Fraunhofer Institute Systems and Innovation Research

Innovation dynamics and competitiveness of Germany in important green future markets

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Executive Summary

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Executive Summary

Background and Objectives

Protecting the environment and its resources is becoming ever more important, both nationally and internationally. As a result, the demand for environment technologies will continue to develop dynamically worldwide and the protection of the environment and resources is acting as an influential driver of innovation. There is increasing convergence between environmental and innovation strategies – modern environmental policy is becoming innovation policy. Politics has registered these emerging trends and using the slogan "ecological industry policy" has transformed them into one of the main missions of future environmental policy.

Environmental innovations are opening up considerable market potentials in domestic and international markets, and great **opportunities for growth and employment** for the European economy, and also for Germany. The report "Zukunftsmärkte Umwelt - Innovative Umweltpolitik in wichtigen Handlungsfeldern" (Environment: Key Markets of the Future – Innovative Environmental Policy in Important Fields of Action) presents a comprehensive analysis of the international capability of single countries and regions in 8 future key markets/fields for action. For each field, a disaggregated analysis was conducted for the individual product groups with the related relevant technologies.

Table 1: Overview of the examined fields and related product groups

Field of activity/ Future key-market	Related product groups
1. Energy generation	Renewable energies; power station and conversion technologies; hydrogen technologies; decentralized energy generation and new distribution concepts
2. Energy efficiency	Building technology; electrical appliances; industrial cross-cutting technologies; industrial processes and procedures
3. Material efficiency	Renewable raw materials; ecodesign
4. Sustainable mobility	Propulsion technologies; vehicle technology; transport infrastructure; emissions' reduction; biofuels; traffic systems
5. Sustainable water management	Water supply; waste water disposal; efficient water utilization; flood protection
6. Waste disposal and recycling/closed-loop economy	Collection; reduction; separation; recycling; waste treatment; energy recovery; landfilling; low-waste production processes
7. White biotechnology	Bio raw materials; cell factory; bio-processing
8. Environmentally relevant nanotechnology	Structural applications; sensory applications; (electro-) chemical applications

Whereas the first six of these eight key markets of the future can be characterized as environmental technologies in the narrower sense, the last two are (new) cross-cutting technologies. Great significance for environmental and resources protection is already being attached to them even though detailed technological specifications are not yet available.

The key markets examined mostly fall under the categories of higher-quality goods or leading-edge technologies. Quality features play an important role in competition. The knowledge base of an economy, but also its capability to transform knowledge into products and to market them, is among the most important prerequisites for future economic success. In this report, on the one hand, **patent applications** are analyzed as describing results of the R&D process. At the same time they are also regarded as an early indicator of future technical developments. On the other hand, **foreign-trade-related indicators** were constructed, which more intensively target the application and diffusion of technologies in R&D-intensive commodity markets. Because the fields of white biotechnology and environmentally-relevant nanotechnology are still emerging, greater uncertainties are associated with them than with the other fields of activity.

The strengths and weaknesses, but also the opportunities and challenges are identified in each field until the year 2020. The object of the whole research project, for which the main executive summary is presented here, also included ten in-depth studies of individual technologies. These are documented in separate publications. The results obtained from these studies were used to derive policy recommendations, with which this report concludes.

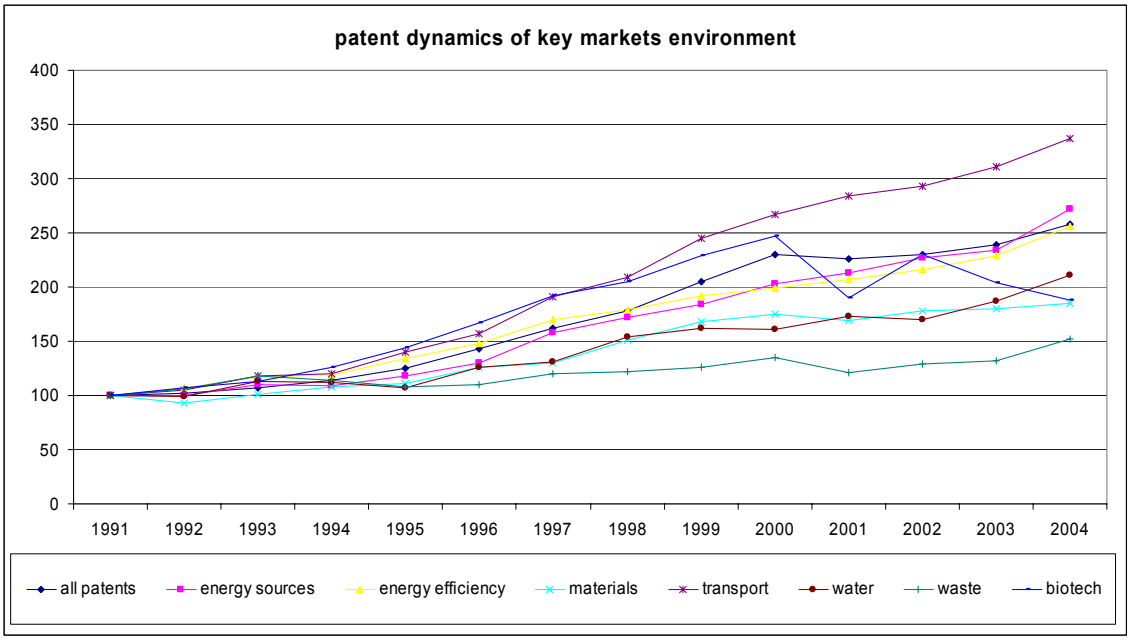
Aggregated overview of all fields of activity

It is possible to estimate the **innovation dynamics** in the fields of activity by observing the development of patent applications. Substantial innovation dynamics suggest that competition will be strongly oriented towards quality criteria. In this case, besides cost parameters, qualitative factors should gain significance in the competition for locations in the foreseeable future.

