mKETs-Pilot lines project
The goal of the mKETs-PL project is to prepare and foster
a common understanding and consensus for future actions
in Europe focusing on multi-KETs pilot lines

mKETs-PL working document

Country report Germany

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- Cambridge University-Cambridge enterprise
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Content

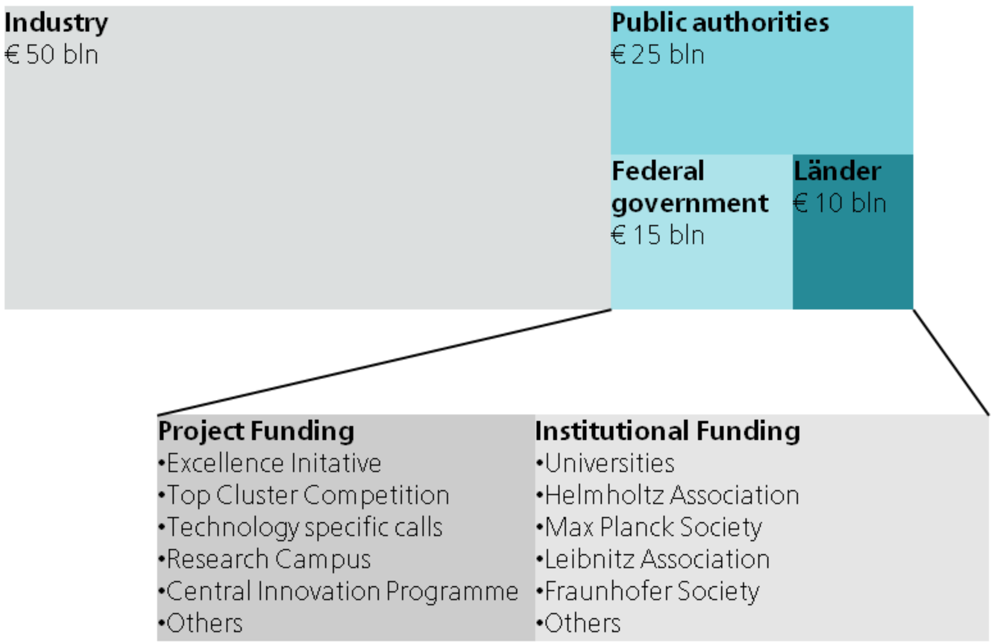
1. Policy perspective

1.1. Country specific innovation system with emphasis on KET

With an overall budget of around EUR 73 billion[i] in 2011, Germany invests 2.88 %[ii] of its GDP in research and development, and so it reaches nearly the Lisbon objective of 3 %. In Germany research and development plays an important economic role, as Germany is worldwide the leading country for high-tech product export. In 2012, exports related to high-tech products accounted for EUR 500 billion[iii] revenue, out of a total export of EUR 1.1 trillion. Thus, the added value comes rather from high-level than from cutting edge technologies. So, it is no wonder the main financing source of technology development in Germany is the industry itself. Companies bear two thirds of the whole research and development expenditures[iv], nearly all for applied and experimental research[v]. Especially medium sized companies are very effective when it comes to implementation of technologies. In contrast to big companies, who turn research outcome into revenue in only 15 % of the cases, medium sized companies use 35 % of their research output to broaden their portfolio[vi].

The public authorities in Germany spend EUR 25 billion in research and development – both, federal government and the German states (Länder) with more or less equal shares[vii]. Objective of public funding is first of all basic research as it is done by universities and research organisations. The responsibility for the Universities is alone with the Länders. Whereas the big research organisations (Helmholtz Association, Max Planck Society and Fraunhofer Society) are predominantly financed by the federal government. Exception to this is the Leibnitz Association, which is financed with equal shares. In particular the Fraunhofer Society is assigned to application oriented research and transfer technologies to the industry as a service. All in all, institutional funding makes half of public spending. Another quarter is invested in mainly basic research at universities via DFG (German Research Foundation) and Excellence Initiative.

Figure 1: Funding of Research and Development in Germany



Even though the main purpose of basic research is not innovation in general, the industry benefits from this state investment. Information on latest scientific outcomes, man power, infrastructure, and research and development services are the main supporting factors to the economy regarding public funded research.

Manifold instruments are established to bring academia and industry together, as there are Top Cluster Competition and Research Campus on federal level or regional networking platforms like Bayern Innovative or Steinbeis Foundation on Länder level.
In the early 2000s the Federal Ministry of Education and Research fostered these networking activities with a broad public supported Competence Network initiative. Since then, many independent, especially technology oriented regional clusters have been founded all over Germany. The current trend goes to more specific platform initiatives as there is e.g. National Platform on Electric Mobility. In addition to networking purposes, these platforms are assigned to adjust national activities on a specific issue. Politics meets economy and academia in order to develop a joint strategy for the whole country.

In 2006, the Federal Government launched the High-Tech Strategy. This was the first approach to align activities of all the ministries responsible for research and development funding, in particular the Ministry of Education and Research and the Ministry of Economics and Technology, and several line ministries. Main purpose of the strategy was to prioritise funding activities to foster the national knowledge and competence base in research and innovation. In addition to this, since then the overall budget for research and development has been increased perceptible.
In its first version the High-Tech Strategy based on 17 technologies[1]. The re-launch from 2010 focuses more on requirement areas deducted from global challenges. Additionally, the so-called High-Tech Strategy 2020 still determines 8 key technologies[2], which are largely identical with the Key Enabling Technologies, defined by the European Commission. But, the general trend heads for more visible, application oriented programs than for technology centred calls.

1.2. Organisation of mKETs policy

In general, it seems that technology innovations are predominantly based upon several KETs. Especially advanced materials and advanced manufacturing occur in most of the other KET-development processes in one or the other form. E.g. today's optoelectronics characterize such a cross cutting field: photonics, micro-electronics, new materials, bio-based materials, and all this processed with advanced manufacturing. Hence, the fact to use different KETs in development is not new, but, to rise opportunities for innovation explicitly, multi-KET-calls could be productive. There seem to be two general approaches for calls, which address more than one technology: different KETs can be the basis to solve a problem of application, e.g. battery technology, or one KET delivers new opportunities in another KET-field, e.g. nano-materials for micro-electronics.

