to develop new programmes specifically for R&I policies in eastern Germany. Neither is there any need to plan new investment programmes, which would only benefit the old Laender. Accelerating or maintaining the convergence process is a concern for structural policy-makers rather than innovation policies. A powerful structural policy instrument are the investment subsidies under the Joint Project "Improving the Regional Economic Structure" (GRW).[132] The Laender should make more use of the scope available to them in order to focus subsidies more on promising sectors of the economy in regions with high development potential.[133] The Expert Commission feels that the instrument of investment subsidies shows deficits both in terms of its efficiency and its effectiveness. Entitlement to investment subsidies only require general conditions to have been met (such as an initial investment by manufacturing companies, production-related services, or the hotel industry). In view of budgetary constraints, it would make more sense to concentrate the support funds.

– The coalition agreement between the parties CDU, CSU, and FDP proposes to evaluate the external industrial research institutions in the new federal states. In consultation with the Laender, the Federal Government will then decide which institutes will be integrated in the research organisations supported by the Federal Government and Laender.[134] The Expert Commission approves of offering institutional support to institutions carrying out important tasks in knowledge- and technology transfer, which can demonstrate adequate quality of research. However, the Commission does not believe that enforced integration in the Fraunhofer Society, the Helmholtz Association, the Max Planck Society or the Leibniz Association would have the desired effects. The Federal Government and Laender could encourage such integration processes where appropriate, but should otherwise leave this up to the institutions concerned.

– The Expert Commission has repeatedly called for the introduction of tax incentives for R&D, improved conditions for the provision of company with equity, and improved framework conditions for business angels and providers of venture capital. This would also have positive effects in structurally weak regions, (e.g. in eastern Germany), where the equity base for companies is particularly weak, little venture capital is available, and large companies are lacking. Innovative new enterprises and financing innovative projects in SMEs would be eased considerably by such measures.

ELECTROMOBILITY B 4

A revolution in the mobility sector

The transformation of the energy systems towards more sustainability is gaining speed. Today, Germany generates 16 percent of its electricity from renewable sources, largely free of CO2 emissions.[135] By 2020 it is planned to at least double this proportion.[136] As a consequence, a largely CO2-free transport system will emerge in the medium- to long-term. This development will be accelerated by the insecurity of supplies of fossil fuels, rising fuel prices, and state regulations driven by climate goals.

Electromobility (Box 12) offers the opportunity to contribute effectively to this transformation process. In addition, it will be possible to achieve a new quality of living in towns and cities. Electric vehicles have the advantage that they release no harmful local emissions[137] and can be designed to

Electromobility BOX 12

Electromobility refers to the use of electrically-powered vehicles, in particular cars and light goods vehicles, but also electric scooters and bicycles and light-weight vehicles, together with the associated technological and economic infrastructure. The various vehicle types under discussion are listed in Table 6.
Both electric power and hydrogen fuel require the construction of appropriate infrastructure. Setting up the hydrogen infrastructure is much more complicated than providing power supplies. Hybrid vehicles are already commercially available, and Asian companies were pioneers in their introduction. Battery electric vehicles currently only find niche applications, e.g. as light-weight vehicles produced in small series. Many car makers have announced that models will go into series production in the coming years.

TAB 06 **Electromobility – types of vehicle**

Type of vehicle	Use of power grid	Key characteristics
HEV – hybrid electric vehicle	Independent of power grid	IC engine plus electric motor, Braking energy recovered to charge a battery
PHEV – plug-in hybrid electric vehicle	Reliance on power grid	IC engine plus electric motor, Battery rechargeable from grid
BEV – battery electric vehicle	100% dependence on grid	Electric motor, battery recharged from grid, (Braking energy recovered)
FCEV – fuel cell hybrid electric vehicle	No power from grid	Fuel cell, electric motor

Source: EFI.

cause less noise in urban traffic. This opens up possibilities for completely new architecture and urban planning. This applies in particular for megacities, which are currently growing very rapidly.[138] The introduction of electromobility thus acquires a cultural dimension.
Determined, long-term initiatives by the Federal Government are necessary to promote research and innovation in the field of electromobility and to support the marketing of electric vehicles if Germany is to reach essential targets such as a significant reduction of CO2 emissions[139] and the medium-term security of fuel supplies. German policy-makers and the private sector must make intensive efforts to achieve a leading international role in the field of post-fossil mobility.