On the whole, strongly marked innovation dynamics can be observed in the examined fields. The field of sustainable mobility in particular has higher innovation dynamics than the average of all patent classes. Only waste disposal shows dynamics clearly below that of the average of all patent classes. Innovation dynamics in the case of water is split into very dynamic sub-areas which strongly target new concepts on the one hand, and supply and disposal concepts which are developing in a more restrained manner on the other. Nanotechnologies, as a new field, show evidence of very high innovation dynamics (tenfold increase, therefore no longer depicted in Figure 1). White

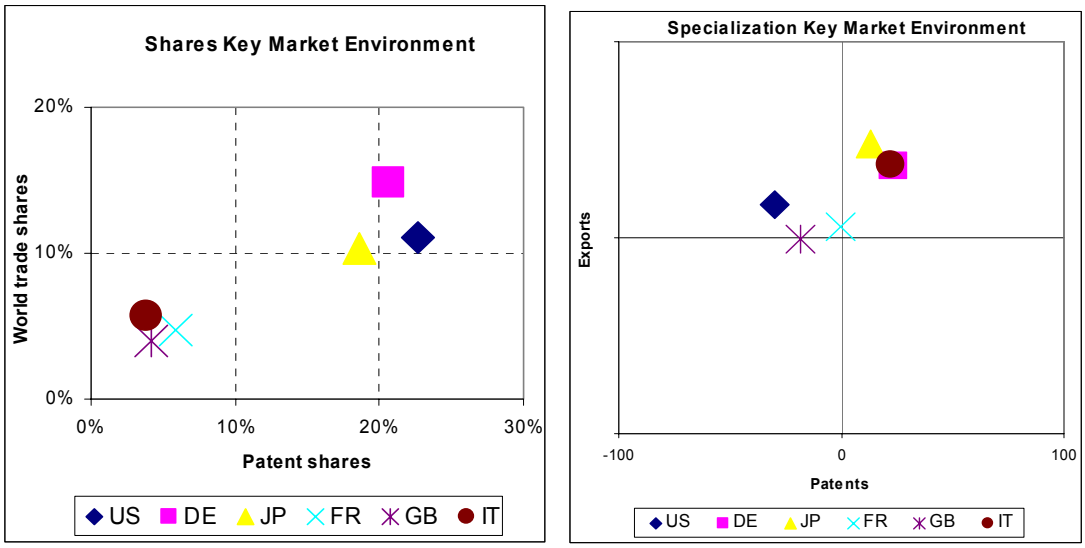
biotechnology showed signs of an equally strong development initially, but in the recent past has followed a more volatile course.

Figure 1: Innovation dynamics of worldwide patent applications (1991= 100)



The **technological performance** of the individual countries was investigated using innovation indicators. In the sum of the environmental technologies, it appeared that Germany, Japan and the USA were able to consolidate the largest shares not only for patents, but also in foreign trade. Both patent shares (PS) and world trade shares (WTS) are influenced by the size and general development pattern of the country. In addition, it is customary to construct specialization indicators. These indicate which status the especially interesting technologies and goods have in relation to the average of all technologies and goods within the country under scrutiny. Positive specialization indicators for patents (RPA: Relative Patent Advantage) and trade (RTS: Relative Export Shares; RCA: Revealed Ccomparative Advantage) show that the competences of the country in this area are above-average, relative to the average of all technologies and goods. The analysis of the specialization pattern underlines Germany's strong position – besides Japan and Italy. Environmental technologies thus feature quite clearly among Germany's particular strengths.

Figure 2: Shares and specialization of leading OECD countries in all future markets



From a **European perspective** as well, environmental technologies are regarded as being of particular significance in achieving the goals of the Lisbon strategy. However, the perspective shifts here to the competitiveness of the EU as a whole, compared with the economic powers of the US, Japan and China. Methodologically, the analysis of competitiveness required a different survey concept as the trade flows between EU countries are not assessed as exports. They were therefore analytically excluded from the analysis of European competitiveness. Thus the world trade shares of Europe are logically clearly below the total sum of exports of the individual EU Member States, which handle a considerable proportion of their exports to other EU countries. The result still shows, however, that the EU is by far the leading economic area for environmental technologies. The environmental future markets represent one area in which the EU has the best starting conditions to successfully implement the Lisbon goals.

The aggregated statistics conceal the considerable differences between the single fields of activity. These differences are, comparatively speaking, less pronounced for Germany, i. e. most fields exhibit both positive patent and export specialization. There are more pronounced differences in other countries, e. g. Italy, which demonstrates an especially high degree of specialization in the fields of energy efficiency and waste. Japan is very strong in the field sustainable mobility, but weaker in sustainable water management and waste. As the detailed analysis of the single fields of activity in the main report demonstrates, the differences between single product groups and disaggregated technologies are once again more strongly pronounced.