In Germany, the Ministry of Education and Research launches most of the technology centered calls. For Key Enabling Technologies the Ministry budgets roughly EUR 400 million in 2013[3]. In the 1990ties and early 2000s almost exclusively technology driven calls were common. Presumably because of both, "valley of death" reasons and a changed political mind setting according to the High-Tech Strategy, in the last few years some calls have become more application oriented. In these cases, not only one but several technologies were requested to solve a – most of the cases – societal challenge. E.g. microsystems technology had been a funding priority for about 20 years. There are still calls addressing this technology, but beside this, the Ministry released a program called "Ambient Assisted Living", where microsystems are expected to deliver relevant solutions. E.g. micro-sensor based systems should indicate, if an elderly person has fallen down. In addition to microsystems technology, especially ICT is essential for solution development in this scenario.

[1] High-Tech Strategy 2006: Nanotechnologies, biotechnology, microsystems technology, optical technologies, materials technologies, space technologies, information and communications technologies, production technologies, energy technologies, environmental technologies, automotive and traffic technologies, maritime technologies, health research and medical technology, plants, security research, services
[2] High-Tech Strategy 2010: Information and communication technologies, optical technologies, production technologies, materials technologies, biotechnology, nanotechnologies, microsystem engineering, innovative services
[3] Material sciences (WING): EUR 116 million, photonics EUR 97 million, Microsystems technology EUR 80 million, production EUR 70 million, industrial biotechnology around EUR 20 million

The technology centered funding of the federal Ministry of Economics and Technology is more or less in general tailored to particular application oriented issues and technology open[4].

In parallel to the explicitly technology centered calls there are increasingly more technology centered programs, which combine different stakeholder from a whole value chain in order to trigger the implementation of a global solution or a disruptive technology. E.g. the federal government supports in particular research and development regarding materials for batteries and components, automation technology and cell as well as battery production within the framework "National Electromobility Development Plan"[viii]. Partly, these activities are financed with money from technology based funding programs, as there are the programs: WING (new materials), Energie 2020+, and Mikrosystemtechnik, co-financed by stakeholders from the industry[ix]. In addition to that the high priority of battery series production becomes obvious, as it was financed within the second stimulus package with EUR 45 million and in the Energy and Climate Fund with EUR 200 million[x].

The common technology centered calls in Germany are increasingly addressing multi-Key Enabling Technologies. E.g. a recent announcement of the Ministry of Education and Research combined explicitly photonics, advanced materials, and advanced manufacturing in a program called "photonic process chains". Main aim of the call was to implement business- and value added chains, in order to deliver control and manufacturing procedures in production processes[xi]. In the same way the program „mikro-nano-integration for the next generation of sensors and actors" supports joint research activities of material and production development.

A very well established but pre-competitive program founded by the Federal Ministry of Economics and Technology is IGF: "Industrielle Gemeinschaftsforschung" (cooperative industrial research). Within this program, there are two sub-types which could be of interest for a cross-cutting, transition oriented prospective program. The sub-type ZUTECH addresses interdisciplinary and cross-sectoral activities especially in order to develop system solutions based on future technologies[xii]. Here it could be of interest that for these projects the committee of appraisers comprises members from R&D divisions and board of directors from companies out of different sectors. In these expert groups gather the national key players of each sector[xiii]. The other sub-type "CLUSTER" is more relevant for pilot lines and therefore mentioned in the next chapter.

1.3. Main policies for Pilot lines

There is no specific funding for pilot lines in Germany, neither in the federal budget, nor in the Länder budgets. But, as "pilot line" stands for supporting technologies with a technology readiness level beyond 4, we will describe measures which support mature phases of application oriented technology development.
First of all, in other countries development activities are supported by tax incentives. But, even though it is claimed for years and years[xiv], there is no tax credit system for R&D in Germany. All kind of financial support from public authorities to innovating companies comes from direct subsidies or interest rebates for loans.

Ministry of Economics and Technology
In Germany, the Federal Ministry of Economics and Technology is in the lead regarding funding of technology based development within the industry. In general, the Ministry is reluctant when it comes to subsidies. Within a new innovation concept launched in May 2012, the ministry underlines explicitly: "Primarily the economy has to look after the utilization of new findings[xv]." But, as particularly the small and medium sized companies are disadvantaged regarding development on the one hand and disproportionate responsible for new employment on the other hand, there is a special emphasis on SME-support. All in all, the budget for SME and start-up funding from the Ministry of Economics and Technology is around EUR 750 million, whereupon the average volume of the projects is in the range of EUR 200 thousand to EUR 300 thousand.

[4] Budget in 2013: Transport EUR 60 million, ICT EUR 40 million, energy EUR 40 million

Deployment of technologies: Central Innovation Program for SMEs
The largest part by far of this technology open funding to the benefit of industry is covered by the Central Innovation Program for SMEs (ZIM)[xvi]. This program addresses explicitly undertakings which already are competitive. All within the Multisectoral Framework on regional aid for large investment projects, the ministry supports single companies and consortia between economy and academia to exploit market potentials of technologies.

In general, this program has a very good reputation among stakeholder from industry, particularly, because the approval probability is around 63 %. Another advantage is a very short time to contract. First of all it is a two-phase approach. So, the effort for a first expression of interest is low. And for the second phase the ministry puts emphasis on an efficient approval procedure: according to the ministry itself, only about two month lie between application and approval. Moreover, applications may be submitted at any time. All this has to be taken into account since really interesting technological developments underlie the urgent requirements of "time to market".

