FROM TECHNOLOGY-DRIVEN ROADMAPPING TOWARDS SUSTAINABILITY-ORIENTED ROADMAPPING:
DEVELOPMENT AND APPLICATION OF AN INTEGRATED METHOD

Erdmann, Lorenz; Behrendt, Siegfried
Institute for Futures Studies and Technology Assessment (IZT); correspondence: l.erdmann@izt.de

Abstract
The Institute for Futures Studies and Technology Assessment, IZT, has developed an “Integrated Roadmapping” methodology, that is capable of linking different innovation contexts, integrating stakeholders, activating learning processes and that has a mid- to long-term time horizon.

In co-operation with the German Electrical and Electronic Manufacturers' Association, ZVEI, the IZT created an “Integrated Roadmap Automation 2015+”. The project aimed to develop a sustainability-oriented innovation strategy for the automation industry and to identify sustainable future markets in the application areas food industry, energy generation and distribution, railway infrastructure, automotive manufacturing, and water supply and sewage management.

Among the most important impacts of the “Roadmap Automation 2015+” are indirect impulses for self-organisation, by empirical involvement of stakeholders:

- 40 interviews with experts on future automation needs in the respective application areas,
- 150 replies to an online survey among ZVEI member companies on the use and market potential of different automation solutions, and
- a series of five workshops on pictures of the futures of the five application areas, bringing together automation industry and users.

The roadmapping process unveiled a clear need to put more emphasis on the public profile of the automation industry and to look for a common voice to contribute to public sustainability-oriented research programmes.

Keywords:
Sustainability-oriented innovation, Integrated Roadmapping, automation industry, self-organization, pictures of the future, wild cards, stakeholder integration

From Technology-Driven Roadmapping towards Sustainability-Oriented Roadmapping
- 1 -
Introduction

The importance of innovation for sustainable development has been widely stressed. However, innovation processes are still predominantly technology-driven. To direct innovation processes to more sustainable solutions, we must also consider other requirements. Various approaches to introduce sustainability aspects into innovation processes have come from regulatory push and pull, public pressure or vision push. Other approaches have emphasised the importance of internal commitment for sustainability-oriented innovation. But “real-world” innovation processes are rather characterised by interaction between different company units, within innovation networks and with other stakeholders. Hence, a relatively open innovation planning method seems to be most appropriate to steer innovation towards more sustainable outcomes.

The instrument of roadmapping is an example of such an open planning method. It is an established and increasingly adopted instrument of technology foresight. Roadmaps aggregate many individual subjects, identify future options and prioritise needs and actions. The main characteristic of a roadmap is the condensed representation of goals, measures and occasionally trends on a time axis. However, most roadmapping activities focus on technology alone. They lack consideration of socio-economic trends and social requirements, such as sustainable development. As a consequence they produce pictures of future technologies, that only look at technological feasibility and, therefore, appear narrow-minded.

The research landscape on roadmapping has developed dynamically in recent years. Two main research lines have evolved, which allow valuable insights into the development of a sustainability-oriented roadmapping methodology:

- The increasing importance of problem-orientated instead of technology-driven roadmapping asks for more open and more complex methodological approaches, such as: complementary creation of technology and product roadmaps (Nippa und Labriola 2005, Specht and Behrens 2005), technical knowledge integration within a company and beyond (Petrick and Echols 2004, Phaal et al. 2004) and the recognition of multiple future perspectives (Geschka et al. 2005, Lizaso und Reger 2004).

Even though some of the factors for success derived from empirical research are discussed controversially they represent important aspects to be considered in the design, implementation and follow-up of roadmapping projects.

Technology roadmapping is undergoing a modification from a linear-deterministic planning instrument into a more open and complex strategic tool for companies and sectors. Integration approaches are predominantly still limited to the technology and product perspective, which are then merged. From a sustainability perspective, it is necessary to put social future needs and risks at the top, as the starting point of the roadmapping process itself.

