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The High-Tech Strategy on Climate Protection



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The High-Tech Strategy for Climate Protection



In Europe as well as in Germany, the Federal Government has set clear and far-reaching objectives for climate protection which must now be implemented. Our aims are the reduction of greenhouse gas emissions, higher energy efficiency and a higher percentage of renewable energies. New answers for economic growth and social development must go hand in hand with climate protection. The task of research is to generate new solutions and facilitate their implementation.

With the High-Tech Strategy for Climate Protection, the Federal Ministry of Education and Research presents the research sector's contribution to the realisation of this task. For the first time, we are presenting a High-Tech Strategy for Climate Protection developed jointly by partners in science, industry and politics. I would like to thank all the players for their great commitment and their participation in this process.

This strategy links climate protection with innovations that create jobs and ensure prosperity. It defines the research policy guidelines for climate protection in the coming years, taking into account scientific, technological, economic and financial factors.

Important tasks can be tackled immediately.

The participants have set up a number of "innovation alliances" and new partnerships, and agreed on concrete measures that can be implemented at once.

Technologies such as carbon capture and storage (CCS) for carbon dioxide (CO₂) play an important role in reducing emissions. Together with partners from the energy industry, the Federal Government will therefore demonstrate the technological, ecological and economic feasibility of CCS technologies and quickly set up the appropriate legal framework.

Low-cost, efficient and durable technologies that use the sun as a source of energy hold out considerable promise in the field of renewable energies. Under the banner of "organic photovoltaics", companies and partners in science are therefore studying alternatives to traditional solar technology in an innovation alliance with BMBF support. These alternatives will have to do without pure silicon, which is very expensive to produce.

However, the great potential of renewable energies can only be used effectively if practicable storage possibilities and a corresponding network infrastructure exist to accommodate the power generated. The BMBF is therefore supporting a cross-industry innovation alliance for the further development of the lithium-ion battery, which sees the challenge being addressed by partners from the chemical industry, energy industry and the energy research and automotive sectors.

Two innovation alliances for automotive electronics and safe, intelligent mobility will work on a further CO₂ reduction in cars. Optimised fine-tuning of the individual vehicle components and of communications between vehicles and infrastructure will make a major contribution to the reduction of fuel consumption. Furthermore, conventional fuels are increasingly to be replaced by biofuels. A strategic partnership between car manufacturers and biofuel facility manufacturers as well as companies in the mineral oil industry and scientific institutes is therefore planning to make the conditions more suitable for the taking up of large-scale industrial production of biofuels and further increasing Germany's technological edge.

Four innovation alliances are thus about to be implemented. The BMBF will provide a total of 220 million Euro. Industry has pledged to contribute 1.2 billion Euro for the implementation of these priority measures. Every

Euro in government funding mobilises five times that amount from industry. Another eight innovation alliances are in preparation. These measures are decisive first steps towards achieving the long-term objective of reducing greenhouse gas emissions in all areas of life as far as possible. When introducing the necessary steps today, we are already thinking of tomorrow's innovations.

We let ourselves be guided by visionary ideas for medium- and long-term technological developments.

In the long term, energy must be generated in virtually emission-free power plants; renewable energies must provide an important part of the global energy supply. We are therefore not only investing in the further development of existing technologies, but also supporting new ideas for clean energy generation. There are already concrete plans covering the whole range, from improved solar-thermal power plants to high-performance materials for generating efficient combustion processes at very high temperatures within conventional power plants.

Clean engines are also important. In the long term, however, our cars should not produce no harmful exhaust gases whatsoever. There are tentative plans to establish a competence centre on the topic of hydrogen, which could promote such a development considerably. The same applies to aviation. We want to create the technological and infrastructure prerequisites for achieving emission-free flight in the long term. We will therefore increasingly invest, for example, in new, multifunctional materials for future resource-efficient vehicle construction. After all, achieving the lowest possible vehicle weight - without cutbacks in security and comfort - is a decisive factor in climate protection.

The house of the future will no longer need external energy sources. It will meet its entire demand for heat and power from solar energy. The potential of geothermal energy in Germany will also have to be fully tapped and systematically linked to other energy sources, such as bio-gas.

The model for many of these developments is the "2000 Watt society". Increased efficiency in buildings, equipment and vehicles, as well as the development of new technologies, should bring our energy needs down to a

sustainable level without any cutbacks in comfort and safety.

In other areas too, we must think about the future. Integrated landscape management holds out the promise of particularly high potential for climate protection. Vegetation and soils can store great quantities of carbon dioxide (CO₂), depending on the type of cultivation. The soil is increasingly becoming a resource for climate protection and a factor for the production of renewable resources. Establishing a competence centre for soil, to enable the study of integrated utilization systems is therefore being considered.

In climate protection, we do not just rely on technological progress - we also focus on social change. We can all contribute to climate protection. However, consumers can only be won over to climate protection if they still have individual choices. For this, we need new business models, innovative products and attractive services that take into account everyday lifestyles, habits and patterns of consumption, thus making it quite natural for people to use resources in a responsible way.

We are enlarging the knowledge base for politics, decision-makers and investors. Indeed, anyone thinking about future innovations must not lose sight of the further development of the knowledge base. We need a sound understanding of the system in order to be able to describe and predict the complex climate processes and interactions between atmosphere, land and oceans in even greater detail. We must also better understand the possible consequences of climate change, and think about possible control mechanisms in politics and industry as well as through our individual actions.

We will therefore also support regular meetings of the world's brightest minds in Germany, and consider the establishment of an Institute for Advanced Studies. It is important to us to create and use this knowledge base as part of the High-Tech Strategy for Climate Protection. Our aim is to interlink basic and application-oriented research more strongly so that achievements in science and industry can effectively complement and reinforce each other, and we will promote new alliances across traditional borders and areas of responsibility. We will

also involve new players, such as companies in the financial sector, who are joining forces in the “Finance Forum: Climate Change”. In order to be able to act as powerful partners in the development and marketing of climate protection technologies, players in the financial markets must join the dialogue on providing appropriate and supportive framework conditions, and be able to create innovative financing tools. To achieve this objective, we will work together to create an improved market transparency for investors, insurers and industry, so as to cushion risks and be able to seize new opportunities arising out of climate protection.

Furthermore, results from climate research must be included in all decision-making processes, wherever they are urgently needed. To this end, the BMBF is establishing a platform for decision-makers, such as authorities at federal, state and municipal level, as well as for investors. In this Climate Service Centre, a new generation of information and guidance programmes will bridge the gap between climate research and climate data users in a well thought-out way.

Germany also wants to be a global pioneer. Germany is increasingly well-equipped to play an important role in providing solutions to the global challenges of climate change. This means that we are ready and willing to initiate innovations also in other parts of the world. As an important industrialised nation, we have a special responsibility to promote the active involvement of the emerging and developing countries, above all, in the process of climate protection. We have, for example, agreed to support our partners in Indonesia in exploiting their underground heat sources, which are the largest in the world. To this end, the location-specific potential will be determined, and the use of pilot plants for decentralised energy generation facilitated.

It is time to forge more research alliances of this kind with those countries whose future development will determine the future of the Earth to a far greater extent than ours. The BMBF will therefore take the lead in the research policy dialogue with those important emerging countries that are currently believed to have the best opportunities for above-average economic growth. This dialogue will be part of a mutual learning process. We

will cooperate on an equal footing with inventive intellectuals in these countries in a dialogue that focuses on a common approach to fighting global warming.

We are, therefore, embarking on a long road, along which many obstacles will have to be overcome. But we know that a lot of staying power in research policy will eventually lead to success. We are guided by a vision for Germany, one that combines the demands of climate protection with the development of a free, dynamic and innovative knowledge society; a knowledge society that knows how to think in terms of interrelated systems and to develop them to its own benefit as well as that of future generations.



Dr. Annette Schavan MP
Federal Minister of Education and Research

Table of Contents

Foreword	II
1. Joining Forces, Accelerating Innovations The High-Tech Strategy for Climate Protection	2
2. Knowledge – the Basis for Climate Protection and Adaptation	6
3. Expertise from Germany Technological perspectives for climate protection	15
4. Making Knowledge Useful Decision-making principles for a world in change	34
5. Taking Responsibility Participating in the global future	38
6. Outlook	41

1. Joining Forces, Accelerating Innovation

The High-Tech Strategy for Climate Protection



The messages of the latest reports of the UN Intergovernmental Panel on Climate Change are clear: climate change is happening, it is accelerating and, in its current form, it is very probably created largely by mankind. The first effects of global warming are already visible and determined action is required to restrict the negative consequences for mankind, the environment and subsequent generations.

Under the German presidency, the member states of the European Union have pledged to reduce emissions of greenhouse gases by at least 20% of 1990's initial level

by the year 2020. The increase in the average global temperature is to be limited to a maximum of two degrees compared to the pre-industrial level. It has also been possible to convince the G8 countries of the necessity for joint action. Finally, international climate negotiations are underway, aiming to agree by 2009 an extensive treaty on the basis of the Kyoto protocol for the period after 2012, when the period of the first undertakings has expired. Industrial countries will have to pledge to reduce greenhouse gas emissions by 30% as compared with 1990.

In order to achieve these ambitious climate protection objectives whilst retaining our standards of living, we need balanced social, economic and ecological policies that offer incentives for an economy that conserves resources and invests strategically in innovations and in technological developments within the industries of the future. Only in this way can economic growth and affluence go hand-in-hand with conservation of the climate and of natural resources.

Achieving climate protection and growth

Setting aside the risks, climate change also presents substantial opportunities. This applies particularly to a nation whose most important raw materials are ideas and the ability to implement them. Future technologies for climate protection have tremendous international market potential, and create growth and jobs. In recent years, several thousand million Euros have been invested in the capital markets in young companies involved in climate protection. German wind and solar technology have already turned out to be winning exports. Every third solar cell and nearly every second wind turbine worldwide is produced in Germany. This trend towards growth will continue. The industry anticipates that the export volume will more than double by the year 2010, to 15 thousand



million Euros. Along with China and India, the USA is a particularly important growing market. The German market for renewable energy media turns over almost 23 thousand million Euros annually. It employs nearly a quarter of a million people, and this number is increasing. Germany is a worldwide leader in many fields relating to the development of clean coal power plants with correspondingly increased efficiency. Technologies for the geothermal generation of energy likewise have potential for growth in Germany as well as worldwide.

Investments in climate protection generate returns in two ways. They contribute to the conservation of our resources, helping preserve our environment for future generations, while at the same time generating new opportunities for our economy. Technologies, products and services for climate protection developed in Germany are already internationally leaders in many industries, and are in demand correspondingly. Investments in these technologies secure long-term jobs and growth in Germany. This makes Germany more attractive for investors, leading researchers and new talent. Only in this way can Germany address its global responsibility for climate protection and simultaneously safeguard and strengthen its international competitiveness.

Setting standards in climate protection

The German government will reduce CO₂ emissions by over 30% by 2020. Scenarios calculated on behalf of the government certify that a CO₂ reduction of 40% is, in general terms, possible by 2020. The German government has therefore addressed the challenge of climate change with the 29 cornerstones for an integrated energy and climate programme that were resolved in August 2007 in Meseberg. Thus dependency on fossil fuels is to be reduced, whilst the proportion of renewable energy in electricity generation overall is to be increased to over a quarter by 2020 and consistently extended thereafter.

Research and development play an important part in this programme. Other measures aside, the German government has initiated the High-Tech Strategy, under the leadership of the Federal Ministry of Education and Research (BMBF), to consolidate research and innovation forces in Germany more closely and face the central challenges of climate

change. This Strategy is based on the more general High-Tech Strategy for Germany. The objective is to address new major markets, and to convert good ideas into new products and applications more quickly.

Within the scope of their research support, the various departments consider topics offering both short and long-term contributions to climate protection, and promising technological breakthroughs and thus also market and export opportunities. The division of work within the German government provides both a reliable basis for coordinated action and a complementary supportive policy by the departments participating in the implementation of the High-Tech Strategy for Climate Protection. The Federal Ministry of Economics and Technology (Bundesministerium für Wirtschaft und Technologie - BMWi) provides the strategic direction and co-ordination of energy research within the German government. The BMWi is also responsible for project-oriented support for the sensible conversion and use of energy, for the development of aerospace technologies, and for the support of research in the transport technologies sector, as well as providing Germany's contributions to European Space Agency (ESA) programmes with which the causes and effects of climate change may be investigated globally and independently of national survey methods. The Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit - BMU) promotes research and development projects in the fields of climate protection and renewable energy with the exception of biomass, which is the responsibility of the Federal Ministry of Food, Agriculture and Consumer Protection (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz - BMELV). The Federal Ministry of Transport, Building and Urban Affairs (Bundesministerium für Verkehr, Bau und Stadtentwicklung - BMVBS) provides important incentives for the building sector and transport technologies, including the national innovation programme for hydrogen and fuel cell technology. The BMBF supports fundamental research in almost every field, and together with the BMWi supports the development of key technologies. It also co-ordinates across all departments a national innovation strategy – the High-Tech Strategy for Germany – aimed at taking Germany back to the pinnacle of the future's most important markets.