Integrating electromobility in a comprehensive mobility strategy

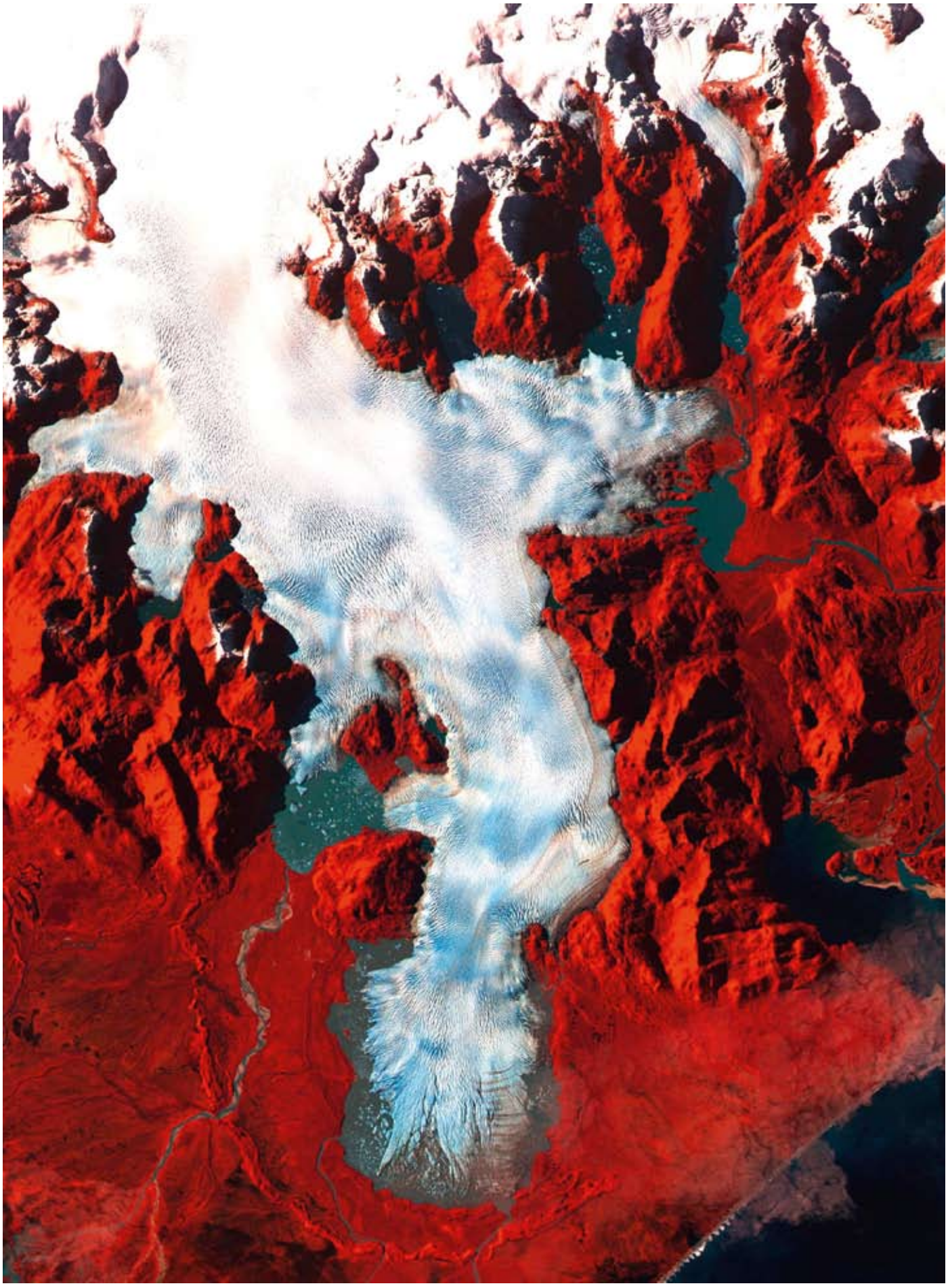
The development of electromobility must be integrated in a multimodal strategy for future traffic and transport systems. These systems cannot yet be predicted with sufficient accuracy. When developing electric cars, attention should therefore be paid to technological adaptability and the flexibility of the concepts.

Against the background of climate change, the transition from fossil to post-fossil mobility must be tackled urgently. In view of the technical constraints, the first objective will be private transport for short trips (100 to 150 km).[140] But it can be assumed that technological developments will make it possible to increase the range in the medium term.