In order to make sure the industry is really interested in the outcome, companies have to pay significantly more than half of the project sum. Nevertheless, especially in co-operation projects in which research organizations and universities are requested to join in the projects, companies are in the lead. In general, it is intended to foster co-operation between companies along the value chain, especially within the sub-type "VP: technologieübergreifende Verbundprojekte" (cross-technology cooperation R&D projects)[xvii]. Material specialists, plant manufacturers, system integrators and users (in an advisory board) are gathered in joint projects to develop a marketable solution for a specific application. In the precursor program "InnoNet", half of the projects have led to new products or services and another quarter have delivered important findings for the companies[xviii].

In addition to the technology funding within ZIM, there is an accompanying assignment for supporting services from a third party, called "DL: innovationsunterstützende Dienst- und Beratungsleistungen" (innovation supporting services and consulting)[xix]. These projects intend to back companies and consortia at implementing the new technologies. For example the measures give assistance in strategic planning, support in implementing a series production, give legal advice regarding standardization, certification, and IP, offer educational programs, or, last but not least, conduct market research.

Different competences, one application: Co-operative Industrial Research
As mentioned above, the program IGF: "Industrielle Gemeinschaftsforschung" (Co-operative Industrial Research), also funded by the Federal Ministry of Economics and Technology, has different sub-types. One of them, called "CLUSTER", could be of interest for a project scope, where especially synergy effects are intended between different stakeholders along the value chain. CLUSTER-projects gather various sub-projects, funded by different financing bodies, on a meta-level. All these sub-projects are working on a specific application oriented technological issue from diverse perspectives. Together, they try to achieve complement findings, both from an academic and an application oriented viewpoint, in order to develop a comprehensive solution. Because of a significant bigger volume, these joint CLUSTER projects reach higher visibility.

Ministry of Education and Research
The German Ministry of Education and Research focuses first of all on technology specific calls, which are described above. But there are several exceptions to this rule: In most cases these are programs to improve structures of the innovation system. One among others is the open-topic program "Validierungsförderung" (validation funding), that benefits research and technology organizations and universities to prepare new research findings for technology transfer. This instrument was established in 2010, preferential to overcome the phenomenon of the "valley of death". With a maximum volume of EUR 1.5 million per project, scientific organizations can apply for feasibility studies, adaption to different applications, demonstration development, or economic research.
Another open-topic program is "Research campus"[xx]. Within the scope of this funding line, companies are invited to join universities along a specific technology issue. With a volume of up to EUR 2 million for a campus

each year, the Ministry supports research activities co-financed by industry. This instrument is exemplary for establishing KETs because of its comprehensive approach: A new industrial competence network is built while research and education is fostered simultaneously in the same technology.

Industry oriented technology calls: Innovation Alliances
Even though the Ministry is predominantly responsible for activities with a technology readiness level <4, there is a vivid interest to transfer technologies – developed with public funding – to application. For this, Innovation Alliances are first launched in 2007 in order to make sure, the industry is willing to take over technological findings after successful research. Within this Innovation Alliances a consortium of stakeholders from different sectors give detailed input for technology centered calls of the Ministry. In exchange for this, the participating companies make the commitment to invest an at least 5 times higher amount in implementation than the public funding was. This commitment is less meant to lever the public research expenses, but to ensure the utilization of research outcome in follow-up activities. Even though the expressions of interest have no legal binding, not only the R&D division, but the board of directors of the participating companies committed themselves. Hence, investments in the technology in question are more reliable for all partners along value chain. So, Innovation Alliances have no specific budget, but are a way of framing technology centered calls.

Regional competence hot-spots for specific sectors: Top Cluster Competition
Another instrument to boost technology transfer is the Top Cluster Competition, equipped with a state budget of EUR 126 million in 2013. First of all, the cluster activities aim to foster co-operation, both between academia and industry, and between different companies. Before 2007 the policy for fostering academia-industry networks was more widespread, supporting competence-clusters on technology issues all over Germany. Since 2007 there have been three Top Cluster Competitions, which still intend to bundle regional competences as it was before, but in another dimension of funding and visibility. Now there are 15 Top Clusters with different topics, located all over Germany. Within these clusters, companies of a sector gather along the value chain. And together with academia they exploit high-technologies for potential future markets. The Top Clusters align research and development in a joint strategy. In the long run the participants build an eco-system with tasks in market development, education and networking.

Examples of public co-funded pilot line projects
However, the public authorities in Germany underline to be reluctant supporting TRL >4-activities, for one or the other reason there are different pilot lines co-funded by federal ministry and the Länders (states).

Shared facility for organic electronics: InnovationLab
One winner of Germany's Leading-Edge Cluster Competition is the Forum Organic Electronics. The cluster covers the whole value chain from organic material suppliers like BASF and Merck, a printing machine supplier as there is Heidelberger Druckmaschinen, to applicants like Osram, Philips or Roche Diagnostics. In order to accelerate product and service innovation, the cluster-participants founded the research and transfer company InnovationLab in Heidelberg. Main purpose of the new company has been establishing of a pilot-production site for organic electronics. Around 100 people from various companies and universities are working side by side on the development of materials, processes and systems. InnovationLab is a public private partnership, 50% owned by industry and 50% by universities.
The investment of the facility is bore by industry, universities and public funding by the involved ministries on both state and federal level. Forum Organic Electronics is supported with 40 Mio € by the Federal Ministry of Education and Research. The state of Baden-Württemberg is supporting the cluster with 5 Mio €. Within the pilot facility industrial and academic consortia run a lot of different development projects, which are most of the cases partly public funded. All in all these projects have a technology readiness level below 5 and are pre-competitive. However, an important purpose of InnovationLab is integration of market needs in an early stage to avoid over-engineering. Especially the participating RTOs conduct an affiliated EU-financed project, so-called COLAE, in order to foster commercialization of organic and large area electronics.[xxi]