Figure 3: Specialization profiles of leading OECD countries

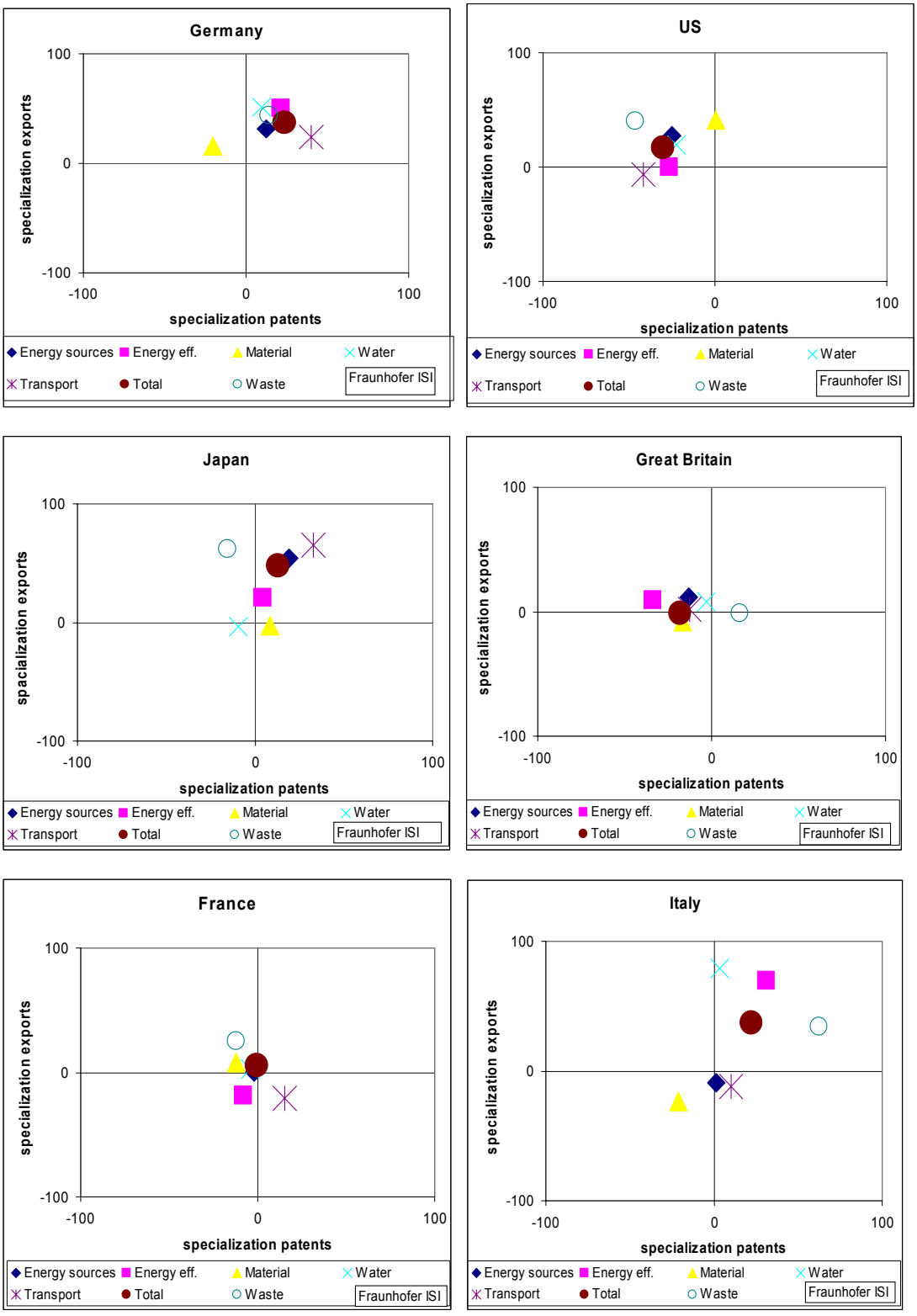
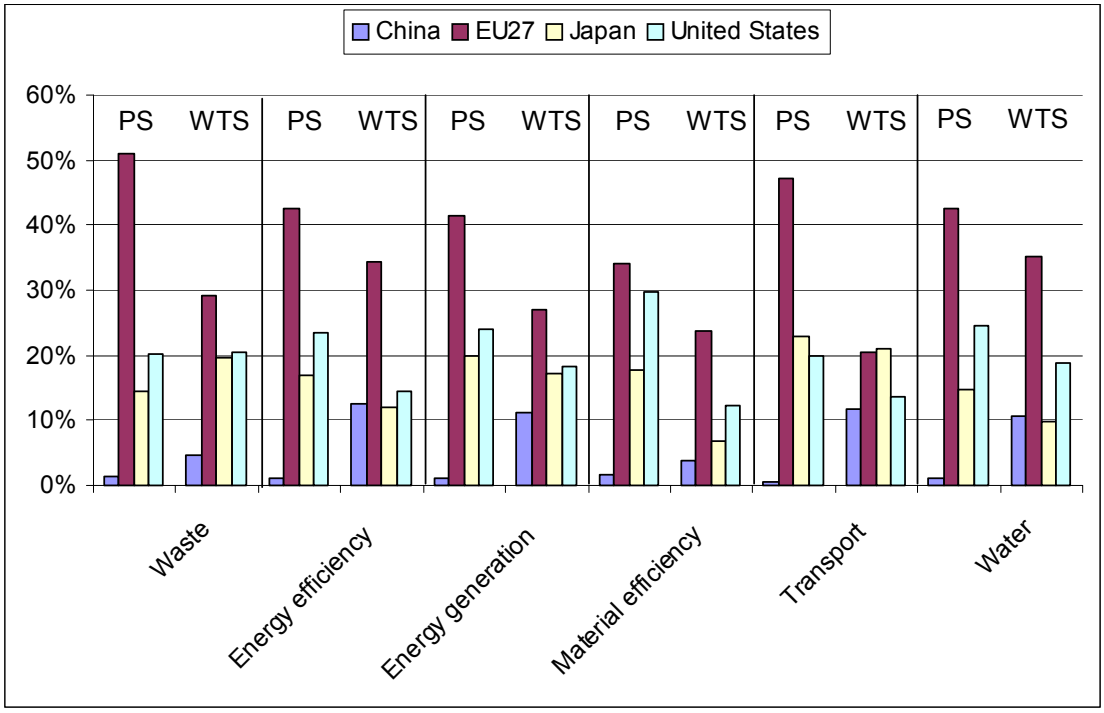