Putting the High-Tech Strategy for Climate Protection into practice

The presentation in October 2007 of the High-Tech Strategy for Climate Protection also saw the beginning of its implementation. Here, the German government relies on the expertise and willingness to co-operate of business and science. The aim is to emphasise research and development, in order to achieve decisive breakthroughs in climate and energy issues. For implementation and development activities of the High-Tech Strategy for Climate Protection departments will regularly consult with each other within a workgroup.

Future points of emphasis will include highly innovative technologies for the development of energy-efficient vehicles, powerful electrical energy storage, and high-performance materials for highly efficient and low-carbon coal and gas power plants or lightweight transport construction. To better utilise the enormous potential of renewable energy forms, technologies must be developed for workable storage systems and a corresponding network infrastructure to handle the electricity generated. Low-emission coal and gas power plants can be implemented only by increasing their energy efficiency in combination with progress in the development of materials and safe storage capability for the separated CO₂. New fields of technology such as organic photovoltaics and solar thermal power generation are at the beginning of their development. OLED technology for high-efficiency lighting is just starting to achieve market success. "Intelligent" electricity consumers in intelligent networks ("smart grids") that can be regulated according to demand are very promising future technologies waiting to be addressed.

Within the framework of the High-Tech Strategy for Climate Protection, representatives of business and science have produced recommendations for joint objectives and road maps for the most important technological sectors relevant to climate protection. Research is particularly necessary in the sectors that have already been identified in the higher-level High-Tech Strategy for Germany. In other fields, the High-Tech Strategy for Climate Protection identifies action guidelines and long-term prospects for research and development. In these research sectors, the German government will continue the fruitful process of

dialogue between science, business and politicians, and so consolidate the existing potential in Germany for long-term solutions to climate issues.

The key questions raised by the High-Tech Strategy for Climate Protection are: in which technological fields are there special requirements for innovative climate protection technologies? How can we develop these technologies as quickly as possible, help them achieve breakthrough, and exploit the dynamics of the capital markets to this end? How can we adapt to climate change? What gaps in our knowledge do we need to fill? And not least: how can we ensure through research that the necessary solutions are available to reach climate protection goals beyond 2020?

The spectrum covered by the High-Tech Strategy for Climate Protection encompasses key branches and sectors of technology, from energy, chemicals, industrial processes and new materials through construction, living, mobility and transport to the bio-geosphere, agriculture and forestry. In particular, important cross-sectional aspects pertain to the ability of financial strategies to act as a powerful partner in global climate protection and to engage business and science better in the encouragement of up-and-coming talent.

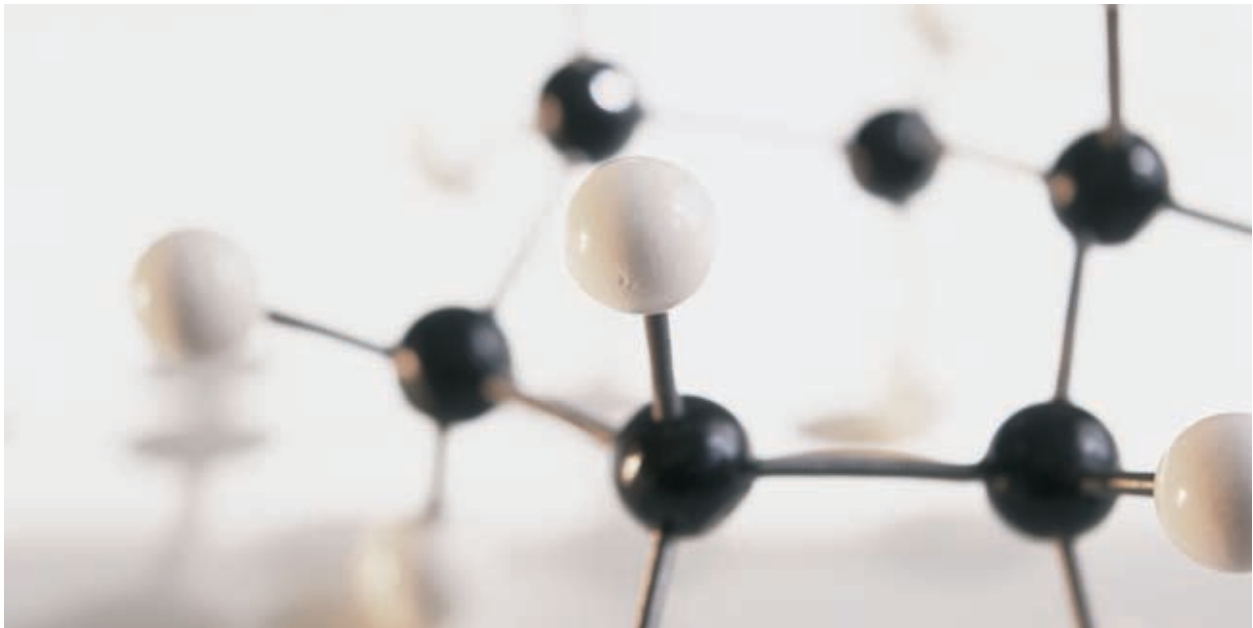
Moreover, the High-Tech Strategy for Climate Protection also addresses the necessary fundamental and long-term priorities for research. Support of a diverse and integrated environment for research into climate change forms a solid part of this research strategy, which, apart from development, also takes into account the implementation and distribution of advanced technologies as well as future progress. Only on the basis of a comprehensive understanding of the climate system and its interaction with other natural or social systems can we react adequately to this fundamental change within our political, economic or personal horizons. The consistent further development of the knowledge base in sciences related to the climate, and the improved exchange between researchers and users, are also intended to provide a fresh impetus for co-operation between scientists, businesses and politicians. With the High-Tech Strategy for Climate Protection the German government is setting out fresh points of emphasis.

Strategic objectives of the High-Tech Strategy for Climate Protection

Three strategic objectives are at the centre of research support within the framework of the High-Tech Strategy for Climate Protection. All three are closely connected and help to further strengthen each other:

- **Joining forces:** The High-Tech Strategy for Climate Protection brings researchers and business closer together. The partners develop solutions for climate protection within innovation alliances and research projects. Research support by the German government is more closely geared and encouragement of new talent is extended.
- **Accelerating innovations:** Knowledge on climate protection is networked, and pitfalls on the path from research proposal to marketable product are eliminated. The entire process, from idea to the positioning of a marketable product, can be seen to adapt itself correspondingly to the prevailing conditions.
- **Forming major markets:** The innovation process is given clear priorities and a joint purpose. The objective: decisively to influence and exploit technological change and the markets for climate-relevant products, processes and services, thus making possible massive reductions in greenhouse gas emissions.

2. Knowledge – the Basis for Climate Protection and Adaptation



Reliable measures to protect the climate, an assessment of the impact of climate change and the necessary consequences for mitigation and adaptation - these all demand a firm scientific basis, and thereby represent a central task of the research and innovation policies of the German government.

The High-Tech Strategy for Climate Protection is therefore calling on scientists in Germany to strengthen the knowledge base for one of the most urgent topics of the 21st century. The objective is to create a firm basis for sustainable and detailed action strategies for a future under changed climatic conditions. Closer networking between those who develop knowledge on all relevant aspects of climate is an important step along this path. Only through the combined efforts of the relevant research sectors can fundamental knowledge be made commonly available to form a firm basis for the successful implementation of climate protection in co-operation between politicians, business and science.

Closer networking of the research community

Germany has great potential for integrated climate research: Germany already possesses an excellent research community that is amongst the best in the world, with numerous university and non-university research facilities. The High-Tech Strategy for Climate Protection defines tangible steps for building this powerful research community into an efficiently networked research infrastructure.

The German government therefore supports universities, research institutes and companies in combining their resources and directing their research activities toward common objectives. The High-Tech Strategy for Climate Protection relies on a continuous dialogue with scientists on research issues and concepts for ensuring the efficient use of funding to achieve high scientific quality. This means first and foremost the support of first-rate research that tackles the challenges of climate change and its effects on society, the economy and the environment with action-oriented solutions. Strong interdisciplinary networks must also be created to take the ongoing discussions and developments forward into integrated climate research, and to put internationally available research into practice in dynamic and innovative research partnerships. The

German government therefore supports universities, research institutes and companies in combining their resources and directing their research activities toward common objectives.

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Focussing research on key topics

The High-Tech Strategy for Climate Protection identifies high-level fields of research in which major progress can and must be achieved over the coming decade to ensure the necessary protection of the climate. At the centre is the analysis and assessment of uncertainties and risks, together with the development of concrete action strategies for politicians and other stakeholders such as consumers, companies and investors.



Focus 1: Reliable interim and long-term climate projections and climate predictions

Simulations of the climate up to the end of the 21st century are a central element of climate research. Within the framework of the High-Tech Strategy for Climate Protection, decisive progress in improving the simulation of climate is targeted. There are great uncertainties in this, particularly in the modelling of cloud processes, precipitation and radiation.

Changes in the cloud cover due to the higher content of greenhouse gases in the atmosphere still remain the greatest uncertainty in models of the climate. Global warming could also lead to the irreversible overstepping of critical limits in some parts of the global system, with consequences such as the death of forests in the Amazon area, the transformation of the monsoon regime, the melting of parts of the polar regions or the thawing of the permafrost regions, releasing large quantities of methane. The likelihood of such non-linear transitions is not well understood at this time. Research activities are therefore an essential building block for an integrated assessment of the risks and for the development of extensive global monitoring and early warning systems. The connection between modelling and measurement is essential in order to be able to achieve decisive progress. To achieve a high degree of correlation of the measured data, the German government is therefore placing reliance on a combination of the detailed investigation of key processes - such as is made possible with the aid of the new HALO and POLAR 5 research aircraft, the new Neumayer III Antarctic station or the new research ship Maria S. Merian - and routine worldwide measurement of the principal global atmospheric and biospheric parameters through observation from space. For example, the joint German-Dutch SCIAMACHY instrument on board the European ENVISAT environmental research satellite permits monitoring of the protective ozone layer; German missions such as the radar satellite TerraSAR-X, the impending launch of the RapidEye satellite fleet and the EnMAP satellite (already in an advanced state of development), together with novel minisatellite arrays, will monitor the state of the polar ice, the great continental glaciers and the deserts, rainforests and oceans.



Setting aside simulations, there is a great need for climate prediction covering coming decades. In fact, concrete planning or decisions on investments for adaptation to the changing climate or for climate protection frequently address shorter periods. It is barely possible to distinguish between changes in the climate that occur naturally and those caused by mankind over a period of just a few decades. Thus, if the climate is to be predicted ten years ahead, the currently occurring fluctuations must be measured, observed and their future course simulated, taking account of the effects caused by mankind. Climate predictions are routinely employed for seasonal predictions, but longer-term predictions have until now been almost non-existent. However, conditions are good for achieving a breakthrough in this field. For this reason, ten-year climate prediction will be one focal point for research within the framework of the High-Tech Strategy for Climate Protection. This raises a whole series of research issues. On the one hand, these pertain to the measurement of the critical values important to the “memory” of the climate system, such as the oceans, soil, ice and snow as well as the upper layers of the Earth’s atmosphere (the stratosphere). On the other hand, the measurement, analysis and prediction of the carbon and hydrological cycle are crucial tasks. Landcover and soils are at the centre of scientific interest. In particular, the storage and sink functions of terrestrial systems with respect to climate-relevant gases have not been adequately understood to

date. The same applies to other large-scale systems such as the oceans, whose future capacity to absorb CO₂ is, from a scientific point of view, extremely uncertain.

Other knowledge gaps, particularly with regard to the development of regionally-based climate models, exist concerning the hydrological cycle, as well as in regional water management and its interactions with ground and land use.

The reasons for this are both a lack of understanding of the processes and also the lack of important measurements. These are essential requirements for global CO₂ management and for the review of future international treaties on the reduction of CO₂ emissions. Finally, the means must be developed to combine many different data flow and to find the most realistic starting points possible for coupled climate and terrestrial system modelling. Apart from carrying out experimental forecasts of the climate on global and regional scales, the goal is also to analyse previous ten-yearly climate fluctuations and their regional effects, in order to examine the variability in the models and so validate forecasts.

Focus 2: Interactions between bio-geosphere and climate

So far, little is known about how the changing climate actually relates to the natural landscape or to different forms of land use. A clear understanding is often lacking of the interrelationships between the discernible changes in landscape, e.g. due to changing use of land, and the landscape’s functions with regard to the climate. This is due not least due to the fact that the appearance of our landscapes is affected by numerous factors which may be ecological, economic, technological or socio-cultural in nature.

It can, however, be assumed that not only the landscape itself, but also the requirements for land use, will be altered by a changing climate. This may be expressed in new forms of land use such as agricultural forestry systems, e.g. the use of specific plants or cultivation methods to obtain bio-energy and renewable raw materials, or regional shifts in forms of use. The effects these changes will have on the climate under different regional and

environmental circumstances remain unknown, as research into the feedback effects between land use and climate change remains at an early stage.