Focus point of "Silicon Saxony": Several pilot line facilities

Saxony today is worldwide one of the major competence regions for semiconductor development. With an immense effort of more than EUR 8 billion, both from public and private investors, Dresden and its surroundings has established all kinds of competences around the issue of process development and production in semiconductors, nano- and micro-electronics [xxii]. In the beginning of the century, in particular Quimonda, former Infineon, and AMD stared several co-operations to settle nana-electronic-development and production activities – not least because of lavish public funding. First joint activity was Advanced Mask Technology Center (AMTC) in 2002. Then Fraunhofer CNT (Center for Nanoelektronic Technologies) and NamLab, as public private partnership, was founded. Latest establishments were Fraunhofer IZM-ASSID (All Silicon System Integration) and ALD Lab (atomic layer deposition). All these activities have been related to pilot production or run shared facility for pilot lines, due to the point, that Dresden has its explicit focus on process development.
The starting point of "Silicon Saxony" was the national cluster policy in the 90ties. Beside this, institutional funding played a major roll. In addition to the support from the federal government, a lot of expenses came from the state of Saxony in connection with ERDF-financing[xxiii]. Today an important public funding source is the Top Cluster grant from the German Ministry of Education and Research for the activity "Cool Silicon"[xxiv].

In 2009, there was a huge disturbance within the cluster, when one of the major players, Quimonda, became insolvent and the other, AMD, spun-off its manufacturing arm as Globalfoundries. Since then, there have been manifold public-private efforts to compensate the loss of one of the key manufacturers. Even though the loss was substantial, today there are several potential companies developing and producing in the region, as there is Globalfoundries, Infineon Technologies, and X-FAB[xxv]. Another disadvantage of the region is the absence of an applicant sectors, e.g. car production or medical device manufacturing. This hurdle could be relevant for integrated development processes. Regarding production, for sure, it is meaningless because shipping is no issue. However, "Silicon Saxony" is a vivid cluster: Today in and around Dresden about 48.000 people are busy in this sector with annual revenue of 10 billion EUR[xxvi].

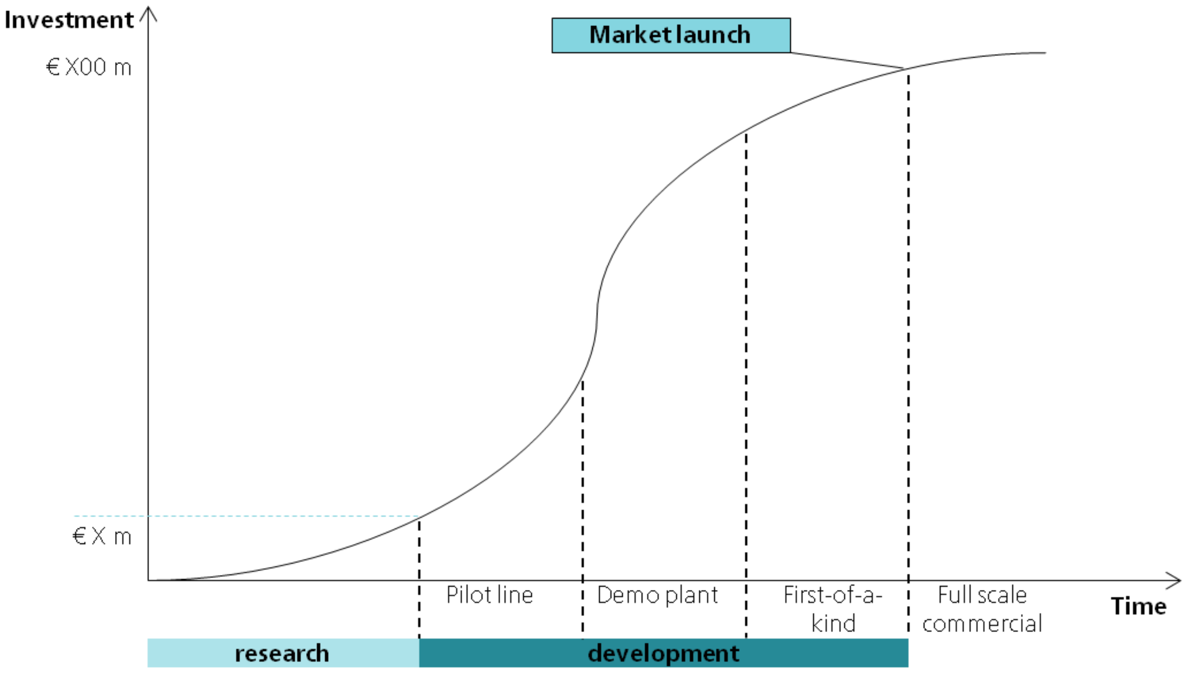
Formation of future manufacturing sector: Pilot line for battery production at the ZSW
The ZSW, a research and development organization in south-west Germany has expanded their activities in Li-ion battery technologies and has established the share used pilot production facility for batteries in automotive applications "eLaB". The undertaking is supported by industry driven Competence Network Lithium-Ions Batteries "KLiB". This competence network works trans-industry and -sectoral and covers the whole value chain of battery production. Specific for this network is the awesome predominance of industry, with 40 companies and 4 industrial associations and only 4 research organizations[xxvii]. Contrary to the expectation, the activity is not in the first place pursued by the huge car manufacturers in south-west Germany but by material and component suppliers, and production engineering companies. This shows that the main driving forces are the expectation to establish a new potential future manufacturing, within the automotive sector.
Even though the pilot facility is intended for the development of close to serial production, the activity is designated as pre-competitive[xxviii], so the character is rather a research facility. Hence, major expenditure of EUR 45 million bears the German Ministry of Education and Research within the funding strategy for electric mobility[xxix]. The state of Baden-Württemberg invests EUR 6 million in the extension building. Costs for operation, estimated with EUR 5 million each year, are covered by the industrial partners. The undertaking complies with a central claim of the National Platform for Electric Mobility to establish a lead market in Germany.

2. Business perspective

2.1. Implementation of multi-KETs pilot lines

The process of implementing a new production line can be divided into different steps. Particularly in chemistry manufacturing, after successful research and the strategic decision to raise a production, a pilot plant is initiated for process development. Main aim of this pilot line is the production of small quantities of material. Subsequently, a demonstration plant is build for scaling up the process. The results of process development lead to the development of a first-of-a-kind system as a prototype for full scale manufacturing. This concept serves as prototype for the commercial plant. At best, with the full scale demonstrator, the innovating company can count on return on investment.

