TAB

OFFICE OF TECHNOLOGY ASSESSMENT
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Barriers to the establishment of new key technologies

Summary

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SUMMARY

Germany is regarded as innovative and, by international standards, as excellent in basic research and technology development. Germany is strong in its traditional markets. This is not new and is repeatedly emphasized in discussions with experts and innovation studies. However, Germany also has problems where fast and broadly based implementation of the innovative ideas and results of the research and development in concrete applications is concerned. Also, market diffusion and market penetration of the applications arising from the new key technologies often present the enterprises with obstacles which can barely be overcome, or only with difficulty.

OBJECTIVES AND APPROACH

On behalf of the Committee on Education, Research and Technology Assessment, the TAB conducted a study entitled »Barriers to the Establishment of New Key Technologies«. The present TAB innovation report »Barriers to the Establishment of New Key Technologies« is therefore devoted to the questions, which obstacles to innovation exist in Germany today, where the realization of key technologies and the creation of German lead markets are concerned, and how they can be overcome. Because lead markets are a crucial pre-condition for future export successes.

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INNOVATIONSYSTEMS ANALYSIS OF BARRIERS TO INNOVATION

The cross-technology analysis aims to take stock of factors influencing innovation, so-called innovation determinants. These can affect innovations positively or negatively (promote or inhibit innovations) and depend greatly on the type of

innovation (e.g. product or process innovation) and the phases of the innovation process (e.g. R&D, implementation, diffusion). Central obstacles to innovation or »barriers to the establishment of new key technologies« can be classified in four dimensions – costs, knowledge, market and institutions.

As a result, primarily barriers in the cost dimension, such as too high innovation costs, lack of private financing or public promotional funding appear to be the problems. Positive factors in favor of the location Germany appear to be the technical information and communication structure, cooperation among innova-tive companies and the intensity of competition. Also the existence of central and crucial promotional instruments as well as subject-specific networks and clusters are positive features. The majority of the factors – including among others some which are assessed as particularly important – tend to be regarded as inhibitory. These include the regulatory environment and bureaucratic hurdles, or a lack of willingness to take risks on the part of German companies.

Cost factors: In terms of cost it transpires that the vast majority of innovations are financed by own capital in Germany. It also appears that it is more difficult for firms in the ‚new' federal states to procure outside financing than for firms in the ‚old' federal states. The European comparison also shows that there is hardly any other country where venture capital is so difficult to obtain as in Germany. Also, the general assessment of the financing conditions for innovation in Germany, comparatively speaking, is much lower than for most other European states and the USA. However, this issue should be considered from a broader point of view, due to the financial crisis which began in 2008, as a lower burden of debt and less dependency on the willingness to invest of private (capital) investors affected the location Germany less negatively.

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Market factors: In the market factors we differentiate between competition and demand. Various data sources show that Germany belongs to the ten most competitive economies in the world. However, the following aspects in particular were identified as problematical or needing to be improved: the less than flexible labor market policy, the rigid bureaucracy, the regulations which can only be met with great effort, unproductive government spending. With respect to demand, it transpires that customers or clients in Germany play an important role as information sources, much more frequently than the European average. As far as innovation-promoting demand conditions are concerned, Germany plays in the mid field, internationally speaking.

Institutional factors: The institutional factors are regarded primarily from the perspective of regulations. It appeared with above-average frequency that German regulations are perceived not only by German firms, but also by other European companies as particularly inhibiting to innovations. Only in the question of safeguarding intellectual property rights is Germany at the top of the league in an international comparison.

THREE TYPES OF KEY TECHNOLOGIES

The analytical frame elaborated in the innovation systems analysis enables a comparative assessment of concrete case studies and a check of the technology-overarching barriers with regard to the factors costs, knowledge, market and institutions. It appears that key technologies can exist as at least three main technology types which are not independent of each other. They must thus be observed in their interaction: cross-cutting technologies (such as e.g. optical technologies, nanotechnology, biotechnology), which are the chances for the future and tomorrow‘s growth markets and can result in numerous applications. Application-oriented technologies (like e.g. medical, environmental, automotive, and energy technology), in which Germany in part displays traditional strengths, and which can also create long-term, global demand. Applications (like concrete products or processes), which can contribute in niche, growth and global demand markets to Germany‘s competitive performance in the future. Typically, cross-cutting technologies arise from various innovative ideas, developments, research results, respectively key technologies, and flow into several application technologies and ultimately applications.