Nonetheless, the anticipated changes in land use in Germany entail substantial opportunities for the sustainable development of the countryside. For this, however, the different requirements of land husbandry must be placed into a much stronger overall relationship. This integrative view has until now been neglected.

For pragmatic reasons the complexity of the topic demands, first and foremost, a clear focus on particularly relevant problems. The High-Tech Strategy for Climate Protection therefore stresses the need for creation of a scientific basis for the concrete decisions in business and politics. A major part of the research efforts is therefore directed at an analysis of the consequences of increased production of renewable raw materials for obtaining energy. A second, closely connected research direction pertains to



the interactions between the bio-geosphere and global material flows, e.g. of carbon and nitrogen. A third research direction must focus on the integration of different interests in land use, which are always dependent on the respective general social, cultural and political conditions.

These research directions are closely interrelated, and can only be investigated with the aid of integrative research concepts to clarify not only practical issues but also questions of fundamental understanding. For example, this pertains to the net effect on the climate of changes to different land surfaces and different forms of land use. The influence of extensive bio-energy production on the carbon cycle plays a part in this just as much an estimation of the overall economic effect of an increased use of bio-energy. Indirect costs must be included, such as the influence of extended cultivation of biogenic raw materials on biodiversity. Another example is the competition between the use of bio energy and the worldwide food supply.

Due to its extensive range of directions, the research programme must encompass measures that extend from large-scale modelling of the carbon cycle and other bio-geochemical cycles down to regional aspects of the interaction between decisions made on energy generation and land use. Existing models on different spatial scales are to be linked for this purpose. The objective is to model and assess land use concepts and, if possible, to resolve conflicts relating to food production, energy generation, climate policies and ecological effects.

Focus 3: Research into adaptation to a changing climate

In addition to efforts to protect the climate, it is simultaneously necessary to adjust to potential future changes and to develop the appropriate adaptation strategies. The High-Tech Strategy for Climate Protection therefore supports research into adaption to the consequences of climate change. Extreme worldwide weather and climatic events such as heavy rainfall, storms, spring tides, heat waves and droughts illustrate that action is required. Crises occur mainly in developing and newly industrialised countries due to their low economic and social resilience.

Against this background, processes to produce adaptation strategies have already begun at EU and national levels. On 29th June 2007, the European Commission released a green paper that creates the basis for a consultation process at EU level between the member states and the most significant stakeholder groups.

The green paper by the Commission makes it clear that the Commission is still in many respects at the beginning of the process of creating such a strategy. It does not yet contain detailed statements on specific measures adaptation to climate change. The objective of the content is therefore to identify the regional effects of climate change, to recognise deficits in knowledge and to develop technical solutions for adaptation measures. The member states are therefore enjoined to compile information and experience with regard to programmes and activities, knowledge on climate-relevant regional risks and extreme events, adaptation programmes and measures as well as scientific methods.

Within this framework, the German government has begun to compile a German adaptation strategy under the leadership of the BMU, one intended to define the structure for the step-by-step development of adaptation measures. Both internationally and nationally, support for the development of adaptation strategies through



research is essential. The High-Tech Strategy for Climate Protection therefore promotes research into adaptation to the consequences of climate change

In essence, means managing the consequences of climate change for people and the environment, for affluence and lifestyle and for economic and social development. This kind of management depends equally on an improved understanding and assessment of the risks and on a definition of the social and economic potential and conditions for adaptation. For example, it remains unclear under which circumstances more and stronger extreme weather events will occur due to global warming. It is also unclear whether future extreme events will affect the same regions as today. Whether we can retain the competitiveness, affluence and lifestyle to which we are accustomed will depend in part on our ability to predict the climatic conditions of the future and to adapt in due time. This apparent dilemma results in a series of questions in two research directions, pertaining to social and economic adaptation and to the recording and prediction of extreme climatic phenomena. The High-Tech Strategy for Climate Protection supports research activities in both directions.

The quality of prediction of such events depends on an improvement of short-term forecasting of extreme weather events and their effects on ecological systems such as the ground or bodies of water, or on economic sectors such as shipping or agriculture. The influence of changes in land use, both on extreme weather events and on susceptibility to such events must also be taken into account. The results of this research direction enable the establishment of effective warning systems and precautionary measures such as dams or reservoirs for restraining flooding and supplying water in periods of drought, as well as political control measures for crisis situations.

German research into social and economic adaptation to climate change, so far has been focused on the vulnerability analysis of individual sectors or stakeholders. Specific strategies for adaptation to possible climate changes or to selected extreme events are the object of most investigations. These investigations enable the success factors of different strategies to be inferred. By contrast, extensive

analyses of adaptation strategies with regard to their interactions and to national economic structures, the international division of work, consumer behaviour and also social and political adaptation patterns are largely lacking.

Regional adaptation strategies to climate change also play a central part in the strengthening and maintaining of competitiveness under changing climatic conditions. Climate change is a direct economic factor for many regions where affluence and value chains are based on local natural resources or are severely affected by extreme weather events. Through the establishment of networks and strategic partnerships in such regions, knowledge gained by climate research is to be included in a suitable way into regional planning practices and employed in concrete decisions in the economy, politics and civil society. The goal is to network the measures of different players to their mutual benefit, thus improving adaptability. Economic and social risks are to be minimised, and market potentials recognised and exploited.

For both sectoral and regional adaptation strategies, there is a great need for methods and indicators to assess adaptation capacities and the success of complex adaptation strategies.

The High-Tech Strategy for Climate Protection also concentrates on a series of further central aspects in research into adaptation. These pertain to the different effects of climate change in different global regions: will natural living conditions change? How will people react? Must large-scale migration streams be expected? On the other hand, a series of economic questions arise: which economic factors are most affected and which have the highest durability? What does this mean to the development of specific national economies? How far-reaching will the effects of changes be on previous price structures, e.g. the effects of the increased use of biomass to obtain energy or the climate-related shortage of environmental resources such as water and farm land on affected regional economic structures? How can the integration of sectoral and space-related adaptation requirements and corresponding adaptation options be achieved at different regional levels? The systematic assessment of different adaptation patterns will enable strategies to be compared, interactions recognised, and factors identified that promote an effective adaptation strategy.



Focus 4: Control factors for climate protection and adaptation to the climate: political and socio-economic potential

We already need to decide the main pillars of an international agreement to replace the Kyoto protocol on the reduction of greenhouse gases after 2012. One of the focal points of German research work is therefore the development of further control instruments for reducing greenhouse gases. This work is based on the investigation of scenarios and on so-called vulnerability analyses concerned with the extent to which people, societies and also economic sectors can be expected to be affected by climate change in the future. These analyses currently remain mainly regional and sectoral in character, and must be placed more firmly within the context of global economic processes and lifestyles. The High-Tech Strategy for Climate Protection therefore supports model-based scenario analyses and qualitative governance studies that serve research into central control factors relating to climate protection and adaptation.

Central market mechanisms, such as for example emission trading, must be further developed and general international factors such as the globalisation of goods, services and capital markets must be taken into account. Is it possible to include developing and newly industrialised countries without such a step causing more problems than it solves? Which principles can be used for the evaluation of appropriate contributions by individual countries? These issues must be viewed in combination with other incentive mechanisms for the employment of climate-friendly innovations. Civil society stakeholders can also represent a decisive factor here.

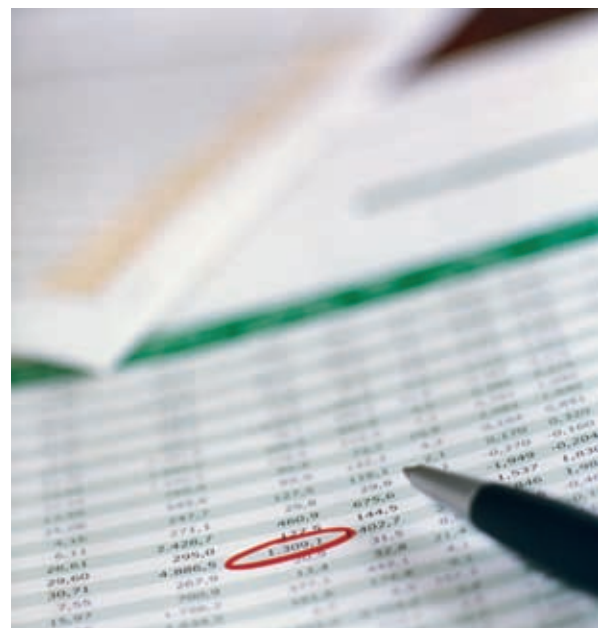
A further central research assignment is the unification of these considerations into integrated scenarios. The central political issue is the definition and justification of climate protection objectives, such as the EU goal of restricting global warming to two degrees above pre-industrial values. What effects do different forms of emission have and how can we evaluate their economic, social, ecological and technological implications? How can feedback between social and natural systems be taken into account appropriately? What risks, latitudes or necessities for emission reduction result from this, and how great are the uncertainties? The central challenge is to develop evaluation instruments that enable us to compare different strategies for achieving the climatic objectives and putting them into a global perspective. This depends on the development of integrated model capacities for combining fundamental scientific research into the climatic system with economic research issues such as the costs and benefits of climate change, technological scenarios and action-oriented social science research.

Successful climate protection also creates obligations for consumers. It calls for adaptation in ways that affect everyday lifestyles, habits, consumer patterns and forms of urbanisation. However, technological innovations can only be successful if they are brought into step with the everyday, complex demands of consumers and citizens. It is only possible to achieve a reversal in the trend of CO₂ emissions when climate-friendly products and services are in demand. Here it is important to prevent the reductions achieved by new, efficiency-improving products from being cancelled out by increased demand. Therefore, if consumers are to be won over to climate protection

effectively, welfare requirements, economic, socio-psychological and socio-structural aspects as well as scope for everyday activities must be taken into account in an integrative research strategy.

The basic knowledge for this is gained in socio-ecological research projects in which the scope for action of citizens and consumers, and also of stakeholders such as municipalities and non-governmental organisations, is investigated and new ways of behaviour are tested as social innovations. This is a matter of methods of assessing and handling the unintended consequences of climate protection methods, e.g. in connection with technologies for extracting and storing CO₂ or with contradictory long-term objectives such as those in respect of the production and use of bio-energy.

With the integration of the potential of socio-ecological research into the High-Tech Strategy for Climate Protection, more durable solution concepts will be enabled and innovative research potential in Germany exploited. German scientists can take advantage of a wealth of experience from market launches of ecological products, processes and services in the energy, nutrition and mobility sectors. For example, socio-ecological



research concepts for the transformation of diets or mobility services have successfully demonstrated that potential reductions of greenhouse gases can be exploited by target group-specific measures and improved communications between companies and consumers. These concepts will in the future be developed in greater depth, thus systematically increasing consumers' capacity to act as partners in climate protection.

Monitoring as a cross-functional task

Monitoring, the regular and systematic observation of important climatic parameters, is an essential requirement for observing change in its totality as it occurs and to expanding our knowledge of the processes of change. In German research into climate-related topics, the emphasis has been on the monitoring of atmospheric and oceanic processes measured worldwide from space, independently of national methods of survey and by measuring networks which acquire detailed data directly “on the spot”. Essential contributions are made by the German weather service through the operation of an extensive network of measuring stations, and by the facilities of the “Helmholtz- und Leibniz-Gemeinschaft” in evaluating data from weather satellites, oceanic measuring systems and research ships. However, apart from a few initial approaches, an internationally-connected monitoring network for measuring all significant natural and social features and effects of climate change systematically is lacking

Thanks to its existing capabilities and those currently being extended, Germany has taken on a leading role in the establishment of a European system for global environmental and security monitoring (GMES, Global Monitoring for Environment and Security). Together with the satellite navigation system Galileo, GMES forms the second pillar of the joint space activities of the European space organisation ESA and the EU. The objective is to consolidate all existing facilities in Europe, thus creating an independent European capacity to support political decisions on the basis of the best available data. Here Europe is making a central contribution to the addition of climate-relevant information to a worldwide, international network of similar information systems (Global Earth Observation System of Systems, GEOSS). GEOSS also



aims to co-ordinate global Earth observation information to create a database on global environmental change. Germany is involved with diverse national contributions in the establishment of GEOSS. Moreover, a workgroup of important national users of Earth observation information, D-GEO, is developing a national strategy for contributing to GEOSS and implementing its benefits in and for Germany. In this way, suitable strategies can be developed more quickly for “operationalising” the extensive monitoring data often obtained from research projects at national and international levels – for ensuring that such data are retained after the actual research project has been completed and to suitably consolidating them. Furthermore, intensive discussions on monitoring are in progress in various international forums, along with discussions on the extension of proven long-term monitoring systems, such as those for air pollution and its effects, to

include climate (effect) parameters. A beginning has been made, but substantial efforts remain to be undertaken before comprehensive monitoring has been established.

German research facilities are very well suited to taking an internationally leading role in the systematic development and evaluation of monitoring strategies. The German government will therefore continue its international efforts to bring about suitable monitoring platforms and systems that can be used for a long period and define, test and assure the long-term observations of important system components. A strategy must be developed that defines clear criteria for the selection of data collection and also includes individual platforms - for example, for model evaluation, predictions or early warning systems.