Figure 2: Investment costs for manufacturing process development



Andre Koltermann (2013, personal communication)

For the whole development process cycle for implementation of a series production one can calculate with approximately 3-5 years – depending on sector and technology. So, including the research phase, a manufacturing process based upon a new technology protracts over 10 years at least for the innovating company. But not until finishing the whole development phase and after successful market release, the company can count on a relevant return flow on investment. Whether a new product is to be seen as a successful innovation or not, turns out even later.

Regarding expenses, research is far less consumptive, compared to process development. Especially in joint projects with industrial partners or public financed activities, research projects are calculated in the range of single-digit million EUR. Product development, respectively process development is in another scale: This phase causes between 80 % and 90 % of the whole R&D costs. According to this, the interviewees, widely irrespective of sector and technology, estimate the expenses for a new manufacturing process with a three-digit million Euro figure. Against this backdrop, it is not surprising that even big companies pursue only one or two pilot production projects at once. Depending on the economic situation up to three pilot activities could be triggered. Even though the costs are that high, time is even more important for the companies than investment money. Or, more explicitly, because of the huge investment sums timing plays an eminent role. Rather months than years are the relevant scale for pilot production activities. The decision to go into a new product is pretty much a strategic one: So – far more than in research issues – management is involved in the decision making process. With transition from research to development, technology innovation gets a new perspective: Market aspects become far more relevant.

Depending on the size of the company, there is a more or less formalized process to assess successful technology outcomes from research. The company representatives expect, technologists from research division to quantify market volume, prices, and investment costs, preferably with consolidated figures, and to draft the strategic approach and communication concept. Even though the researchers come up to this demand, the decision is often made by intuition. Psychology plays an important role, when it comes to the decision to go into a new product. However, the bigger the company, the more reluctant the management seems to be regarding risk. In contrast to this, especially within owner-managed medium sized companies, the managing director often seems to decide to take the risk and push the development of a new technology in person.

Comparison of risks
Risk is a dominant issue for pilot production activities. A company, which plans to release a new KET-based product, has often to bear a double risk: regarding the technology, critical points could be problems with materials or the product itself, production, or IPR. Regarding markets, there are pitfalls of actual application, access to market, price, competition, value chain, and in particular speed. And this list is absolutely non-exhaustive! However, for multi-KET based products the technological risk even rises for all different basic technologies.

As for management, innovation activities mostly compete with expansion activities. For the latter, risk is substantially lower, particularly if applications are well known and/or markets are established. If innovation is asked for, incremental innovation is rather preferred because it is faster – estimated 1-2 years – and ranges within well known markets and technologies. The technology drivers from research department have to prove, investment in a pilot production facility compensates all these risks. After all, due to accounting standards, the pilot investment has to be assessed within the EBIT-framework. So, in general a risk surcharge has to be taken into account of at least 50 % to 100 % over the whole investment.

Information about markets and application are decisive
These expectations of risk by an investment in KET-based pilot production can only be compensated by a qualified assess of market potential. Whether a pilot production is implemented or not depends in the first instance on a market oriented strategic decision of the management, not in the performance of a technology. Hence, market figures are absolutely essential for KET deployment. Even for a KET-company, aim is not technology development but to generate income by delivering customers benefit. So, information is needed not only about technological options and restrictions, but about prices for raw materials, international value chain, today's solution for the application in question, market trends, alternative developments, customers assessment, legislation, and so on. It is necessary to make sure the new development is able to deliver a marketable solution, and all this within a very limited timeframe. Market information is first of all vital for investment decision. But as well, application know-how is significant for prioritization and design of product and production concepts.

Even though market information is so decisive for technology deployment, it is often missing, as different interviewees emphasized.This is of great importance because the internal drivers from the research department are no experts in marketing. Then, often the cost-benefit analysis is difficult, as specifications of the serial product are still not determined. And last but not least, target customers and applications are just globally described but not specifically verified. Several interviewees expressed that support regarding market definition and assessment with technological background would be very helpful and are urgently recommended for ancillary research to raise technology deployment and overcome the valley of death.

Regarding KET activities in general, both, stakeholder from companies and politics emphasize the importance of timelines. KET issues are often internationally boosted in hypes. Many countries and regions engage in research in these technologies. In the past, technological development has sometimes been in vain because markets were “faster”. But as well, often research was too early and was discontinued, even though the technology could have been deployed later.

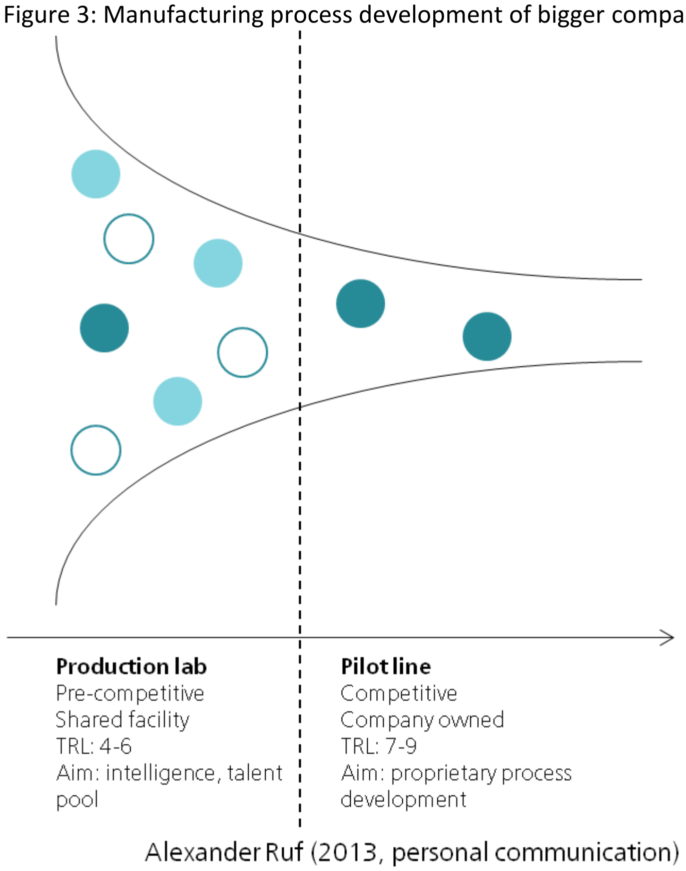
When it comes to huge investments for pilot production activities, timing becomes even more important. In all kind of pilot production projects a special attention should be paid for global trends, affecting technology and application. Special evidence is needed if markets are presumably mature for the technology in question. These timelines do not depend on technology roadmaps but on external market factors, e.g. availability of raw materials, market access, or energy prices.