The case studies on *nano-electronics* as a cross-cutting technology, *wind energy* as an application technology as well as on *MP3 players and mini-projectors* as applications are each representative examples of these technology types. Unifying

characteristics of the case studies are the jointly underlying ex-post perspectives (in nano-electronics from the viewpoint of the already established semi-conductor microelectronics, in wind energy from the perspective of on-shore wind energy plants, in the case of MP3 technology the perspective of the MP3 format or the MP3 player). Unifying also are the ex-ante perspectives (for nano-electronics with respect to alternative concepts beyond today's semiconductor electronics, for wind energy with relation to off-shore wind energy plants, in the case of the mini-projector from the viewpoint of an innovative product not yet established in the market). The results obtained from literature analyses, expert interviews and a workshop in the German Bundestag with experts from the three technology examples can be summarized as follows.

BARRIERS IN NANO-ELECTRONICS

Nano-electronics with their broad potential applications among others in ICT applications, security, the environment, and medical technology present a growth market with enormous opportunities and offer the chance to contribute to multiple innovative applications. They are thus regarded as a strategically important future field in which German research is already well positioned, from today's perspective.

Cost factors: The rising investment costs for production lines which increase with each factory generation, including R&D costs, must be counted among the main barriers, so that the few remaining chip manufacturers worldwide are locked in particularly tough competition. For production, the cyclical business with mass storage in particular is considered problematical and risky. Massive state investment funding programs in the Far East, especially in the form of tax relief and subsidies or the state building complete production lines and infrastructures, are an additional problem for the European semiconductor locations, which are subject to EU state aid rules. The subject of state aid assumes a European dimension, especially in nano-electronics, as there are only a few manufacturers in this sector still in Europe that are active at the »leading edge« in various markets (e.g. Qimonda for DRAMs until its insolvency in 2009, Numonyx for flash memory, AMD for processors). Due to the enormous costs, unequal promotional funding conditions and a lack of industrial policy, there is a danger that production will be relocated from Germany respectively Europe to Asia, until only a few global players dominate the market.

Market factors: The main barriers are seen, besides the SMEs' non-existent or scarce capital, above all in the lack of, or weak, cooperation or technology trans-

fer between science and industry for rapid identification and occupation of new applications and market segments. The dearth of convincing ideas for product innovations in this area, which can be successful and penetrate a market in the long term, are challenges. The lack of focus above all of large-scale industry regarding their product ranges or sustainable business models appears as a barrier und hinders the competitiveness of companies. As concrete areas in which Germany is already well positioned and could occupy a leading position in the future, are nano material sciences, 3-D integration, hetero-integration (sensors, actuators), optical, high-performance or energy-efficient or »green« electronics.

Knowledge factors: The lack of, or need for, better teaching courses and joint activities of universities with companies in order to interest scientists in starting up own companies are a problem. The inadequate and scarcely targeted implementation of academic research results in industrial production or in products, as well as the lack of timely recognition of potential applications and the immediate response in order to be among the first in the market with product ideas are named as further barriers. For instance, promotional funding is needed for targeted research and development of new nanotechnology processes which could be used later for industrial applications. Also the fact that academia fails to concentrate on core topics and issues where Germany is well positioned, as well as systematically promoting nano-electronics beyond today‘s semiconductor technology are perceived as barriers.

Institutional factors: At the national and European level there is no joint vision and political will to commit vigorously to nano-electronics. Synergy effects are often not used and work is frequently duplicated, e.g. in development labs due to lack of division of labor. European semiconductor companies have to struggle increasingly with patent infringements on the part of countries like Taiwan, China, Korea and North America, which could result among others in losses of market share and market value for the firms, thus negatively affecting competitiveness. Over-rigid framework conditions in research or in industry itself, as well as bureaucratic, time-consuming hurdles are further obstacles. The Hightech Strategy of the German federal government is positively assessed, however a clearer and more sustainable implementation and a coordinated, respectively targeted use of instruments are called for.

BARRIERS TO WIND ENERGY

Wind energy can in the meantime be classified as an applied technology with traditional German strengths, or could be one in the future. In Germany, activities

in the area of wind energy range from R&D via implementation up to market penetration or diffusion of the applications of wind turbines. It has developed in the past years into a significant economic factor.