The role of the process moderation in roadmapping processes is hardly addressed and often underestimated. Integrated roadmapping is an interdisciplinary social process in which, different from technology-focused roadmapping, communicative skills, trust and openness also become decisive factors.
2 The Integrated Roadmapping Methodology

Taking into account the deficits of purely technology-oriented technology roadmaps and research approaches on integrated roadmapping, the Institute for Futures Studies and Technology Assessment (IZT) has developed a new concept: „Integrated Roadmapping“.

The Integrated Roadmapping methodology has been developed for the purpose of sector-specific technology roadmapping with sustainability-orientation. It provides a search scheme for technological contributions to meet the challenges of sustainable development. Among the main motives for a sector association to carry out a roadmapping process are the detection, understanding and realisation of new business-relevant areas. The integration of experts, customers and users into the roadmapping process minimises uncertainty in technology development, market introduction and business models. Consequently, the Integrated Roadmapping methodology creates a win-win situation between long-term social interests and strategic business interests.

The framework for the integrated methodology is similar to the common technology roadmapping principles. Trends are forecast into the future. Then alternative future scenarios are developed and after that backcast to the present. By applying both forecasting and backcasting we can identify problems and tasks to achieve more desirable outcomes, arrange them on a timeline and generate a roadmap.

The Integrated Roadmap is different from other technology roadmaps in its acknowledgement of the following aspects:

- Multiple dimensions of sustainable development are simultaneously focused in the innovation process.
- The perspective is shifted from technological feasibility to the potential contribution of technologies to meet socio-economic trends and needs.
- Stakeholders, especially experts, customers and users, are integrated into the roadmapping process.
- Unintended side effects of a technology for companies, users and society are dealt with.
- Multiple futures and Wild Cards are investigated.

To meet these additional requirements, we developed an innovative five-step methodology, which generates knowledge from various perspectives and seeks broad qualitative and quantitative empirical input.

The following figure 1 schematically illustrates the adopted Integrated Roadmapping process:
Step 1: Scoping – Determination of the Search Scheme

To reasonably limit the search process, it is necessary to create a search scheme, comprised of components like: goal definition, the future horizon, geographical focus, system boundaries and search areas. Special attention must be given to the search areas. In addition to technological potential and market needs, sustainability-oriented roadmapping requires more push and pull factors, for example (Fichter and Kiehne 2004):

- the consideration of judicial developments, social guiding principles and visions of proactive companies,
- the question of the contribution of technologies to the solution of socio-economic problems and social challenges
- the inclusion of usage patterns and functional systems, and
- a life cycle analysis and assessment perspective.

The search scheme should be open to adaptation during the roadmapping process.

From Technology-Driven Roadmapping towards Sustainability-Oriented Roadmapping
Step 2: Forecasting - Identification of trends and impact assessment

The forecasting step intends to understand factors, that influence the area under survey. Using information on trends, drivers and constraints, the forecasting step will then assess the potential role of technologies in a range of likely future developments. All the information that profiles a certain search area should then be compiled into a fact sheet, which will be iteratively improved by document analysis, impact assessment and empirical inputs, such as expert interviews and surveys.

Sustainability-oriented roadmapping has to deal with scattered and fragmented knowledge sources. A pragmatic compromise between effort and accuracy is a balance of selected inputs from highly trustworthy sources. The participation of experts, users and other stakeholders is not trivial. Their selection is based on several criteria (e.g. competence, visionary thinking, strategic position, practical accessibility). Without the rigorous selection of qualified participants, arbitrary statements and assessments could mislead the roadmapping process.

That being said, there is no appropriate single recipe. An integrated mix of various methods both qualitative and quantitative must be adopted to meet the specific objectives of the roadmapping process in particular to account for different views, perspectives and validity (see chapter 3).

Step 3: Backcasting – Breakdown of different futures

In contrast to the second step, forecasting, the third step, backcasting, is not extrapolation from the present, but retropolation from the future. The concept of sustainability cannot be sufficiently addressed by trend extrapolation, as this would lead to unsustainable futures. Instead, various pictures of the future are developed as sustainability is not a fixed endpoint, but a process on its own.