Attracting the brightest brains

Top research needs top researchers. The innovative strength of our country depends decisively on the professional qualifications of the people living here. If we intend to remain pioneers in the leadership of global markets in the future, we must awaken new enthusiasm for science and opportunities for new technologies. The creativity and commitment of young people are essential resources for facing the challenges posed by climate change.

The national qualification initiative currently being prepared under the leadership of the BMBF pursues the objective of exploiting the full potential of our education system and creating attractive conditions for up-and-coming scientists. Visible emphasis must be placed on the sustainable strengthening of research into climate protection in Germany, so that universities and research organisations can develop international brilliance via the work of their excellent new talents.

The outstanding education of new scientists must be combined with excellent scientific research. Incentives should be created for top researchers from all over the world to come to Germany and live and work here. In particular, an attractive research and study programme should offer excellent education facilities in the fields of mathematics, engineering and the natural sciences. Companies are also important partners in this field. The

High-Tech Strategy for Climate Protection therefore promotes co-operation between science and business, particularly in the encouragement of new talent – a co-operation from which both sides benefit. Strategic alliances promote research at universities and enable forthcoming scientists to gain initial experience in business in an uncomplicated way. Companies, on the other hand, gain not only an insight into ongoing research projects, but also early contacts to highly qualified candidates.



The establishment of numerous diverse co-operations will be supported by initiatives by acatech, the German academy of technical sciences. As a scientific organisation that recruits its members from science and business, acatech endeavours to achieve co-operation between these players to promote up and coming scientists. In co-operation with the Association of Sponsors of German Science and with support from the BMBF, acatech intends increasingly to promote the encouragement of new talent in the technical sciences and, in particular, to pursue the issue of which measures can improve the general conditions for learning and studies.

3. Expertise from Germany

Technological perspectives for climate protection



The High-Tech Strategy for Climate Protection is based on the understanding by science, business and politicians that they are jointly responsible for climate protection. A central foundation is formed by concrete efforts and agreements by crucial societal stakeholders for the implementation of joint research, development and demonstration projects. The stated objective is to build up the different development stages as a whole, from fundamental research to the development of marketable products, and to achieve rapid and high market penetration through an appropriate working framework and research

support. At the centre are advanced technologies promising great gains in efficiency, rapid implementation and also the strengthening of the German economy within the international “future climate protection market”.

Advanced German technologies are already contributing to worldwide efforts towards climate protection and energy efficiency and strengthening the position of Germany as an export nation. To continue these economic successes, the German government will take measures to increase the German share in the leading worldwide market for climate protection technologies. Within the framework of the High-Tech Strategy for Climate Protection, the participating departments of the German government (BMBF, BMELV, BMVBS, BMWi and BMU) will therefore bring together researchers and business to achieve a breakthrough for future climate-relevant technologies. The decisive issues are: how can energy be efficiently

converted into useful forms and stored, how can production and services be made sustainable and how can we exploit existing resources more efficiently? These questions must be answered in respect of every process in which greenhouse gases are produced.

Within their respective fields of responsibility, the German governmental departments participating in the implementation of the High-Tech Strategy for Climate Protection concentrate on the sectors in which major effects on the climate can be expected and in which incentives for the rapid development of advanced climate protection technologies can be created. These are, for example, energy supply and energy efficiency, intelligent grids and energy-saving, intelligent consumer appliances, mobility or the building sector, land use and also fundamental fields of technology such as chemicals and materials research. The early integration of stakeholders from the financial markets into the High-Tech Strategy for Climate Protection should speed up the availability of technologies under marketable conditions.

Climate protection can only be considered and implemented together with fundamental innovations in energy supply and energy use. Demanding climate protection objectives therefore also require higher-level objectives for the expansion of renewable energy and increased energy efficiency. With its paper on "Cornerstones for an integrated energy and climate programme", the German government has decided upon a concrete series of measures which has, as its terms of reference, security of supply, the economy and environmental compatibility.

As well as the other energy research initiatives announced by the German government in this paper the impetus for research and development resulting from the High-Tech Strategy for Climate Protection forms an important part of the planned series of measures.

Any party developing and producing energy-saving products and processes or, for example, manufacturing vehicles with low fuel consumption, has a competitive advantage, given the rising energy prices in both the domestic and export markets. If we can substantially reduce the consumption of resources in transport, buildings or industrial processes with the aid of advanced technology, we will reduce not only CO₂ emissions but also our dependency on energy imports, thus also lowering fuel and heating costs and electricity bills.

For clean and efficient energy generation

Within the framework of the High-Tech Strategy for Climate Protection, the German government has joined forces with business and science, initiating a drive to support key innovations in important leading international markets. Technological developments will help us to handle existing resources more efficiently and produce renewable energy better. For example, 20 to 40% of the energy consumed in industry could be saved under economically acceptable conditions by 2020. Around two thirds of all electricity is required for electric drive motors alone. This consumption could be reduced by over 15% through the use of electronic speed controllers, intelligent control systems and new materials.

High-Tech in dialogue between science and business

At the first climate research summit on 3rd May 2007 in Hamburg, the BMBF called on high-ranking representatives of science, business and politics to pull together forces in research and innovation in Germany and to co-operate on future solutions to protect the climate. Six technology-oriented dialogue forums (energy, chemicals and industrial processes, new materials, buildings and living, mobility and transport, bio-geosphere / agriculture and forestry) and one extraneous forum for investment strategies and finance were established, within which scientific and business experts have developed road maps with concrete innovation alliances and partnerships. Other milestones were also formulated in order to promote joint research into advanced technology for climate protection. The first projects within the framework of the High-Tech Strategy for Climate Protection are now being put into effect. These measures will then be supplemented by further initiatives and further emphasis on the support of research.

Cornerstones for an integrated energy and climate programme

With the paper on “Cornerstones for an integrated energy and climate programme”, the German government has provided a substantial impetus for modernisation in order to implement the European resolutions on climate protection at the national level. This is an extensive package of legislative initiatives and promotional measures.

- Combined heat and power act
- Extension of renewable energy for electricity
- Low-CO₂ power plant technologies
- Intelligent measuring processes for power consumption
- Clean power plant technologies
- Introduction of modern energy management systems
- Promotional programmes for climate protection and energy efficiency (apart from buildings)
- Energy-efficient products
- Supply regulation for biogas in natural gas networks
- Energy-saving ordinances
- Operating costs for apartments
- CO₂ building refurbishment programme
- Energy modernisation of the social infrastructure
- Renewable energy and heating act (EEWärmeG)
- Programme for energy-related refurbishment of federal buildings
- CO₂ strategy for cars
- Further cultivation of biofuels
- Changeover of vehicle taxation to CO₂ basis
- Fuel consumption labelling for cars
- Improved control effects of tolls for goods vehicles
- Air transport
- Shipping
- Reduction in emissions of fluorine-containing greenhouse gases
- Procurement of more energy-efficient products and services
- Energy-related research and innovation

- Electrical mobility
- International projects for climate protection and energy efficiency
- Reporting of energy and climate policies by German embassies and consulates
- Transatlantic climate and technology initiative

The programme includes, for example, optimised ways in which electricity generated from renewable energy may be integrated into future power supplies, or economically justifiable ways of reducing the demand for primary energy and greenhouse gas emissions, e.g. by the extension of highly efficient combined heat and power. In general, integrated and system-oriented solutions are to be found.

The cornerstones for an integrated energy and climate programme were produced under the leadership of the BMU and BMWi. They are to be jointly implemented by all participating departments of the German government. In this respect the German government will strengthen its ongoing activities in research into energy and the climate. Projects and initiatives for the future are to be defined within this framework. This includes innovative joint research projects together with the support of strategic partnerships between publicly and privately funded research. Equally, fundamental research and applied research are to be extended to achieve the short-to-intermediate-term potential for optimisation, and also to make available innovative technologies for climate protection for the period after 2020.

This gains particular significance set against the background of the rising global population and the explosive growth of emerging economies such as China and India, resulting in a strongly increasing demand for energy. According to International Energy Agency scenarios, by 2020 worldwide demand for primary energy will rise by around 50% and demand for electrical energy by almost 100%. Despite a sharp increase in the proportion of electricity generated from renewable energy sources, in, particular



from wind and biomass, two thirds of electricity is still expected to be obtained from fossil fuels in 2020. The greatest share of this will remain coal, which is still available worldwide at comparatively reasonable prices.

There is no comprehensive alternative to fossil fuels in the foreseeable future. As a consequence, we must ask: how can we make conventional power plants cleaner and more efficient? One part of the answer lies in the development of low-emission power plants with CO₂ capture and storage capabilities (CCS) deep underground. This may be a significant instrument in global climate protection, as it can provide an environmentally friendly and economic electrical supply for large developing countries.

The costs and economic risks of CCS technologies currently exceed the economic benefit. The capture, conveyance and storage of CO₂ is also linked to further demand

Moving towards a sustainable energy system

The answer to the rapid worldwide increase in energy consumption lies in climate and energy policies committed to innovation and to increased market penetration of new technologies. In particular, there is great potential that must be exploited in the increase of energy efficiency. In the short and intermediate term, the objectives of climate protection can therefore be achieved primarily by a major mobilisation of unexploited efficiency potential in conjunction with renewable energy forms and low-CO₂ power plant technologies based on fossil energy sources. In the long term, we expect renewable energy to have a substantial share in securing global energy supplies. For this reason, we are investing in the technological development of renewable energies, including the grid and storage technologies required.

for energy and resources. This means that, relative to the effective energy output, the overall efficiency of a CCS plant is lower than that of a power plant without CCS.

Efforts in research and development must therefore be directed towards further increases in the efficiency of power plant components and of their system integration.

The BMWi places the emphasis on this with its COORETEC (CO₂ reduction technologies) research programme. New materials and production techniques for highly efficient gas and hydrogen turbines must be developed. A substantial increase in the efficiency of coal power plants is anticipated with higher process temperatures, for which the basis is a change in materials to nickel-based steels for the larger components of high-temperature steam turbines. The conditions for fossil fuel-fired, low-emission energy generation in power plants are therefore to be created within the framework of the High-Tech Strategy for Climate Protection by means of close co-operation through an alliance of material manufacturers, plant constructors, plant operators, associations and research institutes in the field of high-temperature materials. German industry can

boost its worldwide position in the materials and power plant sector by increasing the efficiency of power plants while simultaneously reducing the cost of large components.

Capture and storage of CO₂

It is possible to prevent CO₂ from being emitted from conventional power plants using a technological process. This process, by which CO₂ is first separated from the flue gas (post-combustion) or from a combustible gas (pre-combustion), or is enriched in the flue gas by combustion in an oxygen atmosphere (oxyfuel), and then stored safely in geological formations, is known as "Carbon Capture & Storage" (CCS).

In the paper on "Cornerstones for an integrated energy and climate programme", the German government has set the objective of making possible the technical, ecological and economic viability of CCS technologies and quickly forming a legal basis for the capture, transport and storage of CO₂. With a joint declaration as part of the High-Tech Strategy for Climate Protection, politicians and business in Germany have therefore made a clear statement in favour of this technology achieving a marketable status as soon as possible and overcoming all the obstacles to its practical implementation. Some important issues relate to methods of quantifying storage, criteria for the choice of locations and technologies and systems for the monitoring, control and management of operations and the associated risks.

Today, CCS includes different technological sequences targeted at the transition to a low-CO₂ economy. Throughout Europe, researchers and power generating and power plant construction companies are already co-operating to master the technical challenges and the practicalities of implementation. In Ketzin (Brandenburg), the first pilot plant on the European continent to store CO₂ in deep, saltwater-bearing layers will go into

operation in 2007. In 2008, further pilot projects will begin with research and development work at specific storage locations. Adequate legislation is currently still lacking. The Federal Ministry for the Environment has set up a research and consulting project in order to define a legal framework for CCS. The results of this project will be employed in the formation of the CCS legal framework.

Within the framework of the GEOTECHNOLOGIEN programme, the BMBF supports scientific projects on CO₂ storage in geological formations. This will lay down important principles for long-term, safe CO₂ storage and establish the corresponding expertise at German research facilities and in industry. These research concepts are to be more strongly pursued from 2008.

Over and above this, the chemical industry is particularly engaged in finding means of exploiting CO₂ as a source of carbon for fuels and chemical raw materials. Use of CO₂ as a material therefore represents a strategic concept that can make a long-term contribution to securing future raw material supplies through a combination of more economic hydrogen production methods and the use of renewable raw materials. However, to implement the use of CO₂, energy-efficient processes for separating CO₂ from combustion and flue gases must be developed, producing carbon as a raw material. Additionally, even under ideal conditions it will only be possible to exploit a few percent of worldwide CO₂ emissions in associated products. Nevertheless, within the High-Tech Strategy for Climate Protection it is considered important to research means of exploiting CO₂ as a raw material for industrial processes. Efforts are thus being made to set up an innovation alliance with the purpose of intensively linking fundamental research with application-oriented developments and the inclusion at an early stage of an economic evaluation of technological developments.

