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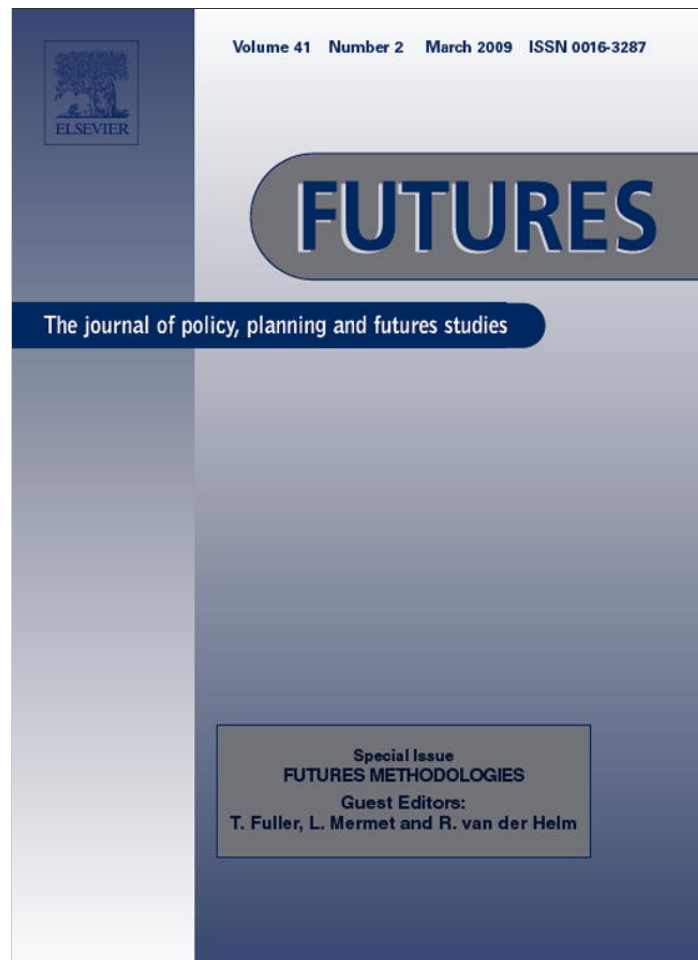
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## The social shaping approach to technology foresight

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### ABSTRACT

The social shaping of technology (SST) approach has been developed as a response and extension to the ideas of techno-economic rationality and linear conceptions of technology development and its consequences. The SST approach seems especially promising in areas of technology where visions are manifold, societal interests conflicting, and applications and markets are non-existing or still under construction. The emerging high technology areas and several areas of more sustainable development like organic food production and renewable energy are examples of this kind, where techno-economic networks are unstable or under construction and social and environmental potentials and risks difficult, if not impossible to assess. The paper explores the potential of a social shaping of technology approach to technology foresight within such technology areas and presents the methodological aspects herein: structure versus contingency, actor-network approach, laboratory programmes, techno-economic networks, actor worlds, development arenas. Experiences based on a recent Danish green technology foresight project concerned with environmental risks and opportunities related to nano-, bio- and ICT-technologies and foresight activities in relation to food are used as empirical references.

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### 1. Introduction

Today, the world is facing large social and environmental challenges due to the environmental problems related to the large resource consumption in the industrialized countries, and to the many economic, social and environmental promises expressed in relation to the so-called high technology like nano-, bio- and information and communication technology (ICT)-technology. Some of the challenges result from the rather linear and simplistic understanding of the expectations of these technologies as they often are expressed in policy initiatives by terms of technology push or market pull. In contradiction to this understanding, the social shaping approach to technological change focuses on the mutual influence of technology and society on technology development. A linear understanding of technological change, where research is seen as the most important base for technological development and the abatement and prevention of social and environmental problems, does not explain the dynamics of technological change and the interaction between research, development and application of technologies. Technological development should be seen as a “bricolage”, a mixture of different elements, and technological change as a continuous process, where technology and social and environmental aspects are co-shaped during research, development and application of technology in society.

Changing our view of technological change has profound theoretical implications for the way in which foresight is to be conceived. Instead of taking technology as an (external) driver of change, limited only by the ingenuity of mankind, technology has to be seen simultaneously as a driver and as the object being driven and given tasks to solve societal problems. The same problem occurs in foresight studies when e.g. economy is seen as such an external driver. In this article we will discuss the implications of this more complex understanding of technological change, which is often named as the

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social shaping of technology (SST) approach, for technology foresight. We will suggest how this approach can help identifying and creating spaces, where emerging and existing technologies can be addressed for consideration and debate in relation to future development and influence hereof and what this approach can offer to foresight.