- The pictures of the future describe the role of basic future technologies in a more sustainable world, by integrating key trends, visions and guiding principles. These pictures of the future are then discussed and it is interpreted, which concrete technologies, applications and services are necessary and which drivers and constraints determine their realisation.

- In addition, the stability of the pictures of the future is investigated by the introduction of “wild cards”. Wild cards are events with low or unknown probability and a high impact (Steinmüller 2003). They could either lead to a drastic acceleration of a trend or to its reversal.

The discussion of pictures of the future and wild cards supports the generation of strategic activities. The discussion should take place in a workshop and involve various stakeholders.

Step 4: Derivation of the Roadmap

In the fourth step, the results of the roadmapping process are condensed and poured into milestones, recommendations and activities. The development of technologies, applications and services is to be displayed on a time axis. The recommendations for a sector organisation are very specific. They address challenging areas for sustainable development, such as:

- Development of key technologies
- Customer relationship
- Qualification needs
• Standardisation
• Dealing with opportunities and risks

The technology portfolios then display technologies that are technologically feasible, have a substantial market potential and significantly contribute to future social needs.

The purpose of the review is to verify the consideration of all relevant knowledge as well as to ensure the transparency and plausibility of the assessments and conclusions. Special attention should be given to uncertainties. Data basis, data quality and methodological correctness should all be considered when interpreting the results. Extreme accuracy and determinism should not be pretended, as the future can be influenced by human action to some degree (Kreibich 2006).

**Step 5: Transfer**

Since sustainability calls for new alliances, the communication and transfer of a sustainability roadmap in particular requires a listing of concrete activities. The sustainability roadmap should not only inform the public, but should also provide different stakeholders with tailored services.

The Technology Futures Analysis Methods Working Group has classified roadmapping as a separate category (TFA Methods WG 2004). The methodology chosen for Integrated Roadmapping also comprises key other methodological elements, such as trend impact analysis, scenario management and expert opinions (e.g. surveys, focus groups, participatory approaches). Hence, sustainability-oriented roadmapping requires several methods which are composed into the Integrated Roadmapping methodology.

### 3 Case Study “Integrated Roadmap Automation 2015+”

The German Electrical and Electronic Manufacturers’ Association (ZVEI) commissioned a project to IZT to develop a roadmap for the automation industry in Germany with a time horizon of 2015. The “Ad-hoc Working Group Technology Roadmap” within the technical committee “Automation” at ZVEI steered the project. The members of the working group were representatives from leading automation industry companies, such as ABB, Endress + Hauser, Moeller, Phoenix Contact, Rittal, Schneider Electric and Siemens.

The Roadmap aimed at

- demonstrating the development perspectives of automation against the background of future customers’ demands,
- identifying technological contributions to deal with socio-economic trends and social future challenges, and
- delivering strategic knowledge for the automation industry sector and for the activities of ZVEI.

The Integrated Roadmapping methodology developed by IZT was applied. In the following subsections selected concrete choices and results are displayed according to the five-step methodology presented in chapter 2 in order to shed light on practical aspects.
3.1 Scoping – Selection of Application Areas and Project Design

Automation technology is a cross-cutting technology, such as information and communication technology or nanotechnology. Concrete application areas have to be identified in order to break down social needs to technologies. To select application areas for further investigation a screening according to five criteria has been carried out:

- technology leadership,
- today’s market relevance,
- potential sustainable future market,
- closeness to end customers, and
- expectation of new insights.

The relevance screening yielded five application areas. For each of the five application areas a sustainability expert at IZT and an automation expert at ZVEI were chosen. They collaborated with their different views and expertise on the individual application fields under the umbrella of the whole project management.

Figure 2: Project Design “Roadmap Automation 2015+”

[Diagram showing the project design with application areas and experts involved.]
3.2 Forecasting – Broad Input and Empirical Validation

To understand the potential future role of the automation industry in a more sustainable world IZT adopted an integrated mix of different methods, giving own sustainability relevant input, seeking empirical input and subsequently interpreting the interim results to compile a profile for each application area. As the documented knowledge on potential future paths of the automation industry is rather fragmented and incomplete, special attention has been given to seek empirical input. At first, IZT carried out qualitative interviews in order to identify future automation solutions and then made a survey in co-operation within ZVEI to assess the proposed automation solutions quantitatively.