2.2. Evaluation of KET polices/KET innovation eco-System

Shape of production development projects: Shared production lab

The interviewees from bigger companies in particular underlined that pilot production activities are in general not pre-competitive. So, shared facilities for pilot production are no option for them. First of all, manufacturing design is a major part of development itself. Process know-how is seen as key knowledge for the company and must be in house. Particularly, regarding IP protection, process knowledge is even more important than patenting. E.g. customization of a machine by electronics and software is a convenient way of IP protection. A purpose designed facility allows right from the beginning a broader and more flexible scope for process design and technology deployment, hence, incremental innovation is easier. A very important aspect, the interviewees mentioned, is the higher speed of implementation within a proprietary pilot facility. And finally, each change of the pilot facility would be too costly – EUR 1-2 million was stated –, a shared facility would probably mean no cost reduction at all.

Figure 3: Manufacturing process development of bigger companies



However, several interviewees, both from bigger and smaller companies, estimated shared facilities as an interesting approach for KET-related process research, for instance as a production lab. As these facilities cover roughly TRL 4-6, questions of competition are less relevant.

Purpose of such a production lab is for the main part the alignment of all the different competences, relevant for manufacturing of KET-based products. Main benefit of a jointly used process lab on one site is short operating cycles and entangled development. This accelerates innovation process substantially, for the benefit of all partners. Within such a location, network structures along the value chain could be tested and established.

Especially for disruptive innovations a whole well balanced, complementary ecosystem has to be built up. For companies in general the production lab is estimated to be important for knowledge transfer and serves as a talent pool. Smaller companies use to utilize the facility for pre-production or as a foundry for highly specialized small scale production. Bigger companies participate in these production labs more for scouting and intelligence reasons. However, the share of bigger companies in activities like that is usually in the one-digit million EUR range, which points to the fact, that it is more seen as joint research than as development activity.

So, these existing manufacturing labs, irrespective if company, RTO or University owned, are rather sensible. But often within these institutions predominantly the technologists are amongst themselves. Application knowledge is most of the cases at best involved as advisory board. You often get the impression all partners are rather waiting for the really interesting markets and applications instead of exploiting them. As a reason for this it was mentioned, that overcoming borders between different subjects, and in particular between technology and economy, is pretty difficult. Instead, the exchange with applicants in an earlier stage would be very fruitful and this co-operation should be far more bindingly than it is today. Technology versed market research regarding key applicants, relevant regulations, market intelligence, or application driven specifications could be integral part of these shared production labs.

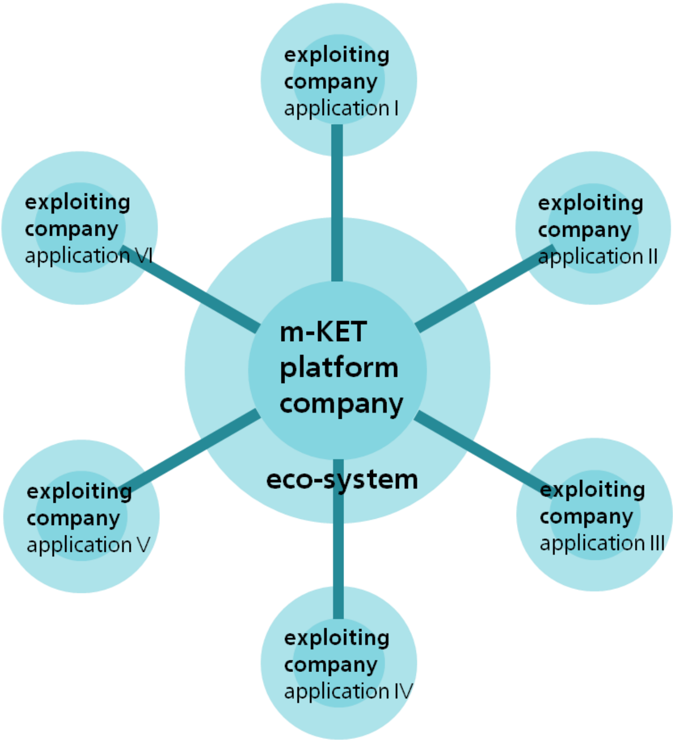
Another problem of the existing shared facilities is the timeframe. Often the start-up investment of EUR 60-80 million is made jointly by public authorities and private stakeholders – not at least because of publicity reasons. But no one is really eager to pay for running costs, which account at least for another EUR 5-10 million annually,. Usually, at best a timeframe of 5 years is covered. After this period, the whole activity comes under scrutiny or is even called into question.

Shape of production development projects: Co-operation of supplier and applicants

The industry representatives remarked co-operation regarding pilot production activities are most reasonable with partners along the value chain. Thereby, in particular down-stream partners are very attractive. As mentioned before, within technologies, markets, and applications are often unclear. Early collaboration or even joint development, with key customers is of tremendous help to reduce risk. But even though a joint development is very desirable, often the volume of technology based input products is far too low to start a testing production of processed goods. Different interviewees reported on an impasse: technology suppliers are reluctant starting pilot production activities because applications and markets are too vague. And processors refuse to commit to a new technology without testing.