Figure 4: Patent and world trade shares of the large economic areas in the fields of activity (without intra-EU foreign trade in each case)



Overview of the results of the individual fields of activity

Germany's international competitiveness in **energy sources** is high. Germany's position – depending on the product group examined – is medium to very strong. With regard to patents, the strong position of renewable energies must be stressed (above all wind and solar thermal systems). Regarding exports, on the other hand, the other product groups tend to be stronger than renewable energies. This should be seen as a temporary phenomenon which is caused by the dynamics of market growth in Germany (e. g. 55 % of the world photovoltaic market in 2006) and the related import peaks. The turnaround observed in 2005 in the area of wind power shows how the coupling of technological market leadership and the establishment of a domestic market can also lead to export successes in the medium term. Important competitors here are Japan, the US and Switzerland. For single product groups, France (e. g. decentralized energy generation and distribution concepts), Great Britain (hydrogen) and China (photovoltaics) also display considerable strengths.

Table 2: Performance comparison of the various product groups in the field of energy generation

Technology	Patents		Foreign trade	
	Relative position D	Most important competitors of D	Relative position D	Most important competitors of D
Energy generation total	**High**	**JP, CH**	**Very good**	**USA, JP, CH**
Renewable energies	High	JP, (USA, CN)	Good (D largest market !)	JP, USA
Efficient and low-emission power stations and transformer technologies	Medium	JP, F, CH	Good - very good	USA, JP, CH, GB, F
Hydrogen technologies	Medium	JP, GB, (USA),	Good – very good	USA, JP
Decentralized energy generation and new distribution concepts	Low to medium	JP, FR	Very good	JP, FR

Table 3: Overview of strengths and weaknesses in the field of energy generation

Strengths	Opportunities
• Good knowledge base and technological potential in important technology fields • Considerable international competitive successes of technology producers; high world market shares of domestic firms as a good starting position for further turnover growth in a number of technology lines • Energy and climate policy as well as security of supply are important innovation drivers • Well-organized enterprises in renewable energies and power station technologies	• Strongly expanding world market • Re-investment required in the power station sector, which allows greater utilization of renewable energies and low CO_2 fossil fuel power stations • Discussion about new policy instruments for the generation of demand for increasing efficiency in electricity generation • Use price increases for energy sources to drive innovation
Weaknesses	**Challenges**
• Markets for renewable energies are still too small in other countries compared with Germany. Therefore export opportunities are restricted • Cost level of single technologies still too high • Lack of societal consensus on low CO_2 technologies using coal	• Use policy developments like the EU Directive for renewable energies more intensively to further strengthen technology lines • Take early account of competition from emerging economies strong in technologies • "Export" successful policies to other countries • More systematic integration of new technology fields like nano-/ biotechnologies

The strengths, weaknesses, opportunities and challenges identified for Germany in energy generation are depicted in Table 2. In the perspective up to 2020, the following technology-specific conclusions result from this situation, which are crucial for policy-making: First, demand must be strengthened, not only in Germany, but also in other

countries. Then Germany can really profit from its strong position in technology lines like wind power, solar thermal systems or carbon capture and storage (CCS). Successful policy innovations which contributed to Germany's success in the past (e. g. fixed payments for power fed into the grid from renewable energies) should be transferred to other countries in Europe and worldwide. The design of emissions trading should be explicitly directed towards achieving further innovation successes. In addition, Germany should utilize the new possible mechanisms of international technology cooperation on climate protection which are being discussed as a further development of the Kyoto Protocol.

Germany has managed to maintain a consistently strong to very strong position for all product groups in the field **energy efficiency**. In foreign trade, in particular, Germany heads the list with a world trade share of approx. 20 %. Export specialization is extremely pronounced in the product groups of building technology and cross-cutting technologies. Important competitors, besides Japan, are Italy and Switzerland. But Korea has also begun to specialize in the knowledge competences relevant for energy-efficient technologies.