- For each application area a series of eight expert interviews was carried out. The experts interviewed were users of automation solutions, original equipment manufacturers, experts from R&D departments, industry associations and sustainability research. Substantial effort was put on the identification of experts, that are able to discuss visionary futures, making use of existing contacts of IZT and ZVEI. The number of eight interviews, in part on-site, proofed to be enough to identify the most relevant future automation needs in each application area.

- To get a broader legitimacy of the interim results a survey was carried out among the members of the technical committees in ZVEI. The questionnaire was developed in close co-operation between IZT and ZVEI, and filled in by almost 150 persons, which yields a return rate of 28 %. It contained two parts: a general section on the importance of strategic challenges for the automation industry and a specific part on the benefit and market potential of automation solutions in the application fields. According to their abilities, the specific part was only filled in part by the population. A major restriction was the assessment of the benefit of automation solutions through ZVEI-members and not by the users themselves. However, the access to a broad spectrum of users is very difficult, as the existing associations are not congruent with the users of automation technology.

All major choices have been discussed and fine-tuned with the assistance of the ZVEI automation experts.

3.3 Backcasting – Pictures of the Future and Wild Cards

To identify alternative future paths of the automation industry and to discover more visionary and robust automation solutions pictures of the future have been developed by IZT and discussed with the help of wild cards. An extract from such a picture of the future shall illustrate its character:

... new sensors have evolved into key technologies for the proactive process management in the food industry of 2030. The dynamic progress in sensor technology ("technology push") and the development of special sensors for the specific future needs of the food industry ("vision pull") enable a zero-waste production and enhanced food quality. These sensors measure inline in real-time important process and product parameters to proactively counteract against quality deteriorations. No expensive and time consuming end-of-pipe food quality analytics are needed any more ... (source: IZT and ZVEI 2006)

These pictures of the future are based on a number of assumptions, such as high public concern for food quality. With the introduction of wild cards these pictures of the future can be validated.
For example EU food quality regulations might be seen as a barrier to trade by the WTO and the public might get used to poorer food quality. Then it has to be discussed whether other motives for the development of new sensors are sufficient, e.g. economic considerations of the food industry.

The discussions took place in five workshops, one for each application area. It was pivotal to have both, sufficient representatives from automation industry and users. A lively dialogue was induced by the interplay of automation industry and users and the various visionary inputs by IZT. The workshops identified future technologies, applications and services, drivers and constraints for their realisation and subsequently an assessment of the range of time of occurrence.

3.4 The Roadmap – Sustainability Relevant Technologies and Action Beyond Technology Development

The Integrated Roadmapping process identified sustainability relevant future automation technologies, such as sensors for micro-organisms or “virtual” production plants. The technologies identified have a broad application spectrum, exceeding the five application areas investigated in detail. In addition to the key technologies and their related development needs, the Integrated Roadmap identifies other strategically highly important areas relevant for the future of the automation industry, which are then translated into recommendations, for example:

- The integration of users and customers has been very inspiring and should be continued. Subsequent common activities range from more in-depth-analysis (e.g. foreign markets), over the discussion of new subjects (e.g. automation in the health sector) to regular roundtables and strategic alliances between automation industry and users.

- Strategic future subjects should be given more attention in ongoing activities. Examples are the acceptance of new human-machine interfaces and the improvement of the supply with qualified young engineers in the near future.

- The automation industry should look for a common voice in the generation of R&D programmes (e.g. 7th EU R&D framework programme) and illustrate the key areas, in which a high sustainability potential could be exploited by automation technology.

- Automation is a technology, which is hardly noticed by the public. It is rather associated as a cause of unemployment, than as a contributor to sustainable development. The automation industry should clarify internally the opportunities and risks of automation and develop strategies for corporate social responsibility. On that basis a trustworthy communication strategy for the public can be developed.