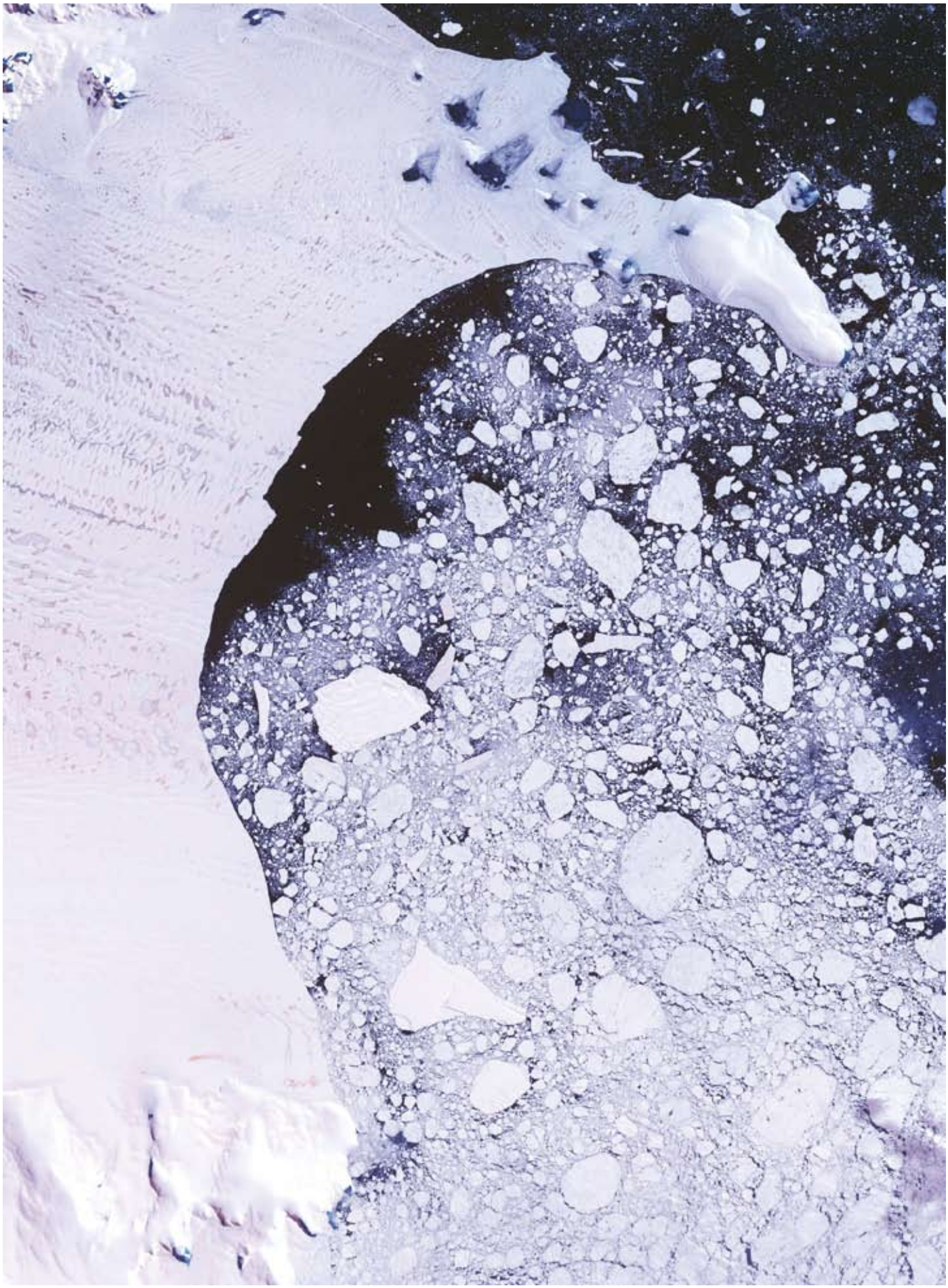
It seems that very long distance individual mobility will continue to require fossil energy for some time to come. Hybrid electric vehicles may cater for some medium distance journeys for a certain period.[141] There will probably be a shift away from the dominant universal profile of cars, which requires that a single vehicle be suitable for short and long journeys, for urban trips and for travelling. Electric rail travel will also play an important role in the strategies of the future. This will apply in particular for inter-city travel. In short there will be a paradigm shift in the entire system of traffic and transport, in which electromobility will play a key role.

Electromobility – a key element of sustainable energy supplies

In the context of “more intelligent” electricity networks, so-called Smart Grids (Box 13), electromobility is likely to become a key factor for stability and economic viability. Vehicles which are not being used can the be recharged by means of optimised remote control whenever there is an over-supply of power available in the grid. With a sufficient number of such vehicles, consumption and generation over the power grid can be harmonised without signif-



Patagonia ice cap



Larsen Ice Shelf, Antarctic

BOX 13

Smart Grids

Information and communications technologies are becoming increasingly important in the power supply sector. This will lead to the development of power supply networks with constantly improving "technical intelligence". These so-called Smart Grids will allow the optimised introduction of decentrally generated power into the distribution network. This includes the regulation of the decentral power generators, in particular those based on wind and solar energy, as well as combined heat and power generators. Power consumers will also be integrated and regulated much more than in the past. This can be supported by variable tariffs and an intelligent response by consumers to the prices. These measures will make it possible to link power consumption and generation dynamically in sustainable power supply structures. Future grids will also be able to utilise stored power, for example in electric vehicles, in order to stabilise the power supply.

icant losses. This will be a particular advantage if there is a large proportion of power from fluctuating sources (e.g. from sun and wind).

Conversely, part of the power stored in the batteries of stationary vehicles can be fed into the grid remotely if there is a short-term undersupply of power. A pre-requisite here will be that the vehicle batteries must be capable of more recharging cycles than are required to operate the vehicle. Future vehicle batteries will very probably have this capability. Electromobility and a sustainable strategy for energy supplies and use are directly linked with one another. This makes it urgently necessary for the automotive sector and the power industry to cooperate closely.

Scientific and technological progress in Germany

The Expert Commission is persuaded that the large-scale introduction of battery-operated electric transport systems is technically feasible. This applies in particular for operating life, number of recharging cycles, weight and cost of batteries, including their potential further use; the availability of raw materials and the feasibility of an extended life-cycle of materials; the possibilities for power electronics and the electric motor; the energetic links between the vehicles and the power grid and the increased use of lightweight construction techniques in the automotive sector. There could be bottlenecks in material supplies, e.g. for lithium, as in other fields of high technology, in particular if there are shortages in important raw materials due to the limited number of suppliers.