With the notion 'technology foresight' two already complex meanings are combined. By foresight we understand the exploration of possible future developments based on a critical comparison of existing paths of development stabilised in techno-economic networks with socio-technical opportunities and visions. This notion contrasts the idea of forecasting and emphasise the openness of future development. By technology foresight we emphasise the focus on technological change as an important part and co-produced entity and possible contributor to solving envisioned societal problems, including environmental problems. Since technology is given a role in many foresight projects and programmes today (including those that are not called 'technology foresight') we think that the discussions in the article may be relevant to foresight in general.

The paper starts out with a short description of technology foresight based on the SST-approach, gives an overall description of the SST-approach, discusses the shaping of foresight methodology based on the SST-approach and its potentials in relation to analysing and debating emerging and existing technologies and ends with a discussion of how this approach to foresight may contribute to governance of technological change, whereby we understand how topics and actors are included or excluded from decision-making related to research, development and application of technology. The article illustrates some of the topics with methodological aspects in a recent Danish foresight project concerned with environmental potentials and risks in relation to nano-, bio- and ICT-technology.

## 2. The SST approach to technology foresight

The SST approach to technology foresight tries to avoid devoting social and environmental impacts to technologies themselves, so that technologies are said to be "good" (for example being "green" or "sustainable") or "bad" (for example having negative environmental impact). An example of such associations of meaning and utility to technology can be found in the discussion of environmental impacts of the technologies in the high tech area. ICT is often said to be an immaterial technology, because it only handles information. Biotechnology is seen as environmental friendly because it is based on biological materials and processes and nano-technology for example as a technology, which might enable reduction of the resource consumption due to the tiny dimensions of nano-technology [1].

The SST approach does not take such properties assigned to artefacts or technologies as givens but focus on the opportunities for influencing the co-shaping of technology and society and the involved process of associating meaning to the involved artefact. The approach attempts herewith to avoid buying into technical fixes to the solution of important social and environmental problems. This type of technology foresight could therefore be built around the following types and stages of analyses [1]:

- Analyses of present emerging applications of technologies. The impact of corporate practice, structural conditions in value chains and life cycles, and use patterns on the social and environmental aspects. Analyses of the prerequisites for further dissemination and implementation based on further developments along the paths assigned by the existing socio-economic networks.
- Analyses of the priority mechanisms in research and development, the existing knowledge regimes in research and development and the visions assigning utilities and properties to scientific outcomes and technologies and hereby shaping the innovation processes, including the role of social and environmental concerns in research and development.
- Dialogue processes among stakeholders related to the technology area emphasising the potentials, user perspectives, environmental impacts, safety issues, regulatory problems and anticipated reliability of other stakeholders. This would also emphasise alternative ways of addressing social and environmental problems.
- Development of scenarios for probable, future development paths and the related social and environmental aspects emphasising both the potentials and outcomes, but also the choices to be made or the controversies involved along the different, multiple paths of development.
- Development of recommendations for integrated social, environmental and innovation policy initiatives that emphasis the creation of variety and opens for social choice in future developments.

This kind of technology foresight activity can be built around the following theoretical and methodological approaches within the SST-approach:

- Research and development processes seen as socio-technical processes shaped by actors' involvement in actor-networks, where persons, technology, etc. consciously or unconsciously are given roles in research, development and use of technology. Theories about actor-networks, laboratory programmes, arenas of development and techno-economic networks are the cores of this approach.
- Innovation processes seen as stabilisation, disintegration, and transition of innovation systems translating them from one set of dominant technological regimes to new and other regimes, including theories related to technological regimes, path dependency, path creation, and transition policies.

The following paragraph provides a more detailed introduction to the SST approach.

### 3. The social shaping of technology approach

The SST-approach seeks to identify spaces and situations, where socio-technical change can be analysed, addressed and politicised [2]. Thus, SST is a broad term, covering a large domain of studies and analyses concerned with the co-shaping of technology and society. In short, actors and institutions undergo to varying degrees mobilisation, displacement, and reconfiguration (including the establishment of new actors and institutions), as an integral part of socio-technical changes.