To overcome this impasse, a new scope of joint projects could be reasonable: The technology supplier builds up a pilot production first and foremost to provide sufficient volume of precursor products for testing. And the processing company commits to overtake the new basis product for development purposes. While Key Enabling Technologies are by definition applicable in different tasks, this kind of joint projects should comprise different applicants with multiple use cases. Public funding should be granted for both, the supplier and the processor in order to trigger this co-operation. The support is, in addition to that, reasonable because both parties have to bear substantial risk. Industry representatives underlined, a modest public share for projects like this would be sufficient. More over the public support can be restricted to the first phase of pilot activities. If the fundamental question of potential applications and market volume is clarified, funding of process development and industrial series production can be borne especially by the technology supplier itself.

Figure 4: KET-development projects with pilot applicants



The advantage of a project scope like that is that one can show feasibility – even for various applications – and one gets an idea of prices and possible markets. Hence, one can reduce both, technology and market risk. This is in particular important to convince management and, if necessary, venture capitalists. In general, it is important not to neglect, investors are often unable to assess and quantify potential of technologies. But a founded application case in combination with a commitment of key customers is a strong argument for an investment.

This joint development with key customers or better to say, pilot applicants supports a definition of technological specifications and of a prioritization of different approaches for actual application reasons. In addition to that, the configuration of the manufacturing machine is target driven from an early stage on. And last but not least, a tangled project scope accelerates the overall development process significantly – the most decisive factor for a successful innovation.

3. Conclusions

3.1. Summary of policy perspective

Institutional funding of universities and research and technology organisations is the most important support from public authorities for the industry, regarding research in particular. For companies, academia is in the same time talent pool, source of inspiration, intelligence, infrastructure, testing facility, and a lot more. So, predominant role of public funding is to foster and finance high-level networking in order to make sure, academia and industry dismantle barriers. This applies for research in relation to both, product and production development – and hence for all application oriented pre-production activities.
The more complex production systems are, the more different technologies are concerned. This is why it comes up to the demand of application to widen the scope of calls. In Germany, more and more of the calls are oriented in solutions for a specific application and address explicitly several different technological subjects.
Another obvious trend is heading towards more concentration: In the beginning of the 2000s, public authorities supported many similar activities all over the country. Today, the federal government fosters singular regional competence clusters, especially with technology open instruments as for instance Top Cluster Competition or Research Campus.
Time plays an absolutely dominant role when it comes to process development. Successful top players would never ask for public funding when it has a decisive impact on time to market issues. That is why long approval procedures cause a negative selection of the best. Being aware of this, the public authorities of Germany try to do their best to accelerate time to contract – especially in close-to-market programs.

3.2. Summary of business perspective

One decisive barrier for an implementation of pilot activities is an impasse between KET-supplier and exploiter, who eventually integrates KET-intermediate products. Especially the management of the first is not willing to invest hundreds of millions in a pilot activity as long as applications and markets are at best vague; and the second sees no reason to make a statement on market opportunities as long as not being able to do some testing – however, for application testing the batch produced in the lab of the KET-supplier is often far too small. Result of this impasse is often that potentially valuable technologies are not exploited.
In general, it seems the key for KET-deployment lies in market validation. The knowledge of markets and applications seems to be surprisingly low within the cycle of KET-stakeholders. But, as long as the technologists from R&D-department are demanded to be the driving forces for KET-implementation, it is not surprising that market knowledge is not pronounced.
Another substantial barrier for KET-deployment is accounting and depreciation standards. From a book-keeping perspective expenditure for a new pilot facility is a common investment and competes with other investments e.g. for expansions. Even though a new production line promises a long term benefit, the expansion investment often guarantees a far safer return on investment. And to make things worse, for multi-KET products or production risks even rise: Here one has to take into account not only market risk, but doubled or tripled technology risk. The value proposition of KET-products has to be extremely high to compensate these disadvantages.
Innovation based on multi-KETs often depends not only on one determinant in one company but on many different management decisions. Within disruptive innovations, eventually a whole sector is involved. A production lab could be an important initial nucleolus to foster a highly tangled research and development process. Other than within a regional cluster, the participating companies do not necessarily have to be located in the same area but the technologists from the companies must be able to interact in closed operation cycles to accelerate the innovation process. For this eco-system development a joint production lab could be a fruitful instrument.

3.3. Recommendations to support pilot lines

Whatever kind of project shape pursued a substantial increase of market and application knowledge should be fostered. Asking the really successful companies, anchor point is always the market, not the technology. The effect of undervalued market knowledge are over-engineering, improper construction of facilities, not suitable timing, or in the worst – but not unusual – case drop of the whole technology. And this is not the question of technology push or market pull, but, it is the question whether technology finds a suitable application and comes up to the demand. Main task to increase deployment of technologies in general, is to dismantle barriers between technologists and applicants. And important to say, this assess of market opportunities should be done not by marketing but by technology experts.

When it comes to close to market activities, time plays a predominant role. On the one hand, time to market is for the innovating company an issue even more important than investment money. To be first in the market is absolutely decisive for the success of the whole activity. And especially within high-tech applications, months determine who gets the major share of the pie. Public authorities have to be aware, that they are stakeholder in this playing field when they put money in pilot activities.

Even though Key Enabling Technologies cover many different applications by definition it makes sense to concentrate on a few valuable applications. Especially, when it comes to multi-KET, an alignment of all the various technological competences is necessary. Both, selection of relevant participating technologies as well as the design of the facility depends on future application case. It is therefore recommended to centre even a KET-oriented funding activity around a specific application issue – in particular, when higher TRL-levels are addressed.

In the past, often technology based undertakings were expected to exploit technological potential with new companies in new markets – the dream of starting with a garage start-up and end up as a world market leader. This model turns out to be absolutely the exception in Germany. In most of the cases, already existing companies go into new technologies and try to adopt them for their existing markets. So, all kind of public funding activities should therefore make sure that the consortium is able to deploy the technology because of proofed access to the relevant markets. In order to keep manufacturing in Europe, it is in particular essential that several "economically healthy" key customers are located in Europe.