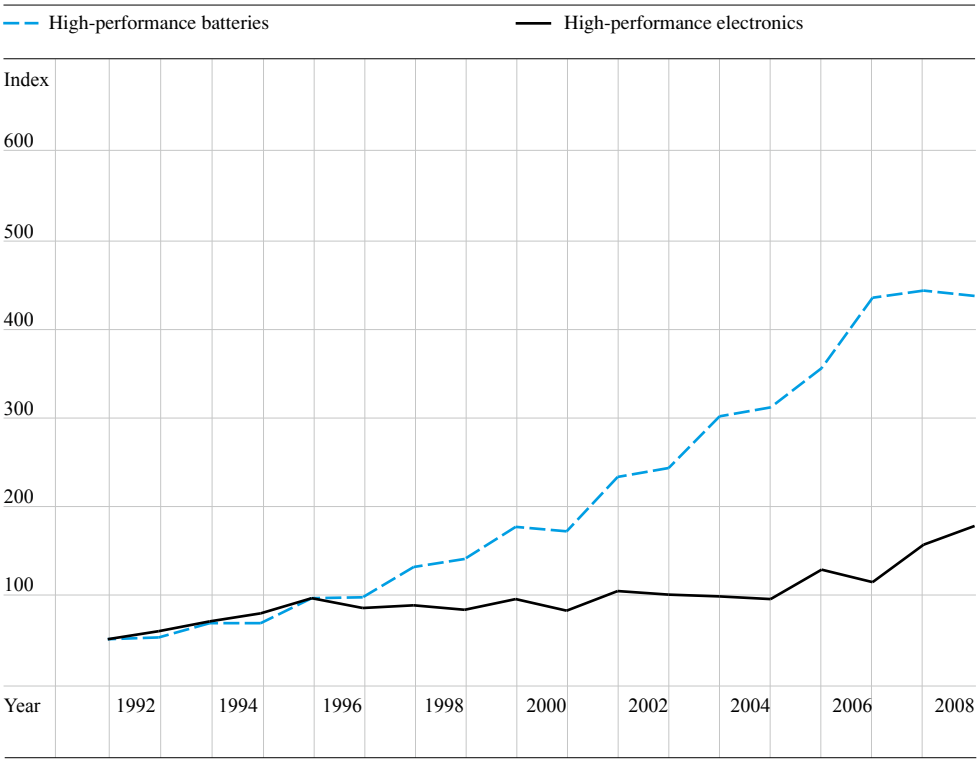
Although a leader in the conventional automotive industry, Germany has some catching up to do in the field of electromobility if it is to reach the worldwide level of technological development and benefit from the described paradigm shift in the transport sector. It is a considerable way behind.

Deficits in science, technology development and training

Key technologies for the electromobility are vehicle batteries, electric motors, mechanical drive strings, power electronics, lightweight construction, and the infrastructure for linking the vehicle systems with the power grid (charging and discharging batteries to support the power supply). Germany is in a poor position in the important sector of vehicle batteries. In power electronics, Germany has at best years a middling position. In both cases, the leadership in research and technology lies with the Asian countries, in particular Japan, Korea and China.

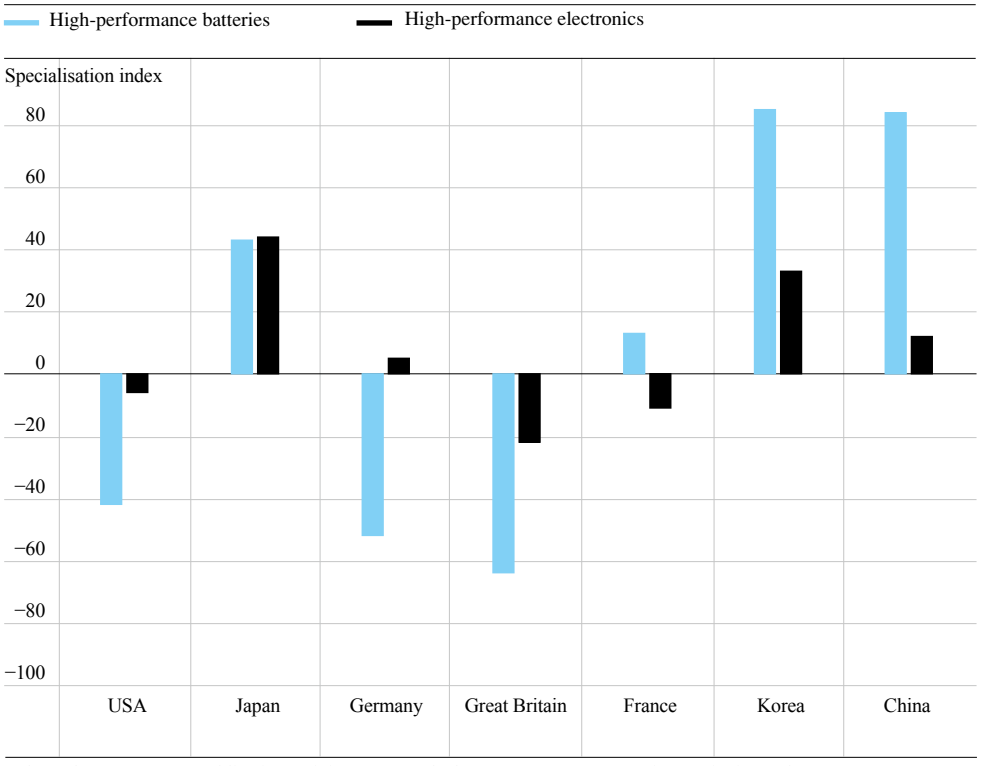
In the past decade in Germany, many Chairs in electrochemistry (the key discipline for battery technology) have fallen vacant or have been given a changed scientific orientation.[142] The focus in research and teaching shifted to other fields which were thought to offer more promise. This trend at the universities was not compensated for by increased activities of the non-university research institutions. It is therefore not surprising that the publication statistics of German scientists in electrochemistry, and in particular in battery technology, have been below average (Box 14). The self-organisation of the German science system has failed in this case from a macroeconomic point of view. The patent balance does not show a more promising position for German companies or research institutes (Box 15).

