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Baden-Württemberg AG

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EnBW 2008 Innovation Report

Energy and Climate Compass
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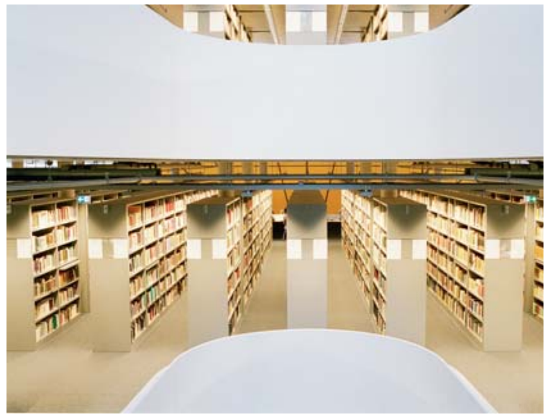


Hans-Peter Villis
CEO of EnBW
Energie Baden-Württemberg AG

Innovations for effective climate protection

The protection of the global climate has been at the top of the agenda in the world of national and international politics for some time: in 2009, a globally effective follow-up agreement to the Kyoto Protocol is to be adopted in Copenhagen with the aim of reducing emissions of greenhouse gases by 2020 – despite the ongoing increase in global energy requirements.

This affects the energy industry to an especially large degree. Cutting emissions of carbon dioxide by up to 40% – as desired by the German government – while continuing to ensure reliable energy supplies and the cost efficiency of these supplies is no simple matter.

We see this as a challenge to the adaptability and the innovative drive of our company and of the entire energy sector. It will be impossible to achieve the highly ambitious political objectives without major innovations in the field of energy generation and energy consumption. This applies to the entire spectrum of relevant issues: from the efficient use of energy, renewable forms of energy and low carbon dioxide fossil fuels all the way through to nuclear energy. What is needed is, firstly, research and development at universities, research institutions and companies – and these activities must be backed up by the close cooperation of all involved parties.

But this only takes us half the way. New inventions and development work on existing technologies must be translated into successful products and services – as they can only have the desired effect if they are accepted by the market and by our customers. This is the goal of an integrative innovation policy of the kind that EnBW attaches major importance to: in 2007, spending on research, development and innovation totalled 32.4 million euros. The strategic core unit comprised 27 employees, while around 150 employees throughout the group were directly involved in R&D activities and innovation projects.

Against the backdrop of the challenge to the innovative capacity of our company resulting from the problem of climate change, EnBW has decided to focus its 2008 Innovation Report on the theme of climate protection. This report is designed to tell our employees, our business associates and our shareholders as well as associations, the media and the public at large about the efforts EnBW already makes in the areas of research, development and innovation in order to promote climate protection. The Innovation Report does not, however, provide a comprehensive overview of EnBW's activities but profiles examples of new developments in individual fields.

In addition to outlining the activities within our company, we will also be looking at what is happening externally in research laboratories and testing facilities. Our goal with this report is to create a kind of reference work on climate protection in the energy industry. And one which is easy for the lay reader to understand.

We have also invited experts to share their own personal view of the future of the energy industry, creating a varied and multi-facetted spectrum of ideas and opinions. Given the topic in question, it is only natural that some of the opinions are controversial. Progress also calls for discussion and debate over which strategy is the most promising and therefore the right one to pursue: How can we achieve maximum success with the limited means at our disposal? This is the question that will determine the nature of the debate in coming years.

EnBW intends to play an active role in this debate and to take a vigorous part in the discussion as a good corporate citizen. We hope that this report also makes a contribution to this endeavour and that it may also generate new stimuli and food for thought.

Hans-Peter Villis
CEO of EnBW
Energie Baden-Württemberg AG

› Changing **climate**

Climate change presents the entire world with an enormous challenge. In order to limit the increase in the temperature of the earth to 2°C, we need to massively reduce the emission of greenhouse gases. This calls not only for changes in consumption patterns but also and above all for new and innovative technologies.

Dr. Peter Feldhaus joined McKinsey & Company in 1999 and is meanwhile Principal. In September 2007, McKinsey & Company presented a study commissioned by the Federation of German Industries on the costs of avoiding climate change.

Combating climate change

Status quo

Ever since the publication of the 4th report of the Intergovernmental Panel on Climate Change (IPCC) there can no longer be any doubt: global warming is the result of an increasing concentration of anthropogenic greenhouse gases in the atmosphere. Several leading industrial nations are therefore working on ways to reduce their greenhouse gas emissions. The German government, for example, has formulated an ambitious target: namely to reduce greenhouse gas emissions in Germany by 30 to 40% compared to 1990 levels by the year 2020. A reduction in the volume of these gases by just over 30% is roughly equivalent to the current target for Germany as stipulated in the EU Directive. German industry is also taking an active stance: the Federation of German Industries (BDI) commissioned McKinsey & Company to conduct a study to determine how and at what cost the targets laid down by the German government can be achieved. In this study, around 70 companies, among them EnBW, outlined more than 300 technical measures to avoid greenhouse gases and analysed the potential for – and the cost of – avoidance.

2020

The 30% reduction target of the German government compared to 1990 levels is indeed achievable given the right conditions and the creation of the appropriate framework. By implementing measures that will cost up to 20 euros per ton of avoided CO_2 emissions and that will in many cases even result in savings, it will be possible to reduce greenhouse gas emissions in Germany by 26% up to the year 2020 compared to 1990 levels.

Even a figure of 31% is feasible if, in addition – and based on the assumption that Germany stands by its decision to discontinue nuclear power generating activities – the energy mix is restructured and geared towards a higher share of renewable forms of energy. This would, however, entail far higher average avoidance costs in the order of 32 euros per ton of CO_2 in the area of electricity generation and a massive 175 euros in the field of biofuels. A reduction of up to 40% in greenhouse gas emissions by the year 2020 would only be possible through the implementation of politically or economically painful compromises or at considerable additional cost.

After 2020

If global warming is to be effectively contained in the long term, it will be necessary to implement more extensive emission reduction measures. New methods and technologies that are as yet unknown or are currently in the development phase will have to be used to cut emission levels. One of the big levers that could enable us to reduce annual greenhouse gas emissions by over 100 megatons by 2030 is so-called carbon capture and storage (CCS). The development of this and similar technologies will require supreme efforts in the area of research and development, in the creation of appropriate regulatory frameworks and in the raising of awareness levels among the public at large. In view of the sheer magnitude of the challenge that faces us, this means that the unprejudiced debate and discussion of all potential levers that can help us to reduce greenhouse gas emissions is an absolute necessity.

Herculean task for the world community

Global climate: the topic of 2007

The debate over the global climate dominated 2007 like no other topic. And hardly any area has been left untouched: our view of the world and its vulnerability, the way we use energy, our opinion on the role of industrial companies in society, the expectations of industry in terms of a global political regulatory framework and, not least, our expectations with regard to a form of international political cooperation that has never been seen in the history of our planet. Climate change is inextricably linked to expectations and demands for innovation in all areas of modern life in which energy is produced and consumed. In this connection, it has not been uncommon to hear of a call for the "second man-on-the-Moon project". This call to action forges a link to the unique efforts of the USA in the 60s, when the exemplary concentration of all the driving forces in science, research, technology, industry and politics enabled the US administration to regain its supremacy in space. As the debate over the need to save our climate is and will increasingly become the dominant theme of our times, it is worthwhile tracing the development of this debate.

The UN's climate committee, the IPCC (Intergovernmental Panel on Climate Change), was the prime mover in a debate over the ongoing and hazardous warming of the earth's atmosphere – a debate that has flared up as never before. In 2007, the IPCC submitted its 4th status report in several stages, and the findings of this report were far more clear-cut and considerably more bleak than all the preceding reports. In view of the published findings, there can no longer be any doubt regarding the ongoing change in the world's climate. The IPCC sees it as being "extremely probable" that humankind causes global warming by emitting greenhouse gases like CO_2. As understood by the IPCC, "extremely probable" corresponds to a probability of 90%.

According to the IPCC, the average global temperature has risen twice as fast during the last 50 years as in the previous 100 years. The mean temperature increase for the last century has been determined at 0.74 degrees Celsius. Eleven of the twelve years between 1994 and 2006 belonged to the 20 hottest years since temperature measurements first began. Sea levels are rising, and the rate at which these levels are rising has increased since the 1990s, while the glaciers are melting worldwide. Extreme weather conditions like heatwaves, drought, storms and torrential rainfall are occurring with increasing frequency. The rate and intensity of climate change is stronger than previously assumed.

Since the pre-industrial times at or around 1750, the carbon dioxide concentration in the earth's atmosphere has increased by 35% and is now at the highest level of the last 650,000 years. Global emissions of greenhouse gases increased by 70% between 1970 and 2004, and by 28% during the last 15 years alone. The main reason for this is the world's growing hunger for energy, a hunger we satisfy by burning fossil fuels like coal, oil and gas. There are, however, also other factors like ongoing deforestation and agricultural practices that play a role.

Ever present: the risks of climate change

The process of climate change can no longer be stopped. Even in the utopian event that the emission of greenhouse gases ceased immediately, average global temperatures would still increase by a further 0.64 degrees, because carbon dioxide et al. remain in the atmosphere for a long time and as the earth's climate is a "slow-working" system. In reality, of course, carbon dioxide emissions are not falling; on the contrary, they are still increasing rapidly. If this process continues at the current pace, the worst-case scenario predicted by experts is an increase in the temperature of the world's atmosphere by up to 6.4 degrees. Climate change would take on uncontrollable and hazardous proportions. The implications of such a development were outlined by Potsdam-based climate researcher Hans Joachim Schellnhuber, who is also climate advisor to the German Chancellor, in an interview with the FAZ newspaper:

"Four to five degrees in average global temperature; that is the difference between an ice age and a warm period. If we deduct five degrees, then the glaciers would extend all the way to Berlin. If we add five degrees, then we don't really know what would happen, but we would possibly be outside the corridor within which the earth's climate system is able to repeatedly re-stabilise itself. (...) In regional terms, it is highly probable that the entire Mediterranean region would become a desert and that there would be steppes all the way to the Baltic. The complete melting of the Greenland ice mass, the collapse of the Amazon rainforest and global coral death would be practically assured."

If the world ignores all the warnings and returns to "business as usual", then climate researchers forecast millions of "climate deaths" worldwide and economic damage of an astronomical magnitude. In a worst-case scenario, the sea level would rise by an entire seven metres in the long term. Ten percent of the world's population live in low-level coastal areas. We are talking about almost 650 million people who live in two thirds of the world's biggest cities. A major part of the world's industry is also concentrated in coastal regions. The environmental risks of increased storm flooding are all too easy to imagine. There is the additional threat of water shortages or scarce food supplies in large areas of the world.

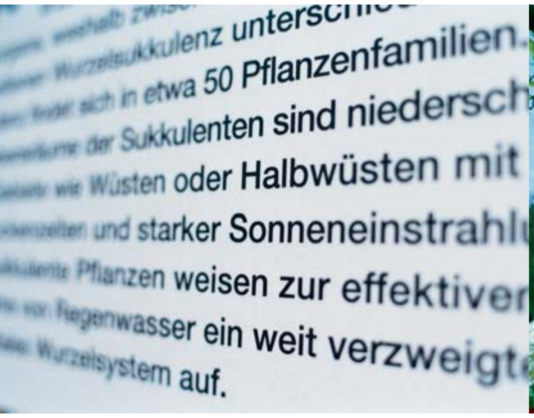
The 2° goal: how to reach it

The IPCC has therefore urgently called for measures to prevent global warming reaching dimensions that would take average temperatures to around 2° C higher than they were in pre-industrial times. They believe that only within this corridor will we be able to master the consequences of global warming to an acceptable degree. If the rise in temperature is any greater, then climate change could pose an extremely serious threat. The only way to slow the pace at which temperatures are rising is to take all possible measures to limit the concentration of greenhouse gases in the atmosphere. The benchmark for the success of such measures are so-called CO_2 equivalents: the climate impact of the different greenhouse gases – such as methane, nitrous oxide and carbon dioxide – varies considerably. In order to define emission limits, the volumes of these gases are converted into units reflecting the impact of the biggest greenhouse gas, namely carbon dioxide. If we are to keep the rise in temperatures within a corridor from 2 to 2.4 degrees with any degree of certainty, the concentration of CO_2 equivalents must not exceed a figure of 445 to 490 ppm (parts per million). Today, the concentration of carbon dioxide alone is already as high as 381 ppm, compared to just 280 ppm in the pre-industrial era. We are already extremely close to the critical limit.

This is why the growth of emissions must be stopped during the next 15 years and why emissions must be reduced by around 50% compared to 1990 levels (60% compared to today's levels) by the year 2050. This clearly underlines the magnitude of the challenge facing our society – and particularly also our industry, the energy sector.

Major challenge: quenching the world's thirst for energy

This challenge is made even more formidable by the – in some cases rapid – growth of national economies around the world. The dangers and hazards are growing at the same dynamic pace. The world's hunger for energy is enormous. According to the International Energy Agency (IEA), the world uses almost twice as much energy today as



it did at the beginning of the seventies, and the figure is set to increase by at least a further 50% by the year 2030. If we carry on with "business as usual", the energy-related CO_2 emissions would increase by an additional 55%!

The central growth drivers meanwhile include the NICs of India, Brazil, South Africa, Mexico, South Korea and, first and foremost, China, which is currently recording two-digit growth per annum. Energy requirements are also increasing rapidly parallel to this economic growth, and this demand for energy is primarily met by coal-fired power plants. Every week, a new large-scale coal-fired power plant goes into operation in China. In 2005, the total number of new facilities was as high as 80. The IEA estimates that, up to 2015, China will put additional power plants with an output of 800 GW (gigawatts) into service – equivalent to the total output capacity in the EU – and that 95% of these plants will be coal-fired. It is therefore only logical that China will match and soon overtake the USA as the world's biggest emitter of carbon dioxide. By 2030, all the NICs together will be responsible for around half of all carbon dioxide emissions worldwide.

Moreover, it should not be forgotten that 1.6 billion people worldwide still have to get by without any electricity at all. This not only means they live a life without what we would consider the basis comforts; more importantly, it means they are totally cut off from information, from communication and from educational opportunities. The global population is forecast to grow from the current figure of 6 billion to 8 billion by 2030 – and these people also have a right to adequate energy supplies.

Alarmed and moved to action: the world of international politics

The wake-up call from the IPCC did not go unheard, either among the public at large or on the political stage. On the contrary: the topic dominated all the political summits and gained further weight and momentum throughout the course of the year. Driven by the desire of broad sections of the population to call a halt to climate change, the political powers-that-be decided to lay down binding political targets with the aim of containing the emission of gases that are harmful to our climate.

A start was made by the European Union at the spring summit of the European heads of state and government under German presidency in March 2007. The European Council decided that the EU states will unilaterally cut their climate gas emissions by 20 percent compared to 1990 levels up to the year 2020. In the event that other industrialised states like the USA make a similar commitment, the EU reduction target is to be increased to 30%. During the same period, the share of renewables in overall energy consumption (electricity, heating and fuels) is to increase to 20%. One of the other goals is to improve energy efficiency by 20% compared to the official forecasts.

The summit of the eight biggest industrial states and the five largest NICs in Heiligendamm in June 2007 was a highlight of Angela Merkel's chancellorship to date. It was seen as a major success that the USA adopted a constructive stance on climate issues for the first time in many years. In the run-up to the summit, the world's biggest CO_2 emitter had – as usual – opposed the inclusion of any binding and quantified reduction targets in the final declaration. The formula of the US government had basically been: stimulation of technical progress and non-binding international agreements on climate protection. Back in 1992 after a summit in Rio de Janeiro, for example, the USA signed the UN Framework Convention on Climate Change (UNFCCC), undertaking to ensure that 2000 carbon dioxide emissions would be no higher than in 1990. In reality, however, these emissions were up 16.3% by 2005.

There was, however, a minor breakthrough at the Heiligendamm summit on the Baltic. An agreement was reached to "give serious consideration" to the goal of halving greenhouse gas emissions by the year 2050. Reference was at least made to the most recent reports of the IPCC and its recommendations, which were consequently also recognised by the USA as the basis for future strategy.

In September 2007, just a few months after Heiligendamm, the USA launched its own climate initiative, inviting the 16 countries in the world with the biggest greenhouse gas emissions (and accounting for around 80% of all such emissions) to Washington. This initiative had a highly unexpected outcome. At the end of the conference, President Bush recognised the lead role of the United Nations in this field, although he unsurprisingly declined to commit to any binding climate targets. This stance was perhaps encouraged by the debate on climate change in the UN General Assembly shortly before the Washington summit. Around 80 heads of state and government made impassioned speeches calling for an effective policy to protect the earth's atmosphere. It became apparent that there was an increasing risk that the USA would become isolated in the world community if it did not rethink its position.

The industrial sector worldwide is also generating increasing pressure for the creation of an ambitious climate protection programme. In Germany, around a dozen companies (among them EnBW) have set up the initiative "2° – German Entrepreneurs for Climate Protection", and the name of the initiative is self-explanatory. The Federation of German Industries (BDI) has created a "Industry for Climate Protection" climate group with around 50 member companies, again including EnBW. This climate group commissioned business consultants McKinsey to identify the most effective method of reducing greenhouse gas emissions and to calculate the avoidance costs.

World climate summit in Bali: hard-fought solutions

These developments fuelled the great expectations for the UN climate summit in Bali in December 2007. Expectation levels were raised even further when it became known that the IPCC and former US Vice-President and climate campaigner Al Gore were to receive the 2007 Nobel Peace Prize. EnBW Energie Baden-Württemberg AG was also pleased to hear this news, as Al Gore was the most prominent guest at the 2nd German Climate Congress in Berlin which took place shortly before the announcement of the Nobel Prize winners. Both the conference itself and the evening event at which Al Gore held his famous presentation were extremely well attended and widely reported.

This was also true – and to a far greater extent – of the UN Climate Summit on the Indonesian island of Bali. More than 10,000 environmental policy-makers from 192 countries attended the conference. And it was once again the USA who showed some movement. When it became clear that the oppositional basic stance of the USA would have left this leading nation isolated on the international stage, the US delegation decided to make some concessions at the last minute.

Joint activities: the Bali roadmap

What are the most important results, what is written in the summit documentation?