A key feature of SST is the lack of a priori distinction between the technological and the social, respectively. To problematise one facet is to necessarily involve the other [3]. In this sense SST grapples with technical and social dimensions as an inextricably intertwined unit of analysis. Whether in the development of technology or in its practical, everyday use, the socio-technical co-construction of technology and social aspects becomes manifest. The technical and the social are phenomena whose emergence is traditionally regarded as distinct, and treated separately.

The SST- approach goes against the understanding of technology, which rests upon the attribution of rather well-delineated, unchanging properties of technology itself. In SST, issues concerning technology are always of negotiated orders, in terms of how issues are raised, as well as in terms of how they come to be resolved. In the case of emerging technologies, but also in relation to existing technologies, it is therefore most fruitful to approach relations between technology and society with a focus on actor choices, strategies and socio-technical learning and adjustment at the forefront of the research process: what may be posed as a relevant problem regarding the technology, for whom the problem may be relevant, and by whom it may be posed as such, are matters which form the basis of negotiations that unfold as part and parcel of the process of technological changes.

Whether in the aspects of design, planning, implementation, or eventual use of technology, SST's analytical stance seeks to draw the understanding of technology into the realm of social influence. The degree of influence on technological change, which may be exercised by different actors, depends on their particular relation to and engagement with respect to the technologies in focus [4]. There are choices in the process of technological development and domestication that may be open to discussion and influence.

The key point has been to do away with deterministic notions (social and economic determinisms also) about technology development and technological change in society. The view being, that neither technology, nor social forces alone, sets the course of societal change and choices concerning technology's influence in this regard. Actor-visions, strategies and resources play into these dynamics, and particular actors' status may change as a consequence of such interactions. The social dimensions of the technology too are shaped, to support and to sustain particular needs, e.g. through the establishment of new actors and institutions or through reshaping of existing actors and institutions [5]. Instead of taking the driving forces or the concerns for granted, the approach opens up for a wider basis of action as to what may be deemed salient, as well as to what the scope of relevant actors, their positions, and their interaction may entail. In this regard, the SST-approach is sensitive to political processes through which actor-positions are identified, negotiated, and redefined, in conjunction with the way technology becomes manifest.

The SST-approach implies also that environmental aspects cannot be connected to materials or processes per se, but are shaped during activities of research, development and application in interaction between technology and society. An example: a hybrid car has less environmental impact than a car with combustion engines, but the important thing is not only the principle of hybrid cars, but also which cars actually are developed and sold and how they contribute to the amount of and pollution from transportation in society. For example whether a hybrid car will substitute a more fuel-consuming car or whether it will be added to the fleet of cars in the household or the company. Another example: the use of organic material for production of bio-ethanol might sound as an environmental friendly process, but the actual environmental impact depends on the type of organic material (is it organic waste or plants grown especially for bio-ethanol) and the alternatives to use of organic material for bio-ethanol (is it for example incineration of the organic material for production of energy) [1].

### 4. Structure and contingency in technological change

When dealing with future technological development and its shaping the SST-approach stresses on the one side the contingency and unpredictability of technological or rather socio-technical change and the plurality of actors involved, and on the other hand the structures and constraints shaping the changes. Among the concepts used to describe regularity in the changes are [6]:

- Trajectories and paradigms (developed by Dosi [7]).
- Regimes as the combination of rules, etc. supporting a trajectory and guiding innovation.

A technological trajectory is the pattern of problem solving activity within a given technological paradigm. Economic priorities, together with social and institutional frames, will operate as selective devices as new trajectories emerge. Dosi defines a technological paradigm as "a model and a pattern of solution of selected technological problems, based on selected principles derived from natural sciences and based on selected materials technologies" [7]. In Russell and Williams [6] a regime is defined broader than paradigm, which is said to focus primarily on the socio-cognitive and technical community and exclude technical artefacts. A regime includes elements like scientific knowledge, engineering practices, technologies, skills, etc. The elements of the regime work as reducers of uncertainty and of the amount of information needed and

influence the search space. A related concept is “search rules”, which is a sociological version of another concept from the evolutionary economics, “search heuristics” (for example Nelson and Winter [8]). Search rules include technical standards, the rules of the market, user requirements and rules laid down by governments, investors, etc. Such rules guide, but do not fix, the kind of research and development for example a company is likely to undertake [9].