3.5 Transfer – An Integral Part and Tailored to Target Groups

The transfer of the final results and their communication is still under way. Apart from the tailored transfer, see next section, it should be emphasized that the methodology and results have been continuously transferred internally and beyond.

- The broad empirical involvement of actors has resulted in a sensitisation of technical experts in sustainability matters. The association ZVEI has acknowledged the valuable insights gained by the concept of sustainability.
The integrated methodology easily leads to networking activities. The contact between automation industry and users has been so beneficial for both of them that self-organised subsequent meetings are very likely.

Other technical committees within ZVEI have shown their interest in the roadmap and its methodology. ZVEI also intends to publish guidelines for Integrated Roadmapping.

With the concept of sustainable future markets it has been possible to reach the innovation management with sustainability subjects.

The Roadmap will be published and presented to the board of directors in autumn 2006.

4 General Recommendations: “Do’s and Don’ts”

The general recommendations are mainly derived from the experiences in the development and application of the Integrated Roadmapping methodology. Other Roadmapping experiences are also considered when they contribute to sustainability-oriented Roadmapping methodology.

4.1 Involve an Independent Roadmapping Facilitator with Relevant Abilities in Sustainability Research

Many technology roadmapping processes have been led by a company or industry association. When only technological and market aspects are concerned the knowledge of technology companies and product manufacturers might be sufficient. However, the development of an Integrated Roadmap requires some additional criteria:

- To include future trends beyond technology and market considerations, such as demographic change, or social demands, such as improved food safety, necessitates the involvement of an independent institution. As many normative aspects enter the roadmapping process, such an institution can moderate the roadmapping process in a transparent and trustworthy way.

- The independent institution should have sufficient fact knowledge of technologies and profound knowledge of possible futures of the application fields and sustainability. The latter two aspects are not usually available in companies or associations. Furthermore, it should provide methodological competence and tacit knowledge when analysing and managing the complex interrelationships, especially because the established state-of-the-art thinking in companies or associations is unsuited for the given task.

- If there is no established co-operation culture (for example between companies and governments) some roadmapping processes need an external process moderation to open doors, bring actors together and mediate in the case of controversies (e.g. Japan SIS 2005).

Apart from these criteria, the external facilitator must have adequate funding. Ideally, there is both an exclusive benefit for the sponsors and a public benefit. For example the published version of the Integrated Roadmap can have another focus than the more detailed version for the sponsors.
4.2 Consider the Participation of other External Stakeholders Carefully

Technology roadmapping predominantly does not need participation of stakeholders, such as NGOs or consumers, because normative questions are usually not addressed. Sustainability-oriented roadmapping though, has a normative dimension. Therefore, the participation of external stakeholders is often postulated. But, this collides also often with the necessity to carry out the roadmapping process rapidly and professionally. This is caused by differing interests and also by a different level of expertise. A pragmatic approach is needed:

- The positions of stakeholders are – if possible – transferred into the roadmapping process by the process moderator. Consensus / dissensus is assessed, fixed and interpreted for action.
- Stakeholders are integrated only at certain points of the process. Thereby, the input of their abilities and positions can be guaranteed.
- The selection of the stakeholders has to consider the individual person and its characteristics. A constructive action-oriented attitude is highly beneficial for roadmapping.

The co-operation between NGOs, the governments and businesses varies from country to country as well as the single institutions’ culture. Consequently, participation can be fairly easy in some cases, and can be highly destructive in others. It is recommended to look for a core set of constructive people, rather than to try to achieve wide-ranging participation (Behrendt and Erdmann 2004).

4.3 Activate Engaged Sector Experts and High-Level Decision Makers

The participation of engaged sector experts and high-level decision makers into the roadmapping process is a key factor for success. There are several reasons for that:

- The participation of sector experts ensures access to knowledge in the companies and associations.
- The relevance for action and the connection to enterprise foresight and innovation processes is especially powered by the integration of decision makers.
- The integration of decision makers supports the continuation of the roadmapping process after the formal end of the initial project.
- Participation of sector experts and decision makers simplifies the transfer of associations into companies or working groups.

