology is, as stated in the fifth hypothesis, that there is sufficient similarity between the TA scenarios and the scenarios of the researchers and engineers. It has to be explored empirically under which circumstances scenarios or other specific forms of technological future concepts provide epistemic orientation both in the context of research and development and in the context of prospective technology assessment. The resulting findings might show if and how such future concepts provide the means to bridge the gap between technology development and technology assessment.

## References


Akrich, Madeleine (1992a): Beyond Social Construction of Technology: The Shaping of People and Things in the Innovation Process, in: Meinolf Dierkes/Ute Hoffmann (Hrsg.), New Technology at the Outset. Social Forces in the Shaping of Technological Innovations, Frankfurt/Main: Campus, S. 173-190.

Akrich, Madeleine (1992b): The De-Scription of Technical Objects, in: Wiebe E. Bijker/John Law (Hrsg.), Shaping Technology; Building Society. Studies in Sociotechnical Change, Cambridge, Mass. u.a.: The MIT Press, S. 205-224.

Albert, Bernhard et al. (2002): Zukunftsforschung und Unternehmen. Praxis, Methoden, Perspektiven, Z_dossier 02, Essen.

Amara, Roy (1991): Views on Futures Research Methodology, in: Futures 23(6), S. 645-649.

Arthur, W. Brian (1989): Competing Technologies, Increasing Returns and Lock-in by Histrorical Events, in: The Economic Journal: The Journal of the Royal Economic Society 99 (394), S. 116-131.

Aschenbrenner, Norbert (2003): Versteckte Wunder, in: Pictures of the Future. The Magazine for Research and Innovation, hg. von der Siemens AG Frühjahr 2003, S. 6-8.

Bender, Gerd (2005): Technologieentwicklung als Institutionalisierungsprozess, in: Zeitschrift für Soziologie 34(3), S. 170-187.

Berkhout, Frans/Adrian Smith/Andy Sirling (2003): Socio-technological Regimes and Transition Contexts, SPRU Electronic Working Paper Series Paper No. 106.

Bonnet, Petra (1994): Methoden und Verfahren der Technikfolgenabschätzung: Exotische Hausmannskost?, in: Hans-Jörg Bullinger (Hrsg.), Technikfolgenabschätzung, Stuttgart: Teubner, S. 33-54.

Brune, Harald et al. (2006): Nanotechnology. Assessment and Perspectives. Wissenschaftsethik und Technikfolgenbeurteilung Bd. 27, Berlin u.a.: Springer.

Bundesministerium für Bildung und Forschung (2006): Nanotechnologie. Innovationen für die Welt von morgen, Bonn/Berlin, www.bmbf.de/pub/nanotechnologie_inno_fuer_die_welt_v_morgen.pdf.

Callon, Michel (1986): The Sociology of an Actor-Network: The Case of the Electric Vehicle, in: Michel Callon/John Law/Arie Rip (Hrsg.), Mapping the Dynamics of Science and Technology. Sociology of Science in the Real World, London u.a.: Macmillan Press, S. 19-34.

Callon, Michel (1993): Variety and Irreversibility in Networks of Technique Conception and Adoption, in: D. Foray/Ch. Freeman (Hrsg.), Technology and the Wealth of Nations, London: Pinter, S. 232-268.

Coenen, Christopher (2003): Utopien und Visionen zur Nanotechnologie, in: TAB-Brief des Büros für Technikfolgen-Abschätzung beim Deutschen Bundestag Nr. 24, S. 5-8, http://www.tab-beim-bundestag.de/de/pdf/publikationen/tab-brief/TAB-Brief-024.pdf.

Collingridge, David (1980): The Social Control of Technology, London: Frances Pinter Ltd.

David, Paul A. (1986): Understanding the Economics of QWERTY: The Necessity of History, in: William N. Parker (Hrsg.), Economic History and the Modern Economist, Oxford: Blackwell, S. 30-49.

Deutscher Bundestag (2004): TA-Projekt Nanotechnologie. Bericht des Ausschusses für Bildung, Forschung und Technikfolgenabschätzung, Drucksache 15/2713, Berlin.

Dierkes, Meinolf (1991): Vom Technology Assessment zum "Leitbild Assessment": Zur Rolle von Organisationskultur und professionellen Leitbildern in der Technikgenese, in: Klaus Kornwachs (Hrsg.), Reichweite und Potential der Technikfolgenabschätzung, Stuttgart: C.E. Poeschel-Verlag, S. 155-175.