While the market is the anchor point for implementation of a successful innovation, public authorities should be aware that they are important stakeholders in the deployment of technologies, not only from a financing perspective. Company representatives expressed that if public authorities ever increase market volume for technology innovations, it would be far more attractive than financial support. One strong instrument could be public procurement. But even a stronger supporting instrument is regulation. Innovation is often based upon a successful overcoming of barriers. Regulation could be a stimulus to prepare for future world markets. Especially because many attractive key markets are highly influenced by regulations, for instance health care, energy, or transportation. Therefore, a sound and clear-sighted legal framework – not determined by old lobbying-networks – can boost technological development and means a competitive advantage for Europe.

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4.2. Interviews

The following companies/ ministries were interviewed for this country study:

Organisation	**Industry/policy**
Bayer MaterialScience	Industry
Clariant	Industry

GKD	Industry
InnovationLab	Industry
KUKA	Industry
NaMLab	Industry
Röchling	Industry
SGL	Industry
Federal Ministry of Education and Research	Politics
Federal Ministry of Economics and Technology	Politics
Minstry of Economics, Saxony	Politics

5. Annex

5.1. Overview of pilot activities in Germany

Name of pilot activity	Location	Discription	Internet
Fraunhofer pilot plant center (PAZ) for polymer synthesis and polymer processing	Schkopau	polymers: new products and technologies along value chain, monomers, polymer synthesis and polymer processing, to testing made-to-measure components	http://www.iap.fraunhofer.de/de/Forschungsbereiche/Pilotanlagenzentrum_Schkopau.html#!tabpanel-1
Fraunhofer Center for Chemical-Biotechnological Processes CBP	Leuna	bio refinery for lignocellulose: The aim is to establish an economical and sustainably integrated process for the complete usage of all the components of lignocellulose on a large industrial scale and to produce bio-based synthesized building blocks and polymers	http://www.cbp.fraunhofer.de/en/Projects/Project_1.html
INVITE	Cologne	open innovation platform for new production technologies and innovative processes for the chemical/pharmaceutical and biotechnology industries	http://www.invite-research.com/
Clariant Biotech & Renewables Center	Munich	pilot and demo facility for the synthesis of bio-ethanol on basis of cellulose from eg. wheat straw; process development (bio catalysis and bio refinery) for higher volume synthesis of second generation of bio fuels and bio based chemicals	http://www.clariant.de/C12576710018E579/vwWebPagesByID/FCF7D4059D4DC077C1257AD20052DB27
Application Center for Innovative Polymer Technologies	Potsdam-Golm	pilot plant for organic light-emitting diodes (OLEDs) and organic solar cells in an industry-oriented scale (on solid and flexible substrates)	http://www.iap.fraunhofer.de/de/Leistungsspektrum/anwendungszentrum.html#!tabpanel-1
Fraunhofer Research Institution for Organics Materials and Electronic Devices COMEDD	Dresden	pilot production of devices and fabrication technology based on semiconducting organic materials, so-called small molecules	http://www.comedd.fraunhofer.de/content/dam/comedd/common/annual-reports/2012_Jahresbericht.pdf
All Silicon System Integration Dresden (ASSID)	Dresden	organic semiconductors with a thematic focus on organic light emitting diodes and vacuum technologies: advanced wafer level packaging and system integration technologies, especially with respect to 3D wafer level system integration using Through Silicon Vias (Cu-TSC); leading edge 300 mm wafer process line for TSV formation, 3D device stacking and assembly	http://www.izm.fraunhofer.de/de/abteilungen/high_density_interconnectwaferlevelpackaging.html
InnovationLab	Heidelberg	organic electronics; 2 pilot lines: printing competence center materials, manufacturing technology and components for printed organic	http://www.innovationlab.de/de/innovationlab/uebersicht/

		electronics; ultra high vacuum equipment (the Cluster Tool) in which film systems with vapor deposited organic thin films can be studied without problematic vacuum interruptions and critical sample transfers	
Heliatek Gmbh	Dresden	organic photovoltaics (OPV) Goal: mass-produce organic solar films using a rapidly deployable and efficient roll-to-roll process	http://www.heliatek.com/uber-uns/was-wir-tun/
PLIANT - Process Line Implementation for Applied Surface Nanotechnologies	Dresden	1. pilot line for the fabrication of aligned carbon nanotubes on electrode surfaces in a roll-to-roll process; 2. pilot line: nanostructured functional coatings for thin film solar cells will be generated by applying thin film technologies at atmospheric pressure; 3. pilot line (planed) for surface pre-treatment processes of lightweight-construction components in aircrafts through atmospheric plasma sources	http://www.iws.fraunhofer.de/en/pressandmedia/press_releases/2013/press_release_2013-07.html
Advanced Mask Technology Center (AMTC)	Dresden	development of mask materials, processes, equipment, and IT methods for both conventional and next-generation lithographies	http://www.amtc-dresden.com/content/index.php?xmlfile=general.xml
ALD Lab Dresden	Dresden	Thermal Atomic Layer Deposition (ALD), plasma enhanced ALD, thermal flash ALD and molecular layer deposition (MLD); large batch, shower head and cross flow ALD reactors; solid and liquid precursor vapourisation and injection systems	http://www.cnt.fraunhofer.de/de/Kompetenzen/Functional_ElectronicMaterials/Front_End_of_Line/ald-lab-dresden.html
Nanoelctronics Materials Laboratory gGmbH (NaMLab)	Dresden	materials for electronic devices (target electron device): re-configurable devices; re-programmable silicon-nanowire transistors	http://www.namlab.com/pages/en_index.htm
Laboratory for Battery Technology (eLaB)	Ulm	share used pilot production facility for Li-ion batteries in automotive applications; development of close to serial production;	http://www.bmbf.de/press/3092.php

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