Table 4: Performance comparison of the various product groups in the field of energy efficiency

Product group	**Patents**		**Foreign trade**	
	Relative position D	**Most important competitors of D**	**Relative position D**	**Most important competitors of D**
Energy efficiency total	**High**	**IT, KR, CH**	**Very good**	**IT, JP**
Energy-efficient building technology	Medium	IT, KR	Very good	KR, IT
Energy-efficient electrical appliances	High	KR, IT, JP	Good- very good	IT, JP, CH
Energy-efficient industrial cross-cutting technologies	High	KR, IT	Very good	IT, JP
Energy-efficient industrial processes and procedures	High	(CH, JP)	Good	IT, GB, JP, CH

In the perspective up to 2020, the following crucial, technology-specific conclusions can be drawn for policy-making: There is a chance to raise the demand for energy-efficient solutions in other countries resulting from the imminent implementation of the European Directive on energy efficiency and energy services. Germany should use this opportunity at home and in Europe to strengthen the demand for energy-efficient solutions. So far, energy efficiency in industrial cross-cutting technologies has been largely

overlooked. Therefore demand should be stimulated, e. g. by introducing energy audits, benchmarking systems and promotion measures for these technologies which so far have seldom been addressed by the policy framework. An intensive demand-side push could further stabilize Germany's very strong position as the leading supplier. As for energy sources, Germany should utilize the new mechanisms of international technology cooperation in climate protection for energy efficiency technologies as well.

Table 5: Overview of strengths and weaknesses in the field of energy efficiency

Strengths	Opportunities
• Good knowledge base and technological potential in important technology fields • Considerable international competitive successes of technology producers; high world market shares of domestic enterprises • Innovation and diffusion driven via energy and climate policy as well as issues of supply security	• Strongly expanding world market • Re-investment needed in power stations which allows a new balancing of energy demand and supply • Use new policy instruments (emission trading, energy efficiency directive) to generate demand and orient use towards innovations • Use price increases for energy sources to drive innovation
Weaknesses	**Challenges**
• Despite broad consensus on the role of energy efficiency, activities are unevenly distribution across the technology lines • Enterprises clearly less well organized than in the renewable energy field • Efficiency technologies do not play a "visible" role in the public eye	• Use energy efficiency guideline more intensively to further strengthen technology lines • Take early account of competition from emerging economies • "Export" successful incentive policies to other countries to create larger markets for the products • More systematic integration of "new technology fields" like nano-/ biotechnologies in the development of more energy-efficient processes and products

In the future market of **material efficiency,** Germany is not badly placed, but its starting position is less strongly pronounced than in most other fields. Analysis of the patent data shows that Germany's share of patents in all product groups has remained constant at 14 %. The EU-27 achieves an accumulated patent share of 37 %. In the product group of renewable raw materials, however, the share of the (industrialized) EU-27 declines over the course of time in favor of the emerging economies. The German RPA is slightly negative in all product groups, which indicates below-average patent activities, not only for renewable raw materials, but also for ecodesign. Germany should not miss the boat here as the increased utilization of renewable raw materials, as a source of energy among others, is a declared goal of the EU and the US. If the large economic areas are considered and intra-EU foreign trade is excluded from the world trade statistics, then the EU-27 possesses a world trade share of approx. 24 %. This is ahead of the US and is also clearly specialized with regard to RCA.

Table 6: Performance comparison of the various product groups in the field of material efficiency

Product group	Patents		Foreign trade	
	Relative position D	Most important competitors of D	Relative position D	Most important competitors of D
Material efficiency total	**High**	**US,JP**	**Very good**	**US, JP, FR**
Renewable raw materials	High	US, JP	Very good	BR, US, FR
Ecodesign	High	US, JP	Good	US, JP

Compared with renewable energies or energy efficiency, the discussion about the political and societal goals for a more efficient use of materials is less intensive. However, it can be foreseen that raw materials and materials will increasingly become a focus of politics worldwide, caused by the growing demand for these products in China, India and other rapidly expanding economies. Material efficiency can contribute towards cushioning the fluctuations of the world market prices for materials. Germany should expand its knowledge competences in order to assume a leading position in the area of material efficiency. Information campaigns, analogous to the information about energy technologies, could inform industry and consumers about the significance of material efficiency.

Table 7: Overview of strengths and weaknesses in the field of material efficiency

Strengths	Opportunities
• Germany has important actors in the recycling technology sector • Chemical industry traditionally well established in Germany, correspondingly good points of contact for e. g. synthetic additives, renewable raw materials as raw materials for chemicals or bio-synthetics • Founding of material efficiency agency, raising awareness for material efficiency, e. g. through a material efficiency prize	• Cost reductions for materials after potentials for lowering wage costs are exhausted • Company-internal potentials to increase material efficiency could be improved • Material shortages due to lower reserves lead to higher prices and thus to possible profitable utilization of more expensive technologies (e. g. recycling processes) • Formation of more enterprise networks to increase material efficiency profitability
Weaknesses	**Challenges**
• Hardly any targets for handling materials, not even for especially vulnerable raw materials • Material efficiency is only slowly being paid more attention • Comparatively low innovation dynamics in the field of ecodesign	• Maintain competitiveness, as Germany is poor in raw materials and would be especially badly hit by disruptions in raw material supply

On the whole, an outstanding starting position emerges for Japan and Germany in the field of **sustainable mobility.** However, there are different focuses within this field, which is also promising from a European perspective. Without intra-EU foreign trade, the EU-27 is in the lead with a world trade share of 19 %, together with Japan. Most importantly, however, about half the worldwide patents in this entire field originate in the EU-27. In the future, the crucial issue for the EU as a whole is to convert this knowledge into marketable products.