With internationally recognised joint research projects in the field of innovative power plant technologies and CO₂ capture, BMWi supports the objectives of the High-Tech Strategy for Climate Protection through the deliberate support of application-oriented research and develop-

ment and accompanying measures for demonstration purposes. The COORETEC research programme, which specifically targets business and science, supplements these extensive efforts in the field of fundamental and institutional research.

For more efficient use of renewable energy forms

In the long term, renewable energy offers the only prospect for a sustainable and reliable energy supply. The objective of the paper on “Cornerstones for a German government integrated energy and climate programme” is therefore also to increase the proportion of renewable energy in Germany’s heat, electricity and fuel supply to 25 - 30% by 2020, and to further expand this by 2030. The High-Tech Strategy for Climate Protection contributes to this by promoting central technologies for efficient energy supplies from renewable energy sources.

The energy gained from wind, water, biomass and geothermal sources is insufficient to meet the overall worldwide demand for energy. By contrast, the solar radiation reaching the Earth exceeds the energy demands of the planet by several orders of magnitude. Business and science are therefore jointly searching for new solutions for exploiting solar energy. The objective of all developments must be a sufficiently economic, efficient and durable technology with which the sun can be exploited as a source of energy.

German companies are already worldwide leaders as technology suppliers and developers of solar thermal power plants. In terms of marketability, parabolic reflector power plants with direct vaporisation and tower-type power plants are particularly promising. Updraft power plants in sunny desert regions are another interesting option. However, substantial research and development work remains necessary in order to master the water vapour cycle. The BMU is therefore promoting the development of these technologies up to the construction of pilot plants, to make their launch on the market possible. One of these BMU-supported pilot power stations, using the most innovative solar technology worldwide, is currently under construction in Jülich. Following a one-year construction phase the solar power



plant, which has an output of 1.5 Megawatts, will supply its first electricity to the national grid. In this way, this demonstration project will substantially improve German suppliers’ opportunities in a swiftly developing global market segment.

In the field of renewable energy forms, bio-energy is another important focal point of research encompassing a broad spectrum of sectors. Support for research into the use of biomass for energy is, as a result, an issue addressed by several departments of the German government. For example, liquid and gaseous biofuels will contribute substantially to meeting the demand for energy in the transport sector in the future. In particular, second generation biofuels manufactured mainly from non-food sector biomass promise to save substantial quantities of climate-relevant gases. However, all projections indicate that biofuels will not only power the vehicles of the future but also contribute to power generation. On the agenda of the High-Tech Strategy for Climate Protection are therefore numerous issues of research, development and production: how can the highest-performing fuels be developed from biomass? What part can biomethane from biochemical and thermochemical processes play?

And finally: how can the requirements of raw material production be unified with those of modern agriculture? As diverse as the possible applications of bio-energy may be, the diversity of the research disciplines addressing the potential of this “all-rounder” of renewable energy forms within the High-Tech Strategy for Climate Protection is equally high. One thing is certain: Germany must take a leading part in the development of innovative technologies for exploiting biomass.

In many countries, increasing competition is already apparent between the agricultural production of biomass for different purposes. Agricultural, forestry and nutritional sciences therefore take a central position in the development of an economy based increasingly on biological resources. The BMBF intends to promote competence networks in agricultural and nutritional research targeted at the entire value chain, from production of natural resources to the provision of high-quality raw materials (food, fodder, renewable raw materials) for the consumer. Holistic and sustainable production taking account of economic

and social aspects must be the standard for innovative and modern agriculture. For this purpose, a competitive process will bring the agricultural, forestry and nutritional competences of universities together with those of researchers outside universities and in business, including the research of governmental departments.

Wind energy is already another global success story. Germany is the world’s leading supplier and user of wind energy plants; over 70% of all wind power plants and components manufactured in Germany are exported. Over 5% of German electricity demand is met by wind energy. Because wind speeds are higher at sea, offshore wind farms or wind turbines away from the coast have greater potential for higher energy. In January 2007, construction work began on the cables to “alpha ventus”, the first German offshore wind farm in the North Sea. The first wind energy plants of this pilot project are to enter operation in the late summer of 2008. However, the continued success of offshore wind energy ultimately depends on whether the individual components can withstand the effects of

Organic photovoltaics and solar heat

German companies, together with partners from the scientific community, are jointly researching alternatives to conventional solar technology capable of functioning without the difficult production of pure silicon as a raw material, in an initiative supported by the BMBF that takes up the issue of “organic photovoltaics”. Organic cells can be connected in series by establishing stacked, layered structures. The strength of these so-called tandem cells is the synthetic diversity of the employed organic semiconductors, which permits the absorption properties of the respective layers to be optimally adjusted to each other. This exploits a wide range of the solar spectrum and loses far less energy as heat than is the case with conventional silicon cells, which are only able to convert a small part of solar radiation. Organic photovoltaic materials open up an opportunity for achieving enormous cost savings in the production process and also for producing completely new, globally marketable products. Organic photovoltaic materials are transparent and flexible. They could make rechargeable batteries and chargers unnecessary in mobile phones, cameras or laptops. Large areas of transparent photovoltaic cells could be also installed on windows or buildings. Substantial research, however, remains to be conducted into the efficiency and service life of organic photovoltaic modules.

Solar thermal power plants also convert solar energy into electrical energy. They can make an important contribution to electricity generation, particularly in sunnier climates (Southern Europe, Australia, California).

The potentials of solar thermal power plants are enormous. The technology is based on the simple principle of generating hot steam using a medium bearing heat from solar radiation and then conveying this to turbines to generate electricity. Various technologies are being developed and are now ready for trials.



salt water, wind and the weather. In particular, foundation construction techniques for extreme depths and innovative corrosion protection present great challenges. The same applies to the connection of the generators to the electricity grid. Against this backdrop, the BMU will promote research activities relating to the “alpha ventus” offshore pilot farm. In close connection with the existing funding activities in the field of wind power, the High-Tech Strategy for Climate Protection will provide a key technological impetus in materials and building material research in order to continue the worldwide success of German wind power plants.

Foundation for energy change: innovative grids and energy storage

The dynamic developments in energy supplies also produce completely new challenges for the management of electricity grids. In order to maintain the stable running of the grids under conditions of widening spread and increasing complexity - for example, due to energy trading and fluctuating supplies - the development of completely new power circuitry and IT systems is necessary. With so-called smart grids, the network shifts from a rigid infra-structure into a dynamic system. The efficient integration of a growing proportion of renewable and decentralised forms of energy within the energy supply system depends on this. The demand-driven extension of electricity grids in order to integrate renewable energy forms is therefore one of the objectives of the Corner-

Second generation biogenic fuels

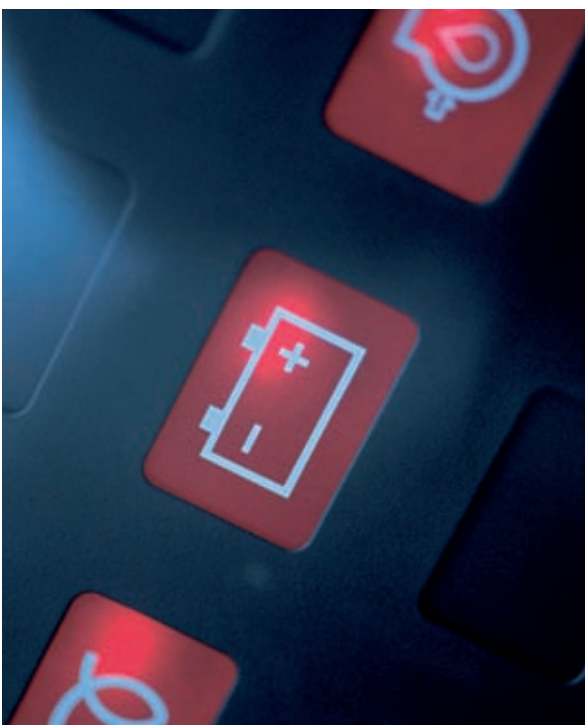
The German automotive industry has decisively advanced the development of biogenic fuel technology and will continue these efforts. The German technological lead is thus to be retained and further extended, entering large-scale industrial biofuels production. A strategic partnership of vehicle manufacturers and biofuel plant manufacturers, as well as petroleum companies and scientific institutes, will create the conditions for achieving these ambitious objectives. A close strategic, content-sharing co-operation with further scientific and industrial partners is planned, as industrial production of biogenic fuels will have far-reaching effects on agriculture, forestry and the energy industry and relies on close links with the chemicals industry. The technologies necessary for this will therefore also be developed and implemented in co-operation with all responsible departments of the German government.

stones for the German government’s integrated energy and climate programme. Development of the grids must occur concurrently with agreements on standards for the switching of different components in households, commerce and industry. This is necessary in order to produce a whole new generation of intelligent, consumption-controlled and intercommunicating consumer devices able to turn themselves on and off, with no loss of convenience, thereby reducing costs and increasing grid stability, and also able to switch according to supply and demand into whatever operating mode has the most favourable cost and lowest burden on the environment. With the intelligent networking of household appliances, peak loads can be minimised to an average of 2 kilowatts per household. The BMWi has already commenced the first measures required for this with its initiative “E-Energy: ICT-based energy system of the future”. The use of modern information techniques and communication equipment for controlling electricity and heat efficiently is at the heart of research efforts. Further pilot projects within the High-Tech Strategy for Climate Protection will illustrate energy-

efficient, “intelligent” applications and the 2,000-Watt society by way of demonstration projects, thus creating the best conditions for German industry in a lucrative future market. Projects are being developed in line with the corresponding design guidelines. Research and development for standard applications with high market penetration can achieve substantial savings in terms of costs and burden on the climate.

The increased significance of renewable electricity generation has brought a further topic close to the top of the research agenda: storage capacities for electricity. Demand for electrical energy is rising faster than supply, and existing electricity grids are now reaching the limits of their capacity. We must find ways to store electrical energy generated outside peak periods longer and more efficiently in order to use it later during periods of high demand. It will otherwise be impossible to exploit to the full the potential of solar and wind energy sources.

Electrical storage batteries for handling electricity grid peak loads will be required, as well as buffer systems for



solar and wind power plants in discontinuous operation. There are many promising possibilities here, ranging from compressed air storage through hydrogen production to batteries for small-scale applications. However, these are nowhere near all the possible applications for high-performance batteries. As well as the typical field of application for mobile electronic equipment, more powerful energy storage systems are also an essential prerequisite for the transport sector (electric and hybrid vehicles), in which only a comparatively small number of accumulator systems have so far reached technical maturity and become commercially available. An adequate performance profile remains particularly lacking.

Securing climate-compatible mobility in the future

Mobility is an important basis for any modern, work-sharing and internationally interlinked society. Around 80% of personal travel and around three quarters of the transportation by land of goods in Germany and Europe is carried by road, and around one fifth of Germany’s total CO₂ emissions originates from road traffic. One reason for this is that roads offer a degree of flexibility unmatched by any other form of transport and are available at all times. It is thus necessary to align climate protection and individual mobility requirements.



However, mobility is not to be equated with traffic. The avoidance of unnecessary traffic and a shift to more environmentally friendly forms of transport remain substantial aspects of sustainable and climate-compatible mobility. In view of the central part played by road traffic in climate protection, the High-Tech Strategy for Climate Protection focuses initially on research tasks that will, in conjunction with efficient, clean but affordable driving technologies, result in the efficient organisation of road traffic as well as lightweight vehicle construction to preserve resources. Of course, other forms of transport also offer substantial potential savings, which are also to be addressed in the course of the implementation of the High-Tech Strategy for Climate Protection. One of the most important tasks for the future is to reduce road transport emissions of CO₂ significantly whilst retaining mobility. Business and science are already working hand-in-hand on technologies to disconnect the car, step by step, from fossil fuels. It has been possible in the past to achieve notable reductions in fuel consumption of individual vehicles - through the development of more economical engines, for example. This development must be rigorously pursued and further accelerated, as many of the cars of the future will continue to be built in Germany.

Energy storage and the lithium ion battery

Electrical storage systems are a key to aligning electrical supplies with demand. On a large scale, such as at the level of electricity grids, it is necessary to develop and implement high-power energy storage systems such as those based on compressed air or hydrogen. For small-scale applications, it is necessary to improve the performance of batteries. The constantly increasing demand for mobile energy supply systems initially results in increased demand for electrical power, as this kind of storage is connected with high energy losses. At the same time, the trend towards more mobile equipment requires batteries with higher specific energy density and power, short charge and discharge times, safe operation and a long service life, as well as lower burdens on the environment and the climate. In particular the linkage of mobile, battery-operated equipment with innovative photovoltaic-based charging technologies, or the use of ambient (human) heat or energy produced by movement, both hold great technical and economic potential. Lithium ion batteries are considered to have the best chances of achieving global success as the standard technology for high-power batteries due to their high energy and power density. In order to advance development of large-scale storage systems and mobile electrical storage (lithium ion batteries) combined with environmentally friendly mobile charging systems, and to secure a technical lead for Germany in this dynamic market, research and development in this field will increasingly be supported in the course of the High-Tech Strategy for Climate Protection. The BMWi and BMU will extend their joint research support for this research sector. Concurrently, the BMBF will establish an innovation alliance for the further development of the lithium ion battery with partners from the chemical industry, automotive manufacturers and suppliers, energy suppliers and other companies and research institutes.