Roadmap
A binding roadmap was agreed for the negotiation of a post-Kyoto treaty. A long-term programme for the reduction of greenhouse gases is to be in place by December 2009, when the climate summit will be held in Copenhagen.

Targets
The final document does not list any binding targets, and the status report of the IPCC is mentioned only in a footnote. At least this means that the targets (2°; 50% to 60% reduction by 2050) are indirectly included in the document. In a separate paper, the signatories to the Kyoto Protocol have stipulated targets for the industrialised nations of a reduction in CO_2 equivalents of between 25 and 40% by the year 2020.

NICs
In the roadmap, the NICs undertake to engage in "appropriate climate protection activities". In addition, these activities are subject to measurement, monitoring and reporting obligations. It must be said that these commitments are more wide-ranging than had originally been hoped. China in particular is seen as playing a highly constructive role. This may well be due to the fact that the Middle Kingdom is already feeling the effects of environmental pollution and climate change. The glaciers are melting and posing a threat to drinking water supplies in the giant country, while desertification is continuing apace.

Adjustment fund
A fund has been set up for the developing countries so that they are better able to protect themselves against the consequences of climate change. The fund is financed through a two-percent levy on the emission certificates resulting from the CDM (Clean Development Mechanism). The money is deposited in the Global Environmental Fund of the World Bank and is already being paid out. A total of around 400 million euros will be made available up to 2012. The World Bank itself estimates the cost of adjustment to climate change in the world's poorest countries at 35 billion euros a year.

Protecting the forests
Forest felling is responsible for around one fifth of all climate gas emissions. The fight against deforestation has now been included in the climate negotiations for the first time, and there are plans for agreement on a concrete programme by the end of 2009.

Technology transfer
Plans have been announced to develop a programme to promote climate-friendly technologies. The aim is to identify suitable projects and to then finance these projects from a central fund. Appropriate key patents are also to be made available.

After Bali, before Copenhagen: modest optimism

If agreement is actually reached on a post-Kyoto treaty with the basic outlined structure by the end of 2009, and if a sufficient number of states sign this treaty to ensure its enactment, then this could almost be viewed as the eighth wonder of the world. Never before in the history of the human race would the world's states have entered into a binding undertaking under international law to permit such widespread intervention in their national sovereignty. They would be expected to forego their own short-term economic gain for a greater goal – and climate protection is surely the ultimate goal: it is about the future of energy supply, about electricity, heating and cooling, about transport, about agriculture and forestry, removing any doubt that climate protection has far-reaching implications for our sector, the energy industry. It will lead to considerable changes in the way we use energy, as individuals and as society as a whole. There will be losers and well as winners in this process. Alongside our climate, the winners will include the players who adapt to the new expectations and requirements in an optimum – in other words, innovative – way.

Climate protection can justifiably be described as the challenge of the 21st century. It is still uncertain whether we will succeed in mastering this challenge. The good news in the midst of this bleak scenario is that the IPCC is optimistic that the targets can be met. The panel bases this optimism on its assessment that the necessary technologies are already commercially available or will be ready for series production in the coming decades. The IPCC also believes that this technology is affordable, forecasting that an ambitious climate protection programme would negatively impact worldwide economic growth to the tune of just 0.12% a year and that the sooner we begin to implement wide-ranging climate protection measures, the lower the eventual cost.

The costs are offset by a number of positive effects: increased reliability of energy supplies, improved air quality and new jobs in future-safe sectors. The cost of doing nothing would be incomparably higher. In his report for the British government, former World Bank Chief Economist Sir Nicholas Stern put the figure at between 5 and a catastrophic 20% of global gross domestic product.

But there is no such thing as "automatism" when it comes to climate protection. Climate protection can only make headway if there is a strong and globally effective political framework. The governments need to create appropriate incentives for investment. Key elements of such a strategy include research and development as well as an effective innovation policy. The central areas of technology are clearly defined.

- › They comprise sparing use of energy (energy efficiency),
- › renewable forms of energy,
- › highly efficient use of fossil energies and the capture and underground storage of carbon dioxide from waste gases (CCS)
- › and further development of nuclear energy.

But many of these things still only exist on paper, have only been shown to work in a laboratory setting to date or are simply far too costly to be practicable. This means the universities, research institutes and R&D departments in today's companies still have a lot to do. Much remains to be invented and discovered, and technical progress is a key to climate-compatible economic activity across the entire spectrum of energy production and energy consumption. Last but not least, coherent innovation processes are needed to convert new developments into marketable and promising products and services.

› Energy **efficiency**

Optimum use of resources and achieving higher output with less input: this is the goal of energy efficiency. Be it in power plants, in the transport sector or in the home – there is always room for improvement. Buildings in particular offer a large amount of untapped potential for better energy efficiency. In future, even entire cities will be optimised to ensure maximum energy efficiency.

Prof. Albert Speer is an urban planner and architect. His firm AS&P – Albert Speer & Partner – combines innovative concepts in architecture, urban development and traffic planning with more than forty years of international planning and construction experience.

The future belongs to the energy-efficient city

Status quo

Today, in 2008, 3.3 billion people (over half of the world's total population) live in cities. There are already more than 130 cities around the world with more than three million inhabitants as well as 27 megacities with populations of over 10 million. There is enormous untapped energy-saving potential in cities and buildings in particular. This is why optimised energy and transport infrastructures already play a key role in urban development projects today.

2020

The presence of an optimised energy and transport infrastructure will become an increasingly important aspect in coming decades, driven by the rapid economic growth of the NICs. Experts predict at least a 30% rise in global energy requirements and global greenhouse gas emissions by 2020 as well as an increase in the number of people living in cities from the current figure of 3.3 billion to over four billion. Existing cities will grow and new cities will be built. Every measure that reduces the energy consumption of the cities of the future will make a key contribution to the solution of global energy problems – as it is precisely in the urban conurbations that the highest percentage of energy is consumed. By 2020, more than two in three of the 60 or so megacities worldwide with over five million inhabitants will be located in developing countries.

2050

The greatest potential for the future lies in sustainable, liveable and innovative urban development. By 2050, integrated solutions for urban development will simultaneously reduce primary energy consumption, greenhouse gas emissions and costs: we will enter an era of intelligent houses and energy-efficient cities with tailored solutions for each civic construction project which take account both of the wide-ranging possibilities presented by energy technology as well as the specific circumstances and requirements of the local population. But all this will only be possible if the bearers of expertise in the fields of energy, traffic planning and urban development are integrated in the urban planning process at the earliest possible phase so that they can join forces in the cross-functional and interdisciplinary search for optimum solutions.

With the EnBW EnyCity concept, EnBW has developed a unique and comprehensive tool for the optimisation of the energy systems of complex urban structures. EnBW EnyCity is consciously geared towards cooperation and partnership with urban planners and possesses the necessary interfaces for this purpose.

AS&P intends to systematically exploit this partnership opportunity. In 2007, AS&P and EnBW agreed to cooperate closely in the field of sustainable urban development. The aim of this partnership is to demonstrate the feasibility of sustainable, innovative and liveable urban development. Both AS&P and EnBW believe this idea is of major promise for the future.

Best practice

Important lever: energy efficiency on all levels

If we are to achieve the set climate targets, then the most important lever is energy efficiency – in other words, obtaining as much as possible (output) from the minimum input (energy). Numerous studies underline the huge untapped potential that exists for saving energy. The problem is that there are no single large-scale levers that can help us to achieve our energy efficiency goals. Success will depend on the effective implementation of many small steps filtering all the way down to individual concepts for individual consumers. In view of the additional obstacles that exist, this means that this topic complex is one that is extremely difficult to navigate from a political point of view, particularly as – due to its complex nature – it has very little "sex appeal" in the broader public arena. The energy-saving potential is distributed evenly between industry – the use of economical electric motors, for example – and households, on which the following sections will focus.

Wide-ranging energy efficiency potential in old buildings: high-tech insulation using vacuum technology

The greatest potential for saving energy is in old buildings. Whereas annual heating requirements in new buildings have long since fallen below 70 kilowatt hours per square metre, the average house in Germany still uses two to three times this amount of energy. Some old residential buildings even use as much as 300 kilowatt hours per square metre.

With its modernisation of a multi-family house on a works estate dating back to the 1930s in the Brunckviertel district of Ludwigshafen, BASF demonstrated that the construction industry is meanwhile also able to achieve satisfactory energy standards in old buildings.

In this so-called "three-litre project" – in other words, three "litres of heating oil" per square metre – BASF used a newly developed insulation material called Neopor. Neopor is a rigid polystyrene foam which the company claims possesses insulating properties which are almost twice as good as those of expanded polystyrene.

The group has also developed a novel interior plaster that contains heat-storing "microcapsules". The so-called latent heat accumulators make use of the properties of paraffin, which is contained in the plaster and which melts at temperatures between 24 and 26 degrees. During this transitional phase, the material absorbs a lot of heat without any tangible change to its temperature. At night, the material gives off this energy once again when the paraffin reverts back to solid condition. According to data published by BASF, two centimetres of this plaster store the same amount of thermal energy as a 20 centimetre-thick hollow brick wall. Maxit is the first company to launch a corresponding gypsum plaster product on the market.

But new foam and accumulator materials are not the only way to achieve major reductions in space heating requirements. Natural substances like cellulose or cork are also well-established in this sector. Then there are also the high-tech insulation solutions – vacuum, for example. Vacuum-type panels for the insulation of living space are already on the market.

Vacuum insulation is based on the same principle as a thermos flask; a double-walled glass tube creates a vacuum which reduces the flow of heat. The theory is elementary: the lower the number of glass molecules in the insulating layer, the lower the amount of heat that can diffuse through the material – and a vacuum completely prevents this diffusion process. The idea is to use this thermos flask effect to keep houses warm, achieving optimum heat insulation with drastically reduced wall thickness: the insulation properties of modern vacuum materials are ten times better than those of conventional insulating materials and this therefore allows far slimmer design. This is of particular interest in old buildings, where there is often insufficient space for insulation materials of classic dimensions.

Microporous silica is a popular material used for vacuum insulation. The insulation panels are made of a compacted powder core consisting of extremely finely structured silica. They are covered with special "metallised high-barrier films" which maintain a vacuum effect. "You can think of it as a vacuum-sealed block of coffee", is how it is described by the Bavarian Centre for Applied Energy Research (ZAE) in Würzburg.

It is impossible to create a totally air-free space in practice, but the considerable underpressure of the kind created in the insulation panels is generally described as a vacuum. In the systems currently being developed, the air pressure is reduced to between 0.1 and 0.01 millibars, a ten-thousandth to a hundred-thousandth of the normal atmospheric pressure.

One of the first demonstration projects was the modernisation of a protected building in Nuremberg-Schoppershof in 2000. Due to the low roof overhang on the gable side, the civic building conservation authorities stipulated that insulating material could only be used if it did not exceed a thickness of six centimetres.

Despite these requirements, the experts achieved a level of heat insulation corresponding to that of a highly insulated low-energy house: the heat transition coefficient of the wall is now just 0.2 watts per square meter and Kelvin.

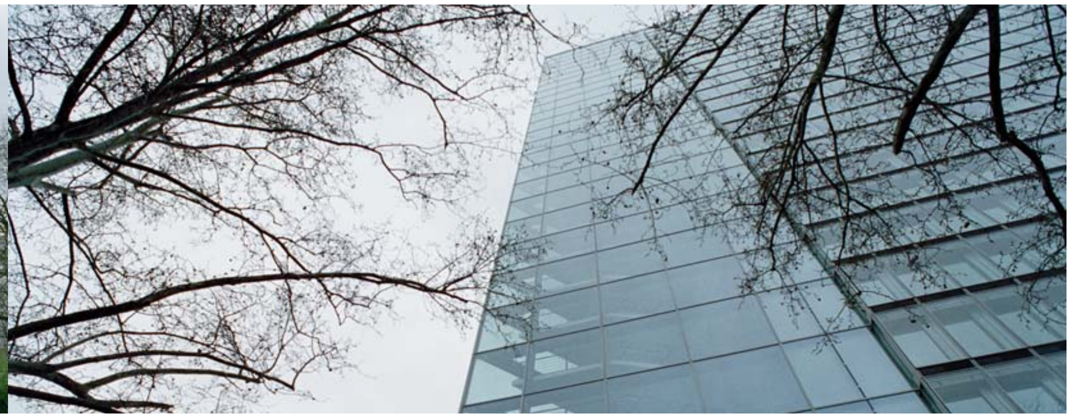
Researchers are fascinated by a further aspect: the insulating properties of the vacuum panels are controllable. And the next step is therefore a system with variable insulating values. Vacuum materials are extremely flexible in this respect: if a gas is pumped into the insulating layer, the material becomes heat-conductive. If the gas is then extracted from the insulating layer once again, the earlier status is restored. The ZAE in Bavaria is conducting research into these kinds of "switchable heat insulation" systems. If the sun shines onto the wall in winter and homeowners want to route the heat energy into the house, they simply switch the insulation to the desired status.

LED: end of the road for the light bulb

The light emitting diode is set to revolutionise the world of illumination technology in the very near future. The first real-world examples of this are already in place: in North Rhine-Westphalia, for example, where the street lighting system in the state capital of Düsseldorf has already been converted to LED technology.

LED technology has major advantages compared to conventional street lighting – first and foremost, of course, the extremely low power consumption. The advent of LED technology will almost certainly signal the demise of the energy-saving lamp. LEDs achieve savings of around 85% compared to the classic light bulb. In traffic lights, for example, 6-watt LED power per colour element achieves the same level of brightness that takes 40 watts using normal bulbs.

But energy efficiency is not the only argument in favour of diode technology. LEDs have only low maintenance costs as their service life of 100,000 hours means they are practically maintenance-free. A light emitting diode is a semiconductor element that gives off light when electricity flows through it. The colour depends on the semiconductor and is almost monochrome – in other words, it comprises light of just one wavelength, and that is why white light can only be created by means of additive colour combination.



In contrast to energy-saving lamps, the diodes do not contain mercury, and their colour can be selected as desired – white light for the pavement, for example, and yellow for the road, or the colour of the light can be one that does not attract insects. In addition, LEDs are impact proof and possess far shorter switching times.

LEDs are already also being used for living space lighting in selected cases. As, in contrast to filament bulbs, they hardly give off any heat radiation, they open up totally new architectural possibilities, including use as spots in floors, for example. Combination of LEDs in different colours switched when and as needed also allows changing of the colour of the light via a switch. This is why LEDs are at present mainly used in designer lamps for living space lighting. LEDs are also already available as bulbs, however, with standard E 27 thread, but at prices of just under 30 euros they are still considerably more expensive than current energy-saving lamps. As production volumes rise, however, prices will begin to fall.

LEDs have been in use for 40 years in areas where only low-level lighting power is needed. For many years, however, their low lighting power was the key obstacle to market breakthrough. In view of the colour parameters of LEDs, it also took a long time to produce models that emit white light. The classic LEDs were always red.

Last year, researchers at the OsramOpto Semiconductors company and the Fraunhofer Institute for Applied Optics and Precision Engineering in Jena were presented with the German Future Award for their further development of the LED. The semiconductor components were made by Osram, the researchers in Jena developed the corresponding optics.

Beware of energy eaters: house-hold appliances, consumer electronics and computers

When people think about saving energy, they generally think of electrical appliances in the household – an area in which there is indeed major potential for economy. Small electrical appliances account for a massive 20% or so of electricity consumed in the household, with refrigeration and freezing devices accounting for a further 20%. Lighting comes in slightly lower at 10%, followed by television and radio with around 7 to 8%.

Computer screens are another area where major savings are possible: flat screens use up to 70% less electricity than picture tube monitors. The fact that they also emit less radiation and are flat and therefore take up less space means that picture tube screens are practically no longer sold. The reason they need less energy is that flat screens use liquid crystal technology (LCD). When these crystals are activated by thin-film transistors, we call this TFT technology (thin film transistor) – and this is the most common technology in use today.

The situation with television sets is often totally different. Increasing screen sizes and ever-higher definition mean higher energy consumption. In addition, consumers often prefer plasma screens due to their greater contrast and wider colour spectrum, and these screens use even more electricity than normal appliances. From an environmental point of view, therefore, TV sets represent a problem: their electricity consumption has been rising for years rather than falling. In future, however, conversion to OLED technology (OLED = organic light-emitting diode) could lead to major savings in this area.

But there are already wide variations between different models when it comes to consumption. This also applies to the "stand-by" mode: efficient appliances use less than 2 watts in stand-by, while other TV sets use over ten times this amount. In this area, energy efficiency is often just a question of the good will of the designers: a conveniently positioned main power switch which can be used to completely disconnect the appliance from the electricity network saves the most energy.

Refrigerators and freezers are also big energy eaters, as they are generally switched on all the time, 24 hours a day and 365 days a year. Watt by watt, this adds up to a lot of energy over the course of the year. The energy consumption of cooling appliances depends on three main factors: how old the appliance is, how big it is and how cold the temperature is set. The energy efficiency classification system currently in use is rather confusing, however, as "Class A" appliances are totally outdated and only appliances with an "A++" rating are state-of-the-art. Compared to an average appliance, a good refrigerator with freezer cabinet uses around 150 kilowatt hours less electricity every year.

Washing machines are also becoming increasingly energy-efficient. Today, good machines with 5-kilogram drums use a maximum 0.95 kilowatt hours of electricity in a standard wash setting thanks to sophisticated programmes. Nevertheless, the de facto environmental impact of any washing machine still depends on the user, who can easily counteract the best eco-profile by operating a washing machine wrongheadedly: the two key factors are that the machine is always well filled and that the washing temperature is as low as possible. Although there are also such things as "intelligent washing machines" with displays that indicate loading status based on weight and even provide dosing recommendations for washing detergent, they are expensive to buy.

As the washing temperature has a major impact on energy consumption, producers of washing detergent are looking into ways of achieving good washing results at lower temperatures. The Ariel brand, for example, claims to offer perfectly clean laundry from temperatures as low 20 degrees thanks to its special technology. A study conducted by the German Institute for Applied Ecology on behalf of Ariel proved that machines use up to 40% less energy per wash programme if the temperature setting is reduced from 40 to 30 degrees. Additional savings can be achieved by connecting the washing machine to a hot water line, an option offered by most modern appliances.