Table 8: Performance comparison of the various product groups in sustainable mobility

Product groups	Patents		Foreign trade	
	Relative position D	Most important competitors of D	Relative position D	Most important competitors of D
Sustainable mobility total	**Very high**	**JP, US, (FR)**	**High**	**JP, US, (FR, GB)**
Propulsion technologies	Very high	JP, (US, FR)	High to very high	JP, US, (FR)
Vehicle technologies	High	US, JP, (FR)	High	JP (US, FR)
Transport infrastructure	Very high	(US, GB, FR)	High	JP (US, GB, FR)
Emission reduction	Very high	JP, US	Very high	US (JP, FR)
Biofuels	High	US, JP, (GB)	:	:
Transport systems	High	UP, US, (FR)	Very high	US (FR, GB, JP)

From the preceding analysis, as well as from the observation of the current developments in transport and mobility, numerous strengths, weaknesses, opportunities and challenges emerge from both a European and a specifically German perspective. Some European countries occupy leading positions worldwide in individual technology areas, but the market is fragmented and there is the possibility of being insufficiently prepared in some areas to meet the increasing competition from large emerging economies. Europe has some isolated, outstanding policy approaches for stimulating new technologies through modern environmental policy measures. However, certain risks for the development, production and demand for vehicles with alternative propulsion methods result from the predicted demographic development as well as from the extremely diverse national legal framework conditions.

Table 9: Overview of strengths and weaknesses in the field of sustainable mobility

Strengths	Opportunities
• Outstanding competitiveness in traditional sectors • Entry to world market in new technologies (e. g. hydrogen and fuel cells) • Approaches to support innovations in new technologies by progressive environmental and transport policy • Advanced liberalization and standardization of the European markets in the area of road and air transport/travel	• Massively expanding world market in the area of logistics services • New policy instruments (emissions trading, road pricing) to generate and direct demand towards decentralized technology innovations • Cause early convergence of technology areas; build up existing competences in conventional vehicle technologies to enter new markets • Expansion and coalescence of the EU and promotion of a standardized railway network • Ambitious goals to promote renewable energies and to reduce climate gas emissions
Weaknesses	**Challenges**
• Technological deficits in single areas in some European countries (hybrid propulsion technology, alternative fuels, ship building and infrastructures) • No standard, widespread approach in the EU to create a market for highly efficient vehicles similar to the zero-emission-vehicle program in California • Strongly national-state-oriented railway structures prevent growth and intermodality in European railways	• Increasing competition of catching-up countries also for technologically high quality products • Resistance from national railway firms to liberalized access to the European railway network • Ageing European society and dwindling demand in passenger transport • Increasing lack of well educated staff in research and development as well as in transport services

Germany has a good starting position in **sustainable water management**. This is confirmed by its positive specialization in patents and in foreign trade, as well as a broad basis supported by outstanding competences in all product areas. The field is also promising from a European point of view. With a patent share of 44 % and a world trade share of 33 % – calculated without intra-EU foreign trade - the EU-27 is by far the leading economic area, ahead of the US.

Table 10: Performance comparison of the various product groups in sustainable water management

Product groups	Patents		Foreign trade	
	Relative position D	Most important competitors of D	Relative position D	Most important competitors of D
Water supply	Medium	CA, IT	Very good	IT, GB, JP
Waste water disposal and sludge treatment	High	FR, CA	Very good	IT, US, (JP, CH)
Water utilization efficiency	High	IT, KR	Very good	IT
Flood protection	High	GB, KR, NL, FR	Good	US, CH, GB, FR

The strengths, weaknesses, opportunities and challenges depicted in Table 11 can be derived for sustainable water management in Germany. Besides technology-specific aspects, two other important factors must be considered in a comprehensive analysis of sustainable water management. First, the regulation of water supply and waste water disposal, which is coupled with emissions and their prescriptive limits, can be regarded as an important driver of innovation. Second, the water management structures in Germany are organized on a rather small scale and any departure from a conventional solution is frequently beset with obstacles. One consequence of this is the low domestic demand for innovative solutions for sustainable water management, despite the existing technical-economic incentives and the future importance of these technology lines.

Table 11: Overview of strengths and weaknesses in the field of sustainable water management

Strengths	Opportunities
• Very good technological position for central components • Considerable international success of technology manufacturers • Innovation and diffusion driven by environmental policy	• Massively expanding world market • Massive reinvestment needs can act as a chance for application of innovative (decentralized) solutions • Use changes in environmental regulation for more decentralized technology innovations • Bring about timely convergence of technology areas
Weaknesses	**Challenges**
• Unsatisfactory demand for new developments, in particular for unconventional solutions • Weak international orientation of water management firms • Lack of integration of numerous (smaller, public) water management firms in the innovation system • Regulations not standardized, e. g. between the federal states	• Divert export successes swiftly to expanding innovative technology lines • Increase the specialization advantage in the knowledge base, not only in established but also in less traditional technology lines • Opening the regulatory regime to new solutions • Develop internationally competitive water management enterprises

On the whole, Germany's position in this field is good. Germany's RPA was positive, but declined in the periods under observation. Half of the worldwide patent applications were filed by the EU-27. Germany is the world leader in foreign trade, ahead of the USA and Japan. Among the large world economic regions, the EU – calculated without the intra-EU foreign trade figures – is clearly ahead and its world market share is approximately double that of the US, which takes second place. Japan and the US are, however, also in a good position based on RCA as the benchmark.

The need for **waste disposal and recycling** technologies will continue to grow in the future. Due to the increase in regulations concerning recycling quotas as well as emission-reducing measures, a growing international demand for these technologies can be reckoned with (policy-driven development). In addition, secondary raw materials are becoming increasingly competitive as a result of rising primary raw material and energy costs (market-driven development). However, the market volume may decrease due to measures to reduce waste (e. g. decoupling waste generation from economic growth).