FIG 13 **International peer-reviewed[143] publications on high-performance batteries and electronics**



Index: 1995 = 100.
Source: Science Citation Index (STN).

FIG 14 **Specialisation[144] in international peer-reviewed publications in selected countries in the fields of high-performance batteries and electronics 2008**



Index value 0 = average publication activity, > 20 much above average. Source: Science Citation Index (STN).

BOX 14

Electromobility – Publications in an international comparison

An analysis of publications relating to high-performance batteries from 1991 to 2008 shows a worldwide increase in peer-reviewed publications, with growth rates of some 13 percent per annum (Fig. 13). The evaluation of country specialisation shows above-average activity in Japan, Korea, and China (Fig. 14). This situation for high-performance batteries is reflected in the wider field of "electrochemistry". Here too the publication figures are steadily increasing. There is considerable specialisation activity in Japan, Korea and above all China. In comparison, Germany has a less well developed specialisation.

There is also a worldwide upwards trend in publications on power electronics, which has increased further in recent years. Here too the east Asian countries are very active, in particular Japan. The German index is slightly above average, and the specialisation is above that for USA, Great Britain and France, although it is much lower than for the three Asian countries.

Meanwhile extensive measures have been introduced at some universities in order to establish research capacity in the neglected areas. In non-university research institutions research associations and electromobility sections are being set up.[145] The Deutsche Forschungsgemeinschaft (DFG) has started a research initiative on lithium high-performance batteries.[146] However, it should not be forgotten that these activities will take time in order to develop their full potential. The shortage of specialists could not be overcome immediately. This makes it all the more important to integrate the universities in the new research initiatives, so that personnel can be suitably qualified as quickly as possible by the integration of research work and teaching.

Assessing the current situation in Germany

The development towards electromobility is not only important and desirable for the above-mentioned reasons. It also offers extremely good economic opportunities, in particular for a high-technology country with considerable innovation potential, such as Germany. The leading position of Germany in the automotive sector is based in the drive area on the technology of internal combustion engines. There are no signs yet that it will be possible to achieve a similar position in electromobility. Other countries started earlier and have invested more massively in electromobility than Germany has. The large part of the value creation for smaller electric cars is from the batteries (about 50 percent), and electric drive systems, including the power electronics (about 20 percent). In both fields other countries are better positioned than Germany. This is shown among other things by the patent analyses (Figure 16).

Science and industry must direct all their efforts towards post-fossil mobility. In view of the current deficits in battery development the German industry will have no choice but to enter into partnerships with international manufacturing companies (in particular from Asia). But Germany should endeavour to develop its own strengths in battery technology.

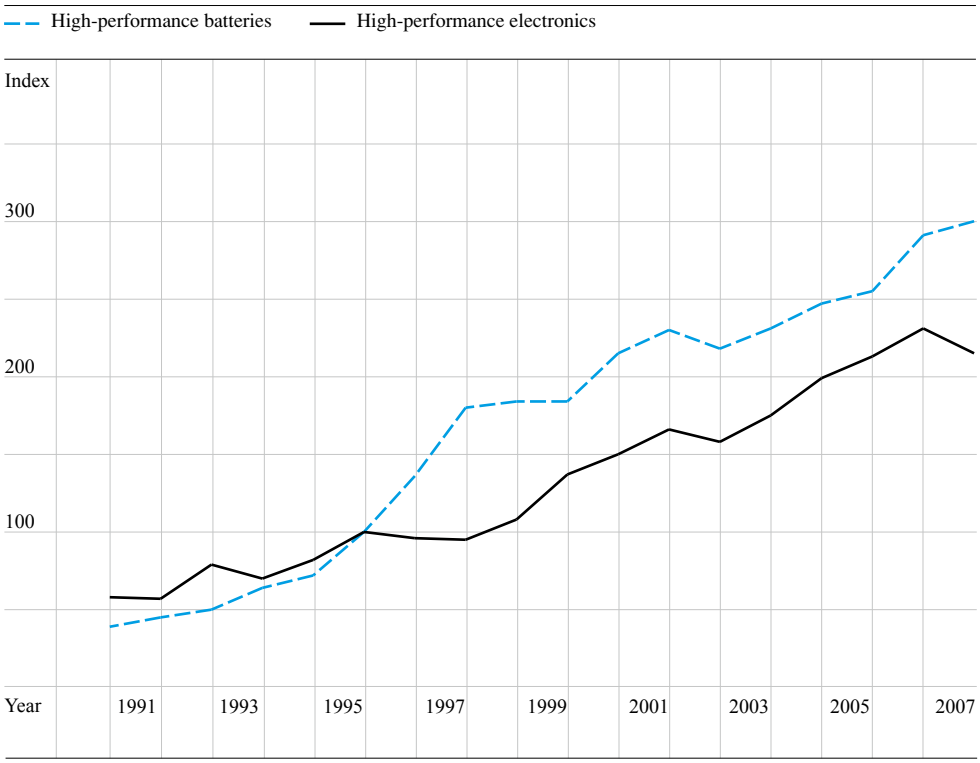
BOX 15

Electromobility – Patents in an international comparison

The analysis of transnational patent applications (PCT applications or applications to the European Patent Office) for two key components of electric cars – high-performance batteries and power electronics – shows a sharp increase in applications (Fig. 15). In 1995 there were 850 patent applications concerning high-performance batteries; in 2007 there were 2 550, or three times as many. There has also been a marked increase in the field of power electronics: Since 1995, annual applications have more than doubled. Concerning inventions relating to high-performance batteries, Germany has a very negative specialisation index (Fig. 16). In contrast, specialisation indices are highly positive for Japan, Korea and China. For power electronics, the German specialisation is average. High levels of specialisation are found again for Japan, Korea, and China.