Modern dishwashers are also quite energy-efficient. The myth that it is cheaper to do the washing-up by hand still lives on. But this has long since ceased to be the case: a modern dishwasher is not only more convenient for washing dishes but is generally also more environment-friendly and cheaper. This is confirmed by a direct comparison conducted by the German Institute for Applied Ecology in Freiburg: a modern dishwasher for twelve place settings uses around 15 litres of water on average – and, altogether, water, energy, detergent, rinse aid and salt cost around 37 cents per washing programme. A person washing the same amount of plates and cutlery by hand uses an average 50 or litres of water and pays roughly 66 cents for water, energy and detergent.

Another area which is using more and more electricity is information technology. The computers themselves may be increasingly energy-efficient relative to their performance. Strato AG, one of the biggest European Web hosters, recently announced that it had reduced energy consumption per customer by 30% in just 18 months through the use of energy-saving hardware. They key factors here are energy-saving processors and energy-efficient cooling.

At the same time, however, the Internet is using more and more electricity, primarily due to flatrate broadband packages and the resulting major increase in the time spent

on the Net and in the volume of data transferred. A single Google search, for example, uses the same amount of electricity as an energy-saving lamp in an entire hour. The upshot of this is that electricity consumption by computers has doubled during the last five years – and this trend is set to continue in the future.

EnBW practice

› Energy city of the future:
EnBW EnyCity

"EnBW EnyCity" is an innovative modular planning system for civic energy supply systems of the future. The computer-based model comprises the entire urban supply system complete with all framework conditions and optimises the entire chain from energy generation and conversion to transport and distribution all the way to the end consumer. For the first time, the planners can combine tried and tested systems and components while also incorporating the entire spectrum of renewable and fossil technologies in their concepts. In addition, new construction technologies and materials for the reduction of building energy requirements are incorporated in the planning and design functions.

Alongside the ecological aspects – such as the reduction of primary energy requirements and emissions – equal importance is attached to economic considerations: the economic assessment of the overall concept for an urban supply system takes account of both macroeconomic and business management factors as well as the amortisation times of the corresponding investments. This provides both decision-makers and investors with a reliable basis for the far-sighted and sustainable development of urban areas.

The EnBW EnyCity concept can basically be applied to any city. Where urban structures have grown organically, as is the case in Germany, the first step in the planning process is analysis of the existing situation. The Research Institute for Energy Economy (FfE) has calculated that implementation of an EnBW EnyCity planning concept could cut primary energy requirements in German cities with more than 100,000 inhabitants by an average 5%. This figure would probably be considerably higher for new urban developments. One example of this is the draft design for a new industrial city on the east coast of China. When completed, it is expected to be of a similar area to Greater Munich and home to a population of around 850,000. EnBW has drawn up front-to-end plans for energy supplies in this city based on different scenarios in order to determine the benefit of the EnBW EnyCity model for new cities. The plans incorporate both central supply structures with large-scale power plants as well as highly decentralised structures comprising a large number of small and highly efficient cogeneration plants. The plans also take account of the potential of renewables in the region as well as energy efficiency measures. Based on this example, the experts were able to show that planning in line with the integrated approach of the EnBW EnyCity concept results in an energy supply structure with 25% less greenhouse gas emissions and 30% lower primary energy requirements compared to the current levels in China.

› Back to school:
Energy savings performance contracting

The business model for energy-saving measures developed by EnBW is designed for use in smaller municipal or commercial properties. There is a major need for modernisation in the segment of school buildings alone, and an estimated 30% of the approx. 18,000 schools in Germany are to be refurbished and modernised during the next ten years.

In a model project supported by scientific back-up, EnBW cooperated with the public authorities on the modernisation of three selected schools with the aim of cutting energy consumption by up to 60 – 80%. Typical measures included the insulation of external walls, cellar floors and roofs as well as the replacement of oil boilers by gas or pellet heating systems, the replacement of heating circuit pumps, the optimisation of heating regulation systems, the modernisation of ventilation systems and the fitting of energy-efficient lamps. Upon completion of this work, EnBW also guaranteed maximum consumption limits for fuel and electricity.

The data collected in past projects can now be used as a basis for the reliable analysis of the weak points of buildings in need of modernisation as well as calculation of the required expenditure and the potential for saving energy. The commissioned contracting company bears the cost of planning, supervision and implementation of all modernisation measures. This complex service package is funded over a longer period through part of the energy cost savings.

The modern financing model of energy savings performance contracting has various advantages for the municipalities: it provides a modernisation incentive, the resulting energy savings mean that the construction measures mostly pay for themselves, and the buildings come out at the other end complete with an up-to-date energy passport in line with the new DIN V 18599. In the case of schools, there is the added possibility of providing students, teachers and parents with direct and easy-to-understand information on the topic of energy efficiency.

› Better together:
Energy Efficiency Network

Using energy more efficiently, cutting costs and sparing the environment and the climate – in short, these are the goals of the "Energy Efficiency Network". In 2005, EnBW was the first energy supply company in Germany to launch such a project. One year later, networks were set up in Ravensburg and central Germany - followed in 2007 by networks in Weser-Ems, Franconia-Upper Palatinate and Danube-Alb. The model, which does without public funding, is supported by expert organisations like the Fraunhofer Institute for System and Innovation Research in Karlsruhe as well as EnBW's R&D unit.

10 to 15 small and medium-sized companies from a wide range of different sectors but based in the same region participate in such a network over a period of three years. Each project begins with individual company inspections complete with an energy efficiency diagnosis designed to pinpoint optimisation potential. The participating companies then meet every three months. The findings of the energy efficiency diagnoses are presented at the first two meetings. At the third meeting, the companies agree on their energy-saving quota, with realistic figures ranging from 5 to 8%. Other focal points of subsequent meetings include the discussion of planned or implemented measures as well as presentations on topics such as heat generation and recovery, compressed air, electric drive systems, cogeneration or business issues like feasibility studies, contracting or CO_2 trading.

In the periods between the meetings, the network participants conduct the relevant surveys and analyses in their companies and implement the identified efficiency improvement measures. They are supported in these efforts by an advisory hotline available for the entire duration of the project. They can additionally arrange or request one-on-one advisory sessions, studies, measurements or information on how to apply for subsidies and funding.

The goals of the first two pilot projects in Ravensburg and central Germany are certainly ambitious: when the projects are completed in 2009, the participating companies will have improved their energy efficiency by a total of around 50 GWh per year. This is equivalent to a annual reduction of approx. 15 million kg in CO_2 emissions.

EnBW also supports a research project of the German Environmental Foundation aimed at creating a uniform quality standard for energy efficiency networks. In future, this standard is to serve as a certification benchmark for potential providers of such projects as well as for the definition of minimum quality requirements. The project draws on experience, methods and instruments from previous networks.

› Ideal for large-scale customers:
Energy Efficiency Forum

With the "Energy Efficiency Forum", EnBW offers a product specifically tailored to the requirements of large-scale customers and focusing on the situation in a specific company. The main responsibility lies with a project team set up by the customer; EnBW provides methodological and energy technology support and supplies the analytical and measurement techniques. This is another area with major untapped energy efficiency potential – as shown by the savings targets of between 8 and 10% laid down at the forums staged in 2007 at Mannesmann-Röhren Mülheim GmbH in Mülheim, Walter Hundhausen GmbH in Schwerte and Diekerhoff Guss GmbH in Gevelsberg.

› Test, improve, test again:
Fuel cells

EnBW has been cooperating with fuel cell manufacturers Hexis, Vaillant, Baxi Innotech, Alstom and CFC Solutions since 2002 on the development of efficient and environmentally sparing solutions. The suitability of this future-oriented technology for electricity and heat supplies in the household, commercial and municipal sectors is being investigated in various long-term trial programmes on the premises of customers and partners. As the fuel cells for building energy supply are unsellable pilot plants, EnBW has developed a special concept for these pioneering customers: the plant remains the property of EnBW and the customer only pays the price of heating supply as well as a one-off innovation levy. All the other costs for the plant, including maintenance, servicing etc. are paid by EnBW.

New-generation fuel cell heating devices have far longer fuel cell stack lives and are considerably smaller, lighter and easier to use than their predecessors. One of the test units, produced by Swiss manufacturer Sulzer Hexis, set a new record with its five-year trial run and almost 43,000 operating hours. This unit is expected to be ready for series production from the beginning of the next decade.

The results obtained with medium-sized fuel cells for municipal and industrial use are also encouraging. Over a period of three years, for example, a natural gas-driven molten carbonate fuel cell at the Michelin tyre plant in Karlsruhe generated an electricity volume of 4 million kWh, a record for a system of this kind and one which remained unbeaten for a considerable time.

EnBW's involvement in the field of fuel cells for biogenic fuel gases combines two future-oriented technologies and builds a bridge to renewable forms of energy. The first pilot project worldwide was launched at the waste digestion plant in Leonberg near Stuttgart in October with a molten carbonate fuel cell. Several aspects of this project are mouldbreaking in terms of efficiency and climate protection: the high electrical efficiency of the plant is designed to increase the electricity yield by around one quarter compared to a conventional unit-type heating and power plant – while considerably reducing pollutant emissions. Moreover, the waste heat from the plant is put to good use in the drying of fermentation residues – a process that would normally need to be performed using heating oil.

The use of biogenic gases in fuel cells is still in the early stages in terms of technology. The sulphur and trace gases in the fuel gas pose a particular challenge. EnBW intends to gather experience in this field and to adapt fuel cells for use with new fuel gases. It is therefore involved in a further pilot project in Stuttgart-Möhringen which has been up and running since November 2007 and where sewage gas is obtained from digested sludge and converted into electricity in a fuel cell system supplementing the three existing unit-type heating and power plants.

› New model:
Intelligent system platform for energy services

The "intelligent system platform for energy services" is an innovation that serves as an interface between customer and supplier, bringing energy and data flows together on a common platform for the first time. In this way, the individual systems like measuring and metering devices, broadband communication technologies, the end user units in the household, control and regulating systems and Internet and Web technologies are combined to form a new integrated solution.

The "intelligent meter" which went on trial with 1,000 EnBW customers in 2007 is the first building block in this innovative overall system. It is an electronic electricity meter with an Internet-based communication interface which records the current electricity consumption of a household and makes the data available to the customer via an individualised and protected Internet portal.

Electricity customers have a transparent overview of their energy consumption for the first time. Consumption levels are measured continuously and transmitted to EnBW's computing centre. The transmission of data to the system platform is totally secure and is subject to the data protection regulations. At the computing centre, the data are combined to create an itemised consumption profile in real time and linked to the respective customer tariff.

Our customers can view and analyse their personal electricity consumption via an Internet portal operated by EnBW. This enables them to pinpoint appliances that consume a lot of energy and to then either switch off these appliances or replace them with more efficient models. Moreover, the "intelligent system platform" allows the transmission of control commands to individual devices or groups of devices – the lights in a particular room, for example. The system can also be used to create an optimum room climate while minimising energy consumption based on measurement data for parameters like the temperature, humidity or brightness in a room.

In addition, the "intelligent system platform" provides information on fluctuations in electricity demand. Flexible time-based tariffs create an incentive to schedule individual electricity consumption in low-demand periods – and therefore to save money.

The pilot project called "Price signal at the power socket" uses this approach to optimise "customer self-organisation" on the basis of price incentives: a price signal enables customers to move the operation of household appliances from expensive peak load periods to time windows with lower tariffs. The price signal concept comprises an "intelligent meter" in the cellar, a radio-controlled electricity price display in the home and an Internet portal. In this pilot project, we transmit dynamic information on exchange-based electricity tariffs to the 1,000 selected customers throughout the course of the day.

Initial experience shows that the transparent depiction of consumption and demand data does actually prompt changes in consumer behaviour. It is estimated that this concept would reduce annual household electricity consumption by around 6%. There is additional untapped economy potential in the targeted regulation of heating and cooling systems in the household as well as in the control of electricity consumption via the "intelligent system platform".

› Renewable **energy**

Wind, sun, water, geothermal energy and biomass – these are the buzzwords that fuel the great hopes for CO_2-free energy generation from renewables in the endeavour to protect our climate. Many innovative products, technologies and processes are currently being researched and tested in these areas.

Prof. Eicke Weber is Director of the Fraunhofer Institute for Solar Energy Systems (ISE) in Freiburg. He enjoys a worldwide reputation based on 23 years of research in the USA and his extensive work in the field of semi-conductors.

Renewables generate locational advantages

Status quo

Today, renewables account for less than 10% of global energy generation, with the biggest contributions coming from hydropower and biomass. Two key developments will lead to major changes in this situation in coming years: not only is the risk of global climate change ever more apparent; there are also clear indications of an increasing shortage of fossil fuels, above all oil.

This realisation has resulted in a fundamental shift in public opinion in recent years. Broad sections of the population now recognise that a rapid changeover to renewables is the order of the day. In Germany, highly effective measures have been implemented to this end in the form of, among other things, the introduction of a feed-in tariff. This creates major financial incentives for renewables, although it should not be forgotten that the cost of most forms of renewable energy – in particular solar energy – is still considerably higher than that of energy from fossil fuels. This has led to an unexpected boom in this segment in Germany, above all in the fields of wind power, solar energy and photovoltaics. One of the consequences of this trend is that the demand for solar modules currently outstrips production output. The production of the high-purity silicon that is still an essential part of solar cells has not been able to keep pace with the rapid capacity expansion of the sector, which is growing at a rate of between 30 and 50% every year.

Thanks to the favourable political framework, Germany has become a world leader in this key technology sector in recent years. As a result, we expect to see a two-fold locational advantage in the near future: firstly, as Germany will be a centre of innovation in this important segment – which will translate into new jobs, particularly in the structurally weak region of central Germany – and, secondly, due to an especially high share of renewables in the overall energy mix, a development that will initially increase costs compared to conventional forms of energy due to the need for up-front investment but that will ultimately pave the way for the production of energy without ongoing fuel costs.

2020

It is probable that daily worldwide oil production has already topped 100 million barrels and that we will now have to adjust to gradually falling oil production volumes. In combination with ever increasing demand, this growing shortage will drive the oil price up to levels no one could have imagined. As a result, the firing of this valuable liquid raw material for the generation of energy will become less and less cost-efficient. It will increasingly only be used for the transport sector and as a basic substance in the field of organic chemistry. The high oil price will also lead to a strong rise in the price of gas, coal and uranium, as prices on the world market are determined not by costs but by supply and demand. National economies who have built up a strong renewables sector to cushion this effect will enjoy locational advantages. The global share of renewables is already higher than 10%, but a figure of 20% appears highly optimistic.

In the period up to 2020, there will be fierce competition between all forms of renewables in the developed countries – from wind power, biomass and geothermal energy to photovoltaics and solar thermal energy generation – to see which one achieves the highest growth. Increasing use will be made of hydropower, as it offers the ideal flexible back-up option to cover dips in electricity production from other sources. The creation of renewable energy systems will be one the world's leading economic sectors. Electricity networks will become sufficiently "intelligent" to handle the fluctuating feed-in of renewable forms of energy during the course of the day; end consumers will adjust their consumption to take advantage of differing electricity prices at different times of the day and night.

2050

The world's population will peak at perhaps just under 10 billion and then start to decline in the following decades. The global share of renewables will have increased to 50% or even more. The exact figure largely depends on how long it takes for global climate change to lead to a big turnaround in public consciousness worldwide. This major rethink will focus attention on the salvation of the planet as we know it. Companies and corporations specialising in the generation of renewable energy systems will account for a considerable share of global value added. Direct utilisation of solar energy in general and photovoltaics in particular will grow rapidly. By this time, it will be competitively priced due to large-scale automated production all the way up to terrawatt level. The distribution of solar energy across large distances will be facilitated by the integration of electricity systems based on high-voltage direct current and supraconductive lines. Energy storage technologies will allow both local and decentral energy storage. The conversion of solar energy into hydrogen will already have begun on a large scale. The use of wind power and geothermal energy will be a global standard, as will the use of biomass for energy generation, in particular biomass obtained from waste. It is also conceivable that processes that have not yet been discovered will allow the direct production of liquid fuels from the energy of the sun. This would in turn make it possible to reduce annual global emissions of gases that are harmful to the environment. Based on the information that is available today, however, it is very difficult to predict whether all this will happen soon enough to prevent an irreversible change in the earth's climate due to shifts in critical natural regulating mechanisms like the monsoon cycles or the Gulf Stream.

Best practice

Wind: the new giants

For several years now, the debate over wind energy has focused on size – and the installations have improved their performance parameters from year to year. The beginnings of modern wind power in the late eighties were characterised by small machines with outputs of under 100 kilowatts. By 1996, the new machines boasted an average output capacity of 500 kilowatts, subsequently topping one megawatt in 2000. In 2007, the average output of a new rotor was probably in the order of two megawatts, while the world's largest machines generate an output of six megawatts. Today, with hub heights of over 130 metres and rotor diameters of up to 126 metres, the technology is gradually reaching its size limits. Accordingly, the focus is no longer just on size but increasingly on other parameters.

In several companies, for example, and in some cases more intensively than ever before, designers are working on the shapes of the rotors, where there is still major potential for optimisation. The Enercon company in Aurich is the German market leader and has already brought a pioneering modified set of rotor blades with angled tips onto the market. This allows the blades to make better use of the inner part of the rotor disk area by ensuring evenly distributed flow parameters along the entire length of the blade profile. These rotor blades are also said to be less susceptible to turbulence and to cause less air flow noise. Enercon says the new rotors alone can boost the yield of wind power installations by up to 12%.

The drive and generator technology is also developing apace. Several years ago, the conventional machines with gear systems were joined on the market by gearless systems. In these latter systems, the rotor hub and generators are directly joined to one another – something that is welcomed by the operators of these installations, as the gear unit is susceptible to wear.

Amidst all this, a totally new type of generator has been developed in recent years. In previous generators, the flow of electricity was always induced solely by electromagnets. Today, engineers are increasingly using a combination of rotating permanent magnet and stationary electromagnet. These permanently energised synchronous generators possess superior network properties, are 30 to 40% lighter than comparable machines of conventional design and also around 25% smaller. Their efficiency is also slightly higher.

The precondition for the construction of high-performance magnets of this kind are new materials based on rare earth metals like neodymium, the production of which has only become possible at all during the last ten years. The use of rare earth metals like neodymium is the only way to produce permanent magnets that provide not only sufficiently high energy densities but also the required stability against demagnetisation.

Probably the biggest challenge for wind power technology is the move from land to sea. It will be necessary to develop new types of foundation and address the problem of the aggressive salt air. Offshore wind energy installations require a far higher degree of maintenance and servicing than their land-based counterparts.