Table 12: Performance comparison of the various product groups in waste disposal and closed-loop economy /recycling

Product group	**Patents**		**Foreign trade**	
	Relative position D	**Most important competitors of D**	**Relative position D**	**Most important competitors of D**
Waste and recycling total	**Very high**	**US, JP, IT**	**Very good**	**US, JP, IT**
Collection	High	GB, US, ES	Very good	US, IT
Crushing	High	US, JP	Very good	IT, JP
Separation	High	US, GB	Good	US, IT
Recycling	Very high	US, JP, IT	Good	US, JP
Waste treatment	High	US, JP	Very good	IT, US, JP
Energetic utilization	High	JP, US, IT	Very good	JP, US, IT
Landfilling	Medium – high	JP, US, KR	Good	US, JP, GB
Low-waste production processes	High	US, JP, KR	Good	JP, US

Table 13: Overview of strengths and weaknesses in the field of waste disposal and recycling

Strengths	Opportunities
• German actors well placed due to top-performing industry and research as well as high environmental standards in the international community • Collection of waste as well as presumably first sorting will remain local; jobs remain at the place of waste origin • Selective collection and reprocessing in Germany as well as in several other EU Member States is highly developed and modern	• Rise in raw material prices improves competitiveness of recycled materials; stronger market-driven demand for closed-loop technologies • Optimization of recycling end-of-life products • Increasing scarcity of raw materials plus new technological processes support emergence of new markets (comparable with PET recycling) • Transfer of experience regarding collection and re-processing to other countries (e. g. EU members, EU candidate countries, threshold countries)
Weaknesses	**Challenges**
• Labor and landfill costs for residual waste are relatively high compared with other countries; work-intensive activities which are not locally bound, are outsourced to cheaper countries (especially second sorting and synthetics recycling) • Fully automated processes reduce consumers' problem and environmental awareness	• Reduction of waste amounts can lead to a reduction of total market volume • Increasing automation (material recognition and separation processes) can lead to a considerable reduction in number of jobs • Fully automatic sorting process makes sorting waste by the consumer obsolete; societal learning processes necessary, which should be politically supported

On the whole, Germany's competitive position in **white biotechnology** can be certified as relatively good in an international comparison. The traditionally strong chemical and biotechnology industries in Germany already have turnovers of several 100 million euro per year. Europe's biotechnology patent share is still below average compared with Japan and the US, but the gap is getting smaller. The EU countries specialize in different fields. In foreign trade, Germany is particularly successful in international competition in the white biotechnology product group of bio-processing. The EU has large world trade shares; the individual Member States are diversified with regard to technological performance.

Table 14: Performance comparison of the various product groups in white biotechnology

Product group	Patents		Foreign trade	
	Relative position D	Most important competitor of D	Relative position D	Most important competitor of D
White biotechnology total	**High**	**US, JP, FR, GB**	**Very good**	**US, JP, FR, GB**
Bio raw materials	Medium – high	US, JP, FR	Good	FR, NL, US
Cell factory	Medium	JP, US, DK	Medium	IT, CA, GB
Bio-processing	High	US, JP	Very good	US, FR, GB

The future development will be characterized by continued growing demand on the one hand and by increasing differentiation of the technical solutions on the other. Of the sub-fields of white biotechnology, the greatest market potentials are expected for biofuels, fine chemicals and biopolymers. The realization of these potentials will, however, depend on the price development and availability of renewable raw materials. One important question to be clarified, besides the utilization competition for renewable raw materials, concerns the environmental-friendliness of individual processes. Finally, it must be taken into account that white biotechnology is undergoing a dynamic development in the US and South-East Asian countries.

Table 15: Overview of strengths and weaknesses in white biotechnology

Strengths	Opportunities
• Good economic starting situation in the sub-field of white biotechnology; Germany has a good position in foreign trade • Good location conditions, strong research and industry landscape • High EU share in worldwide patent applications	• High potentials for energy and resources efficiency of biotechnology processes • Rising number of patent applications indicate growing markets
Weaknesses	**Challenges**
• Lack of national research strategy or roadmap with thematic focuses • Applications of white biotechnology dependent on raw material prices; products therefore not always competitive at present • Germany has a poor competitive position in the sectors of cell factories and bio raw materials	• No "national bio-refinery concept" exists and should be developed • environment effects of bio-synthetics, bio-fuels and bulk and fine chemicals need to be clarified in individual cases (life cycle assessment) • High innovation dynamics in Asia (Japan and China) • On the whole stronger specialization in BT-patents in CA, USA

With a share of 45 %, the EU-27 is in a favorable world trade position with goods which could potentially be manufactured using **nanotechnology**. The EU-27 is generally relatively competitive in nanotechnology. With one tenth of world trade, Germany is also well placed in the international scene. However, the patent analysis reveals that Germany and other European countries still have to catch up with the US in the field of nanotechnology. A positive aspect for Germany is its relative strength in the product group of chemical applications, as this is the fastest growing patent area among nanotechnology.

Nanotechnology is regarded as one of the key technologies of the 21st century. Considerable turnovers can already be achieved today with products which can only be produced using nanotechnology. At present, it is not possible to define the exact application areas for nanotechnology in the environmental sector. Important questions to be clarified concern, on the one hand, the clarification of and communication with regard to the possible risks involved in nanotechnology and the establishment of rules to regu-

late the safe and responsible handling of nanotechnologies. On the other hand, it must be remembered that products using nanotechnology may be rapidly implemented in other countries, which will intensify the pressure to act even more.