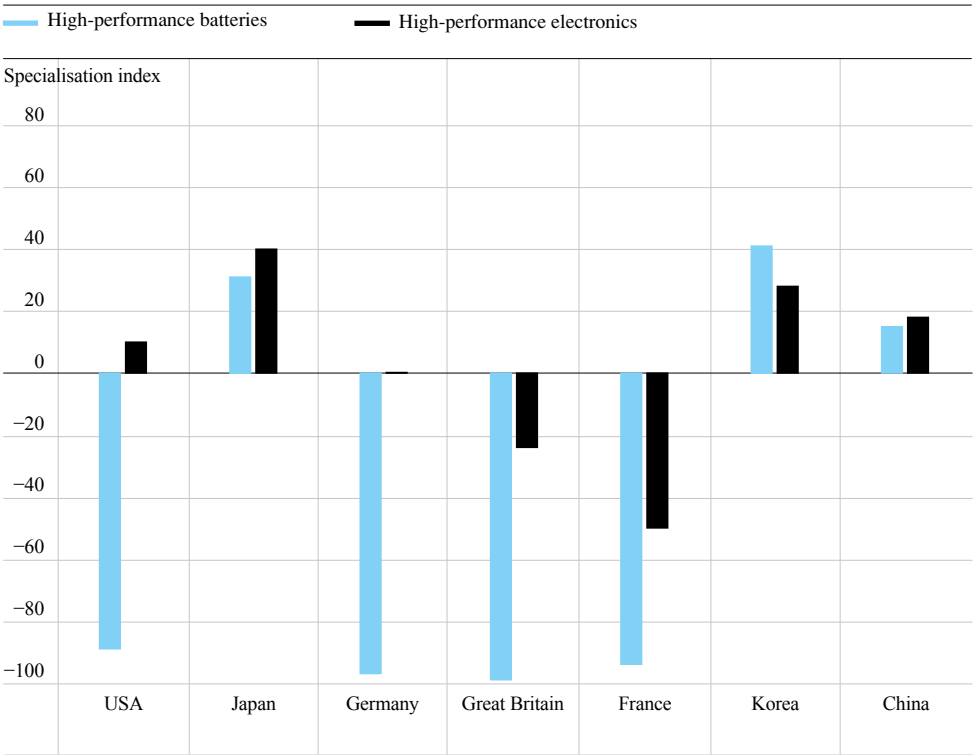
For high-performance batteries, the dominance of Japan is also considerable when expressed in absolute numbers. Although it has nearly 70 percent fewer overall transnational applications than the USA and only 14 percent more than Germany, more than one third of all applications for high-performance batteries in 2007 were from Japan. Germany is considerably under-represented in this sector.

FIG 15 **Transnational patent applications for high-performance batteries and electronics**



Index: 1995 = 100.
Source: World Patent Index (STN).

FIG 16 **Specialisation of transnational patent applications of selected countries in the fields of high-performance and electronics, 2005 to 2007**



Index value 0 = average patent activity, > 20 much above average. Source: World Patent Index (STN).

In this promising field of high technology, a considerable amount of value creation should be kept in Germany. It would probably make sense for the German research and development sector to concentrate on next generation batteries.[147] This will definitely require increases of public support programmes.

Inadequate cooperation and coordination

The transformation to electromobility cannot be made by a series of small changes. Electric vehicles have little in common with current fossil-fuelled cars, in particular concerning energy storage, the drive string, and the supply infrastructure. Such changes are referred to in the research as radical or architectural innovations, because they lead to completely new product concepts and technological solutions. Current strengths in dominant technologies, e.g. internal combustion engines, can not necessarily be converted directly into leading positions in electromobility. It has been shown that in such situations established producers often recognise the threat too late, and they rely for too long on their tried and trusted technology.[148]

In addition, the German automotive industry and its suppliers are competing with one another in the field of electromobility, for reasons which are hard to understand. This leads to a fragmentation of R&D efforts and is harmful for the international position of Germany regarding electromobility. There is a need for pre-competition cooperation projects, in which all the important actors are fully involved – even if they are in competition with one another in the field of fossil mobility. For macroeconomic reasons, the government should coordinate these developments with structured research programmes.
In addition, the lack of an independent national test centre for electromobility currently represents a strategic constraint. Here too, state involvement would seem advisable, at least in the initiation and planning phase.

If German research and development does not gain ground on the international leading group quickly and effectively, the transition to electromobility will considerably weaken Germany as an industrial location. Such a development would be disastrous. About 15 percent of industrial value creation in Germany is based on the conventional automotive industry and its suppliers.[149] According to RWI calculations, about 1.8 million jobs in Germany are directly or indirectly dependent on automotive production.[150] Even if the transition to the widespread implementation of electromobility were to take a decade or longer, massive changes in the economic structures in the automotive sector must be anticipated.