The sector experts serve as kind of a tutor for certain subjects, because they have the expertise in technical and market developments. They should be engaged and also feel responsible for the final outcomes, for example being available for fine-tuning and helping open doors in industry (IZT and ZVEI 2006).

It has been difficult to sensitise companies to sustainable development in the past. Since innovation policy is usually dominated by the top management, incorporating future markets into an innovation strategy through roadmapping is a promising attempt to feed sustainability subjects into high-level processes.
4.4 Shift the Technology Perspective: From the Developers to the Users

The systematic integration of users is a key characteristic of the Integrated Roadmap. Innovative technologies will only prevail in the market if they meet needs or demands. In integrating the users of technology more visionary solutions can be identified. Furthermore, the early integration of potential users might minimise risks.

The search for suitable users is a huge challenge for the roadmapping process. The function (e.g. idea generator, requirement articulator, etc.) and the role of the user (e.g. representative, extreme, end customer, lead user, analogous areas, experts) must be clarified. In practice, different methods of recruitment are available:

- Make use of existing contacts to users with high expertise and visionary thinking is the easiest way, but usually not enough to get the envisaged level of participation.
- Few known users are asked to nominate further users, who meet the requirements.
- The participants are selected from the pool according to their abilities, which can be easily verified with a test question by telephone call.

The recruitment normally requires substantial effort. Participants' willingness to contribute often depends on the expected information benefit for the user himself. The participation of certain manufacturers and users might motivate others to participate. Expert interviews can be conducted on-site or, with less effort, by phone. Frequent sessions deter participants and should be avoided in place of one-day workshops.

4.5 Focus on Sustainability-Relevant Areas

The roadmap practitioner has the task of detecting sustainability-relevant areas of technology. The international debate on sustainable development in science and politics repeatedly focuses on similar subjects (e.g. reduction of greenhouse gas emissions, dealing with demographic change, poverty reduction). These subjects can serve as a filter to look for sustainable future markets, without claiming to be the only ones (Erdmann et al. 2004). Conversely, there are technological lines which enable new functionalities, products and services. The linkage of sustainability subjects to technologies and applications is difficult to standardise. Therefore, it requires broad expertise and tacit knowledge. Hence, there are only very soft recommendations:

- Unfold a broad umbrella, comprising sustainability areas and technological lines.
- Gather data from document analysis (e.g. EU sustainability strategy and TA bodies) and other expert opinions.
- Break-down technologies into functionalities.
- Carry out a relevance-screening, e.g. by cross-wise combination of functionalities and sustainability areas.

This screening-approach has typical strengths and weaknesses. The extremely wide range of sustainability areas and technology lines absolutely requires a pragmatic complexity reduction, yet at the same time, the rough assessments are often very uncertain. The chosen areas either appear justified or unjustified in the following process. The areas not chosen for more detailed analysis might be relevant to sustainability as well.
4.6 Seek Multiple Perspectives and Broad Empirical Input

The sustainability-oriented roadmapping process has to deal with extremely complex "real-world" innovation conditions, that can only be determined to some degree. Consequently, getting lost in detail has to be avoided. It turns out that it is better to pursue various perspectives roughly than to be extremely accurate in only one method. It is recommended to combine at least four perspectives:

- **Document analysis**: When it comes to the future of technology applications fields, such as mobility, housing, or energy systems there are numerous studies, that analyse trends, formulate visions and indicate technology potentials. Meta-studies published by technology assessment bodies, such as IPTS, often condense the information from many single studies. The high quality criteria and the political relevance of these technology assessment bodies are a strong argument to use these studies as a starting point.

- **Expert interviews**: The complex interactions between drivers, future trends and technologies are best identified in interviews. A series of interviews should address experts in different positions of the value chain, various sub-branches, other stakeholders, such as R&D or industry associations, and sustainability research. A demanding task is the identification of potential interviewees with visionary thinking.