The Multibrid company is using a creative idea to combat the problem of corrosion due to air with high salt concentrations: an air treatment system is installed at the bottom of the towers to suck in ambient air and filter out the moisture and the salt. The treated air is then used to generate overpressure in the tower and the nacelle, ensuring that no salt air can penetrate into the machine in the first place.

Solar energy: struggle for lower prices and higher efficiency rates

Electricity generation from the light of the sun is becoming more and more efficient: 25 years ago, most solar modules only achieved an efficiency rate of 8%; today, some series-produced modules are already approaching the 20-percent mark. The most efficient models are the monocrystalline cells sawed from a single big silicon crystal which do not have any grain boundaries; they currently account for around one third of the market. Multi or polycrystalline cells are cheaper to produce – and therefore more common – and meanwhile achieve efficiency rates of up to 15%. Higher efficiency rates have been registered under laboratory conditions, and the world record for silicon cells is 24.3%. But the nearer efficiency rates get to the theoretically maximum figure of 29.3%, the greater the expense and complexity of the production process. Alongside silicon cells, there are also cells made from other semiconductors like gallium arsenide or gallium indium compounds. These compound semiconductors pave the way for the production of so-called "monolithic tandem cells". It is important to know that each semiconductor can only use a limited wavelength range of natural sunlight. To bypass this limitation, tandem cells combine semiconductors with different properties to ensure maximum possible utilisation of the light spectrum and hence maximum yield. To this end, semiconductors with different energy band gaps are stacked on top of one another. The semiconductor with the biggest energy gap is at the top and lets the light through for the layers stacked underneath. In this way, it is possible to theoretically achieve efficiency rates of up to 50%; figures of 40% have already been recorded at research institutes. The cells are so expensive, however, that they can only be used over small areas. Nevertheless, as they can utilise 500-fold magnified sunlight without any problems, one option is to combine these cells with concentrators, above all Fresnel lenses, named after French physicist Augustin Jean Fresnel (1788 – 1827). These lenses are optical lenses that can concentrate light to a far higher degree than normal lenses. The experts in the field agree that silicon will continue to dominate the market in the medium term, while the use of cells made of thin-film silicon is expected to increase. In these latter cells, the amorphous silicon is deposited onto glass. Although they are not as efficient as their counterparts made of precision-cut crystalline silicon wafers, they are still an attractive proposition due to their low production costs. Alternatively, thin-film cells can also be made of copper indium diselenide (CIS) as well as copper, indium, gallium and selenium (CIGS) or copper, indium, gallium, sulphide and selenium (CIGSSe).

Visionary designers have great hopes for photovoltaically active substances that can be applied cheaply and easily to suitable base surfaces like a kind of coating. Others are looking into solar cells with organic colorants. The Swiss professor Michael Grätzel prompted a wave of euphoria back in the early nineties with his publications on dye-sensitised cells , but these hopes proved to be premature. There are still two major obstacles to the implementation of this concept: the transition from small cells to big modules and the long-term stability of the dyestuffs.

In the future, a marked fall in the price of silicon cells could well lead to the use of

"dirty" silicon as suggested by Professor Eicke Weber and his working group in Berkeley a few years ago. The cell yield depends not only the number of metal atoms that contaminate the silicon but on the distribution of these atoms. Even cells with a high concentration of foreign atoms can still achieve high electricity yields as long as the foreign matter is concentrated in a small number of areas. The use of "dirty" silicon would not only result in major savings but would also solve the problems caused by the bottleneck in the availability of high-purity silicon.

Meanwhile, the sun-drenched Southern European countries are stepping up the development of solar thermal power plants for the generation of solar energy. In these plants, the heat of the sun is used to produce steam, which in turn drives a conventional turbine. This can be achieved using parabolic reflectors ("solar dishes") or parabolic troughs. Fresnel collectors are a further attractive alternative. In the latter concept, the parabolic trough is replaced by a field of flat reflectors tracking the sun and concentrating the rays of the sun on the collector tube.

Biomass: "storability" a major advantage

The utilisation of biomass has been considerably expanded in recent years. In 2006, almost 17 billion kilowatt hours of electricity were generated from biomass, including over 10 billion kilowatt hours from wood, more than 5 billion from biogas and around 1 billion from vegetable oil. On the latest figures, biomass accounts for around 3% of the national electricity mix.

The use of bioenergy is meanwhile also well advanced in technological terms. In particular the upgrading of biogas to biomethane – in other words, to gas of the same quality as natural gas – and subsequent feed-in of this gas into the conventional natural gas network are seen as promising concepts for the future. One of the first examples of this in Germany is a biogas plant in the town of Pliening in Bavaria which has been in operation since the end of 2006. Another example is a facility in Zurich which ferments eco waste from organic waste bins and then feeds the gas into the Zurich gas distribution network.

This remedies a shortcoming of many of today's biogas plants: namely that they make inadequate use of the occurring heat as there are often not enough customers at the location. If, however, the gas is routed via the natural gas network to a consumer which can use of all the occurring heat, then this considerably improves the overall energy profile.

Although biogas processing is highly manageable from a technical point of view, it is also costly and complex, which means it is only feasible in large-scale facilities. The untreated gas leaves the fermentation reactor with a methane content of between 60 and 65% and has to be purified to natural gas quality. This primarily involves the removal of CO_2, moisture and trace gases like hydrogen sulphide from the gas.

The expansion of bioenergy exploitation is a sensitive matter in other ways as well. The competition for space between bioenergy and food could cause major problems. Researchers are looking into new organic sources of raw materials in response to food shortages. Two different processes are being developed at the Institute of Technical Chemistry at Karlsruhe Research Centre: one is a two-tier process combining pyrolysis and gasification that uses solid biomass like straw and wood; the other is designed to allow the gasification of moist biomass like sewage sludge, waste from the food industry, algae and contaminated organic waste water from industry. At the end of each process, the biomass will have been converted into mainly one substance: hydrogen.

Geothermal energy: renewable source of energy for baseload demand

Geothermal energy basically has huge potential. And the use of this energy for heating purposes – in thermal springs, for example – has a long tradition. The difficult thing is to generate electricity from geothermal energy, as the temperatures are often too low to ensure efficient turbine operation.

But since 2004, when attractive subsidy rates were also laid down for electricity from geothermal sources in the German Renewables Act (EEG), there has also been a great deal of movement in this sector. Nevertheless, the utilisation of deep geothermal energy still presents a major challenge. Geological conditions are not as easy to simulate as many people would like: if less water flows underground than hoped, or if the temperatures are lower than assumed, geothermal projects can soon become unviable. Or there is the possibility of problems of the type encountered in Basel, where work on a geothermal power plant had to be postponed for an indefinite period after it had caused several tremors.

But there are also successful projects, and two of them are more or less complete: two geothermal power plants went into operation in the autumn – one in Landau in der Pfalz and one in Unterhaching near Munich. They were the first two large-scale projects of their kind in Germany. Previously, only one small installation had been up and running – the plant that went online in Neustadt-Glewe in Mecklenburg-West Pomerania in November 2003 with an output of 230 kilowatts.

What the two projects in Landau and Unterhaching have in common is that they proceeded quite smoothly; they also use the same technique: both power plants utilise hydrothermal geothermal energy, in other words, water from the depths of the earth. The other primary technology is the so-called HDR concept (hot dry rock), which uses the hot rocks as a kind of continuous-flow water heater. This technology is difficult to implement, however.

Unterhaching uses deep-seated water at a depth of 3,300 metres which is pumped in quantities of 150 litres per second and at temperatures of 120°C. A steam turbine, operating on a liquid ammonia-water mixture due to the low temperature, is designed to convert part of the thermal energy into electricity. This process is known as "Kalina" and was developed by Siemens. The electrical output is in the order of 3.4 megawatts, while low-temperature heat is simultaneously distributed in the community via a local heating network for the purpose of supplying heating energy to residential buildings and companies.

The situation is similar in Landau in der Pfalz. Water with a temperature of 155°C was found at a depth of 3,000 metres, which means that the power plant can generate an electrical output of 2.5 megawatts. A so-called ORC process ("Organic Rankine Cycle") is being used in Landau. This process uses an organic medium as heat transfer medium.

The EEG subsidies allow geothermal power plants to operate cost effectively – which means that further plants will be commissioned. The German Environment Ministry says there are currently around 150 projects in the pipeline in Germany with a total investment volume of 4 billion euros. Worldwide, the geothermal power plants already in operation have a total installed capacity of 9,000 megawatts. The biggest generators of geothermal electricity are Italy, the USA, the Philippines, Indonesia and Mexico.

Experts do not expect to see any major technological innovations on the geothermal front. The drilling methods are based on the oil exploration model and therefore already highly developed; above-ground turbine technology such as Kalina and ORC is also state of the art, although additional operating experience is still needed in the case of Kalina. As hydrothermal geothermal locations only account for 4% of overall potential in Germany, the developmental potential of geothermal electricity generation lies in the ongoing development of processes for the cost-efficient utilisation of its other location-independent advantages. In many quarters, there are great expectations of developing even deeper rock formations with higher temperatures while simultaneously using special methods to render the rocks more permeable.

Storing electricity: from battery to salt dome

In contrast to geothermal energy, most other renewables are dependent on the weather. Engineers are therefore looking into various storage technologies for electricity. These include novel chemical battery types based on vanadium (redox flow batteries), the size – and therefore the storage capacity – of which can be increased more or less as needed. In addition, development is ongoing in the area of supercapacitors and supraconductive coils in which the electricity circulates with zero resistance – and can hence be stored. In the area of emergency power supply, flywheels are already being used that can be accelerated to many thousand revolutions a minute before being braked within fractions of a second to produce electricity.

Another idea is to store wind in northern German salt domes using compressed air. EnBW is currently planning a project of this type. Last but not least, there is regular talk of hydrogen storage options. However, the cheapest way of storing high capacities as well as high volumes of energy with high efficiency rates is still to use the power of water in pumped-storage power plants – but the potential for this method in Germany is also limited.

More recently, an innovative means of storing heat has made it possible to continue the generation of electricity in solar thermal power plants (solar thermal energy) even during hours when there is no sun. To this end, the heat is stored in salts that melt at low temperatures. These salts can then release the heat again when needed.

There are, however, also potential storage options on the consumer side. One example is large cold-storage warehouses, which can operate without electricity for several hours as they store the cooling energy and which are primarily supplied with electricity when it is in abundant supply.

EnBW practice

› Geothermal energy:
The fireplace beneath our feet

In view of its great potential, geothermal energy can play an important medium to long-term role in the overall heat and electricity supply concept. This is particularly true in Baden-Württemberg, which is home to around 15% of all the geothermal heating systems in Germany; and yet we have not even exploited 1% of the existing technical potential.

EnBW intends to continue developing the utilisation of geothermal energy for heating purposes in both theory and practice. As part of this strategy, it sponsors a professorship of geothermal energy at Karlsruhe University. The company also plans to gather experience in the construction and operation of geothermal power plants with the aim of helping to make the generation of electricity from the earth's own energy cost-efficient. The positive effects of this commitment are readily apparent: it helps to save primary energy, to reduce CO_2 emissions and to create new jobs in the region.

› Near-surface concepts:
Geothermal energy for heating purposes

In the near-surface area, the utilisation of geothermal energy via heat pumps and soil probes down to a depth of between 100 and 400 metres is fairly common. In its new buildings, EnBW always reviews the possibility of implementing geothermal concepts. Both the logistics centre in Herrenberg and the new office complex in Biberach are each provided with heating and cooling energy via 40 soil probes. Moreover, the geothermal plant of EnBW-City, the future administration building for around 2,000 employees, was – at the time it was built – the biggest of its kind in Germany with a total probe length of 13,000 metres.

EnBW's "Geothermal Energy" promotion scheme is designed to support the spread of geothermal heating in single and two-family houses. Almost 1,800 applications had been approved by the end of 2007, of which 852 dated back to 2006. A geothermal heating system can save an average 1.8 tons of CO_2 a year. The "cold local heat" pilot projects in March Hugstetten or the CO_2 probe in Triberg are a size bigger but still belong to the "near-surface geothermal" category due to the fact that the drilling depths are below 400 metres. The innovative supply solution using heat pumps in the new residential estate in March comprises 154 houses or dwelling units. Hot groundwater is pumped to the houses from a decentral well installation and then routed back into the earth. In Triberg in the Black Forest, EnBW is conducting trials on a novel soil probe filled with CO_2. The key advantage of this concept is that, in contrast to conventional probes filled with brine, it does not need a recirculating pump. Filling it with CO_2 makes it particularly environment-friendly and means it is especially suitable for use in areas where groundwater protection is a key consideration.

› Hot topic:
Deep geothermal energy

Deep geothermal energy concepts with drilling depths down to 5,000 metres offer a wider range of options – such as direct heat utilisation or electricity generation. They also pose greater challenges, however: once the reservoir has been made accessible, factors such as temperatures, pumping speed and the mineral content of the thermal water make high demands on pump technology and material. Setbacks are also part and parcel of these operations. At the geothermal project in Basel, earth tremors occurred when water was being pressure-injected after the first borehole had been completed in December 2006. Water injection to create the underground heat exchanger was stopped and an investigation was mounted into the cause of the tremors. The findings are expected at the end of 2008. EnBW is involved in this project via its Energiedienst Holding subsidiary. The project is a geothermal power plant designed for long-term commercial operation with an electrical output of 6 MW and a thermal capacity of 17 MW complete with district heat extraction.

› Researched in depth:
Soultz-sous-Forêts

Through its commitment in Soultz-sous-Forêts in the Upper Rhine Graben area, EnBW has access to one of the most important geothermal research locations in Europe. After 20 years of intensive examination of the substratum, work began on the construction of an above-ground power plant at the location in summer 2007. The plant went into operation in the spring of 2008.

The system in Soultz is an EGS system (enhanced geothermal system, also known as the hot dry rock technique). Three boreholes were drilled down to a depth of around 5,000 metres. One borehole is for the injection of water, which – in a process akin to that used in an instantaneous-flow heater – is heated to around 200°C by the hot granite rock and then routed back to the surface through the other two boreholes by pump. As the pumping process is naturally crucial due to the fact that the temperatures, pumping speeds and mineral content of the water make extremely high demands on both material and technology, different kinds of pump systems are used in Soultz-sous-Forêts to gain wide-ranging insights that might contribute to the further development of this technology.

The installed turbine is based on the "Organic Rankine Cycle" principle and has been optimised for the generation of electricity from low-temperature sources: in the heat exchanger, the hot low-lying water gives off its heat to the organic working medium isobutane, which vaporises and is depressurised in the turbine. The turbine generates an electrical capacity of 1.5 MW. Before the end of 2008, this energy is to be used to supply around 3,500 households in Alsace with electricity from geothermal energy.

› Happy geological coincidence:
Bruchsal

The foundation stone for the first geothermal power plant in Baden-Württemberg was laid in Bruchsal in January 2008. The plant has a capacity of 550 kilowatts and will supply around 1,000 households with electricity generated with zero CO_2 emissions from the autumn of 2008.

The joint project of the EU, the German government and the state government as well as Energie- und Wasserversorgung Bruchsal dates back to the year 1983. The two boreholes were drilled in the same year and in 1984/85, after which the project was put on ice until 2001 – when the subsidy options under the German Rewewables Act made geothermal electricity an attractive proposition once again. EnBW came on board in 2005. The project has a total investment volume of roughly 17 million euros, with EnBW providing around 6.5 million euros of this total.

Bruchsal is a happy coincidence in geological terms: drilling operations hit upon a hydrothermal spring with a temperature of around 130°C at depths of 1,900 and 2,500 metres. Hydrothermal systems account for only around 4% of the total geothermal energy potential in Germany. In contrast to other geothermal systems, it is also possible to use the existing groundwater at these locations. At the same time, however, the Bruchsal project poses different kinds of challenges for the operator: unlike conventional circuits with pure water or projects with thermal water, the water in Bruchsal is extremely highly mineralised and has a high salt concentration. This means special attention has to be paid to the water chemistry and the interaction between the thermal water and the materials used in the plant.

The power plant technology has also been newly developed: due to the thermal water temperatures, the Kalina process is to be used, a technology that has only been employed in a small number of plants worldwide to date. While steam circuits in conventional power plants work at temperatures of up to 600°C, the Bruchsal thermal water at the power plant has a temperature of just 118°C. As water is not suitable as a medium in a process with such low temperatures, the working medium used is a mixture of liquid ammonia and water. This minimises heat transfer losses between the thermal water and the power plant process.

› Optimum value added:
Natural gas from biomass

In summer 2007, EnBW subsidiary Erdgas Südwest began building Baden-Württemberg's first plant for biogas feed-in in Burgrieden near Laupheim. A generating community made up of 22 farmers from the region built the corresponding biogas plant with an annual production volume of 5.1 million m³ of biogas from energy-producing plants and agricultural waste. The technical foundation for this pilot project was created by preliminary studies covering the entire production chain – from the substrate and the production of biogas to gas transport and gas processing. These studies were conducted by the R&D unit at EnBW in cooperation with the universities in Hohenheim and Karlsruhe. Since spring 2008, an annual volume of 2.8 million m³ of biogenic natural gas has been fed into the network. This volume is enough to supply 1,000 households.

The project is characterised by the highly sustainable and cost-efficient organisation of the value added chain from the farmer all the way to the biogas user. In addition, this is the first time in Germany that the climate-polluting methane gases that escape during gas cleaning have been captured and used to heat the fermenters, thus saving energy. Gas cleaning takes place by means of so-called flameless oxidation, a process developed at Stuttgart University. Normally, small amounts of methane also escape together with the carbon dioxide captured from the biogas and are no longer combustible in this low concentration. With the new technique, even these low calorific gases can be post-combusted by adding small amounts of combustants and the heat can also be used to produce energy. The use of this method for the incineration of low calorific gases is a first in a biogas processing plant.

› Wood ash:
Back to the roots

Together with the Baden-Württemberg Forest Research Institute (FVA), EnBW launched a three-year pilot project in 2007 for the further use of furnace wood ash from biomass heating and power plants.

Ash from forest wood has a particularly high calcium, potassium and phosphor content. The idea is to mix it with lime and reuse it in the forest as fertiliser. This would create a closed nutrient cycle for the energy-based utilisation of forest wood; it would also save expensive fertiliser and provide a dependable disposal method for the waste from biomass power plants fired using forest wood only.