Internal combustion engines will initially remain the most important propulsion form for vehicles. Accordingly the short-term emphasis is on increased efficiency through the use of new combustion processes and hybrid technologies; then, step by step in the medium and long term, we must become less dependent on fossil fuels and further reduce CO₂ emissions through the use of second generation biofuels and hydrogen in conjunction with combustion engines and fuel cells. CO₂-saving strategies must look not only at the individual vehicle, but also at traffic as an overall system. The potential for efficient traffic management for climate protection exists and must now be exploited. New information and communication technologies with which the flow of traffic can be optimised are therefore needed, as are traffic management systems.

In addition to the measures and innovation alliances mentioned above, the German government will, in close dialogue with business and science, commence further initiatives that will contribute to climate conservation and securing the mobility of people and the transport of goods.

A new German government traffic research programme is currently underway, under the leadership of the BMWi. The objective is to build Germany up further as Europe's



The car of the future

The car of the future must be climate-neutral. The first step toward this is the more efficient use of fossil fuels through the optimisation of driving and automotive technologies. A further important step is more efficient traffic flow management, because avoiding traffic jams means fuel savings. In the medium term, the emphasis will be on the substitution of fossil fuels with biogenic types. In the long term, automobiles could be driven by electric motors powered by fuel cells and batteries. Developments towards emission-free cars must therefore also be looked at in close conjunction with a comprehensive concept for a sustainable energy supply. As part of this, economically viable methods of hydrogen production using renewable energy play a particularly important role.

logistical hub, to secure individual mobility sustainably and to improve infrastructure performance through the use of information and communication technologies. Publication of the programme is planned for 2008. Currently ongoing or imminent points of emphasis in BMWi's research are adaptive and co-operative technologies for intelligent traffic, alternative driving technologies, and intelligent logistics in goods and business traffic and in seaport technologies. Through research and development of innovative solutions for reducing vehicle fuel consumption and achieving better organisation of traffic flow, significant contributions will be made to climate protection.

The fuel consumption of a vehicle depends greatly on its weight. The rule of thumb is that a vehicle weighing 100 kilograms less saves 0.2 litres of fuel per 100 kilometres. To protect the climate, it is therefore vital to develop the lightest possible vehicles – without sacrificing safety and

Innovation alliances for CO₂ reduction in cars

The High-Tech Strategy for Climate Protection can take three major steps toward the reduction of CO₂ emissions from cars with innovation alliances under the headings of “Automotive electronics”, “Safe, intelligent mobility – testing ground Germany (SIM TD)” and “Electrical energy storage”. Whether through more economical engines, electronic assistants or communications between vehicles and the infrastructure – experts are searching for solutions which can be quickly implemented and rapidly achieve climate-friendly results.

The innovation alliance “Automotive electronics”, whose participants are automotive manufacturers, suppliers and scientists, makes a substantial contribution to reducing fuel consumption by optimising the interactions between individual vehicle components. With regard to environmental conservation, driver assistant systems can be employed that reduce CO₂ emissions, e.g. by avoiding traffic jams. In addition, improvements to the energy balance through energy recovery and effective energy management of the vehicle as a whole can make an important contribution. Electronics will also support the successive substitution of fossil primary energy sources with renewable energy forms. These developments will be supported by research activities in the field of microsystem technology. Electronic control systems will be the basis for the optimisation of the drive chain, which will still have an internal combustion engine as the most widespread drive type in the future. Hybrid technology will also play an important role, and its potential is also recognised in purely electric drives.

The innovation alliance “Safe, intelligent mobility – testing ground Germany (SIM TD)” has set itself the objective of developing innovative technologies for interlinking vehicles (car-to-car communication) and for linking vehicles with stationary control

systems (car-to-infrastructure communication). These technologies are the basis of efficient traffic management, which makes important contributions to environmentally friendly traffic control and safety. Companies in the auto-motive and communications technology industries, as well as regional traffic authorities involved in this innovation alliance, are conducting research into the technical and economic conditions for the introduction of vehicle communications.

Electrical energy accumulators are particularly vital for a coherent, successful hybrid concept and for the efficient use of hydrogen and fuel cell technology. A central objective of the innovation alliance for the development of lithium ion batteries described above, which has implications for several sectors, is therefore also the development of high-performance, economical batteries for mobile applications in vehicles. The relevant players from the automotive industry will take an active part in this innovation alliance.

comfort. In an ongoing concerted initiative by university and non-university research facilities working on materials sciences, and by leading automotive manufacturers and their suppliers, new, multifunctional materials for future lightweight vehicle construction are to be developed and implemented, making efficient use of resources. The results will have significance far beyond automobile construction. Vehicles for rail, air or sea traffic as well as, for example, agricultural machinery, can be made lighter by innovative materials and so can be constructed to be more environmentally friendly. These types of applications for materials are highly complex and require a great deal of interdisciplinary co-operation. This will gain Germany a technological lead and specific expertise in one of the leading markets of the future.

Conventional engine technology also leaves room for further increases in efficiency. Current research and development work is directed at combining the advantages of the petrol engine (low emissions) with those of the diesel engine (low consumption) in combustion. Further



significant reductions in exhaust gas emissions and fuel consumption can be made in this way. Additional savings of up to 10% in fuel consumption can be achieved by intelligent energy management. There is great potential for this in increasing the efficiency of auxiliary equipment and exploiting energy that is lost as heat. Electrification of the drive systems plays an important part in this. One of the objectives of the Cornerstones for a German government integrated energy and climate programme is to increase the use of vehicles with electric and hybrid drives. The automotive industry and the German government are already working together in various programmes for developing innovative driving technologies. In particular, since May 2006, the German government has supported the market development of the young German hydrogen and fuel cell industry under the leadership of the BMVBS in the national innovation programme for hydrogen and fuel cell technology (NIP).

Formation of a sustainable air transport system

Air transport is gaining increasing significance for the mobility of the world population, and is thereby developing into the fastest growing form of transport.

Scientific studies estimate that the volume of air traffic will more than double in the next 20 years. With a predicted increase in air traffic of 5 to 7% annually, the result is significant potential for growth and jobs in Germany as the European country experiencing the heaviest traffic, but with additional associated burdens on people and the environment. A new, ambitious efficiency strategy must be pursued in order to reduce associated burdens as far as possible. In particular, the use of new, innovative technologies for reducing fuel consumption and noise is needed. This is the only way of ensuring the long-term public acceptance of this form of mobility.

To prevent this growth in air traffic having a negative effect on the environment, increasing investments must be made in research and development for a sustainable air transport system. The starting points for achieving this objective are aircrafts themselves as well as air traffic management. The BMWi is therefore promoting the development of technologies for next generation aircrafts and engines in the aviation research programme, and in so doing it is making an important contribution to the creation of a sustainable air traffic system for the future.

The industry is already speaking of the vision of emission-free flight. However, until the technological and infrastructural conditions for this can be created, achievement of the 2020 targets through the improvement of currently available technologies remains a priority.

Environmental conservation targets and technological viability

The aviation industry has set itself concrete environmental conservation targets to be attained by 2020: the reduction of specific fuel consumption, CO₂ emissions and noise disturbance at takeoff and landing by 50% each, and reduction of specific NOx emissions by 80%. With these targets, the absolute increase in emissions due to the predicted growth in air traffic will be reduced.

The reduction in climate-damaging emissions from individual aircraft will be achieved mainly by

reducing fuel consumption. To achieve this, it is necessary to combine development potentials optimally in the field of airframes (fuselage and wings) with engine technology. The use of new, lighter materials that permit a substantial reduction in weight and thereby fuel consumption without impairing passenger comfort or safety is essential to this. The modern composite fibre construction of the next generation promises a potential reduction in weight of up to 30%, incurring only around 60% of the costs for conventional airframes.

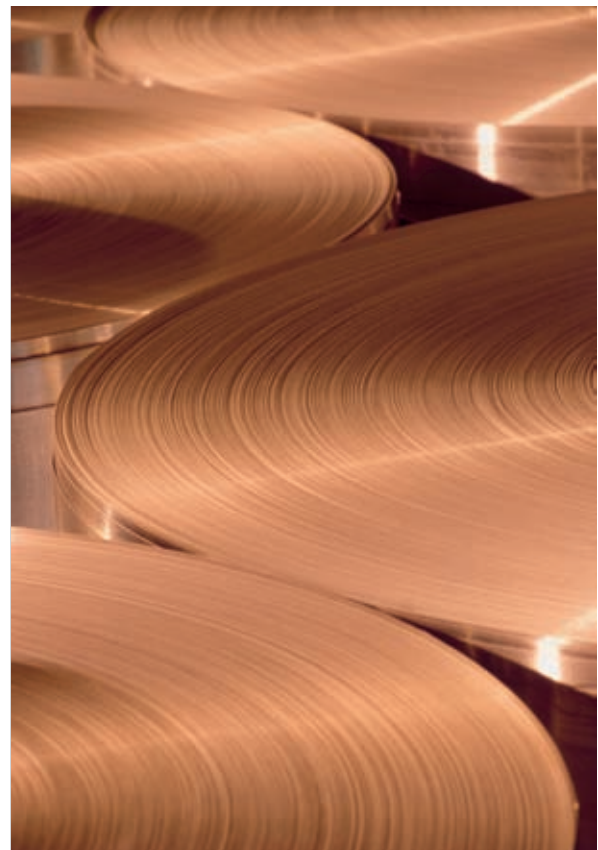
In addition, propulsion offers great potential for increasing energy efficiency and reducing climate-damaging emissions. Apart from further improvements in pure propulsion efficiency, work is currently in progress on concepts for improving the combustion of conventional fuels (lean combustion). In addition, long-term concepts are examining the use of renewable or synthetic fuels for powering aircraft. Furthermore, research is in progress, for example, on how to employ fuel cells for on-board electricity and service water or as power supplies for emission-free taxiing at the airport.

Innovation forces for climate protection: chemicals and new materials

The intermeshing of chemical research and materials sciences with research and development projects in other fields of technology has already been conducted in central areas of the High-Tech Strategy for Climate Protection. This interaction has strategic significance for technological measures to conserve the climate.

Fundamental research and development in the fields of chemicals and materials play a critical role as a technological pacemaker in many innovations for the climate. High-performance materials and lightweight construction systems were the first to make gains in efficiency in vehicle construction or in power plant technology possible through new methods of construction, materials and technologies. Examples such as lithium ion batteries or second generation biofuels also demonstrate that a whole

series of current innovation alliances and partnerships currently being addressed in other fields of technology by the High-Tech Strategy for Climate Protection would be inconceivable without fundamental contributions from chemical and materials sciences. Those who wish to succeed in the future in the rapidly changing markets for climate protection technologies must therefore invest now in this field. The High-Tech Strategy for Climate Protection pursues numerous promising approaches for this purpose.



Innovative luminants and light emitting diodes are an example of the extraordinary possibilities for cost-effective climate protection on a large scale arising out of technological innovations in chemistry. We use almost one fifth of global electrical energy consumption for lighting. A major proportion of this is wasted as heat because conventional light bulbs operate relatively

inefficiently. By contrast, luminescent lighting has a higher energy efficiency and also a substantially longer life. With the initiative for organic light emitting diodes (OLEDs), the BMBF is already investing on a large scale in an innovation alliance in this field. All major industrial partners in the value chain are involved. This support will continue within the framework of the High-Tech Strategy for Climate Protection.

Realising the climate protection potential of buildings

There is an enormous potential for energy-saving in our immediate urban environment in residential houses, offices and factories. Around 40% of energy consumption and 20% of CO₂ emissions in Germany can be attributed to buildings. Currently, they emit some 170 million tonnes of CO₂. Substantial potential savings, with benefits for the climate and economy, can be exploited in the field of buildings and private households in the long term.

Without a doubt, the greatest impact can be achieved through the refurbishment of existing buildings. The refurbishment of old buildings in particular offers numerous possibilities for saving energy. It is already possible, using existing technologies, to retrofit old buildings to be environmentally friendly. With the development of existing and new insulation, materials, concepts and methods, scope for this can be substantially widened.

Just as important is the need to meet the demand for



On the road to energy-efficient buildings

There are a number of good ideas for saving energy and resources in buildings. Some of these concepts are already in the trial phase or are in use in some places. Nonetheless, substantial research is required with regard to materials, building designs and energy conversion as well as with regard to tools for implementing this great potential. The most important tools for CO₂ reduction are (a) insulation, storage, building material manufacture and building design, (b) intelligent modules and system technology, (c) energy-optimised buildings and (d) refurbishment of old buildings. These are therefore the focal point of the BMWi research programme “Energy-optimised construction”. Furthermore, the complete life cycle - that is, not only the operating phase but also manufacture, transport, processing and disposal - must be considered. As a supporting measure, great weight should also be given to the subject of training and further education in the “Energy-optimised construction” research programme.

qualified people able to offer consultancy and the construction of energy-optimised new buildings as well as refurbishment using existing technologies. Attempts to implement existing technologies nationwide in the field of more efficient energy use and renewable energy supplies fail because, in some cases, the interfaces between these individual technologies can be mastered only with expert knowledge. The training and further education of skilled personnel must be adapted at all levels to the higher requirements. Centralised education and information campaigns as well as simple planning aids for architects and engineers can also contribute to ensuring rapid and widespread take-up. The BMWi already contributes significantly to this within the scope of the specialist programme “Energy-optimised building”.