The criticisms of the focus on regularities in innovation processes argue that the extent of patterns easily is overstated and often happens afterwards. On the other hand the stress on fluidity and contingency has raised concerns too, because the analyses mainly are complex descriptions without recognition of the patterns and continuities that can be observed and the social structures which these patterns reflect [6]. In a SST-based technology foresight it is important to include both a focus on structure and stability and a focus on fluidity in the analyses of emerging and existing technologies and their applications and the analyses of research and development.

## 5. The actor-network approach

The actor network theory (ANT) developed by Callon [3], Latour [10] and Law [11] is useful in technology foresight for several reasons. An actor-network approach argues that a technology is not just working through a technical artefact, but as “an emerging and increasingly stabilised network of associations between diverse material and non-material elements – artefacts, humans, texts, symbols, concepts, etc.”. The approach follows the network-building strategies of an actor and stresses the mutual constitution and transformation of elements in the process and in the generation of agency, knowledge, institutions and power as effects of the network-building [12]. “Actant” is used as a common notion of both the human and the non-human, and both material and non-material elements in an actor-network. The notion actor-network refers to the definition of actors through the network relations they are part of. In a foresight project an actor-network approach can be useful in the analyses of both emerging and existing applications within a technology area and of the priority mechanisms in research and development and the visions about future applications. The approach supports a focus on all the elements that seem to make a technology work or not work and thereby ensure a broader focus than just for example a single high technology element like nanoparticles, but also a focus on the standards and measurement protocols which the particles would need in order to work in a technically and socially acceptable way, and the societal agendas they refer to (around competitiveness, health, environment, etc.). In the analyses of research and development the approach supports a focus on those actants, which the researchers and developers consciously or unconsciously think can be enrolled into a network with the technology itself.

## 6. Laboratory programmes

The notion “laboratory programmes” can be used in the analyses of how researchers and developers organise the focus of their research and development activities and is based on the assumption that research and development processes are not arbitrary, non-biased search processes. Through the concept of laboratory programmes it is possible to identify what is influencing the choices and drawing the attention of the researchers and developers. The notion should be understood as a way of avoiding a focus on the single scientist as a “hero” or the laboratory as a rational space for scientific practice. Rather the idea is to relate to the notion of the laboratory as a place for reducing and ordering complex processes [13]. The concept of laboratory programmes argues that the “world” is researched and addressed by the way the researchers and the developers understand the world, which could be called the researchers’ “map” of the world. This means that research and development in foresight projects should not be analysed as researchers’ and developers’ simple search for solutions to well-defined problems. Rather the problems addressed should be seen as shaped parallel to the solutions developed in research and development, when certain achievements are reached. This implies that the “solutions” sometimes are found first, and afterwards the researchers and developers try to identify societal problems, which they think could be solved by these solutions. This implies so to say that what is legitimate as parameters, problems, etc. within a researcher’s or developer’s understanding and what is outside an understanding is shaped at the same time. Through these processes the boundaries between what is seen as the technical aspects and the social aspects are drawn in the complex dynamics among social actors and their relation to the technology. The boundaries and their displacement influence the scope of action that may be exercised by individual actors upon the technology, where particular facets of the technology are opened up to problematisation and are worked on to accommodate particular needs [10]. An example: the discourses around genetically modified (GM) food and plants show examples of reverse search processes. GM researchers and companies pointed initially to pesticide resistant plants as an efficient agricultural strategy and only after critique from the environmental movement, also as an environmental strategy referring to its claimed potential for reduced pesticide consumption.

A laboratory programme might get more stable when instruments and theories are attached to it and alignment processes take place, where physical objects, procedures, actors, etc. are given roles. An example is the recently approved risk assessment procedure for GM-crops in the European Community, which is an attempt to stabilise the GM-based development track.

## 7. Techno-economic networks, appropriations and enrolments

During the identification and analysis of emerging and existing technology applications and the priority mechanisms in research and development, the techno-economic networks [14], which researchers, companies, etc. either are part of,

or which they (directly or indirectly) anticipate will be developed in the future as part of possible future applications, is a useful concept. As part of the analyses of the techno-economic networks, focus is on the dynamics between the past experience of the researchers, companies, etc., the ongoing activities and their thoughts about the future development and applications. It is also important to analyse relations to existing development paths and the connected regimes and how these, consciously or unconsciously, have an impact on the research and development or how the paths and the companies and institutions shaping and “carrying” them might be challenged or might be enrolled in certain visions for the future.