› Electricity on tap:
Adiabatic compressed-air storage plant

Together with the state of Lower Saxony, EnBW is reviewing – among other things – the option of developing and building the world's first adiabatic compressed air storage plant. Due to their salt deposits, the northern German lowlands provide ideal geological conditions for the creation of large underground storage caverns for compressed air. If the expansion of renewables – and in northern Germany as well as northern Europe, this would primarily take the form of wind energy – creates a need for the integration of efficient and logistically expedient energy storage facilities in the supply system in the medium term, then adiabatic compressed air storage plants would be an attractive option.

The generation of energy from wind power is not a controllable process. If the wind is strong and the demand for electricity is low, for example, this can lead to an imbalance between supply and demand. These imbalances will continue to grow parallel to the expansion of wind energy. Large-scale energy storage systems like adiabatic compressed air storage plants can overcome this discrepancy.

The first attempts to store electricity in caverns in the form of compressed air date back to the 70s. In these storage power plants, the stored compressed air is used as combustion air to drive a gas turbine power plant. This process creates CO_2 emissions and has an efficiency rate of just 54%. The resulting financial and economic drawbacks are the major obstacle to the market launch of these facilities.

EnBW's adiabatic compressed air storage system will be designed to store electricity in the form of compressed air and heat. The conversion process emits zero CO_2 and has an efficiency ratio of 70%. For the first time, all systems for air compression, heat storage, compressed air storage and electricity generation using compressed air can now be integrated in a single, technically optimised storage facility.

› Fossil **fuels**

The incineration of fossil fuels like coal and gas releases greenhouse gases that are harmful to our climate. This means it is all the more important that we achieve higher efficiency rates and develop new fuels to ensure that power plants operate more effectively. Another focal point of research is the potential separation and storage of CO_2. This is an area in which much research still needs to be done.

Dr. Michael Süß is a qualified mechanical engineer and CEO of the "Fossil Power Generation" division at Siemens Energy. He is convinced that, with the help of innovative technology, fossil fuels will in future secure worldwide energy supplies in a climate-friendly manner.

Fossil energy – fuel for the future

Status quo

One of the big global challenges of the 21st century is to ensure the reliable, cost-effective and above all climate-friendly supply of electrical energy. The thirst for electricity is huge, and experts predict that demand will almost double by the year 2030. In the coming decades, fossil fuels – mainly coal and gas – will continue to be the mainstay of the energy mix. It is estimated that the extraction and production of oil and gas will remain economically worthwhile for another 60 to 70 years, while coal should be with us for the next two centuries. Moreover, reserves of these sources of fuel that we will be able to exploit using future technologies should last a great deal longer.

Greater demand for electrical energy covered by fossil fuels does not necessarily mean a bigger burden on the environment and therefore accelerated climate change. With the technology at our disposal today, it is already possible to avoid major amounts of CO_2 during the incineration of fossil fuels, and the innovation curve is a steep one. The aim of current research is to develop highly efficient power plants with maximum efficiency rates and therefore maximum energy yields.

A few figures serve to illustrate this aim: while the efficiency rate of a lignite power plant was in the region of 36% around 25 years ago, today levels of 43% are already the norm. Efficiency rates of 50% and more have been targeted for lignite and coal-fired power plants by 2020. Gas and steam power plants possess particularly high efficiency potential. The combination of gas turbine and steam turbine driven by the hot waste gases is already one of the most efficient power plant technologies. Plants with efficiency rates of 58% are already state of the art, and each additional percent in efficiency leads to a further significant reduction in CO_2 emissions. One example: development work and tests are currently being performed for a gas-and-steam plant with an efficiency rating of over 60%. The two percentage point increase in efficiency would in future avoid up to 40,000 tons of CO_2 emissions per year and plant. This volume of CO_2 is equivalent to the emissions from around 10,000 midrange cars with an annual mileage of 20,000 kilometres!

Alongside their high efficiency, gas turbines have another advantage: they are flexible and can supply electricity at extremely short notice – when no wind energy is available due to a lack of wind, for example, or if there is a short-term high demand for electricity. The keywords are flexibility and efficiency. If, for example, all fossil fuel power plants were to be converted to the state-of-the-art technology with its high efficiency ratios, this would save an annual 2.5 billion tons in CO_2 emissions worldwide, equivalent to around half of annual CO_2 emissions by China.

Outlook 2020

Alongside increased efficiency, a second further innovative step is the extensive avoidance of CO_2 emissions from fossil fuel electricity generation. The coming years will see the commissioning of the first pilot and demonstration plants which capture the CO_2 created during the incineration process and then route this harmful gas into underground hollows like empty gas caverns for permanent storage. This technology will be ready for market by around 2020.

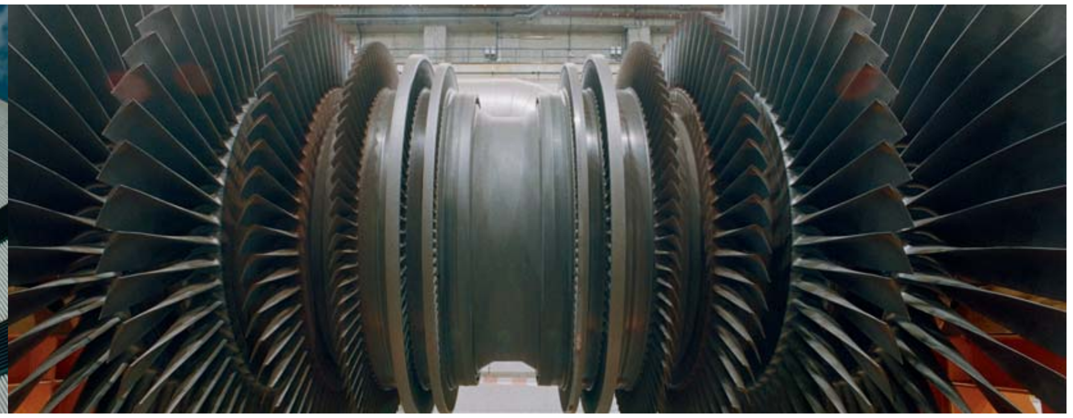
In this way, it would be possible to comply with emission limits to the extent needed to meet the so-called "2 degree target" from the year 2020 through an intelligent energy mix made up of electricity generated from fossil fuels with high efficiency and low-CO_2 emissions combined with a high percentage of renewable forms of energy. The "2 degree target" means that the average temperature increase of the planet should not exceed 2 degrees Celsius compared to the temperature at the beginning of industrialisation.

Scenario 2050

Life without electrical energy is no longer imaginable. Electricity is becoming ever more important as a safe, efficient and above all clean form of energy. Areas like transport and building heating which still depend directly on fossil fuels will almost completely switch to electrical energy. The huge resulting demand for energy will then be met from various different sources: fossil power plants will continue to provide the lion's share. Equipped with a series-produced technology for the capture and storage of CO_2 with a strong market, they will make the biggest contribution to a climate-friendly and reliable energy supply system. Although there are a number of potential additional sources of energy that are still being researched – such as methane stored in frozen water (so-called methane hydrate) which exists in large quantities throughout the world's oceans – the potential of these sources, like that of other energy sources, for worldwide energy supplies has already been recognised.

One thing is clear: in future, we will use the "energy capital" bequeathed to the inhabitants of the earth by the process of geological evolution since the dawn of time with the requisite efficiency and frugality so that we can in turn bequeath these treasures together with an intact climate to future generations. Oil, coal and gas are changing their image from the fuel that drove industrialisation to the source of energy for our future.

Best practice



Efficient large-scale power plant technology: increased efficiency rates

Alongside construction costs, the key factors that determine the cost-efficient operation of fossil fuel power plants are rising raw material prices and political targets for the reduction of CO_2 emissions. The efficiency of a power plant plays a key role in solving both problems – in other words, the ratio of the energy input into the power plant in the form of fuel to the energy volume supplied to the customer in the form of electrical current. The more electricity the power plant obtains from the fuel, the more efficient it is.

With few exceptions, whenever coal-fired power plants are built anywhere in the world, steam power plants are also planned and built. In these steam power plants, fossil fuels are incinerated, water evaporates in a boiler and is then heated further. The steam produced in this way drives a turbine which generates electrical energy. The efficiency of these plants is largely determined by the pressure and temperature of the generated steam – the so-called steam parameters. Both pressure and temperature are limited by the availability of suitable materials. This is why research is focused on finding materials that can withstand higher temperatures and pressure. It is also by this means that it has been possible to achieve significant improvements in the efficiency of coal-fired power plants in the past decades.

The average efficiency rate of power plants fired with fossil fuels is in the order of 31% worldwide. In Germany, the average value for the existing coal-fired power plants is estimated to be in the region of 38%. Germany's most modern coal power plant, the "Heizkraftwerk 2" heating and power plant operated by EnBW in Altbach, has a maximum efficiency rate of 44.2%. The generated fresh steam is under a pressure of 248 bar and is heated to a final temperature of 545°C.

New, improved materials are to be used in the planned block 8 at the EnBW Rheinhafen steam power plant as well as in other new construction projects to further optimise steam parameters and therefore the efficiency rate. These high-alloy stainless steels allow pressures of up to 275 bar with maximum steam temperatures of 600°C. This means efficiency rates of over 46% can be achieved for the first time. Compared to the current power plant portfolio in Germany, this is equivalent to an improvement of 21%. The use of this innovative technology paves the way for reduction of the specific CO_2 emissions from the original 1,000 g/kWh electricity to just under 800 g/kWh.

For some years now, research projects have focused on the endeavour to significantly raise efficiency rates even further to values of around 50% and more. In order to achieve this figure in future coal-fired power plants, it must be possible to generate and process steam with a pressure of up to 350 bar and temperatures around 700°C. The specific CO_2 emissions of a power plant of this kind are just above 700 g/kWh – equivalent to a 24% reduction in CO_2 emissions.

The aforementioned steam parameters mean it is no longer possible to use iron-based materials. One solution to this problem is the use of nickel-based materials that meet the highly demanding profile.

The European power plant manufacturers and energy supply companies are playing a pioneering role worldwide in the development of the 700° power plant with the highest steam parameters and the highest efficiency. All the parties in question are cooperating in the operation of two trial plants, one in Esbjerg, Denmark, and one in Scholven, Germany, where material samples and individual components are being tested under realistic day-to-day power plant conditions.

Moreover, the companies involved in the project are working on the design of the first 700° power plant of large-scale dimensions. The focus is on questions relating to the construction of the power plant, the design and arrangement of the various components and the anticipated investment costs as well as on the cost of operating such a power plant.

Parallel research projects focusing on the further development, production, processing and inspection of materials are being conducted in Germany within the framework of the programme initiated by the German Ministry of Economics and Technology and entitled "CO_2 reduction technologies for fossil fuel power plants" (COORETEC).

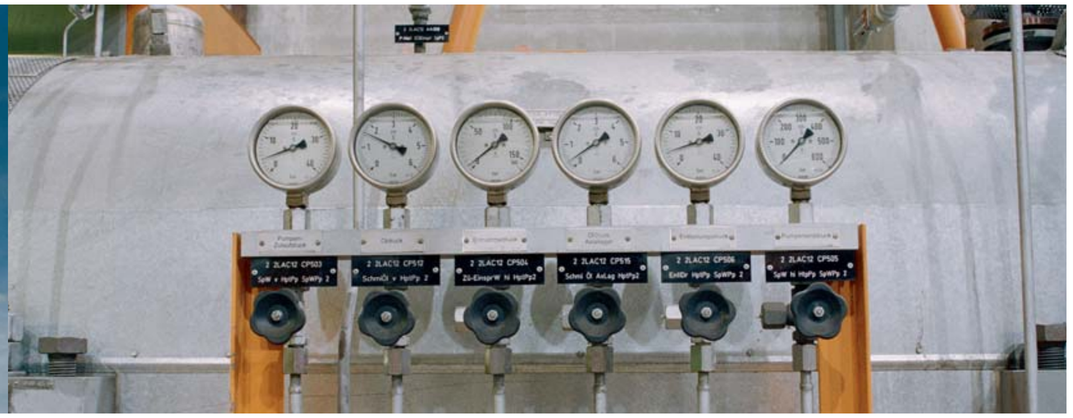
Based on assessment of the current status of knowledge and development, the 700° technology is not expected to have been fully tested until 2020. A further intermediate step on the road to commercial market launch is the construction and operation of a demonstration power plant.

Solid fuels: alternative power plant technology

In addition to being directly incinerated in steam power plants, solid fuels can also be converted into gas under high pressure and at high temperatures for the purpose of generating electricity. After pollutants like ash, nitrogen oxides and sulphur oxides have been removed, the fuel gas is used in a conventional gas and steam turbine process – the standard method when natural gas is used as a fuel. This so-called "integrated gasification combined cycle technology" (IGCC) has already been implemented worldwide in several large-scale technical demonstration plants for various fossil as well as renewable solid fuels.

The potential efficiency of coal-fired IGCC plants is estimated at >45%, a figure similar to that listed for steam power plants. The advantages of gasification plants compared to conventional plants are lower emission levels, greater flexibility in terms of the input fuels and the option of generating not just electricity but also other products like hydrogen or fuels for engine-powered road vehicles. In combination with the practice of CO_2 capture which will be necessary in future, coal-fired power plants based on the gasification principle have major advantages compared to steam power plants: due to the pressurised status of the combustion gas, the CO_2 in the gas can be washed out using a comparatively simple wet washing concept. The main drawback of IGCC technology is that investment costs are 20 – 25% higher due to the complex nature of the process and the requirements with regard to the construction of pressurised plants. Moreover, the availability level of the plants has been relatively low to date, which means that maintenance and repair expenditure has been comparatively high. This is due to the fact that IGCC technology has been employed on a large scale for the first time in these plants and that some of the components used were developed specifically for this application and therefore not always ideally coordinated for use with one another.

However, many new projects are being developed around the world. An IGCC plant for biomass is currently at the planning/implementation stage in the Dutch town of Buggenum, while a similar lignite-fired plant is being built in Germany.



High performance: new-generation gas turbines

The use of natural gas in a gas-and-steam turbine power plant is the most efficient means of generating electricity from fossil fuels at the present time. The achievable efficiency rates of the latest-generation gas turbines for which the first power plants are currently being built are in the region of 60% plus. These values are underpinned by the gradual optimisation of gas and steam turbine technology – including, for example, the use of new, complex blade geometries or the installation of sophisticated material cooling systems to allow higher inlet temperatures in gas and steam turbines.

Focus of research: CO_2 capture

Fossil fuel power plants account for around 40% of all CO_2 emissions in Germany. The carbon dioxide emissions in this sector can be reduced by roughly one fifth by increasing the electrical efficiency rates to levels of around 50%. In other words, the changeover to highly efficient power plants could cut overall CO_2 emissions in Germany by up to 8%. On its own, this will not be enough in the long term to achieve the emission reduction targets in the area of energy supply set by the European Union and Germany.

In order to allow even greater reductions in CO_2 emissions from power plants, several technologies are currently being developed to capture the carbon dioxide occurring during the use of carbon-containing fuels: the idea is to process, compact and liquefy the CO_2 and then store it in certain geological formations. Suitable locations for this purpose include spent oil and natural gas deposits as well as lower-level strata carrying saltwater, so-called saline aquifers.

In the capture techniques currently being investigated, CO_2 is either removed from the flue gases following incineration (post-combustion capture) or washed out of the fuel gas prior to combustion (pre-combustion capture) – or the fuel is burned together with pure oxygen to directly create CO_2 (oxyfuel).

Of the processes for post-combustion capture, the main focus of research is on wet washing using aqueous amine solutions. In this process, the CO_2 is removed from the flue gas flow through contact with the aqueous washing solution and bound to the amine molecules. The washing solution with its CO_2 load is heated in a separate container using steam and the attached CO_2 thereby re-released. The regenerated washing medium is routed back to the absorber where it absorbs CO_2 once again. The advantages of this process are its high level of technical maturity resulting from the use of this technology in other industrial sectors and its comparatively simple transfer to large-scale technical applications in fossil fuel power plants. The main drawback of the process is the high volume of energy required for regeneration of the washing medium, and this factor cuts the efficiency of the power plant by up to 15%.

A pilot plant in Esbjerg in Denmark is a focal point for the further development of the post-combustion capture process. Other pilot plants are currently being planned, and the central goals of research and development activities in this area will be the optimisation of process-related details as well as research into new washing media and mixtures of different amines.

The processes in which CO_2 is captured before combustion are based on the principle of coal gasification or IGCC technology. The combustion gas made from solid fossil fuels is mainly composed of hydrogen (H_2), carbon monoxide (CO) and carbon dioxide (CO_2). In order to achieve high carbon capture rates, the CO in the combustion gas has to be converted into CO_2. This step is performed in the so-called "shift reactor", where CO and steam are converted into CO_2 and hydrogen. In a subsequent phase, the CO_2 is washed out in a wet washing station using (for example) an aqueous methanol solution. The washing medium with its load is regenerated by heating (similar to the technique used in the post-combustion capture technique), releasing the CO_2 to be captured. In this washing process, the CO_2 is only physically bound to the methanol molecules – with the result that far less heat energy is needed to regenerate the washing medium.

Current focal points of research in the development of this technology include the processing and cleaning of the combustion gases and the modification of existing gas turbine combustion chambers to accept combustion gases with high hydrogen content.

The efficiency losses associated with the pre-combustion capture process are estimated at up to 10%. This technology is almost exclusively suitable for new projects, as it requires a changeover in power plant technology to coal gasification.

In the oxyfuel process, coal is not incinerated together with air but with technically pure oxygen. The oxygen is obtained in the power plant by separating it from the air and forwarded to the combustion system. Following the removal of fly ash, nitrous oxide and sulphur oxide, the occurring flue gas mainly contains steam and CO_2. The steam is removed by cooling the flue gases, supplying almost pure CO_2 for further pretreatment en route to storage. If this technology is used, the existing steam power plant technology can be retained without any fundamental changes. The efficiency losses are similar to those in the pre-combustion capture method.

With the oxyfuel process, more research is necessary in connection with the provision of the required oxygen, the return flow of flue gas into the combustion chamber to limit the combustion temperature and the purity of the occurring CO_2, as an oxygen surplus is needed during combustion for full utilisation of the fuel.