Planning and execution in both new and old buildings can be greatly simplified by development of so-called intelligent modules (“Smart Modules”). These are pre-



manufactured, partially pre-assembled kits designed for specific size ranges and surrounding conditions, and can be installed in appropriate combinations in a user-friendly way with mainly standardised installation and connection elements. They enable energy-efficient control and regulation of the overall system as well as the efficient coupling of different systems, such as heating with solar and geothermal sources or the integration of decentralised power generating equipment (small combined heat and power plants) and household appliances. The frequently difficult linking of old and new systems can in this way also be simplified. As yet no efforts are being made to develop such modules for the entire market. However, successful implementation of smart modules would form a substantial basis for the nationwide realisation of the potential for climate protection within the construction industry, with international marketing potential. Within the framework of the High-Tech Strategy for Climate Protection, research groups are therefore to be supported and a strategic partnership established between the construction industry, technical universities and other relevant partners in order to lay the foundation for Germany's technological and market leadership in this field.

The research groups, and the strategic partnership for resource-efficient buildings commencing in 2008, will implement innovative and marketable energy-saving

technologies in projects during the coming years. Central research issues are passive cooling and heat supply, associated storage technologies, building shells and construction techniques as well as the design of buildings for extreme weather conditions. In addition, practical and industry-usable life-cycle calculation tools must be developed for the optimisation of costs, resources and environmental impact. On the basis of a broad platform for the numerous stakeholders involved in construction, the viability of integrated construction concepts for energy-optimised buildings must be demonstrated, thus inducing a leap in innovation for energy and resource efficiency.

The landscape changes with the climate

Climate change is already altering our landscapes. In the fields of agriculture and forestry this is already perceptible in the form of changes in regional climate, extreme in some cases. Consequently, production risks are already present in the agricultural and forestry sectors. Concepts for coming to terms with this, however, still remain at a very early stage of development.

At the same time, changes in land use have an influence on our climate. The progressive exploitation of land for residential and transport purposes increases urban heating effects, raises CO₂ emission through the increased commuting arising out of the dispersion of communities, changes the ability of surfaces to reflect incoming radiation, favours extreme weather and reduces the assimilation of CO₂ in humus-bearing soils.

The way land is used can therefore play a decisive part in the issue of whether landscapes function as CO₂ sources or CO₂ sinks. This depends on the interaction between cultivation systems and their long-term effect on the form and extent of carbon storage. The largest quantities of greenhouse gases are stored in forests and oceans. However, the storage capacity of soil can possibly also be increased by suitable treatment, for example by enrichment with humus.

Whether through adaptation or climate protection, climate change heightens the emphasis on competing forms of land use. The production of biomass for obtaining energy and materials is becoming increasingly controversial, since it

The “zero energy home”

The home of the future will adapt to general climatic conditions. In summer, it will provide protection against the sun and store the surplus energy, in winter it will produce heat and passively exploit solar energy. Thermal insulation plays a key part in this. Special insulating materials with increased performance, such as hyper-insulating materials and building materials capable of storing energy, prevent energy from escaping unused. Energy can also be saved in the manufacture and recycling of building components. If, for example, the prefabricated elements of a five-storey building are reused, 1.4 million kilowatt hours of primary energy and 322 tonnes of CO₂ can be avoided and construction costs for a new building shell reduced by 25 %. A research partnership within the building industry, in close co-operation with materials scientists and chemistry research, therefore intends to initiate a series of basic innovations and integrate these quickly into house construction and refurbishment. Transparent thermal insulation, solar energy capture and decentralised room air circulation with heat recovery - pilot refurbishment projects using such methods will be executed within the scope of the BMWi’s “Energy-optimised construction” research programme in the future and will, for example, reconstruct old buildings as “zero energy homes”.

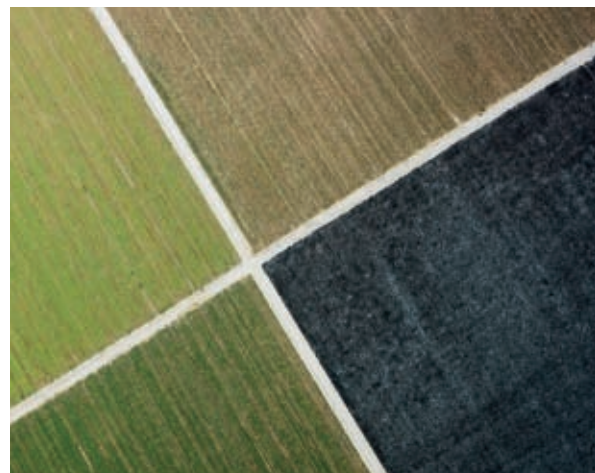
conflicts with conventional farming aimed at producing food and fodder and brings with it the risk of increased greenhouse gas emissions under unfavourable production conditions. Biomass production for obtaining energy and materials must therefore be examined from the perspective of climatic compatibility throughout the entire value chain, from expansion to use.

Taking these developments together, the issue arises of the adjustment of traditional forestry and agricultural use systems to climate change. Novel systems for land use rely increasingly on the further cultivation of biomass for energy purposes in areas that are currently unused.

Moving towards climate protection through landscape management

Landscape management can make a substantial contribution to climate protection. This requires a better understanding of the fundamental mechanisms and interactions in the interplay between landscape and climate. Based on this, research is to be conducted into sustainable land use methods and technologies for enabling landscape management to achieve climate protection objectives. The long-term use of these methods and technologies depends on how successfully the numerous different influencing factors and interests for land use can be aligned in integrated landscape systems.

The possibilities of the further cultivation in these areas are not being fully exploited. Research projects therefore address the exploitation of areas not previously used for agriculture - for example, through the creation of energy gardens that enable efficient multiple use, and through the use of open urban areas or unused areas of former coal mining regions. The emphasis is on methods and techniques that permit the economic reworking of areas not formerly used for agriculture and minimise obstacles such as those of planning and traditional agriculture. Suitable adapted techniques and technologies in the field



Landscapes for climate protection

The question of the appropriate response to climate change is particularly important for agriculture and forestry. The list of partly contradictory interests in landscape use is added to by the issue of how to adapt successfully to climate change and simultaneously contribute to climate protection. Regarding production of renewable raw materials for conversion into energy and materials, new concepts of land use are gaining in significance, not least in order to fulfil the requirements of existing cultivated landscapes. In issues of adaptation, system concepts with novel technologies are being discussed that will, acting together with the individual components, make it possible, for example to respond flexibly to local circumstances of soil properties or water management, or that are better able to resist extreme droughts or storms.

Until now no reliable data has existed to enable Germany to assess the effects of different agricultural and forestry use systems on climate protection and adaptation. The High-Tech Strategy for Climate Protection addresses this matter. The emphasis of a strategic partnership on novel land use systems is on the issue of how climate change can be countered by land use and its response to a changing climate. In the forefront of this partnership of different agriculture and forestry industries, together with associations, is the co-ordination and addressing of fundamental research tasks and the short-term implementation of system innovations such as agroforestry systems and the support of adapted use technologies with high global market potential.

of the cultivation, harvesting and processing of renewable raw materials are also to some extent lacking. Agricultural harvesting technology modified for these requirements currently remains in the development stage. The objective is to develop a robust harvesting technology, based on existing expertise, with which a substantial contribution

to the use of existing open spaces can be made for the cultivation of woody biomass. Corresponding land use systems will achieve positive climate protection effects for a limited period through the increased amounts of carbon stored in the topsoil and underground biomass and, depending on the tree varieties selected by location, also enable adaptation to extreme weather.

Setting aside the adaptation of land use systems and technologies, research and development work is also being initiated in close co-ordination with the higher-level High-Tech Strategy for Germany in the innovation field of “plants”, in which the stress tolerances of plant species to different influences can be deliberately improved. In the future, agricultural crops must do more than better survive phenomena such as water shortages or high wind speeds - a further objective is improved resistance to pests, whose numbers will in many cases increase due to climate change. Of particular interest are plants that are both high yield and particularly resilient. Furthermore, plants which are particularly good for the supply of raw materials in the future are also of interest. The objective is to make a wider range of varieties available for different purposes. This objective can be approached from two directions: one option is to optimise the features of existing crops through breeding, and the other is to obtain a systematic overview of the many different genetic properties and capabilities of cultivated and wild plants, both land-based and aquatic, and to make use of these according to their potential and environmental compatibility. Particular potential for innovation lies in the combination of plant genome research and system biology with plant biotechnology, bioenergy, plant design and the use of other innovative and sustainable forms of biomass production. The BMBF co-operates with the BMELV and the BMU in this sector.

Finally, resource-efficient land use can also be achieved through high urban densities, and such urban forms usually result in reduced demand for mobility. A new philosophy for urban and residential construction is therefore required for climate policy reasons. The concentrated city, with its efficient exploitation of the advantages of close living, a central energy supply, general relinquishment of motor transport within the core of the community and the closest possible interaction between homes,

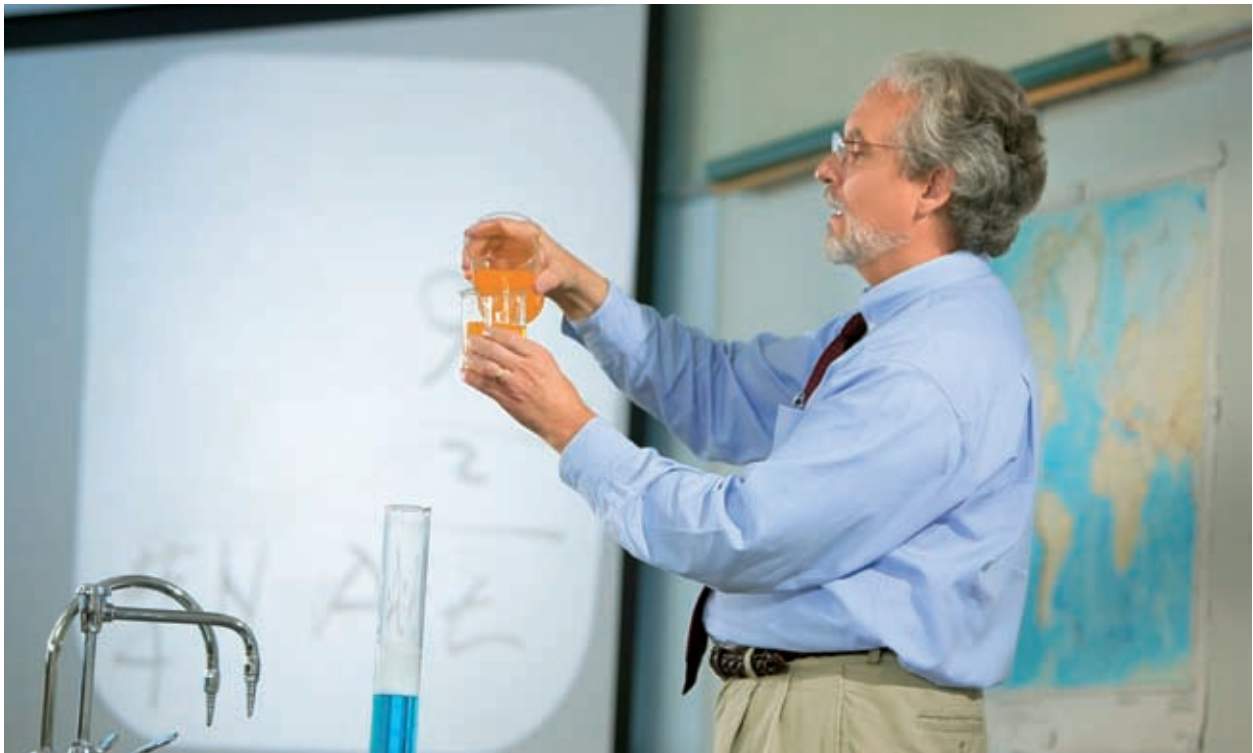


consumer amenities and work, have again become concepts discussed anew in this context. This relates to the combination of high-density construction and low-emission, car-free accommodation, having independent energy supplies from block heating power plants and combined heat-and-power, together with the rigorous integration and production of renewable energy forms and local and remote heating networks.

Numerous technical solutions can strengthen Germany as a high-tech country for the energy use of the future.

4. Making Knowledge Useful

Decision-making principles for a world in change



What does climate change mean for the decisions made daily by businesspeople, scientists and politicians? The possible variables due to climate change must be taken into account in the future in many strategic decisions. For companies, this means determining how climate change will influence the general conditions for their investment decisions or market development. Farmers and foresters take account of the climate changes in their regions when planning cultivation. Tourism, water management, infrastructure planning by transport companies – many

industries and sectors are affected. Politicians also require reliable predictions and suitably organised climate model data in order to initiate changes in society as a consequence of global warming.