- **Survey**: To improve the legitimacy of the knowledge, mainly based on document analysis and expert interviews, it is necessary to carry out a broader survey. This survey should identify new aspects, and it can quantitatively prioritise future needs, usage potential and market potential. The support of an industry association or the existence of an own data base are often essential, but sometimes not available. Practically, the survey is best carried out online.

- **Workshops**: Especially for the discussion of pictures of the future and wild cards, workshops seem to be most appropriate. The invitees should represent a broad spectrum of stakeholders. The integration of users is a key success factor.

The depth of analysis of all these perspectives will depend on time and budget restrictions: the number and depth of meta-studies analysed, the number of experts interviewed, the population of the survey or the number of workshops. The adequacy of the scope highly depends on the heterogeneity of the subject under study. In a step-by-step approach it can be easily noticed when the seeking of input does not produce further relevant knowledge, for example when subsequent interviewees do not deliver more additional information.

The estimation of the time of occurrence is at the core of the roadmapping process. This is either done in workshops or in surveys. In particular Delphi studies, in the second step of the survey the population is confronted with statistical values of the first step, have been conducted to assess the occurrence of technologies. However, the cost/benefit relationship is increasingly seen critically. In a workshop assessing the time horizon might be more roughly, but the common discussion unveils implicit assumptions, drivers and constraints, which determine the realisation of technologies. Thus, action-relevant knowledge can be generated.

In general, the degree of uncertainty of all these methods should be made clear. The combination of qualitative and quantitative empirical input contributes to a comprehensive understanding as well as credibility (IZT and ZVEI 2005).
4.7 How to Deal with Future Uncertainties - Pictures of the Future and Wild Cards

In addition to data uncertainty, roadmapping has to deal with future uncertainties. It is essential to avoid mid-to-long term deterministic representations of the future. Usually technology roadmaps are based on an analysis of trends and drivers. However, some trends are unsustainable and many are uncertain as well. This is due to the unknown complex interrelated processes, but also due to the different possibilities of human action.

Megatrends, such as globalisation or demographic change cannot be interpreted easily on the technology level, but they must be mediated several times and placed into different application contexts. Taking into account the inherent future uncertainty it is advisory to use the established methods scenarios, pictures of the future and wild cards to identify possible future corridors in cooperation with manufacturers and users.

- Pictures of the future aggregate trends, visions and guiding principles. They can be prepared with the help of scenario-technique and assist to clarify the opportunities for action and strategic implications.
- Wild Cards disturb or disrupt stable trends, plans or daily activities (Steinmüller 2005). Their probability is low or unknown, but their impact is high. Rapid acceleration, trend breaks or the generation of new trends are all examples for their potential impact.

The development of pictures of the future, scenarios and wild cards requires profound expertise and tacit knowledge, in order to consistently reduce the complexity of the potential role of future technologies. The assumptions should be stated explicitly. Software-based scenarios have not entered common practice for good reasons, because the human brain is still more powerful at analysing and combing extremely heterogeneous variables in rapidly changing contexts. Since mostly short-term thinking in companies and associations is predominant, long-term thinking is best contributed by the independent roadmapping facilitator.

4.8 Consider Side-Effects

Most technology roadmaps are oriented at technological feasibility. By adding the product perspective, functionality can become a requirement (e.g. iNEMI 2005). Sustainability is a concept with several ecological, social, economical and sometimes cultural goals. When future technologies with a high sustainability potential are identified, only one or a few sustainability dimensions are in focus.

The intention of technology assessment is to provide a broad panorama of the opportunities and risks of a technology. Innovative technology assessment drives the innovation process from its birth to its implementation with progressive results that minimise negative side-effects. Otherwise the project dynamics could make certain paths impossible or excessively expensive. The assessment of unintended side-effects is a complex and demanding task on its own. So there is the temptation to skip technology assessment at all. However, innovative technology assessment delivers valuable insights into the maturity and potential acceptance of technologies.

- In the best case, the process moderator already has a broad knowledge about the opportunities and risks of technologies. Then, these can be broken down into drivers and constraints and integrated into the roadmapping process.