In general, it is fair to say that there is currently no clear preference for one or other of these technologies. This is due, firstly, to the different costs of the different processes, to the extent that they can be compared based on their developmental status at the present time. All of them are associated with considerable uncertainties. The second factor concerns the framework conditions and stipulations that are of a non-technical nature. These include regulations, fuel prices and factors that depend on the location of the power plant. All of these things have a major influence on the choice of CCS technology. Accordingly, the bodies promoting research, the power plant manufacturers and the power plant operators agree that the aim should be to develop and test all available technologies on a continuous basis.

EnBW practice

› High efficiency:
Next-generation power plants

New materials that can withstand higher process temperatures play a key role in improving the efficiency of conventional power plants. Together with other European energy suppliers, the manufacturers and the world of science, EnBW is participating in the COMTES 700 research programme. The aim of the project is to develop materials that can withstand combustion temperatures up to 700°C and pressures up to 350 bar. The materials and steam parameters currently at our disposal allow efficiency rates of between 37% and 45%; the 700°C power plant is designed to boost efficiency to over 50%. Wide-ranging tests in the area of production processes, component production, system integration and approval need to be performed, however, before the new materials are ready for market towards the end of the next decade.

› Flexible solutions:
New fuels

The goal of the fuel flexibilisation project is to test whether gas power plants can in future also be operated with combustion gases of varying composition – in others words, synthesis or biogases. One of the special aspects of the research remit is the development and production of a synthesis gas with high hydrogen content which combusts reliably while emitting only a low level of pollutants. Another question is how gas turbine combustion chambers need to be designed to handle the special combustion properties of these new synthesis gases. The idea is that this new power plant generation will not only be able to burn synthesis gases obtained from solid fuels like coal and biomass but that they will also allow efficient CO_2 capture from the outset. Institutes at Stuttgart University and the German Aerospace Centre (DLR) in Stuttgart are cooperating on fundamental research in this field. The project is receiving technical and financial support from EnBW, Alstom and the state of Baden-Württemberg.

› Stepping up research:
CO_2 capture

Due to the increasing volume of fossil fuels being converted into electricity worldwide, it will probably not be enough to simply reduce CO_2 emissions by ensuring efficient conversion of primary energy. What is also needed is the development of techniques and methods for CO_2 capture which will enable us to achieve the ambitious climate targets. However, a great deal of research and development work is still needed on these future-oriented technologies – with regard to both the transport and storage of the captured CO_2. Then there is the added challenge of keeping the – on current information – considerable efficiency losses resulting from CO_2 capture as well as investment and operating costs within acceptable limits.

Given the current status of research, it can be assumed that CO_2 capture using amines will be ready for market soonest of all. This is an area in which EnBW is active on both national and international level: we support research work at the Institute of Process Engineering and Power Plant Technology (IVD) at Stuttgart University as well as at Munich University. We also intend to participate in studies on a demonstration plant at the Esbjerg power plant in Denmark.

Since autumn 2007, EnBW has been supporting the development of a new technique for capturing CO_2 from power plant gases using conventional lime as a CO_2 carrier substance. This highly efficient method, which reliably limits the usual efficiency losses due to CO_2 capture processes to around five percentage points, is to be comprehensively tested in a trial installation at the Institute of Process Engineering and Power Plant Technology (IVD) at Stuttgart University. The research project is scheduled to last for four years and will cost around 1.6 million euros. The trial plant with a thermal capacity of 200 kilowatts should be ready to go into operation by the end of 2008. 2009/2010 are earmarked for operation and optimisation; the remaining period up to the end of 2011 will comprise studies on the technical and financial feasibility of a large-scale plant.

In this novel process, lime and CO_2 react at temperatures above 600°C to form calcium carbonate (calcite) in a reactor through which the flue gases flow. This process releases energy in the form of heat which, thanks to the favourable temperature levels, can be used to generate steam and hence electricity with a high level of efficiency in the power plant. The occurring calcium carbonate is heated to a temperature of over 900°C in a second reactor, causing it to disintegrate into its original components lime and gaseous CO_2. The CO_2 is cleaned and then liquefied for transport and permanent storage, while the lime is returned to the reactor through which the flue gases flow.

Other research projects are focused on CO_2 capture via carbonates or liquid ammonia. In this area, EnBW is cooperating with the Institute of Process Engineering in Stuttgart and the Electric Power Research Institute in the USA. This process is still in the early testing phase and will not be available until 2020 at the earliest.

› Retrofitting:
Making coal-fired power plants fit for future

Retrofitting of CO_2 retention units in existing conventional power plants is another major area of research and development. One of the most promising solutions currently looks like being CO_2 capture from the flue gas (post-combustion). In this connection, the power plant operators are also focusing on the concept of a CO_2 wash using monoethanolamine (MEA). This technique is already being used in the cleaning of industrial gases but still needs to be adapted to the complex context of a power plant. Due to the high energy requirements and its toxicity, this process also has high costs in environmental terms – which means there is an urgent need for alternative concepts.

An alternative to the CO_2 wash is the use of microporous ceramic membranes. There is no residual matter that needs to be disposed of, and the long service life and efficient separation method suggest that these membranes are more cost-effective than other separation techniques. Since 2006, EnBW has been supporting the three-year METPORE project at Jülich Research Centre focusing on the development of these membranes. This project combines the findings of two earlier research projects: Queensland University in Australia succeeded in developing nanoporous membranes with particularly high separation effects for nitrogen and carbon dioxide, while the Institute for Materials and Processes of Energy Systems at Karlsruhe Research Centre developed metallic carrier substrates. The new membranes are initially being produced on laboratory scale and will soon be tested for durability in a real-world setting in the flue gas of unit 7 at the Rheinhafen steam power plant in Karlsruhe.

The retrofitting issue also concerns our plans for new power plant facilities. The projected unit 8 of the Rheinhafen steam power plant in Karlsruhe scheduled to go into operation at the end of 2011 includes the necessary space for the subsequent installation of a CO_2 capture system.

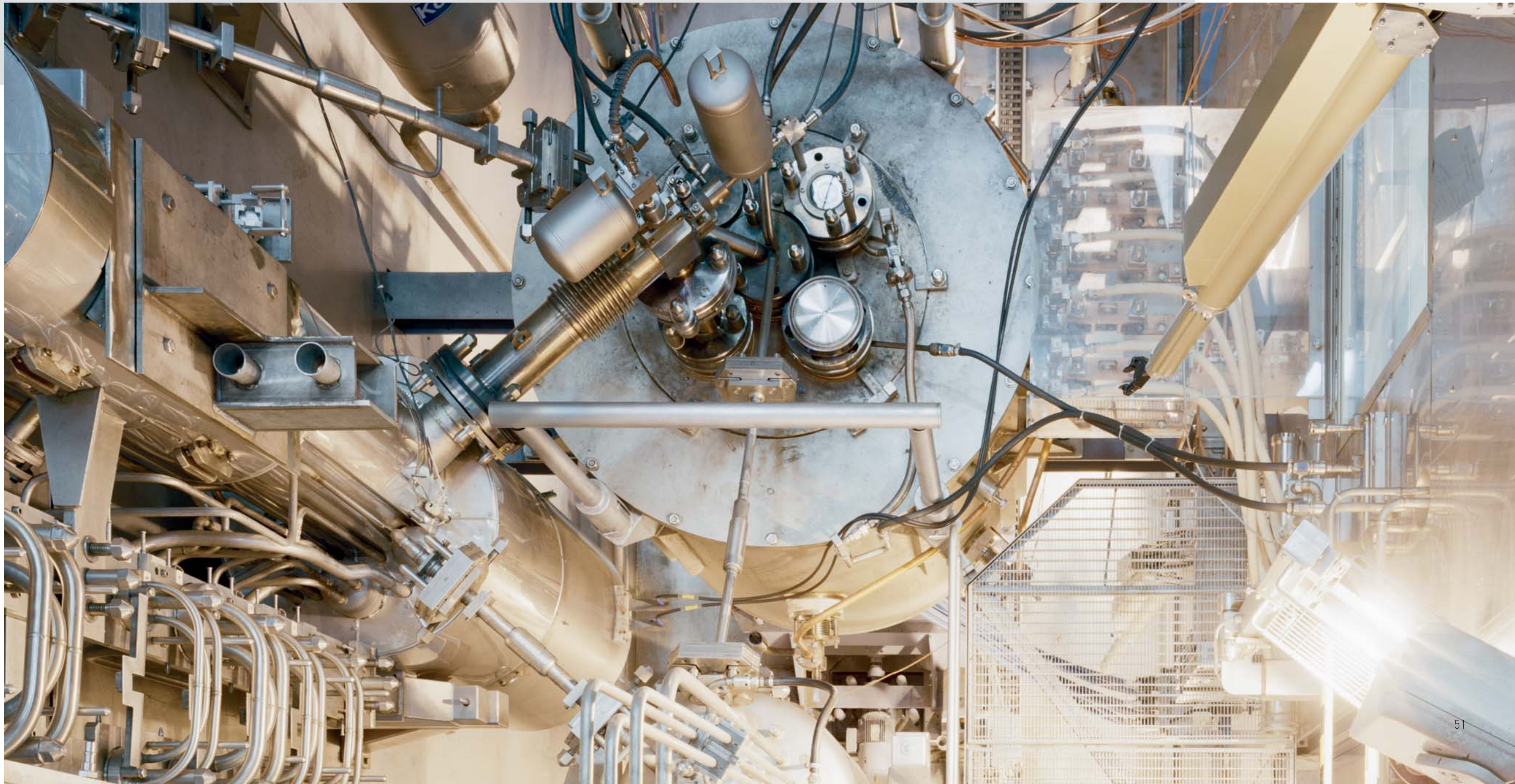
› Active involvement:
National and international research forums

Our commitment is rounded off by participation in key forums. EnBW is involved in the European research platform with the title ZEP (ZERO Emission Fossil Fuel Power Plants) as well as, at national level, in the Emax Taskforce, a coordination group headed by the German Association of Big Power Plant Operators (VGB) and the COORETEC research initiative into CO_2 reduction technologies for fossil power plants launched by the German Ministry of Economics and Technology.

EnBW is also a member of the "TZ Klima" information group for climate-friendly coal-fired power plants; the aim of the group is to promote the social and political debate that is necessary for the development of CCS technology.

› Nuclear **energy**

Even though the situation in Germany differs from that in other countries, the major challenges posed by climate change mean that low-CO_2 nuclear energy is seen as an increasingly significant factor worldwide. Coordinated international research activities are constantly improving the performance and safety of these facilities.



Dr. Peter Fritz works at Karlsruhe Research Centre, where he is responsible for nuclear safety and disposal research, renewables, atmosphere and climate. He is also a member of the administration board of Karlsruhe University.

Outlook for nuclear energy

Status quo in Germany

Although it has only a comparatively small number of reactors – 17 in all – Germany is the world's fourth-largest producer of electricity behind the USA (104 units), France (59 units) and Japan (55 units). In Germany, 50% of baseload supply is generated in nuclear power plants, which accounted for around 25% of annual gross electricity generation of 620 TWh during each of the past five years. At the same time, nuclear energy makes a major contribution to climate protection: it avoids the same amount of CO_2 emissions in Germany each year as are given off by the country's entire road transport and traffic sector (around 160 million tons).

Status quo in Europe

At the end of 2007, a total of 197 nuclear power plants were in operation in Europe with an overall rated capacity of 180 GW. Nuclear energy meets around one third of total EU electricity requirements. On September 12, 2005 the foundation stone for Finland's fifth nuclear power plant was laid in the town of Olkiluoto. It will be the first EPR (European Pressurised Water Reactor), an advanced "Generation III+" reactor equipped with numerous safety features, such as a so-called core catcher system for the systematic retention of core melt in the event of a serious hypothetical reactor incident. Even in the extremely improbable event of a core melt accident, this would keep maximum radioactivity emissions at such a low level that no disaster prevention measures would be necessary outside the installation. In France, Electricité de France (EDF) is building the country's first EPR at Flamanville in Normandy; work on the skeleton structure was officially begun in December 2007. In Switzerland, planning is underway for the construction of up to three new nuclear power plants. Due to the foreseeable shortage of fossil energy reserves, other European countries – like the UK, Lithuania, Bulgaria and Romania – have also specifically integrated nuclear energy in their energy programmes. In Finland, energy suppliers are preparing applications for the construction of a further nuclear power plant.

Status quo worldwide

At the end of 2007, there were 439 nuclear power plants in operation in 31 countries worldwide with a total rated capacity of 390 GW. Overall, this added up to a total of around 2,700 TWh of electrical energy which were produced by nuclear means around the globe. Three units with an electrical capacity of 4 GW went into operation in 2007.

2020

The exit from nuclear power based on the 2001 decision to reduce the operating times of nuclear plants in Germany is in no way a reflection of global trends. On the contrary: in the USA, the operating permits of 48 of 104 nuclear power plants have been extended for a further 20 years. Eleven applications are currently being reviewed, and applications are being prepared for the other nuclear power plants with shorter operating times, which would result in an operating life of at least 60 years. In China, the Tianwan 2 nuclear power plant has achieved first criticality. Construction work is being continued on five additional units and is soon expected to begin on four new "Generation III" reactors. The Kaiga 3 nuclear power plant has gone into operation in India; in Romania, the country's second reactor recently went online in Cernavoda.

Worldwide, a total of 31 nuclear power plants are under construction. In 2007, new construction applications were filed in the USA for the first time in 29 years – by four companies for seven new units. Around 50 nuclear power plants are at the detailed planning stage worldwide, and a further 100 or so projects are at the preliminary planning stage. It is particularly countries expecting rapid economic growth who are looking to nuclear power for their electricity supplies. South Africa, for example, is not only planning to build the first commercial HTR high-temperature reactor (15 more in module design are to follow) but is also involved in negotiations concerning the construction of several EPRs in order to satisfy the growing demand for electricity. Russia has redefined its nuclear power plant programme. Not only is Russia building several conventional nuclear power plants; construction work on the "BN 800" is also at an advanced stage. The BN 800 is a fast sodium-cooled reactor with a rated capacity of 800 MW. It is scheduled to go into operation before 2015. In addition, work began in Russia in 2007 on the construction of a floating nuclear power plant on which two nuclear reactor units are to be installed to ensure reliable supplies of electricity and district heat to regions that are difficult to supply by overland routes. Plans are even more advanced in India, where a fast breeder reactor with a capacity of 600 MW is expected to go online from 2012.

2050 – "Generation IV" reactors

The "Generation IV" research and development programme is a joint initiative of various countries as well as of Euratom as the coordinating body for the EU member states. "Generation IV" reactors are designed to meet all future requirements in terms of the sustainability of nuclear energy. The plants are expected to ensure improved utilisation of uranium and are suitable for transmutation of long-lived highly radioactive waste. Transmutation significantly reduces radiotoxicity and facilitates final storage. A further aim is extended technological proliferation resistance.

Uranium deposits

On current estimates and assuming constant exploration costs, we should have enough uranium for at least 150 years. In modern reactors, however, not even 1% of the atoms contained in the uranium are actually utilised. The yield can be improved by up to 30% by reprocessing fuel elements and recycling of the plutonium as well as the unused uranium. In addition, there is major technological potential for the development of reactor types which use considerably less uranium and therefore achieve many times the energy yield per kilogram of natural uranium. If breeder technology is included in the equation, the uranium reserves are practically unlimited by human standards. Another fissile material that occurs in nature is thorium, deposits of which are probably twice as large as those of uranium. Electricity generation from thorium has been tested in the type of high-temperature reactor (THTR) developed in Germany and currently being made ready for market in China and South Africa.

Best practice

New focal point: nuclear safety research

The amendments to the German Atomic Energy Act in 2002 included the plans made by the German government of the time for a long-term exit from the use of nuclear energy. Regardless of the energy policy debate over the logic and future of the decision to shorten the operating times of the nuclear power plants, this decision does not mean the end of nuclear research and innovation in this sector.

In line with the research policy objectives laid down by the German government, research is currently focused on the safety of the existing nuclear reactors as well as the safety of nuclear waste disposal. What is also important is to retain the required knowledge and expertise for the operation and eventual decommissioning of the reactors. In Germany, work on new reactor concepts can only be performed in the context of international cooperation and with funding from the EU and industry, as there is no longer any government funding in this area.

Evolutionary and safe: European Pressurised Water Reactor (EPR)

In December 2003, an agreement was signed between Finnish electricity generator TVO and the Framatome ANP/Siemens AG consortium on the turnkey construction of Finland's fifth nuclear power plant, "Olkiluoto 3". This EPR will represent the first-ever operation of a third-generation pressurised water reactor – an evolutionary further development of tried and tested European reactors.

The EPR is a pressurised water reactor in the 1600 MWel output category developed by AREVA in cooperation with European operators. The design concept incorporates the worldwide experience from thousands of operating years of light water reactors, in particular the most modern reactors currently on the market – the French "N4" and the German "Convoy" plants. It also draws on the findings of decades of research and development programmes, especially those of the French CEA atomic energy commission and Karlsruhe Research Centre in Germany.

The EPR possesses innovative properties which further reduce the already low risk levels of existing plants and which would limit the effects to the plant itself even in the event of a worst-case scenario. In addition, it provides maximum protection against damage due to external factors like aircraft hits or earthquakes.

A further EPR is currently being built in France. In October 2004, the EDF Group decided to also build an EPR at the Flamanville location, and the projected five-year construction phase of this plant began in 2007.

International programme: "Generation IV" reactors

The "Generation IV" research and development programme is an initiative of ten states: in 2000, Argentina, Brazil, Canada, France, Japan, South Korea, South Africa, Switzerland, the UK and the USA agreed on a framework for international cooperation in the field of nuclear technology. In July 2003, Euratom became the 11th member to sign the agreement on cooperation in the Generation IV International Forum (GIF), thereby paving the way for the participation of all Euratom members in this forum.

Generation IV reactors are nuclear energy systems that differ significantly from Generation III, the category that also includes the EPR. The goal is to develop future-generation nuclear energy systems that can supply competitive and reliable energy products – in other words, not just electricity. They are designed to adequately fulfil future requirements in terms of safety, disposal, proliferation (the term for the illegal spread of weapons of mass destruction or technologies for the production of such weapons) and public acceptance. The aforementioned countries joined forces in the GIF with the aim of preparing and implementing the development of Generation IV nuclear energy systems.