Dierkes, Meinolf (1993): Organisationskultur und Leitbilder als Einflußfaktoren der Technikgenese. Thesen zur Strukturierung eines Forschungsfeldes, in: Meinolf Dierkes (Hrsg.), Die Technisierung und ihre Folgen. Zur Biographie eines Forschungsfeldes, Berlin: Edition Sigma, S. 263-276.

Dierkes, Meinolf/Ute Hoffmann/Lutz Marz (1992): Leitbild und Technik. Zur Entstehung und Steuerung technischer Innovationen, Berlin: Edition Sigma.

Dierkes, Meinolf/Lutz Marz (1992): Technikleitbilder und Anwenderinteressen. Ein Beitrag zum vorbeugenden Verbraucherschutz, in: Verbraucherpolitische Hefte 15, S. 39-58.

Dosi, Giovanni (1982): Technological Paradigms and Technological Trajectories. A Suggested Interpretation of the Determinants and Directions of Technical Change, in: Research Policy 11, S. 147-162.

Dosi, Giovanni (1988): The Nature of the Innovative Process, in: Giovanni Dosi et al. (Hrsg.), Technical Change and Economic Theory, London u.a.: Pinter Publishers, S. 221-238.

Drexler, K. Eric (1986): Engines of Creation. The Coming Era of Nanotechnology, New York: Doubleday.

Drexler, K. Eric/Chris Peterson (1991): Unbounding the Future. The Nanotechnology Revolution, New York: William Morrow.

Eberl, Ulrich (2001): Pictures of the Future - A process to help shape tomorrow's world, in: Pictures of the Future. The Magazine for Research and Innovation, Siemens AG Fall 2001, S. 4-5, www.siemens.com/innovation/en/publikationen/publications_pof/pof_fall_2001/pictures_of_the_future_introduction/process_to_help_shape.htm.

Edquist, Charles (1997): Systems of Innovation Approaches - Their Emergence and Characteristics, in: Charles Edquist (Hrsg.), Systems of Innovation. Technologies, Institutions and Organizations, London u.a.: Pinter, S. 1-35.

Eggermont, Ludwig D.J. (Hrsg.) (2002): Embedded Systems Roadmap 2002.Vision on technology for the future of PROGRESS, Utrecht: STW Technology Foundation/PROGRESS.

Feynman, Richard P. (1960): There’s plenty of room at the bottom, in: Engineering & Science. Magazine of the Califorina Institute of Technologie February 1960, S. 22-36, http://www.zyvex.com/nanotech/feynman.html.

Fogelberg, Hans/Hans Glimell (2003): Bringing Visibility To the Invisible: Towards A Social Understanding of Nanotechnology. Göteborgs Universitet Section for Science and Technology Studies Research Reports No 6, Göteborg.

Freeman, Christopher/Carlota Perez (1988): Structural Crisis of Adjustment, Business Cycles and Investment Behaviour, in: Giovanni Dosi et al. (Hrsg.), Technical Change and Economic Theory, London u.a.: Pinter Publishers, S. 38-66.

Friedewald, Michael et al. (2005): Safeguards in a World of Ambient Intelligence (SWAMI). The brave new world of ambient intelligence: A state-of-the-art review. Deliverable D1, Karlsruhe: Fraunhofer Institute for Systems and Innovation Research, http://swami.jrc.es.

Garud, Raghu/Peter Karnøe (2001): Path Dependence and Creation, Mahwah: Lawrence Erlbaum Associates.

Gausemeier, Jürgen/Alexander Fink/Oliver Schlafke (1997): Szenariotechnik, in: Raban von Westphalen (Hrsg.), Technikfolgenabschätzung als politische Aufgabe, München u.a.: Oldenbourg, S. 203-221.

Geels, Frank W./Wim A. Smit (2000): Failed Technology Futures: Pitfalls and Lessons from a Historical Survey, in: Futures 32(9), S. 867-885.

Godet, Michel (1986): Introduction to la prospective, in: Futures 18(2), S. 134-157.

Grin, John/Armin Grunwald (Hrsg.) (2000): Vision Assessment: Shaping Technology in 21st Century Society. Towards a Repertoire for Technology Assessment, Berlin u.a.: Springer.

Grunwald, Armin (2002): Technikfolgenabschätzung. Eine Einführung, Berlin Ed. Sigma.

Grunwald, Armin (2004): Vision Assessment as a New Element of the Technology Futures Analysis Toolbox, EU-US Seminar: New Technology Foresight, Forecasting Assessment Mathods, Seville, 13-14 May 2004, www.jrc.es/projects/fta/papers/Session%204%20What%27s%20the%20Use/Vision%20Assessment%20as%20a%20new%20element%20of%20the%20FTA%20toolbox.pdf.