State support for electromobility in Germany

The Federal Government and the Laender have already adopted various measures in the field of electromobility (Box 16). The National Development Plan Electromobility of the Federal Government from August 2009 was initially implemented by the ministries BMBF, BMU, BMWi and BMVBS. With so many ministries involved it was not possible to reach an optimum solution, so that attempts are being made to bundle responsibilities. The current market launching programmes of BMVBS offer scope for further improvements: the Ministry's regulations for support are unclear and changing; there have been delays issuing approval notices.

At the federal level, EUR 500 million has been made available in 2009 and 2010 from the second economic stimulus package. Without these funds, Germany would no longer be able to compete in research and development with countries such as the USA, Japan or China.[151] The National Development Plan is due to run for ten years. However, the continuation of the funding is not ensured, although it is of vital importance if Germany is to play a significant independent role in the development of electromobility. In the opinion of the Expert Commission, the Federal Government's support projects are not sufficiently harmonised with those at Laender level or those of the European Union. There is considerable potential here for optimisation.
The Expert Commission broadly supports the focused activities of the Federal Government and individual Laender in the field of electromobility. However, a precondition for Germany's success in this field is the excellent coordination of R&D efforts in basic research and development. This requirement explicitly extends to the private sector – all those actively involved must rapidly come together in meaningful cooperation. This is currently not being done.

BOX 16

Federal government and Laender support for electromobility

The Federal Government's National Development Plan for Electromobility launched in August 2009 aims at developing and implementing a comprehensive strategy from basic research through to marketing of electric vehicles. A strategy is also to be developed to meet the additional demand for electricity created by electromobility, with the aim of meeting the demand with power from renewable sources and ensuring that electromobility can contribute to the load management of the power grid. In this way, Germany is to become a lead market for electromobility. By 2020, the plan is to have a million electric vehicles on German roads.[152]
The Federal Government made a total of EUR 500 million available for this from the second economic stimulus package. Companies receive up to 50 percent support for approved projects, and public research institutions receive 100 percent. The National Development Plan Electromobility is promoting a range of measures. These include the Federal Ministry of Transport's priority programme "Electromobility in model regions", in which eight model projects receive a total of EUR 115 million in support. As part of its High Tech Strategy, the Federal Government has already initiated the Innovation Alliance Lithium-Ion Battery (LIB 2015). These research activities started at the end of 2008. At total of EUR 60 million Euro will be made available through to 2015; the private sector will be participating with EUR 360 million.[153]
Individual Federal Laender have also set up programmes to support R&D and market launching measures in the field of electromobility. For example, Bavarian companies can receive support amounting to up to 50 percent of their relevant costs, if they carry out R&D in the field of electromobility. In Schleswig-Holstein a centre of competence has been set up for electromobility at the University of Applied Sciences Kiel. North Rhine-Westphalia has a Master Plan Electromobility, which also includes establishing the battery research centre MEET (Münster Electrochemical Energy Technology) at the University of Münster. In April 2009, Lower Saxony also launched its Land Initiative Fuel Cell and Battery Technology and through until 2012 it is providing some EUR 10 million to bring together relevant actors. Baden-Wurttemberg is investing some EUR 15 million in structural measures and projects as part of its Land Initiative Electromobility. A Land Agency Electromobility is to promote interdisciplinary innovations for this field of technology. For this reason, a Land Agency for Electromobility was founded in order to guarantuee the support for interdisciplinary innovations in this field of technology.

Uncertainties about a lead market for electromobility in Germany

Progress towards electromobility requires the coordination of many actors, including government authorities. This not only involves research, but also the introduction on the market. It would be unrealistic to leave this to the private sector – central government is a key player and has direct influence with its decisions on the acceptability of new mobility systems. In view of the obligations arising from the climate discussion and growing international competition, possible concepts should rapidly be tested and implemented.

Politicians frequently speak of a "lead market" for electromobility. In innovation research this indicates particularly favourable structures, which make it possible for providers to develop and market new products rapidly and then to introduce these onto other markets first, and with cost advantages. It is argued that the development of telefax machines was faster in Asia because people there were willing to pay a premium for the transmission of graphic symbols and language characters. The use of a lead market can result in market dominance for a certain period.
It is not currently possible to identify a lead market for electromobility in Germany. If anywhere, such a situation is more apparent in Chinese urban agglomerations, where a process of basic motorisation is underway for local transport, where the demand is in the main not for large, heavy and fast cars with a long range. An example in this context is the technology for the electric cycles and electric scooters, which are currently experiencing an enormous boom in China.[154] The next step will be inexpensive, light-weight electric cars. China has adopted timely measures to ensure the development of this market with comprehensive and strategic technological development, in particular in the field of battery technology.

Coordinating trial projects and extending these to the European level

It would only be possible to establish a lead market in Germany if the major urban centres undergo a rapid and radical conversion to electric transport. A precondition would be that the customers switch over from "powerful, fast and long-range" to "light, small and flexible". Such a change in purchasing behaviour will have to be supported by government programmes during the market launch in order to achieve the large production figures, which can offer significant cost reductions. However, in contrast to other countries, little importance has so far been attached in Germany to planning market incentives. Research into the future acceptability of electromobility is only included in current research proposals in a rudimentary fashion.

Currently in Germany there are 17 model regions and fleet trials for electromobility, with more being planned. This large number of trials could turn out to be counterproductive. It is not possible to identify a real concentration, which could lead to the generation of lead markets. Furthermore, there are no signs of planned coordination of these trials. There is a risk that isolated results will be obtained without producing a meaningful overall picture.