Following a comprehensive evaluation procedure, the following six nuclear energy systems were selected by the GIF in consultation with the Nuclear Energy Agency (NEA), the European Commission and the International Atomic Energy Agency (IAEA) for further development:

› Gas-cooled very high temperature reactor systems (V/HTR),
› Gas-cooled fast reactor systems (GFR),
› Supercritical water-cooled reactor systems (SCWR),
› Lead-cooled fast reactor systems (LFR),
› Molten salt reactor systems (MSR) and
› Sodium-cooled fast reactor systems (SFR).

The work of the research centres is primarily focused on the V/HTR and the SCWR; the costs are covered by third-party funding agreements with industry and the European Commission.

The human factor: research into communication and team behaviour

When it comes to the safety of nuclear reactors, research cannot concentrate solely on technical issues. The human factor is equally important – as part of the multi-facetted interplay between technology, human beings and organisational structures in the control of complex technical systems. The focus is on communication and teamwork. The phenomenon of human error is meanwhile a central area of research in various disciplines.

Communication is understood as quite a comprehensive process covering all forms of human behaviour that impact or are noticed by the environment. If complex technical systems are controlled by a team of human beings, this creates a hypercomplex overall system.

Research is based on the hypothesis that most disturbing influences can be prevented by professionalism in the area of communication. Communication is seen as being communication between individuals as well as between human beings and machine. Accordingly, professional communication is a key skill for the safety of technical systems. It can reduce the influence of so-called "human error".

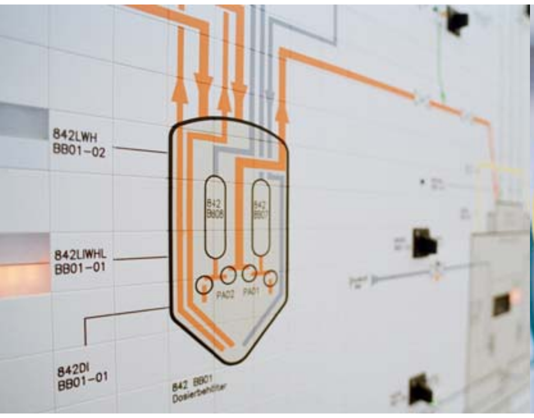
Many specialists are involved in the drawing up of rules for professional communication. They come from the fields of aviation, medicine and nuclear power; they are social and biopsychologists, psycholinguists and general linguists. They use different models to investigate behaviour patterns and the effects of key context parameters such as pressure of time and stress as well as culturally driven variations in communication.

Researchers and scientists have identified various areas of communication that require closer investigation. The findings of these investigations are incorporated in the best practice models of the companies. These areas include pre-work meetings, the manner of communication during the performance of work, work follow-up discussions, team climate, working environment and the culture of communication within the company.

Operation of nuclear power plants: simulation on PCs

Most people are familiar with computer-aided simulators from the aviation sector and airplane construction – especially since flight simulators have long since ceased to be confined to pilot training and have become a standard leisure time application on

home PCs. Simulation programs also play an important role in researching the operational safety of nuclear power plants. The nuclear plants supply real-world data for the programs – such as data on start-up processes following standstill periods for maintenance and repairs. This data is used to perform simulation experiments. It also allows realistic review and testing of the results of theoretical investigations. One important



example are the flow characteristics of liquids used to cool the fuel elements. At Dresden Research Centre (FZD), for example, thermohydraulic experiments are conducted in a multi-purpose trial installation. Programs for the calculation of complex flow patterns are also developed there. The accuracy of these predictions is tested in simulation calculations based on real-world examples. These activities are incorporated in the national initiative for the further development of CFD methods (computational fluid dynamics) and in the EU's integrated NURESIM project (nuclear reactor simulation).

Experiments on pressurised and boiling water reactors are ongoing at the University of Zittau/Görlitz. The findings are also particularly relevant for the development of new reactors. Theoretical studies play an important role in the evaluation of these experiments.

At a trial installation at Karlsruhe Research Centre (FZK), experiments using so-called fuel element dummies (fuel elements without fissile material but with electrical heating devices inside the fuel rods) are being conducted outside the reactor on pressurised and boiling water reactor fuel elements and Russian WWER fuel elements (WWER: water-water-energy reactor). These experiments analyse the heat given off by the fuel element to an ambient medium under different trial conditions up to temperatures of 2,000°C. Experiments of this kind take place within the framework of the EU.

Nuclear waste disposal: behaviour of the actinides

Another focal point of research is the safety of nuclear waste disposal – the final storage of radioactive waste in underground shafts. The aim is to ensure and document the long-term stability of stored waste. The key area of research is long-lived radionuclides, in particular actinides. This group also includes substances like uranium or plutonium.

Research always assumes worst-case scenarios. The objective is to ensure that the consequences are manageable even in the worst conceivable case. For example, a final repository should be designed in such a way that it stays dry for as long as the stored waste emits any significant levels of radioactivity. If there should be any kind of water penetration, however, the casing and packaging of the spent fuel elements should ensure that there is no possibility of a reaction between the water and the radioactive material. Research is still needed, however, to determine what happens when actinides come into direct contact with water in the final repository. This is why investigations are focused on chemical reactions – involving plutonium, for example – under the kind of conditions prevailing in final repositories. Research into the chemistry of plutonium in aqueous media has been highly successful at Karlsruhe Research Centre, paving the way for more extensive investigations.

Dresden Research Centre has set up a radiochemical laboratory for the specific purpose of performing long-term safety analyses. The lab investigates processes that occur during the transfer of long-lived radionuclides from the geosphere to the biosphere (the part of the earth within which life occurs, including flora and fauna).

Decommissioned high-temperature reactors: disposal of fuel elements

High-temperature reactors used to be in operation in Hamm-Uentrop and at Jülich Research Centre (FZJ). They were also known as pebble-bed reactors. The trial reactor in Jülich was shut down in 1988 and was soon followed by the commercial reactor in Hamm-Uentrop in 1989.

A fuel element of a high-temperature reactor (HTR) consists of small fuel particles surrounded by gas-tight casings made of pyrocarbon and silicon carbide (SiC) and embedded in a graphite matrix. At Jülich Research Centre (FZJ), scientists are investigating the chemical and mechanical long-term stability of HTR fuel elements for the event of direct final storage. The central question is: in what matrix can the fuel elements be embedded in order to meet all the demands in terms of long-term stability? It is possible that silicon carbide already fulfils all the stipulated conditions.

Reducing radioactivity: transmutation

Long-lived highly radioactive isotopes remain radioactive for thousands or even millions of years. Research is currently being conducted into a method to reduce this time to around 1,000 years by means of isotope conversion. This method is known as transmutation. If the work is successful, it will considerably simplify final storage operations. This question is being investigated at the Paul Scherrer Institute in Switzerland as well as at Dresden-Rossendorf Research Centre.

On the horizon: nuclear fusion

The decision has now been made to build ITER (international thermonuclear experimental reactor, in Latin: the way): Cadarache in southern France has been chosen as the location for the research facility. The ITER experimental reactor represents the next major step in worldwide fusion research.

The reactor is designed to demonstrate the scientific and technical feasibility of energy generation from nuclear fusion and to show that it is possible to create an energy-supplying fusion plasma in which the isotopes deuterium and tritium are fused together to form helium.

Preparations for ITER have been underway since 1988 in a worldwide alliance of European, Japanese, Russian and US researchers. China and South Korea also joined the project in 2003.

ITER is to generate an ever-burning and energy-yielding plasma for the first time with a fusion power of 500 MW. The aim is to achieve an energy amplification factor of at least 10 – in other words, to obtain ten times more in fusion energy than what was originally needed to heat the plasma.

After the ten-year construction phase, around 600 scientists, engineers, technicians and other employees will work at the facility for around 20 years. Karlsruhe Research Centre is involved in the development of key technologies for the fusion process and is one of the European leaders in this field alongside institutes in France (CEA) and Italy (ENEA).

Now that the decision on the site for ITER has been made, the challenge is to implement technologies that have been researched and developed for more than two decades. On account of its recognised expertise, the FZK will act as the lead manager for design and the procurement of components and systems for ITER and will supervise their installation in the reactor.

EnBW practice

› Nuclear power:
Low-emission source of energy

Nuclear energy is increasingly part of the agenda again in many countries – not least due to the problems posed by global warming. As the only large-scale energy source without significant greenhouse gas emissions, it plays a key role internationally in the energy mix of the future. Ongoing optimisation of existing plants and research and development in connection with future projects sustainably underpin global efforts to contain climate change.

In recent years, EnBW Kernkraft GmbH has done a great deal of pioneering work in the areas of safety and optimisation. Numerous innovations have been implemented at and across the individual locations, and some of them have even been exported.

› Safety with a capital "S":
OSART and SMS

EnBW is the only nuclear power plant operator in Germany who has arranged for evaluation of all its production locations by the International Atomic Energy Agency within the space of just a few years. The IAEA is an autonomous scientific technical organisation reporting to the United Nations and conducts so-called OSART missions (Operational Safety Review Team) worldwide. The aim of the missions is to perform a comprehensive assessment of the operational management of a nuclear power plant as well as safety levels based on international standards. At the same time, the IAEA uses the insights gained during these missions in the ongoing development of its guidelines for the evaluation of nuclear power plants.

The IAEA rated the facilities in Philippsburg and Neckarwestheim as excellent plants which possess many of the features of a high-level culture of safety. The agency described EnBW as an operator for whom nuclear safety has top priority and as a company with highly motivated employees.

EnBW is also a pioneer in Germany when it comes to the continuous, systematic and cross-locational improvement of safety. An indicator-based dynamic safety management system (SMS) geared towards the permanent ongoing development of all relevant processes was introduced at all three nuclear power plants in 2007. The principle of continuous improvement adopted by EnBW's nuclear power plants many years ago has now been standardised and rendered measurable with the introduction of the SMS. This system is based on updated international standards defined by the IAEA and the Organisation for Economic Cooperation and Development (OECD) or the affiliated NEA.

› Gains through efficiency:
Green megawatts

In the period from 2004 to 2008, EnBW has succeeded in creating so-called "green megawatts" by implementing measures to boost efficiency in its nuclear power plants: the technical optimisation of the plants increased the electricity yield by around 50 MW with the same fuel input. This additional volume of electricity is equivalent to the annual consumption of over 100,000 households.

› Idea management:
Sparing resources and the environment

Through their innovative ideas, EnBW employees also play an important role in the optimisation of power plants and therefore help to save resources and spare the environment. In 2007, for example, three employees at the Philippsburg nuclear power plant were paid a hefty bonus for their idea of using vitamin C in the reactor cooling water to bind volatile radioactive species. Thanks to this idea, it was possible to considerably reduce the number of radiation protection and decontamination measures during the next annual plant inspection.

› Research and teaching:
Concentrated in southwestern Germany

Of all the German states, Baden-Württemberg can draw on the most wide-ranging scientific and technical resources for research and teaching in the field of nuclear technology. In line with a decision by the Baden-Württemberg Council of Ministers, the "Southwest German Nuclear Technology Research and Teaching Association" was set up in October 2007. The founding members are Karlsruhe Research Centre (FZK), EnBW, the European Commission's Transuranium Institute, the Universities of Heidelberg and Stuttgart, the Technical University of Karlsruhe, Ulm University and Furtwangen University. As a result of this cooperation, the number of professorships also increased from four to six: EnBW created a foundation professorship for "Dynamics of Nuclear Technology Systems" at the FZK, and the state of Baden-Württemberg is sponsoring a chair of "Innovative Reactor Systems" at Karlsruhe University.

In cooperation with research institutes, primarily the FZK, the Stuttgart Material Testing Institute and the Universities of Karlsruhe, Stuttgart and Heidelberg, EnBW also supports PhD candidates whose research makes a significant contribution to the improvement and optimisation of existing or future nuclear facilities. A dissertation completed in 2007, for example, which was prepared in cooperation with the Institute of Nuclear Chemistry at Marburg University focused on the use of lithium hydroxide as an anti-corrosion agent in reactor cooling water. To date, it has been necessary to dispose of the lithium that was added and extracted during the course of the year as radioactive waste. The new findings resulting from the research project have led to the testing of a recycling process that reduces the quantity of radioactive waste.

› The future of nuclear energy:
International cooperation

Young up-and-coming researchers at EDF and EnBW are cooperating closely within the framework of the "We offer a future" (WOAF) programme. On European level, EnBW is involved in the "Sustainable Nuclear Energy Technology Platform" (SNETP). The SNETP was set up in Brussels in September 2007 and unites all the players in the field of nuclear energy. Its goals include the development of a new and fully integrated European research concept based on joint objectives and targeted funding, and it also provides expert advice to the European Commission and the governments of the member states. In addition, it is tasked with conducting a dialogue that extends beyond the scientific aspects and focuses on central issues like waste disposal, safety and protection.

In addition, EnBW is also involved in several working groups within the framework of the "European Nuclear Energy Forum" (ENEF). The ENEF was set up by the European Commission to improve the exchange of information and to prepare European policy for the nuclear sector in the EU.

› Politics and **society**

Committed cooperation and well-adapted political instruments are the key to international climate protection. But the fight against climate change cannot be won by the politicians and industry alone. Consumers will also have to rethink – and there are already signs of a changing consciousness among the public at large.

Dr. Axel Michaelowa is advisor to the UN Climate Secretariat and heads the Climate Policy Research Group at Zurich University. The IPCC lead author for flexible mechanisms is a member of the CDM Supervisory Board and his firm "Perspectives" advises companies on the implementation of climate protection projects.

International greenhouse gas markets – playing with fire?

Status quo

In the 20 years since its inception, international climate policy has already brought forth several innovations. The most important of these are the international market mechanisms for the reduction of greenhouse gas emissions. Four such mechanisms are rooted in the 1997 Kyoto Protocol: the one-time redistribution of emission targets within a group of countries (the so-called "bubble"), trading of surplus emission allowances on governmental level (international emissions trading) and the development of reduction projects in countries with emission targets (Joint Implementation, JI) as well as in developing countries without such emission targets (Clean Development Mechanism, CDM).

Back in the 1990s, few climate policy experts gave the CDM a chance, claiming that both the cost of monitoring projects and the risk of investment in developing countries were too high. They said the complex project cycle with its external audits would scare off private project developers. And, indeed, the only bodies that provided funds for the purchase of emission credits were the World Bank and the Dutch government. They laid down a price level of 3 dollars per ton of CO_2.

Nothing changed until the 2003 EU "Linking Directive" gave companies in the EU emissions trading system the right to use emission credits. The price for EU emission allowances then became the benchmark for the price of CDM emission credits. The EU prices rapidly rose to 30 euros per ton of CO_2, and this created a high demand for CDM projects. Subsequently, numerous financial institutions began to launch CDM funds and major energy suppliers set up CDM procurement teams.

Since this time, the project pipeline has swollen to a massive 3,000 projects, of which just under 1,000 have been registered. It is estimated that over 2.5 billion emission credits will have been used by the end of the Kyoto commitment period in 2012. In something akin to a gold-rush fever, CDM project development companies came into being overnight, mainly in India and China but also in Latin America. The shares of six or so of these companies are meanwhile listed on the London Stock Exchange. The governments and banks in the industrialised countries have budgeted a total sum of 9 billion euros plus for the purchase of emission credits. At the current price of 16 euros, however, this is equivalent to fewer than 1 billion credits. Will we soon see a supply overhang and falling prices? If Russia overcomes its institutional chaos, the billion-dollar volume of surplus emission allowances could crush the CDM more or less at a stroke.

2020

It is probable that the climate negotiations for the period after 2012 will stipulate emission targets for 2020. If the EU pushes through its 30% reduction target and other industrialised countries follow suit, the international shortfall for the period from 2013 to 2020 would be in excess of 20 billion tons of CO_2. The "hot air" of the transformation states would only cover 9 billion tons. The CDM projects that have already been announced would contribute a further 3.2 billion tons, which would leave a gap of 8 billion tons which would have to be met either by emission reductions in the industrialised countries or additional CDM projects. If, however, the EU Commission succeeds in forcing through its restrictive attitude towards the import of emission credits, this is exactly the amount by which emissions would have to be reduced within the EU and the CDM market would already be in a supply overhang situation today.

2050

The long-term political success of the CDM system depends largely on its credibility and its effectiveness for climate protection. One decisive aspect is that CDM projects would not have been implemented anyway on account of their commercial profitability alone. For a number of decades now, companies have been investing in hydroelectric power plants without any incentive in the form of emission credits. The aim of CDM projects is to additionally avoid greenhouse gases. Today, project developers must therefore either document that there are more lucrative investment options than the CDM project or prove that the project would have been unfeasible due to insurmountable obstacles. These claims are reviewed by independent auditors. In the past, it has unfortunately been the case that the auditors have simply accepted the arguments of the project developers without further ado and that many projects have therefore been registered which would have been implemented anyway. It is only since an additional review by independent experts and the UN Climate Secretariat has been introduced that projects have been regularly rejected. Nevertheless, large-scale wind and hydroelectric power plants at attractive locations still slip through the net. The first media reports on CDM scandals have already been aired, and there is a serious risk of CDM getting a bad name in the increasingly critical public arena. If this is indeed the result, then a highly promising instrument will have been ruined by the greed of a small number of project developers.

Best practice

Kyoto Protocol: flexible mechanisms

The Kyoto Protocol which came into force at the beginning of 2005 contains three "flexible" instruments that enable countries to achieve part of their commitments in the period from 2008 to 2012 at lower costs. The German government allows German companies to meet a maximum 20% of their reduction commitments abroad by using the Joint Implementation (JI) and Clean Development Mechanism (CDM) instruments. The third mechanism is international emission trading. By using these three instruments, emissions can be avoided where this is possible at the lowest cost.

Joint projects: Joint Implementation

Since 2008, industrialised countries who have undertaken to cut their greenhouse gas emissions under the Kyoto Protocol are allowed to cooperate on the implementation of projects under the JI mechanism. A country or a company that carries out emission-reducing projects in another country can have the achieved emission reductions credited in its home country, thereby enabling it to meet its reduction obligations at lower cost.

Investing in developing countries: Clean Development Mechanism

The CDM allows industrialised countries to implement emission reduction projects in developing nations. This serves to integrate the developing nations in international climate protection efforts and also promotes sustainable investments in these countries. Companies can then credit the avoided emissions to their reduction commitments. Just under 1,000 CDM projects are currently registered in 49 countries and more than 2,000 applications are being reviewed for sustainability. CDM projects have been permitted since 2000. In addition to meeting the criterion of sustainability, CDM projects must also be implemented in addition to projects that are already planned.