Grunwald, Armin (2006): Nanotechnologie als Chiffre der Zukunft, in: Alfred Nordmann/Joachim Schummer/Astrid Schwarz (Hrsg.), Nanotechnologien im Kontext, Berlin: Akademische Verlagsgesellschaft, S. 49-80.

Hellige, Hans Dieter (1993): Von der programmatischen zur empirischen Technikgeneseforschung: Ein technikhistorisches Analyseinstrumentarium für die prospektive Technikbewertung, in: Technikgeschichte 60(3), S. 186-223.

Hellige, Hans Dieter (1996a): Technikleitbilder als Analyse-, Bewertungs- und Steuerungsinstrumente: Eine Bestandsaufnahme aus informatik- und computerhistorischer Sicht, in: Hans Dieter Hellige (Hrsg.), Technikleitbilder auf dem Prüfstand. Leitbild-Assessment aus Sicht der Informatik- und Computergeschichte, Berlin: Edition Sigma, S. 15-35.

Hellige, Hans Dieter (Hrsg.) (1996b): Technikleitbilder auf dem Prüfstand. Leitbild-Assessment aus Sicht der Informatik- und Computergeschichte, Berlin: Edition Sigma.

High Level Expert Group “Foresighting the New Technology Wave” (2004): Convergence Technologies - Shaping the Future of European Societies. European Commission Research Report, by A. Nordmann, Rapporteur.

Hughes, Thomas P. (1987): The Evolution of Large Technological Systems, in: Wiebe E. Bijker/Thomas P. Hughes/Trevor J. Pinch (Hrsg.), The Social Construction of Technological Systems. New Directions in the Sociology and History of Technology, Cambridge, Mass. u.a.: The MIT Press, S. 51-82.

ISTAG (1999): Orientations for Workprogramme 2000 and beyond. Report of the Information Society Technologies Advisory Group, Sevilla: Information Society Technologies Advisory Group, ftp://ftp.cordis.europa.eu/pub/ist/docs/istag-99-final.pdf.

ISTAG (2001): Scenarios for Ambient Intelligence in 2010. Final Report of the Information Society Technologies Advisory Group compiled by K. Ducatel, M. Bogdanowicz, F. Scapolo, J. Leijten & J.-C. Burgelman, Sevilla: Information Society Technologies Advisory Group, http://www.cordis.lu/ist/istag.htm.

Kahn, Herman/Anthony J. Wiener (1967): The Year 2000: A Framework for Speculation on the Next Thirty-three Years, New York: Macmillan.

Kemp, René/Derk Loorbach (2005): Dutch Policies to Manage the Transition to Sustainable Energy, in: Frank Beckenbach et al. (Hrsg.), Jahrbuch Ökologische Ökonomik: Innovationen und Transformation. Band 4, Marburg: Metropolis, S. 123-150, http://kemp.unu-merit.nl/pdf/Kemp-Loorbach%20chapter%20for%20Yearbook%20OO.pdf.

Kemp, René/Jan Rotmans (2004): Managing the Transition to Sustainable Mobility, in: Boelie Elzen/Frank Geels/Ken Green (Hrsg.), System Innovation and the Transition to Sustainability: Theory, Evidence and Policy, Cheltenham: Edgar Elgar, S. 137-167, http://kemp.unu-merit.nl/pdf/Kemp%20and%20Rotmans%20sustainable%20mobility%20 chapter.pdf.

Konrad, Kornelia (2004): Prägende Erwartungen: Szenarien als Schrittmacher der Technikentwicklung, Berlin Ed. Sigma.

Lösch, Andreas (2006): Means of Communicating Innovations. A Case Study for the Analysis and Assessment of Nanotechnology's Futuristic Visions, in: Science, Technology & Innovation Studies 2(2), S. 103-125.

Marz, Lutz/Meinolf Dierkes (1992): Leitbildprägung und Leitbildgestaltung. Zum Beitrag der Technikgenese-Forschung für eine prospektive Technikfolgen-Regulierung, WZB, FS II 92005, Berlin: WZB.

Marz, Lutz/Meinolf Dierkes (1994): Leitbildprägung und Leitbildgestaltung (Zum Beitrag der Technikgenese-Forschung für eine prospektive Technikfolgen-Regulierung), in: Gotthard Bechmann/Thomas Petermann (Hrsg.), Interdisziplinäre Technikforschung. Genese, Folgen, Diskurs, Frankfurt/Main: Campus, S. 35-72.

Meadows, Donella H. et al. (1972): The Limits to Growth, New York: Universe Books.