Cost factors: Innovative projects (e.g. in the off-shore area) frequently fail, due to lack of willingness to take risks, acceptance and enthusiasm on the part of the sponsors. In addition, the off-shore conditions in Germany are comparatively difficult, expensive and risky (inter alia because of nature reserves or the Wadden Sea). High investment costs as well as technological and market-side uncertainties about implementation and diffusion and associated high risks lead to significant concerns for all involved actors and make e.g. assessing risk even more difficult. As this is a politically driven market, the accuracy of the forecasts depends in addition on political factors which need to be calculated. Transparency and stable framework conditions are therefore important. For Germany in addition a too late and inadequate promotion of the off-shore industry along the entire value added chain was identified as a barrier (including installation and logistics).

Knowledge factors: The imminent shortage of highly skilled workers, particularly in the areas natural sciences and engineering, inhibits technology development in wind energy, above all in the off-shore area. With increasing diffusion the need for a systematic, demand-oriented education for highly skilled personnel also increases. It becomes clear that a closer cooperation, respectively coordination, between educational institutions and industry will be increasingly important. Besides the educational issue, for instance, a uniform national research strategy and the realization of the formulated global objectives (e.g. on the future share of renewable energies) into a defined, consistent research program which includes the entire value added chain is missing. Wind energy is primarily sponsored by the BMU (presently focused on off-shore projects). By involving other ministries more closely and pursuing a coordinated, national and cross-cutting research strategy, present promotional policy could more systematically exploit the potentials.

Market factors: Barriers arise through lack of client and consumer acceptance. In wind energy the »lack of aesthetics« and noise pollution are often named hindrances. Furthermore, uncertainties are caused by the lack of political goals. There is for instance still no clear »global commitment« to CO_2 targets. A further barrier is seen in the fact that international demand is not always known. The increasing decoupling between R&D and production facilities as well as sales markets, also through the shift in key consumer markets, requires a more rapid internationalization which is also associated with the focus on internation-

al demand specifics. The influence of policy on single markets becomes especially clear here, as the success of wind energy in Germany is determined more by politics or the political will (in particular in environmental issues) than by the market. This can impede private sector R&D investments or lead to market distortions. On the other hand, large-scale projects like GROWIAN demonstrated that interaction between the »state as intelligent buyer« and free market/ technology development is advantageous.

Institutional factors: With respect to international market development and international competitiveness in wind energy, a barrier to innovation is perceived at present in the fact that e.g. no single EU market exists, although there is a demand for market potential and »critical mass«. To achieve this, in the field of legal regulations, an early European standardsetting for the network access and a worldwide standardization of the »grid codes« are required, among others. Closely connected with this is a central criticism that the German players are still inadequately involved in international standardization processes or do not drive along these processes actively enough.

BARRIERS WITH MP3 PLAYER AND MINI-PROJECTOR

Although the MP3 format was developed in Germany, the diffusion and market potentials of the MP3 player were not adequately exploited by German companies. Firms in the USA and Asia today control the market for MP3 players. In the case of the mini-projector, as a second application, a similar development took place. The success of the MP3 technology as such, as well as the research results in the development of mini-projectors was considerably influenced by the early actors. This was expressed in the broad commitment of these actors to produce high-class research, to license this on a broad base to companies and by follow-through activities such as active participation in standardization processes at international level to strengthen the impact of the technology.

Cost factors: In the case of the MP3 player the lack of access to sufficient financial sources is crucial, above all in the transition from prototype to market introduction. Market penetration was suboptimal here, for instance due to lack of venture capital. In addition, the required production capacities in the consumer electronic branch are almost exclusively concentrated in the Asian region. The access to complementary technologies, i.e. access to additional components, is often not possible in Germany, as in the case of the MP3 player. Also in the comparable case of the mini-projector it turned out that certain chips were not

available which would have been necessary to develop prototypes and above all develop first small batch series of the product.

Knowledge factors: Besides the problem of lack of personnel, the case of MP3 technology demonstrates that the difficulty of finding suitable cooperation partners in the marketing sector is a main problem. A similar situation can be cur-rently observed in the case of the mini-projector. A different perception of the commercial exploitation of German research results on the part of foreign and domestic enterprises has been identified here as a barrier. The risk aversion of German businesses is diagnosed as an internal problem.

Market factors: Frequently the role of strong trademarks and the associated market dominance of established companies present a hurdle to the market penetration and diffusion of new technologies; this was also the case with the MP3 player. The foreign competition succeeded here in further developing their business models, so that the commercialization of the MP3 technology is not restricted to the production and marketing of appliances, but enables other forms of value added, e.g. via the distribution of media, also in the service sector. The relevance and promotion of marketing partnerships, respectively marketing consortia, were especially emphasized in the MP3 player case.