From Technology-Driven Roadmapping towards Sustainability-Oriented Roadmapping
• If this initial knowledge about the opportunities and risks of technologies is insufficient the need for technology assessment must be explicitly stated.

Taking into account the large amount of effort required to conduct a technology assessment, it is recommended to deal with the side-effects of any technology as described above. This procedure backs the hypothesis that a roadmap should be placed within a broader innovation strategy (de Laat 2004).

4.9 Stimulate Communication by Various Means of Visualisation

Roadmaps are able to simply and clearly portray technologies, goals and milestones on a time axis. This applies for both, sustainability-oriented roadmaps as well as other, more common roadmaps. In sustainability-oriented roadmapping, social processes are highly important. This is due to the heterogeneous stakeholders, perspectives and disciplines involved. The contributors to a sustainability-oriented roadmap should have a mutual understanding of the key elements, that can be supported by group visualisation methods:

• Common problem conceptualisation, goals and priority-setting can be easily fixed either on flipcharts or with the help of computers. The same applies to technological solutions and their timely occurrence.

• The roadmap itself can be displayed in a variety of ways, such as portfolios, action sequences or technology areas over time (e.g. Phaal et al. 2004). The form should be adapted according to the goal of the roadmapping process.

A main characteristic of sustainability-oriented roadmapping is the derivation of technology needs from socio-economic trends and social demands. This step is not trivial and requires expertise and tacit knowledge, which are difficult to visualize. Therefore, it needs to be as transparent as possible, for example a schematic figure should be prepared.

Contrary to the advantage of simple communicability stands the implicit, mostly one-dimensional and deterministic graphic representation of the future. Therefore, the consideration of alternative futures paths and how to read the roadmap are essential and should be explicitly expressed.

4.10 Transfer Results Tailored to Target Groups Actively

A roadmap delivers an informative basis for technology identification. If the roadmap is not limited to a small circle, instead reaches many companies and other actors, a target group transfer should be envisaged. The target groups are, for the most part, already determined in the planning process. The most important target group is often the innovation management within a company, but customers, working groups in associations or the general public can also be important. The information should be tailored to the specific needs of the target groups. The following aspects for dissemination should be considered:

• Publication of the roadmap as an easily readable brochure: Online distribution and download option today facilitate widespread dissemination.

• Presentation of the roadmap to single target groups (e.g. press conference, annual meeting of the association).

• Active service offers of the association for companies to present the roadmap results.

From Technology-Driven Roadmapping towards Sustainability-Oriented Roadmapping
It should be noted, that the dissemination of the Integrated Roadmap has a much broader potential interest pool, as many more interests are touched than in purely technology-oriented roadmapping.

5 Conclusion

The paper presents an Integrated Roadmapping methodology for a sector and its application in the automation industry. According to the dimensions to categorise foresight (see: Porter 2005a) the Integrated Roadmap methodology has been successfully applied for a sector with a mid-range time-horizon. The wide-ranging scope has delivered mostly action-oriented knowledge. The study was carried out in about a year. The experiences from this application and other sustainability-oriented roadmaps have been condensed into 10 recommendations, which stress crucial points in sustainability-oriented roadmapping.

The project design with its well balanced recognition of automation expertise and sustainability expertise has incorporated other knowledge sources selectively. The access to experts and users of automation industry for empirical input and workshops counts among the factors for success. To ease communication and minimise arbitrariness the whole process has been documented and reviewed often by automation technology experts. The methodological key to sustainability-oriented roadmapping is to vary perspectives and integrate different methodologies and various stakeholders, i.e. to be rather comprehensive than to be too accurate.

The key impacts of this first Integrated Roadmapping exercise in ZVEI have been the sensitisation of the innovation management for sustainability and the impetus for self-organisation, fuelled by broad empirical activities.

References


From Technology-Driven Roadmapping towards Sustainability-Oriented Roadmapping


IZT and ZVEI 2006: Institute for Futures Studies and Technology Assessment (IZT) and German Electrical and Electronic Manufacturers' Association (ZVEI): “Integrierte Technologie Roadmap Automation”, Frankfurt am Main 2006