The concept of techno-economic networks supports technology foresight in the following way: in the analyses of the emerging and existing applications of a technology it is necessary to understand the background for the breakthroughs, the dead ends, etc. in the research and development activities. It is not enough to know whether it now is possible to manufacture for example a certain type of bio-chip. It is also important knowledge whether this achievement is based on a certain type of equipment, material, co-operation with others, demand from clients, etc. Such analyses tell about path dependency and path creation in research and development (and thereby also the potential influence of certain equipment, clients, etc. in the future). It is also important to try to understand the technological systems enabling the applications, like necessary supply of energy and materials, standards, competencies, etc. It is also important to know whether these system elements are emerging or need to emerge, so that relevant value chains and life cycles and social and environmental aspects can be identified and prerequisites for further dissemination can be analysed. Furthermore the role or appropriation and domestication [15] of the users of the technology is important to analyse and understand in order to understand the co-shaping of technology and social and environmental aspects.

In the analyses of research and development it is important to understand the background and the prerequisites for the expectations the actors have for the future: what is the role they are anticipating, for example nanoparticles, will have (for example a certain behaviour in terms of reactivity, stability, etc.), who are expected to be the future users, in which technological systems does this imply that the nanoparticles will be integrated. This understanding draws on the actor-network theory by focusing on actors and material objects (the “actants”), which the researchers and developers try to enrol and delegate roles to in the future use of a technology in order to make it work [3]: what are the necessary scientific and technological breakthroughs, which are considered as necessary in order to obtain the results and obtain a ‘working’ version of whatever component it might be? Hereby it is possible to develop a picture of the future research needs as seen by the actors. These pictures might later on become the basis for the development of recommendations for future research, development, governmental regulation, etc. The shape of possible future applications will also enable the sketching of elements in some future value chains and life cycles as basis for assessments of the social and environmental potentials and risks.

## 8. Constructing possible development paths in foresight

Actors that are involved in a foresight process as informants can be viewed as being enactors of a technology area themselves. This means they build, among themselves, a repertoire of promises and expectations and strategies how to position the research or the technology in focus. They even might feel obliged to promise outcomes in order to mobilise (more) resources for research and development activities in the future. Other actors might see themselves as outsiders or comparative selectors, who do not see a necessity to buy into the constructed visions or promises, but are assessing whether a certain field seems to be relevant for their own interests, compared to other possibilities. It might also be possible to experience “mutual positioning”, where some actors try to exclude others by for example referring to them as too much into “hype” in relation to a technology area [16].

Information from the different actors has to be deconstructed and compared in order to identify mechanisms in applications and in research and development processes and draw up possible (maybe conflicting, maybe converging) scenarios. The identification of such possible futures within a scientific or technology area can be based on identification of emerging irreversibilities. The thoughts of researchers and developers (and other actors, i.e. policy makers) about the possible futures are based on combined thoughts about technological and social aspects of the future in terms of thoughts about the scientific and technological progress and about the future society, which is going to use or implement these technologies. The dynamics of these expectations and the agenda building they are part of can be recognised through [14]:

- Shared research agendas among actors.
- Collective learning processes, maybe as forced or antagonistic learning.
- Emerging mutual dependencies in network linkages.

Changes in expectations might be seen at three different levels, where relations between changes at the three levels are indications of emerging irreversibilities [14]:

- *Macrolevel*: overall societal visions—as preferred futures.
- *Mesolevel*: research programmes and investments.
- *Microlevel*: heuristics in actual research practice.

The construction of scenarios building upon research, development and applications within an area enables anticipation of the possible future impacts of the scenarios and discussions of whether these impacts are desirable. The construction of such scenarios can be seen as construction of actor-worlds based on those delegations, narratives, translations, etc. which the researchers, developers and maybe also policy makers represent. Delegations and translation can for example delegate a role to functional food in relation to obesity problems, to sensors in relation to environmental problems, etc. Latour [10] mentions that science and technologies in many cases have been successful in setting themselves up as obligatory passage points supporting a certain actor world. Callon [3] mentions that “technologists” are endowed with a capacity to construct a world, their world, to define its constituent elements and to provide for it a time, a space and a history. A very recent example is the ongoing shaping of the field of nutrigenomics (knowledge around the interaction between food and genomics) as a scientific and technological solution to problems around diet and health.