Institutional factors: Institutional factors are less significant for the application examples MP3 player and mini-projector and only concern the problem of bureaucratic obstacles – at least for SMEs when applying for public promotional funding. The procedures are often regarded as cost- and timeintensive. Here too it is criticized that small and innovative chip manufacturers do not have the infrastructures required to test the chip designs.

MEASURES TO ESTABLISH NEW KEY TECHNOLOGIES

A comparison of the three case studies enables a technology-overarching summary of the options for action arrived at and a check of the barriers identified in the general analysis in the four dimensions *costs, knowledge, market and institutions*. Cost factors are always the first of the barriers mentioned and knowledge factors too are relevant throughout all innovation phases. Institutional factors are of significance, above all for an early change of direction and market factors gain relevance with increasing proximity to application.

Also the perspective of the individual technologies shows that barriers in the field of cross-cutting technologies, like e.g. semiconductor electronics or optical

technologies are primarily to be found in the R&D and implementation phases. Application technologies, such as the automobile, mechanical engineering or energy branches, have to deal with obstacles during all innovation phases. For specific applications like the MP3 player or mini-projector, barriers become increasingly relevant towards the end of the value added chain, i.e. for implementation and diffusion. The comparison of the technology-specific obstacles over the three case studies reveals a strong thematic relationship between nano-electronics, the MP3 player and the mini-projector. Here overlaps can be found in the identified barriers, whereby it becomes clear that problems in nano-electronics can have a long-term impact on high-end applications and can pose problems for them downstream. The example wind energy presents a sector which is strongly politically influenced and shows for example the impact that the interventions of the state as customer can have in market and technology development.

On the whole, from today‘s perspective a rather demand-oriented promotional policy appears appropriate, which can be combined with national and international political goals (e.g. climate, energy, environmental policy, or demography). Promotional policy measures would then be applied at suitable times in the phases of the innovation process, or along the value added chain, and be expanded in conjunction, i.e. educational measures, R&D promotion, support for start-ups and SMEs, infrastructure measures, location policy possibly creating demand in specific sectors (as happened in the case of wind energy). Although the specific barriers in the case studies differ to a great extent, often similar or identical measures and policy options are named, which is why they are jointly presented for the three case studies:

Cost factors: R&D, prototype development and product manufacturing are becoming more cost-intensive in almost all technology areas and the ever growing costs can no longer be borne by only a few actors, but should also not be exclusively covered by state aid. In order to overcome the main problems of high investment costs, as well as lacking financial sources and funding (e.g. rising R&D costs and costs for production lines in semiconductor nano-electronics, high costs in the transition from prototypes into market-mature products, see the example of the MP3 player or high investment costs and expensive off-shore conditions in the wind energy), several measures can be deployed. Whereas in individual cases the active search for e.g. foreign investors is gaining significance, as in the case of the insolvent memory chip manufacturer Qimonda, state investments and subsidies as measures are regarded as controversial. However, the Dresden region, which was heavily subsidized in the past, is now known as »Silicon Saxony«, which shows that this type of state measures and a location policy can promote the building of internationally visible clusters. Particularly in

the case of nano-electronics, the increasing significance and relevance of cooperation between actors and clusters at the EU level is demonstrated.

By means of strategic alliances, primarily between R&D institutes and industry, development costs for example can be shared (e.g. according to the IBM-Alliance model in the nano-electronics field). Further measures, which provide stronger support for industry, concern specific business models of the firms (e.g. address important high-end markets, specify product ranges, serve demand and niche markets, expand marketing by service aspects, negotiate exclusivity contracts with suppliers of complementary technologies). At the same time, start-ups and SMEs also require constant promotion, in order e.g. to establish themselves in niche markets internationally (among others, by promoting scientific transfer in companies). Promotional policy has the possibility to create appropriate incentives here. The development of new, more flexible project models (e.g. PPP models), transnational cooperation models (e.g. more via R&D institutes and enterprises directly than via projects) are further, positively assessed approaches.

Knowledge factors: A consistent, national promotional strategy, which has global goals in view, is crucial for the sustainable development of new key technologies. In order to position innovations in the market on a broad and long-term basis, and to occupy the German leading role in certain sectors and branches, not only private enterprises but also the state must set priorities. This starts already in the early recognition and definition of new topics and technologies with many and varied application potentials which could grow into significant niche or growth markets.