Minx, Eckard/Ewald Böhlke (2006): Denken in alternativen Zukünften, in: Internationale Politik 61(12), S. 14-22.

Mobile IT Forum (2003): Flying Carpet. Towards the 4th Generation Mobile Communications System. Version 1.00, www.mitf.org/public_e/archives/Flying_Carpet_Ver100E.pdf.

MPMHAPT (2004): Information and Communications in Japan. Building a Ubiquitous Network Society That Spreads Throughout the World, White Paper 2004 of the Ministry of Public Management, Home Affairs, Posts and Telecommunications, Japan, http://www.johotsusintokei.soumu.go.jp/whitepaper/eng/WP2004/2004-index.html.

Murakami, Teruyasu (2001): A Development Scenario for Ubiquitous Networks: Vieved from the Evolution of IT Paradigms, NRI Papers No. 26: Nomura Research Institute, www.nri.co.jp/english/opinion/papers/2001/pdf/np200126.pdf.

Murakami, Teruyasu (2003): Establishing the Ubiquitous Network Environment in Japan - From e-Japan to U-Japan, NRI Papers No. 66: Nomura Research Institute, www.nri.co.jp/english/opinion/papers/2003/pdf/np200366.pdf.

Murakami, Teruyasu/Akihisa Fujinuma (2000): Ubiquitous Networking: Towards a New Paradigm, NRI Papers No. 2: Nomura Research Institute, www.nri.co.jp/english/opinion/papers/2000/pdf/np200002.pdf.

Nanologue (2006): The Future of Nanotechnology: We need to talk, www.nanologue.net/custom/user/Downloads/Nanologue_we-need-to-talk.pdf.

National Academy of Sciences (2001): Embedded, Everywhere. A Research Agenda for Systems of Embedded Computers, Washington, D.C.: National Academy Press, http://www.nap.edu/html/embedded_everywhere/.

National Science and Technology Council (1999): Nanotechnology. Shaping the World Atom by Atom, Washington, DC, http://itri.loyola.edu/nano/IWGN.Public.Brochure.

National Science and Technology Council (2004): The National Nanotechnology Initiative. Strategic Plan of December 2004, http://www.nano.gov/NNI_Strategic_Plan_2004.pdf.

National Science Foundation (2001): Societal Implications of Nanoscience and Nanotechnology. NSET Workshop Report. Prepared under the Guidance of the Nanoscale Science, Engineering, and Technology Subcommittee (NSET) of the National Science and Technology Council, ed. by Mihail C. Roco and William Sims Bainbridge, Arlington, Virginia, http://www.wtec.org/loyola/nano/NSET.Societal.Implications/nanosi.pdf.

Nelson, Richard R./Sidney G. Winter (1977): In Search of a Useful Theory of Innovation, in: Research Policy 6, S. 36-76.

Punie, Yves et al. (2006): Safeguards in a World of Ambient Intelligence (SWAMI). Dark Scenarios on Ambient Intelligence: Highlighting Risks and Vulnerabilities. Deliverable D2., Karlsruhe: Fraunhofer Institute for Systems and Innovation Research, http://swami.jrc.es.

Rammert, Werner (1994): Prozesse der Technikgenese und der Stellenwert von Leitbildern der Technikentwicklung, in: Else Fricke (Hrsg.), Zur Zukunftsorientierung von Ingenieuren und Naturwissenschaftlern, Bonn: Friedrich-Ebert-Stiftung, S. 9-18.

Rammert, Werner et al. (1998): Wissensmaschinen. Soziale Konstruktion eines technischen Mediums. Das Beispiel Expertensysteme, Frankfurt/Main u.a.: Campus.

Renn, Ortwin/Mike Roco (2006): Nanotechnology Risk Management. The International Risk Governance Council White Paper No. 2, Genf.

Rip, Arie (2002): Co-Evolution of Science, Technology and Society, Expert Review for the Bundesministerium Bildung und Forschung's Förderinitiative Politik, Wissenschaft und Gesellschaft (Science Policy Studies), www.sciencepolicystudies.de/dok/expertise-rip.pdf.

Roco, Mihail C./William Sims Bainbridge (2002): Overview, in: Mihail C. Roco/William Sims Bainbridge (Hrsg.), Converging Technologies for Improving Human Performance. Nanotechnology, Biotechnology, Information Technology and Cognitive Technology (NSF/DOC-sponsored Report), Arlington: National Academy Press, S. 1-27, www.wtec.org/ConvergingTechnologies/Report/NBIC_report.pdf.