National initiatives alone will not prove sufficient in the view of the Expert Commission, and they should be augmented by transboundary European measures. With European cooperation projects it would probably also be much easier to achieve the necessary comprehensive framework conditions for the widespread introduction of electromobility than with an isolated national strategy. This affects aspects such as standardisation, infrastructure, or preferences in the traffic routing for electric vehicles (the public could be shown the advantages of electromobility under a range of conditions). Such coordination is essential if the economies of scale are to be achieved, which would rapidly lower the costs of new, environmentally-friendly technologies.

Recommendations

Electromobility is an important building block for achieving objectives in the fields of climate protection and the security of energy supplies. However, given the extent to which research and development are lagging behind in Germany it represents a particular challenge.

– The National Electromobility Development Plan is an important first step towards strengthening the position of Germany. Markedly improved coordination and a tighter control of public sector activities are now required in the field of electromobility in order to achieve significant progress. The fragmentation of the national and Laender programmes must be overcome; strategies and initiatives must be developed with a long-term perspective.

– Universities, non-university research institutions, and research promotion organisations should develop stronger and more comprehensive activities in the field of electromobility. In addition to research work, suitable training programmes are necessary to address existing shortages in skilled personnel.

– German companies are not cooperating sufficiently with one another on electromobility. A dialogue should be initiated rapidly with the business companies in order to bring the actors out of their isolation. The Federal Government should only provide further state support when appropriate cooperation is achieved in the field of electromobility.

– On the basis of the existing development expertise in the European automotive sector (for instance in countries such as France and Italy), the Federal Government should work towards a joint European approach in order to strengthen the European position overall and to achieve economies of scale.

– The Federal Government should choose a few regions as locations for the market launch of new mobility strategies and rapidly plan and implement the necessary trials. Possible candidates are metropolitan regions, which ideally would include areas in various countries, e.g. the Ruhr area of Germany and parts of the Benelux countries. European conurbations such as Paris, Rome, Madrid, Athens, or London could also be suitable test regions in a Europe-wide development strategy.

– It must be made attractive for car buyers to turn their backs on the heavy, high-powered vehicles of the fossil-fuel era. Users of electric cars should not only be offered financial stimuli but also additional benefits, e.g. the use of bus lanes in urban areas, or special E-lanes on main highways around the city.

B 5 CURRENT DESIGN OF THE PATENT SYSTEM

The Expert Commission draws in its analyses on patent information and statistics as summarised in Section C 5 of this report. But the patent system is also an important institution of R&I policy-making, and it has been the subject of controversial discussions in recent years. In Section B 5-1, the Expert Commission therefore comments on recent developments in the national and international patent systems, focusing in particular on the behaviour of the patent applicants. In Section B 5-2, the use of patent data in R&I studies is discussed against the background of these changes.

B 5 –1 ON THE INSTITUTIONAL ORGANISATION OF PATENT SYSTEMS

Innovation and patent protection

Patent systems should provide incentives for R&D activities. The patent holder is entitled to exclude other parties from the use of patented inventions. In extreme cases, this means that patent protection can establish a monopoly. The theory is that the right of exclusion improves the patent holder's prospects of making a profit and thus strengthens their willingness to invest in R&D. At the same time, the publication of the patented invention should then make it easier to develop related innovations. Whether the current systems satisfactorily fulfil this purpose has increasingly been called into question in recent years. Numerous studies in the USA analysed the developments there and were reticent in their assessment of the extent to which the US patent system promoted innovation.[155] It is now generally accepted that patent systems only create a strong positive incentive for innovation in a limited number of technologies or industries.[156] In particular, patent protection has a positive effect on R&D activities in the chemical and pharmaceutical industries. However, patents can also impede innovations and competition in various ways.[157]

The extent to which incentives or dysfunctional effects are generated depends to a considerable extent on the patent system itself, so that it is not meaningful to make generalisations. In particular a comparison of the American and European patent systems shows many important institutional differences. In its evaluation, the Expert Commission assumes that a suitably organised patent system can provide incentives for research and innovation and thus create economic benefits. But what are suitable adjustments to this system?

The development in the USA

In the USA there has been a considerable increase in patent activities since the mid-1980s. Following the creation of the Court of Appeals for the Federal Circuit (CAFC),[158] the rights of patent holders were strengthened considerably. In particular it became much easier to enforce patents in court. Over time, the CAFC also extended patent protection to cover software and business methods. Patent applicants responded to these changes with an increased demand for patent protection. The number of applications increased significantly, and the US Patent Office also had a very high approval rate in an international comparison. Competition escalated between companies for more and more patents.[159] In most sectors there was also an increase in litigation. Patents were also used to exert pressure to pay licence fees by so-called patent trolls, who do not carry out any research or production, but acquire patent rights in order to conduct aggressive patent infringement lawsuits.[160]

The developments in the USA have been criticised in a series of studies, including a comprehensive investigation by the Federal Trade Commission (FTC 2003). The call for reforms has meanwhile resulted in various bills being put before the Senate and the House of Representatives. However, the attempts at reforms have failed to date as a result of disagreements between key actors in the political parties and in various industrial associations. The United States Patent and Trademark Office has begun to apply its rules more restrictedly in an attempt to limit supposed abuse of the system by the applicant. In addi-