Addressing global social policy needs such as climate, the environment, energy, demography as well as strategic, political endeavors and economic future markets in the form of pilot programs or lighthouse projects, which are associated with clear targets (e.g. reducing CO_2 emissions, energy-efficient technologies) can help to create international visibility and global demand for German technologies. The »Cool Silicon Cluster« in the Dresden region, which has been promoted by the BMBF since 2009, to develop energy-efficient electronics is one example that networks several research and industrial actors addressing a joint problem. Similar measures could be appropriate for further strategic high-tech sectors, e.g. in energy technology.

Joining together the existing topic-specific and -overarching clusters at the national, transnational as well as pan-European level (e.g. the nano-electronic locations Dresden, Grenoble, Leuven) can help to raise the international visibility and strengthen strategic branches. At the national level, R&D centers e.g. in the

area of wind energy and nano-electronics are proposed, to encourage data and knowledge exchange as well as cooperations. The presently lacking utilization of linkages, complementarities and »cross fertilization« through groups of actors or disciplines could additionally be made possible. Transfer offices which broker between science and industry, can put in place or expand science and technology transfer activities, management of knowledge monitoring as well as targeted technology consulting. Transfer offices or R&D institutions of this kind which can carry out these tasks are often already in place (e.g. alliances of the Fraunhofer-Gesellschaft), but they do not have a budget for these activities or are not sufficiently familiar with these tasks.

For a sustainable expansion of knowledge and increased development of human resources, training collaborations between science and industry, internships in science, R&D institutes and firms or technology-specific or demand-oriented adjustments in training are recommended which take into account not only technological changes but also (new) competences required by industry. Measures can continue to run innovation competitions or image programs to reach target groups (e.g. pupils, students), or specific technical training centers which research institutes and industry run jointly. Tomorrow‘s scientists and entrepreneurs can begin to build up their own personal network early on, using such measures. Similarly, it should be considered to offer potential entrepreneurs a better platform for networking, access to knowledge (as e.g. market infor-mation) in the form of information centers or »incubators«. Often existing infrastructures and groups of actors can be utilized in this context (e.g. transfer offices) whose range of tasks would merely have to be exactly specified.

Market factors: In the case of market factors, the development and promotion of marketing partnerships or commercialization consortia by broadening the promotional range to include demand-oriented exploitation aspects could be a possible measure to support young, innovative companies and is recommended in the case of the MP3 player. For these firms and also for already established companies, it is imperative to focus on global market niches. Also, the presence of German firms abroad can be helpful with regard to an international visibility and the marketing strategies and is particularly significant for branches which are of special strategic importance for Germany. Further, it is recommended to continue to exploit existing potentials in traditional markets and to create appropriate framework conditions for this to succeed.

Institutional factors: The concentration of already existing and proven structures, an even stronger focusing, creating thematic or sectoral profiles, networking among the actors as well as bundling public investments in R&D are empha-

sized, in order to better utilize synergies among actors. A network of the actors involved for example can also be possible via e.g. the umbrella organizations and platforms (like technology platforms), as is recommended for wind energy. But also a coordination of political activities at the federal state, national and EU level, as well as the consistent and long-term commitment of policy-makers and the political will to declare support for strategic sectors (e.g. targeted location policy, promotion for cooperation networks between science and industry, communication platforms for industry and industrial research centers), is significant in this context. By centralizing and synchronizing processes and political decisions, existing bureaucracy can be further reduced, work and responsibilities can be better distributed and cooperation better facilitated.

The need for test infrastructures and test centers is expressed in all three case studies and can represent a particularly important support, above all for SMEs. Also the timely creation of regulative framework conditions for technical standards and an increased exploitation of IPR, together with increased IPR protection are recommended. For instance, in the case of the loss of production facilities in the semiconductor sector, the question arises whether at least the know-how generated in this connection (among others, in the form of patents) can be protected and marketed at a profit via licenses or new business models.

But a stronger political involvement is called for to implement the measures mentioned, which would require a concentration and coordination of the activities at the federal state, national, and transnational levels, even up to the EU. Politics could be advised in decisions which concern the support for specific technologies by means of increased scientific-technical foresight activities, roadmaps and instruments for technological early recognition. These instruments would be specified with regard to important examination criteria and evaluated according to technologies (such as e.g. technological feasibility, economic viability, market and growth potentials, sociopolitical relevance, solutions to global needs and problems, sustainability), in order to identify important topics and sectors for Germany or even define new technologies, as was proposed in the case of wind energy. With the participation of science, industry and politics, criteria and priorities for an appropriate allocation of promotional funds can be arrived at.

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