Although global warming is now beginning to play a part in practically all aspects of life, decision-makers usually lack the understanding to handle data from climate projections competently. Although future climatic conditions for specific regions and periods can be estimated with the aid of the extensive results of climate system research, each method has its strengths and weaknesses, being based on particular assumptions and therefore reaching specific conclusions. This limitation is of great significance for the use of different climate scenarios.

We smooth the way for competent strategic decisions

Extensive consultations and interpretations are therefore needed, so that a substantiated basis for decisions in widely varying fields may be obtained from the results of climate research. It is important that data be prepared with the application in mind and put into an appropriate perspective; equally, the data generated must be what is specifically required. This is the only way that information can be employed appropriately in strategic planning.

The High-Tech Strategy for Climate Protection also addresses this issue: the improvement of possibilities for information and consultancy is one of its central tasks.

The results gained from climate research are to be made easily accessible in all parts of public life, and proper awareness of the scientific predictions of climate change is to be supported. To this end, the gap between climate system research and the users of climate data must be closed in a carefully considered way. This can best be achieved if a competent institution undertakes the role of a service provider, offering the existing, decentralised



The Climate Service Centre (CSC)

The CSC will be provided with expertise and resources in all fields important to the task, such as climate research, communications and technical implementation. The CSC will not enter into competition with existing research facilities, but will be integrated into the existing network of the numerous institutions already working successfully in Germany on issues of climate change and its consequences. Through intensive communication with users and scientists and clear orientation to demand, the CSC will be able to prepare climate data in the form of required products and to offer advice in its use. For example, it will also undertake the routine operational generation of global and regional climate scenarios and predictions and co-ordinate important, higher-level research and development work. The results of these activities will be distributed and clarified in numerous ways. With the facilities of the CSC, research results can be better marketed. Also, awareness of the value of this information can be created in CSC's users.

knowledge and advice from a single source and thus operating as an interface between the various stakeholders in fundamentally-oriented climate research and concrete applications.

To this end, the BMBF is establishing the Climate Service Centre (CSC). The fundamental principle of the CSC is customer orientation, with a close connection to leading German research. This will result in its key strength as a competence centre and mediator between science, business and politicians.

By setting up this national service centre with flexible tools for information dissemination, the BMBF will provide decision-makers in business and politics with better means of incorporating climate change predictions into planning processes and investment strategies. The CSC and the Competence Centre for Climatic Consequences and Adaptation (Kompetenzzentrum Klimafolgen und



Anpassung - KomPass) set up by the BMU at the Federal Environment Agency, which concentrates on the synthesis, preparation, communication and combination of specialised knowledge on climate consequences and adaptation, will complement each other in this work. Scientific users and engineers in high technology, who can provide Germany with important knowledge advancements in the future by using tailor-made and appropriately classified data, will be amongst the CSC's customers. Developments in climatology itself will be advanced because the data and products supplied can be constantly reviewed via feedback from the applications and used for the further development of climate models.

The financial sector as a strategic partner in climate protection

Investors and decision-makers in banks, insurance companies and other financial service providers bear particular responsibility for successful climate protection and adaptation strategies. Without the required capital and the necessary loans, insurance policies and investments, innovations will not be converted into products and services, and will not conquer global markets.

Specific research and development measures are needed in order to empower the financial sector and so provide support to innovators and users in various areas in the implementation of their advanced objectives.

This relates particularly to the development of corresponding information systems and the development of methods for integrating newer aspects into the assessment of companies, projects and technologies. The support of systems for making public pertinent research and development can contribute substantially to market transparency, without which the capital market cannot fulfil its task of efficiently allocating capital.

In order to realise an efficient and effective climate policy, one that Germany and its domestic companies can optimally exploit, the German government regards co-operation with stakeholders in the financial sector as being of prime importance within the framework of the High-Tech Strategy for Climate Protection. Leading financial service providers have adopted this initiative.

Many financial service providers have recognised climate change as a central challenge for their strategic business development. They have therefore initiated and supported initiatives at national and international levels, so as to build up the appropriate expertise and to develop products and services that take account of climate change. However, climate change remains a special challenge for the financial sector with regard to the estimation of future opportunities and risks. The possibilities for forecast development and calculation are therefore to be improved. The support of systems for making public pertinent research and development can make a substantial contribution to market transparency, without which the capital market cannot fulfil its task of efficiently allocating capital.

The German government has therefore entered into a dialogue with the financial sector concerning the opportunities and risks of climate change. For example, at a conference of financial service providers the BMU discussed opportunities and risks with over 150 representatives of inland and foreign banks, insurance companies and investment companies. The results were discussed at the ministerial meeting in the framework of the Gleneagles dialogue under the German G8 presidency in September

Financial forum: climate change

The BMBF and German financial service providers have established the “Financial Forum: Climate Change” within the framework of the High-Tech Strategy for Climate Protection. This permits close coupling of financial expertise with scientific, technical and economic research, and provides a means of initiating an effective learning process that has great significance for Germany and also internationally. In the “Financial Forum: Climate Change”, the measures necessary to achieve mutual objectives are to be agreed, evaluated and ways of implementing them are to be resolved. In this way, financial markets can contribute to optimising the costs and benefits of climate protection and adaptation strategies, and to the better use of the opportunities offered by technological developments.

2007 in Berlin. This meeting of the Environment and Energy Ministers of the 20 countries with the largest energy consumption was also concerned with investments for a sustainable energy supply.

Within the scope of the High-Tech Strategy for Climate Protection, the BMBF will contribute to providing the financial market with optimal transparency on climate change and on the resulting technical and economic challenges. The subject of climate change thus poses fundamental new challenges for the “information architecture” of the financial market. Suitable climate information is not usually freely available for financial service providers since the corresponding climate research data must first be matched to the requirements of the financial market and supplemented by further market data. This is a task whose resolution requires substantial research and development. Better networking of the relevant research facilities with the financial sector is necessary in order to meet the demands of the financial sector. Work will be conducted in close co-operation with the appropriate competence centres, such as the CSC, so as to build up the necessary information systems and to network with other information providers through a suitable architecture.

Furthermore, the High-Tech Strategy for Climate Protection is pursuing the objective of integrating the viewpoints of German financial service providers into technical innovation processes better and earlier in order to speed up the implementation of promising ideas. Corresponding research co-operations will thus be developed with partners in the fields of technology and application.

5. Taking Responsibility

Participating in shaping the global future



No country faces the challenges of climate change alone - no-one is exempt. Thanks to its strength in research and innovation, and its ability to achieve technical strides in the performance of these tasks, Germany can play an important role worldwide. However, the general conditions for this will not be created in an isolated, national context. The global dimension of the task demands new forms of international co-operation.

Germany as a reliable partner in the climate protection market of the future

As a significant industrial nation, Germany has a special responsibility to involve both emerging and developing countries actively in climate protection. Up-and-coming economies such as China or India are already contributing significantly to the release of climate-damaging emissions. For this reason, the German government must become a reliable partner for those countries which, due to their economic development, are of global significance not only as markets, but also in terms of climate protection. The dissemination of expertise and advanced technology from Germany can and should make a decisive contribution to the sustainable and dynamic economic development of emerging and developing countries. International co-operation in the development and application of new technologies plays a central part with respect to overcoming global warming.

“Sustainable solutions” in dialogue with emerging countries

The BMBF is taking the initiative in the research policy dialogue with important groups of emerging countries that are currently acknowledged as having the best opportunities for above-average economic growth. Since March 2007, a BMBF workgroup has been operating to establish strategic partnerships with these countries. Experience from public and private research into sustainability will be combined and exploited on the basis of best practice models to formulate joint initiatives. The effectiveness of research-based solutions will thus be increased and long-term future markets secured. With the international dialogue on research into sustainability, the BMBF will support the internationalisation objectives of the High-Tech Strategy for Climate Protection and contribute visible to the German government’s objectives in terms of sustainability. A series of international conferences on this subject in 2008 and 2009 will place the dialogue within a broad political, economic and social framework, documenting Germany’s leading international role.

The development of new methods and applications is of course not only relevant to climate protection - it also opens up excellent opportunities for German companies in one of the most important technology markets. Renewable raw materials, efficient machines alternative forms of energy – environmentally friendly technology from Germany is in global demand. Already, nearly one-fifth of the environmental technology sold worldwide originates from Germany. Our climate-friendly technologies must remain export hits into the future, so that their success ensures Germany’s long-term security as an industrial nation.

Realising the High-Tech Strategy for Climate Protection in international dialogue

With the High-Tech Strategy for Climate Protection, the BMBF has initiated a process whose effects will unfold not



just nationally but, above all, internationally. New alliances, particularly with the major emerging countries but also in transatlantic and transpacific dialogue, are prerequisites for offering and implementing innovative and adapted solutions worldwide. These new alliances must suitably complement the existing technology partnerships and initiatives, such as those coming under the umbrella of the UN climate convention. Exporting products and specialist knowledge is just one important aspect. It is equally important that innovation alliances, particularly those with emerging countries, are understood as a mutual learning process and jointly developed. The German government regards these countries as equal partners. The foundation is global responsibility, which acknowledges the role of the industrial nations in the past, just as it does the requirement for action in climate policies by all governments in the present and the future. We intend to develop scenarios in which there are no losers – for example, by enabling partner countries to benefit from the development and sustainable formation of their national economies through climate-efficient technologies from Germany, while simultaneously allowing German research institutions and companies to take up important impulses from new markets.

This will allow German companies to achieve their full performance potential in co-operation with their partners in emerging countries, and to implement innovative solutions on a wide scale. In order to implement the most environmentally friendly technologies globally in conjunction with emerging countries, favourable frameworks for co-operation must be created by the governments. This includes the establishment of the corresponding capacities in science and the economy alongside the operation of joint research institutions and the creation of suitable means of financing for developers and clients.

A strong partner for joint climate protection and technology initiatives

We intend to forge sustainable innovation alliances with globally important partners to overcome the global challenges of climate change. For the BMBF, the focus for joint action against global warming is on the large and rapidly growing emerging countries – most particularly India, Indonesia and China in Asia, as well as Brazil and Mexico in Latin America. Russia and South Africa are equally significant. Taken together, these countries represent almost half the world's population. Other important partners in the future include the remainder of the so-called Next Eleven (apart from Mexico and Indonesia, these are Egypt, Bangladesh, Iran, Nigeria, Pakistan, the Philippines, South Korea, Turkey and Vietnam).

Against the background of the need for action on climate change, the BMBF will push for the establishment of dynamic innovation alliances by 2009, and will open dialogues on climate protection to identify the options for joint action, equipped with suitable and strategically appropriate resources. The existing agreements on bilateral science and research co-operation with Germany and the numerous existing technology partnerships provide a stable foundation. In addition, the BMBF will orient itself toward the guidelines of the European sustainability strategy of the G8 process and the UN climate convention. By mediating technological solutions, Germany will provide vital support for the objectives of the "Gleneagles dialogue on climate change, clean energy and sustainable development" begun in 2005 and

continued under the German presidency in 2007, and for the climate protection objectives formulated at the G8 summit in Heiligendamm. It has already been agreed to establish future partnerships through a support programme for energy-efficient structures in rapidly growing urban centres.

Apart from the emerging countries, the German government is making every effort to engage the USA as one of the largest emitters of greenhouse gases in the struggle against climate change. The Foreign Office has therefore instigated the "Transatlantic Climate and Technology Initiative" under German EU Council presidency. Europe and the United States intend to co-operate more closely in the future on climate and energy issues, particularly in the field of "clean coal", the development of renewable energy forms and energy efficiency.

6. Outlook



With the High-Tech Strategy for Climate Protection, Germany has set its sights on the achievement of technological breakthroughs that can be implemented quickly and to great effect. Progress already made has impressively demonstrated that the forces for innovation in Germany can be greatly strengthened if politicians, business and science pull together. The German government intends to reinforce this tendency further.

Together with partners in science and the economy, the German government will work to ensure that the relevant issues are addressed. We will continue the dialogue that has been initiated into the future, in order to make the wide-ranging facilities of science, technology and business in Germany available to meet the global challenges of climate change. We expect existing partnerships to be continued, and will add new ones that make a general contribution to the achievement of climate protection objectives.

Implementation of the High-Tech Strategy for Climate Protection is an important element of a policy that sees the German government responding to the economic and ecological challenges of climate change. The

departments of the German government that are involved participate, within their respective fields of responsibility, with concrete supporting measures. They will support research, development and innovation in the designated fields of research and technology central to climate protection. The BMBF will report regularly, with the participation of stakeholders from science, the economy and politics, in order to document the progress of work. This will show the progress made, and what new milestones will be achieved. This applies to advanced technology for climate protection that is “Made in Germany” just as much as it does to research into the climate at a global level and to the bringing together of diverse players for a mutual objective: for Germany to confront the challenges of climate change hand in hand with scientists, business people and politicians, accepting its global responsibility.

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