Table 16: Performance comparison of the various product groups in the field of nanotechnology

Product group	Patents		Foreign trade	
	Relative position D	Most important competitors of D	Relative position D	Most important competitors of D
Nanotechnology in total	**High**	**US, JP, FR**	**Very good**	**US, JP, FR, GB**
Structural applications	High	US, JP, FR	Good	US, JP, FR
Sensory applications	High	US, JP, GB, FR	Good	US, JP; KR
(Electro-)chemical applications	High	US, JP, FR	Good	US, JP, FR, NL

Table 17: Overview of strengths and weaknesses in the field of nanotechnology

Strengths	Opportunities
• Strong in basic research; but ousted from place three in publications by China (after USA and Japan) • Widely differentiated research landscape: strong participation of non-university research institutions also in nanotechnologies • Positive prevailing mood: population open to nanotech innovations • Next generation interested: growing demand for new training and study courses in nanotechnology • Good industrial basis: already approx. 600 enterprises (of which approx. 480 SMEs) involved in nanotechnology	• More versatile and efficient materials: new characteristics and functionalities for conventional materials • Creation of new application diversity: materials with tailor-made characteristics, in particular via self-organizational processes • Competitive advantages: nanotech innovations possible across all branches • Good innovation climate: society integrated in dialog about chances and risks • Potential investor interest: high in the area of nanotechnology • Risk communication: a dialog process established which concerns all societal groups and contributes to understanding as well as acceptance and simultaneously examines the risks
Weaknesses	**Challenges**
• Implementation deficit: despite leading position in Europe, large gap in patents and number of involved firms compared with US and South-East Asia • Difficulties for start-ups: insufficient venture capital; bureaucratic obstacles • Information deficits in industry: in part potential investors do not have a clear picture of the chances for nanotechnology, but the same is true for industry which has produced and utilized nano parts for decades without using the label "nanotechnology"	• Rapid implementation of research results in products which are also manufactured in Germany • Scientific risk assessment: possible toxic effects of nano particles not yet sufficiently examined • Safer, more responsible handling of nanotechnology: consumer education and consumer protection, health and safety standards at work • International standardization, standardization and examination strategies: more active role for Germany necessary

Conclusions

Germany has very good starting conditions for **realizing economic success** in the future key markets examined here. To attain this success, continuous and, in some fields, clearly intensified efforts will be necessary, particularly as new competitors are entering the market. Innovation dynamics and Germany's competitive position will only be able to be improved by promoting conditions under which technologies in the future markets can be further developed. More recent innovation research has brought numerous insights which emphasize the significance of learning successes in the market as well as the path dependency of technological developments:

- The development of technologies is not linear, but is characterized by numerous feedbacks between research, development and application. Therefore early market penetration is a prerequisite for the targeted further development of technologies.
- The emergence of a dominant design in technologies is a process which takes time. At the same time, diversity is necessary: the technologies must be further developed in competition with each other. Restricting promotion to only a few technologies is not appropriate from an innovation policy viewpoint.
- A successful innovation system is characterized by networking between research, development and application. The essential functions of an innovation system are influenced by the interplay between the different actors in the innovation process. Soft context factors play an important role here (e. g. situative conditions for action, for policy design and impacts). Their significance has been confirmed by the results of research on the environment and innovation.

In the sector of environmentally-friendly technologies, the **development of demand** is strongly influenced by environmental policy measures. Ecological industrial policy comprises thus not only traditional supply-oriented measures to strengthen R&D capacities, but also environmentally-friendly policy measures in the sense of a demand-oriented innovation policy. It is necessary to construct an innovation-friendly regulation system, which, on the one hand, promotes networking, but also, on the other hand, provides actors with long-term, reliable framework conditions and at the same time incentives for further innovation. When faced with the task of implementing such an ecological industrial policy, the following fundamental challenges must be tackled:

- Not all technology lines in the future key markets can be simultaneously promoted with the same degree of intensity. **Priority-setting** is mandatory. The criteria used in the selection process should be linked with the preconditions for establishing lead markets. Furthermore, they should reflect environmental policy priorities and also take the institutional framework conditions and the situative context factors into consideration.

- Ecological industrial policy must consist of a context-dependent **mix of instruments**. These include dialog-oriented instruments, the classical instruments of state technology policy, and the trade policy instruments, as well as support and guided restructuring of actor networks. Demand-oriented innovation policy is crucial and this needs to be realized via ambitious environmental policy. An environmental policy orientation is called for in which the innovation impacts of the individual measures are systematically analyzed and integrated into the design (process).
- Admittedly, it is not possible to unambiguously assign instruments to innovation phases. However, the importance of the different functions seems to differ according to the innovation phases. In the early innovation phase, the decisive factors of success comprise new knowledge, supporting the search process, networking and development of legitimacy. In the second phase, which is characterized by market expansion, market formation and the supply of resources become more important.
- **Long-term orientation** is essential for the efficiency and efficacy of the technology policy toolkit. This makes it possible for the actors to adapt to stable framework conditions.
- The single instruments are discussed in the context of different specialist policies and at different levels. Therefore, **policy coordination** is a major theme. Besides department-internal policy coordination, horizontal coordination between the individual operating bodies at the same political level – e. g. federal ministries - is also necessary. At the same time, vertical policy coordination is mandatory in order to dovetail activities at EU level with national and regional activities.