Ropohl, Günter (1997): Methoden der Technikbewertung, in: Raban von Westphalen (Hrsg.), Technikfolgenabschätzung als politische Aufgabe, 3., gänzl. rev., neu bearb. und erw. Aufl., München u.a.: Oldenbourg, S. 177-202.

Rosenberg, Nathan (1976): The Direction of Technological Change: Inducement Mechanisms and Focussing Devices, in: Nathan Rosenberg (Hrsg.), Perspectives on Technology, London u.a: Cambridge University Press, S. 108-125.

Royal Society (2004): Nanoscience and Nanotechnologies: Opportunities and Uncertainties, London: The Royal Society, www.nanotec.org.uk/finalReport.htm.

Salin, Cynthia (2007): Expectations and the Emergence of Nanotechnology, in: Science, Technology & Human Values 32(2), S. 196-220.

Schaper-Rinkel, Petra (2006): Governance von Zukunftsversprechen: Zur politischen Öknonomie der Nanotechnologie, in: Prokla 36(4), S. 473 - 496.

Schirrmacher, Frank (Hrsg.) (2001): Die Darwin AG. Wie Nanotechnologie, Biotechnologie und Computer den neuen Menschen träumen, Köln: Kiepenheuer & Witsch.

Schot, Johan/Arie Rip (1997): The Past and Future of Constructive Technology Assessment, in: Technological Forecasting and Social Change 54(2/3), S. 251-268.

Schulz-Schaeffer, Ingo (1996): Software-Entwicklung zwischen Ingenieur- und Designwissenschaft. Überzeugungskraft und nützliche Widersprüchlichkeit von Software-Engineering und Software-Gestaltung, in: Hans Dieter Hellige (Hrsg.), Technikleitbilder auf dem Prüfstand. Leitbild-Assessment aus Sicht der Informatik- und Computergeschichte, Berlin: Edition Sigma, S. 115-140.

Schwartz, Peter (1993): La planification stratégique par scénarios, in: Futuribles 05/1993, S. 31-50.

Steinmüller, Karlheinz (1997): Grundlagen und Methoden der Zukunftsforschung. Szenarien, Delphi, Technikvorausschau, WerkstattBericht 21, Gelsenkirchen: Sekretariat für Zukunftsforschung.

Steinmüller, Karlheinz (1999): Szenarien in der Technikfolgenabschätzung, in: Stephan Bröchler/Georg Simonis/Karsten Sundermeyer (Hrsg.), Handbuch Technikfolgenabschätzung, 3 Bde., Berlin: Edition Sigma, S. 669-677.

Steinmüller, Karlheinz (2003): Szenarien. Instrumente für Innovation und Strategiebildung, Essen: Z_punkt GmbH, www.conspect.de/jonas/PDF/SzenarioWS_Reader_2003.pdf.

Van de Ven, Andrew H. et al. (1999): The Innovation Journey, New York: Oxford University Press.

van Lente, Harro (1993): Promising Technology. The Dynamics of Expextations in Technological Development, Delft: Eburon.

van Lente, Harro/Arie Rip (1998a): Expectations in Technological Developments: An Example of Prospective Structures to be Filled in by Agency, in: Cornelis Disco/Barend J. R. van der Meulen (Hrsg.), Getting New Technologies Together. Studies in Making Sociotechnical Order, Berlin u.a.: de Gruyter, S. 203-229.

van Lente, Harro/Arie Rip (1998b): The Rise of Membrane Technology: From Rhetorics to Social Reality, in: Social Studies of Science 28, S. 221-254.

VDI (Hrsg.) (1991): Technikbewertung Begriffe und Grundlagen. Erläuterungen und Hinweise zur VDI-Richtlinie 3780, Düsseldorf: Verein Deutscher Ingenieure (VDI).

von Westphalen, Raban (Hrsg.) (1997): Technikfolgenabschätzung als politische Aufgabe, 3., gänzl. rev., neu bearb. und erw. Aufl., München u.a.: Oldenbourg.

Weber, Karl (1990): Wirtschaftsprognostik, München: Vahlen.

Weiser, Mark (1991): The Computer for the 21st Century, in: Scientific American 265(3), S. 94-104, www.ubiq.com/hypertext/weiser/SciAmDraft3.html.

Wilson, Ian H. (1978): Scenarios, in: Jib Fowles (Hrsg.), Handbook of Futures Research, Westport, CT Greenwood, S. 225 - 247.

Woyke, Andreas (2010): Philosophische Überlegungen zum Status und zur Charakteristik nanotechnologischer Visionen, in: Arianna Ferrari/Stefan Gammel (Hrsg.), Visionen der Nanotechnologie, Heidelberg: Akademische Verlagsgesellschaft, S. 51-77.