Rip sees two important steps in the discussions of such possible futures as [14]:

- Socio-technical mapping, including the expectations of the actors.
- Foresight researchers' elaboration of socio-technical scenarios, based on the expectations and containing elements of co-evolution of technology and society.

When developing the scenarios it is also important to include aspects of path dependency and path creation. Karnøe and Garud emphasise [5], based on the analyses of the Danish wind turbine experience how markets, competencies, institutions, etc. all should be seen as the results of transition processes shaped by

- The initial conditions.
- The interaction between four systems of production, consumption/use, knowledge and regulation.
- A mixture of use or reproduction of existing technology, knowledge, institutions, etc. and the shaping of new technology, new institutions, new regulation, etc.
- Random events.

In the development of policy recommendations one important element is the identification of branching or bifurcation points as a kind of tipping point, where the decision about a route to take within a technology area will have big impact on the further development of technology and society. “Crossroads” has been used as a similar concept in some Danish foresight projects [17]. A bifurcation point or a crossroad is for example the future impact of a focus on (national) security in the US society on the development of nanoscience and nano-technology activities in the US.

## 9. Development arenas

In the development of scenarios actor-network theory contributes with descriptions of how actor-networks are built and maintained and how they break down or how they are not built. The theory also describes what is included and what is excluded from certain translations. There are, however, no good descriptions of how different actor-worlds may interact and compete in shaping future developments. To supplement the concept of actor-worlds and -networks, the concept of development arena focuses on the configuration of this space based on the actions performed. The concept is hereby providing a spatial expression of the processes of competition and co-operation. The concept conveys the idea that several actor-worlds are being construed within the same or intertwined problem areas though not a priori envisaging each other as involved. A development arena is defined as a “cognitive space that holds together the settings and the relations that comprise the context for product and process development” and includes [13]:

- A number of elements such as actors, artefacts and standards that populate the arena.
- A variety of locations for action, knowledge and visions that define the changes of this space.
- A set of translations that have shaped and played out the stabilisation of relations and artefacts.

The concept conveys a flexible view of the space in which technologies are being envisioned and developed and is thereby a useful element in technology foresight, not least because it may help identify directions from which potentials and risks are coming, because it concentrates on a problem or solution space and not on specific technologies or markets. This involves questions about the robustness and pertinence of expectations.

An important element of technology foresight is the quality of the processes of promises and requirements and methods for judging the robustness and pertinence of expectations [18]. An example: genetic engineering has demonstrated how scientific research is informed by tacit visions and imaginaries of the social role of technology. Although utopian, these visions form the basis on which research priorities are negotiated and planned. Furthermore, such visions are seldom subject to public discussion and debate, before the priorities for research and innovation are made. Such visions need to be more articulated by their scientific authors and subjected to wider social deliberation, review and negotiation. Controversies should be seen as necessary and productive from a societal perspective [19]. A SST-approach to technology foresight with its



focus on actor-networks and the conditions for their development and stability can support review and negotiation of expectations.

## 10. Perspectives in SST-based foresight

As a summary the perspective of an SST-based approach to foresight processes and studies might be characterised by

- Focussing on technologies not as single elements, like chemicals and materials, but as actor-networks and that these networks and their interaction with each other must be included in the identification and assessment of expectations and of social and environmental aspects.
- Showing that some potential social and environmental aspects related to a technology area might be identified in advance, whereby the societal discussion of the direction of research and development might include these aspects.
- Showing that the social and environmental aspects and the technologies are co-shaped during research, development and application, so that more iterative and adaptive policy concepts need to be applied.
- Building the assessment of social and environmental aspects through a process involving many different kinds of stakeholders.
- Illustrating different scenarios calling upon different technologies, competencies, infrastructures, etc., so that the identification of branching points and crossroads in the future development of a technology area become visible and demonstrate eventual important choices to be made.
- Comparing different solutions to social and environmental problems going beyond for example the simple comparison of consumption of chemicals and resources, and including for example cultural impacts as well as the impact on society's perception of nature.
- Identifying the "hype" in relation to potentials for prevention and abatement of social and environmental problems and identifying what might be or become more real potentials and under which circumstances.
- Identifying the prerequisites for the shaping of development paths, which supports the implementation of the social and environmental potentials and reduces the social and environmental risks.

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