Global market: emission trading

The international trade with emission certificates is an important element in the efforts of the industrialised nations to meet their obligations under the Kyoto Protocol. If the emissions of a country exceed the agreed reduction commitment, the country in question may purchase certificates from other countries who have not used up their budget. The launch of international emission trading in 2008 will create a global market for trading in emission certificates. For the participating companies, comparison of the specific CO_2 reduction costs and the market price for CO_2 emission certificates is a key aspect. If the price exceeds the specific costs, this means measures implemented by companies to avoid CO_2 make financial sense. In the opposite case, the emitter purchases certificates in the market or via CDM and JI projects and can then meet his obligations in this way. Climate protection therefore takes place where it can be achieved most cost-effectively. In 2006, around 1.6 billion tons of CO_2 equivalents with a value of 29 billion dollars were traded worldwide, twice the volume recorded in 2005. The overwhelming percentage of trading takes place within the European Union on the basis of the EU Emission Trading Directive. At the end of 2007, the European Commission, nine EU member states including Germany, 12 US states, Australia and New Zealand formed the "International Climate Action Partnership" (ICAP) in Lisbon. ICAP is initially looking into issues connected with the linking of regional emission trading systems, and it is hoped that this will generate key stimuli for the creation of a global carbon market in the long term.

New criteria for investors: climate protection as a growth driver

Environmental and climate protection concepts are increasingly becoming part and parcel of the global economy. Investors will also take account of new criteria when making investment decisions in years to come: the conventional criteria of profitability, liquidity and safety will be supplemented by social, ethical or ecological considerations.

The environment-friendliness of companies in particular is becoming an increasingly relevant parameter for financial investors. The independent, nonprofit Carbon Disclosure Project (CDP) has developed methods and techniques for the collection of information on CO_2 emissions that are recognised worldwide. The influence of the CDP is considerable: it is backed by 385 institutional investors who manage a total investment volume of 57 trillion dollars. The CDP conducts an annual survey on the topics of climate change and CO_2 emissions among the world's biggest companies. The result is the biggest publicly accessible database of company-related emission data complete with the corresponding corporate strategies. In 2007, a total 1,300 companies from around the world voluntarily submitted their data.

Key changes can also be observed in the USA: "cleantech" investments in clean, sustainable and environment-friendly technologies have become an innovation and growth driver. In the venture capital investment segment, cleantech is already in third place in the USA behind Internet and biotechnology – and is expected to move into pole position in the next few years.

The market belongs to the best: "Top Runner" approach

In 1998, the Japanese government introduced an important innovative concept: the "Top Runner Programme" stipulates standards based on the electrical appliances that save the most energy. The promotes the market penetration of the most environment-friendly and resource and/or energy-efficient technology. Manufacturers of rival products have to follow suit before a specified deadline – and this also applies to foreign manufacturers. If rival products do not achieve the required energy-saving effect in the stipulated period, they risk legal sanctions, penalty fines or even a sales ban.

The programme meanwhile comprises 21 categories, from cars, fridges, freezers, copiers and kettles all the way to PCs and other appliances. The deadline for improve ment of energy consumption is set at between three and twelve years. If a product category reaches the target earlier than planned, then the efficiency targets are sometimes reset at even more ambitious levels. In this way, Japan could well achieve up to one quarter of the national emission reduction goal targeted for 2010. The Top Runner Programme will therefore take Japan a big step closer to fulfilling the greenhouse gas reduction obligations it entered into under the Kyoto Protocol.

The German government is one of the parties that has called on the EU Commission to launch a European Top Runner Programme to stimulate competition and innovation in the aim to meet the 20% target increase in energy efficiency by 2020 – as provided for in the European climate and energy strategy. The Commission intends to define the necessary regulations before the end of 2008.

Offsetting emissions: climate neutrality

The term "climate neutrality" is at first sight misleading. Emissions cannot be neutralised – but they can be offset. Carbon dioxide is also released by private and commercial activities like air travel or the production, packaging, transport and distribution of consumer goods. For some time now, a growing number of organisations and companies have been offering project implementation advisory services to offset these emissions. The customers, in this case both private individuals and companies, pay the costs of the projects in question.

Critics of these developments complain, however, that the problem with emission compensation is that there are still no uniform, recognised standards for the calculation of so-called "climate-neutral" processes and products.

Part of the corporate strategy: communication with consumers

More and more consumers react positively to environment-friendly products and companies. Polls show that they would also welcome it if companies played a bigger part in the field of climate protection. Companies who do not incorporate their own environmental compatibility and that of their products in their strategic thinking run the risk of losing ground in the market. It is hoped that new, more efficient transport methods and changes to production and growing processes will help to reduce CO_2 emissions. The retail industry, a sector in which consumer pressure is often highly concentrated, is already taking this issue extremely seriously. Companies are analysing their production chains and stepping up their cooperation with suppliers who minimise their emissions. One new trend is for companies to list the CO_2 profile of their products.

UK supermarket chain Marks and Spencer, for example, promises that its activities will in future be CO_2-neutral and that it will not dispose of any more waste on landfill sites in the period up to 2012. Wal-Mart has announced that all its shops in the USA will in future be operated using renewable forms of energy only. In addition, the production chains of all Wal-Mart suppliers are to be examined for untapped CO_2 reduction potential. In 2007, UK supermarket giant Tesco began to declare the "carbon footprint" of all its products. A small sticker states how much CO_2 was emitted during production, storage and transport of a product. However, the CO_2 emission figure alone does not tell us anything about land consumption, noise or other socio-ecological factors. Consumers will find it difficult to recognise differences without transparency and access to all the necessary information.

EnBW practice

› Climate development:
Issue of core interest for energy suppliers

It is particularly important for energy suppliers to know all the facts on climate development so that they can prepare strategies and instruments to protect the climate and adapt their own operations. Taking an honest, in-depth look at the problem of climate change and tackling this challenge head-on is not only our responsibility as corporate citizens – it is also in our best interests from an economic point of view.

› International forum:
EnBW's German Climate Congress

We were looking into the problem of climate change before it ever became a media issue: at the beginning of 2006, EnBW set up a scientific advisory council whose members include Germany's most highly respected climate researchers. Together with these experts, we planned the 1st German Climate Congress entitled "Changing Climate – Facts, Impacts, Perspectives". The result was an international, interdisciplinary forum focusing on the serious discussion of the facts, scenarios and consequences of climate change for society as a whole. The staging of the 1st German Climate Congress represented the first time that an industrial company took the initiative to bring the worlds of industry, science and politics together at one table. Such an exchange of ideas and information was by no means a matter of course back in 2006, but we were already firmly convinced over two years ago that the interaction and cooperation of all the various parties involved was the only way to develop meaningful global plans of action and that industrial companies would play a key role in any solution to the problems with which we were – and still are – faced.

EnBW continued its high-level commitment with the 2nd German Climate Congress. In October 2007, the Berlin event with the title "The Economics of Climate Change" brought together international Nobel Prize winners, knowledge bearers and decision-makers and provided them with a forum for the development of joint strategies for climate protection. CEO Hans-Peter Villis welcomed German Foreign Minister Frank-Walter Steinmeier, Baden-Württemberg Minister President Günther Oettinger and his Environmental Affairs Minister Tanja Gönner, climate researchers and Scientific Advisory Committee members Prof. Mojib Latif and Prof. Stefan Rahmstorf as well as further experts from China, the USA and the UK. The undisputed highlight of the Congress was the appearance by Al Gore. The former US Vice-President and recent Nobel Peace Prize winner showed his Oscar-winning presentation on the threat of climate change and emphasised the importance of taking a determined stance on climate protection.

› Campaign to mark the Climate Congress:
Al Gore answers your questions

The Congress not only provided new insights for the attendees from the worlds of business, science, politics and society but also succeeded in encouraging people to rethink their outlook on some of the central issues: the competition "Al Gore answers your questions" was a case in point. The questions for the Nobel Prize winner were published on the Internet and rated by the users themselves. The winners of the competition were invited to Berlin as guests and had the opportunity to put their questions to Al Gore in person. At the end of 2007, EnBW was presented with the European Excellence Award for the campaign in the run-up to the Climate Congress.

› Industry becomes pro-active:
New corporate initiatives

EnBW firmly believes that industry will play a key role in solving the world's climate problems. It was in this spirit that the final document of the 1st German Climate Congress, the "Berlin Declaration", announced the intention to set up a group of entrepreneurs who are actively committed to climate protection and who support the political powers-that-be in their endeavour to create the necessary framework conditions. EnBW followed up this declaration by calling for and supporting the creation of various corporate initiatives. We are, for example, a founding member of the group "2° – German Entrepreneurs for Climate Protection" as well as part of the initiative "3c – Combat Climate Change"; we also played a major part in the development of the "Industry for Climate Protection" climate group of the Federation of German Industries (BDI). In 2007, the BDI initiative actively promoted the debate on the implementation of climate protection measures with a comprehensive study on avoidance costs. This climate study prepared by McKinsey describes over 300 technological avoidance levers and contains an economic evaluation of their cost and potential. The findings of the study were presented to the German government and the European Parliament as well as at the UN Climate Conference in Bali.

› EnBW as sponsor:
The Baden-Württemberg Energy & Climate Protection Foundation

At the end of 2007, EnBW acted as sponsor in the creation of the nonprofit "Baden-Württemberg Energy and Climate Protection Foundation". The work of the foundation is designed to improve the general understanding of the interrelationships between the energy industry and climate protection as well as to secure the future of Baden-Württemberg as a centre of research. Within the framework of this foundation, a network of international experts discuss, analyse and assess effective climate protection measures. Other topics include renewables, energy efficiency, energy saving and the post-Kyoto process. The findings will be presented for public debate, thereby promoting the targeted discussion of these topics and questions. In addition, the Baden-Württemberg Energy and Climate Protection Foundation systematically encourages young scientists to take part in this debate.

› Green pilot project:
Jatropha cultivation in Madagascar

EnBW is taking an in-depth look at JI/CDM projects and reviewing various options for concrete commitment. The company has already taken the first step in this direction: together with partners who have ties to Hohenheim University, EnBW launched a pilot project for the cultivation of the jatropha plant in Madagascar in 2007. The goal is to implement the CDM procedure on a plantation measuring 3,000 hectares. The aim of the project is to prove that the planting of additional jatropha crops can reduce CO_2 emissions, as it is estimated that one hectare of jatropha bush can bind an annual volume of around 2.5 tons of CO_2. In a parallel sub-project, the nuts of the plant are also to be harvested – as the oil from these nuts is suitable for the production of biodiesel. If the project is successful, the cultivation of jatropha will be extended to cover 100,000 hectares.

The jatropha plant is a small miracle: as the bush belongs to the euphorbia family, it does not compete with food production. On the contrary it is eminently suitable for the recultivation of degraded land: its deep root system prevents soil erosion and increases the soil's water storage capacity. It can also survive droughts. Trials with jatropha, particularly for the production of fuel, have been underway in places like India and China for a number of years – but there have not been any experiments with large-scale plantations, and this is where the EnBW project should provide new insights.

› Key to success:
Innovative drive

Companies with a strong innovative drive enjoy far greater success and more growth in the medium and long term. A company with the capacity to innovate is able to continuously adapt its products and services to changing market conditions and requirements.

Before the market was deregulated, innovation management was of little or no consequence in the energy industry. Today, the energy market is a dynamic market; the availability and price of primary sources of energy are constantly changing and are increasingly subject to political influences. New technologies for the generation and conversion of energy are coming onto the market, and customer expectations are growing in the area of prices and sustainability.

› Professional process:
Innovation management

The process of innovation itself essentially consists of invention and innovation. Invention means the discovery and development of new ideas up to the point where they reliably meet all the stipulated functional requirements. In the next step, they become concrete innovations – in other words marketable products, services or business models.

A successful innovation management system standardises this process within a company and ensures ongoing feedback between the sales organisation – which is close to the customer and in a position to identify the products that could be successful in the future – and the research and development function. In turn, the activities in the field of research and development ensure that all relevant technological developments are continuously monitored and assessed in terms of their technical functionality. Innovation management is the connecting link between these two corporate activities and its task is the economic evaluation of technological innovations for EnBW and the ongoing development of these innovations to create lucrative business models.

› Decision-making support:
System analysis studies

In order to decide which technologies or processes may be of significance for the continued reliability of energy supplies in future, it is necessary to formulate ideas about potential future developments in this area. Investigation of the interaction between these developmental options sheds light on innovation potential and highlights areas of action in which innovation activities can be meaningfully focused.

The often complex interactions can be depicted in various scenarios with the help of computer-aided system analysis. Analysis of these scenarios paves the way for coherent recommendations for action, which can consist both of individual actions and packages of measures.

According to Prof. Wolf Fichtner, Head of the Energy Industry Department at Brandenburg Technical University in Cottbus, these system analyses are used for such tasks as the preparation of action strategies to meet climate protection targets. "So-called optimising energy models are employed at energy supply companies, research institutions and government agencies in order to conduct system analysis studies", says Prof. Fichtner. "These models facilitate the simulation of the energy supply systems under investigation. For this purpose, existing installations and investment alternatives are described on the basis of technical (e.g. efficiency), economic (investments, fuel costs etc.) and ecological characteristics (e.g. emission factors) and the system modelled in this way is then optimised based on the definition of a specific target."

› Core units:
Research & Development and Innovation

In 2007, EnBW spent 32.4 million euros on research and development and innovation, an increase of 57% on the previous year's figure of 20.6 million euros. The two strategic core units comprising 27 employees – primarily engineers, physicists and economists – are based at the Holding company and are supported by over 120 employees across the various group companies.

The two units also cooperate with project partners from the worlds of science and industry in the field of basic technical and energy-related research. The focal points of these projects are increased efficiency of electricity generation, environmentally sparing use of resources and the development of new sources of energy.

Our most important external research and innovation partners are the universities and research institutions in Baden-Württemberg, in particular in Karlsruhe, Stuttgart and Hohenheim. Close ties also exist with the universities and research institutions in Munich, Darmstadt and Cottbus.

› Energy **perspectives**

Active climate protection is also about the systematic promotion of technological development and the expansion of research. Innovations for which there is no market worldwide will not be adopted in the longer term. Accordingly, it is important that the potential of innovations is realistically assessed and that promising developments are pursued at high pressure.

Dr. Annette Schavan is the German Minister of Education and Research. Last year, the German government stepped up its activities in the field of energy and climate research, also launching a number of initiatives to accelerate the pace at which new ideas are transformed into concrete products and processes.

Energy research: securing sustainable energy supplies

Status quo

Energy is one of the dominant issues of our time: rising oil, gas and electricity prices, limited raw material reserves and the emission and climate impact of greenhouse gases demand action from the worlds of politics, science and industry. The German government is a driving force behind a sustainable energy industry both nationally and internationally. At the G8 Summit in Heiligendamm, Germany put the issues of climate change and energy efficiency right at the top of the international agenda. We need an environmentally sparing and reliable energy supply system – both in the industrialised states as well as in the NICs and developing nations.

2020

With Germany leading the way, the European Union forms the vanguard of international climate protection and has laid out highly ambitious goals. In concrete terms, this means we must increase the share of renewables in our energy supply system and make major progress in development of technologies for the utilisation of renewables – in areas like photovoltaics and bioenergy – during the next few years. Coal will continue to play a key role in energy supplies for decades, and this is why developing more environment-friendly coal-fired power plants is a matter of urgency. And why the development of technologies to capture CO_2 from coal-fired power plants and the subsequent storage of this CO_2 underground is of central importance.

For safety reasons alone, and to enable us to assess developments in other countries, we also need to continue to promote radiation research as well as research in the fields of safety and disposal. In addition, we intend to conduct research in the area of fusion in order to lay the long-term foundations for reliable energy supplies.

Climate protection and sustainable energy supply concepts create opportunities for innovations and employment. Around 170,000 people are currently employed in the field of renewables in Germany alone; it is estimated that this figure could rise to around 500,000 by the year 2020. Environmental technology offers an enormous amount of untapped potential that we need to exploit to underpin the status of Germany as a key location in the endeavour to tackle global challenges. It is also our goal to ensure that environmental technology “made in Germany” continues to be one of our most successful exports.

In our search for outstanding solutions, we must attach far greater importance to research and development as well as knowledge and expertise. To this end, we must integrate all existing sources of expertise: we need improved coordination and cooperation between universities, non-university research institutes and in-house research in companies.

Innovation and technical progress play the key role in all efforts to promote climate protection and sustainable energy supplies. We must continue to increase the energy efficiency of power plants, buildings, technical processes and products, to develop new sources of energy and make this energy available. Energy research also provides us with a major opportunity to achieve our energy and climate policy goals more effectively, faster and more cost efficiently, to secure jobs and to underpin our international competitiveness.

2050

In the long term, energy must be generated in practically emission-free power plants, and renewables will have to meet a high percentage of global energy demand. This means our future efforts must not only be directed at the ongoing development of existing forms of energy. We must develop and promote new ways of generating and using clean energy.

All this calls for visionary ideas in areas such as the “house of the future”, which meets its heating and energy requirements solely from the power of the sun. By increasing the efficiency of buildings, appliances and vehicles, as well as by developing new technologies, we must reduce energy requirements to sustainable levels without curtailing comfort, convenience or safety. A further key objective is to exploit the potential of geothermal energy in Germany and to systematically integrate this innovative form of energy with other energy sources like biogas.

In order to accelerate these innovation processes, the worlds of science, industry and politics must cooperate even more closely and enter into international alliances. Together, we can develop acceptable compromises and solutions to meet the challenges of climate change and to create new energy strategies.

Last year, the German government stepped up its activities in the field of energy and climate research, also launching a number of initiatives to accelerate the pace at which new ideas are transformed into concrete products and processes. Fundamental research must be integrated in a process that feeds into applied research, subsequently leading to the utilisation of new insights in the development of specific products.

Today, Germany is a global leader in the field of energy technology: German power plant technologies lead the field worldwide. German companies are also frontrunners in many areas of renewable energy. We must work to expand this position. Germany must become a centre of excellence, a kind of think-tank that makes it an attractive science and research location of international repute in questions relating to climate protection and energy supply.

Energy world of the future

Pacemaker: the German government at the head of the climate movement

With its ambitious targets, the German government has put itself at the head of the international climate protection movement: in the period up to 2020, carbon dioxide emissions in Germany are to be cut by 40% compared to the reference year 1990, when 1.23 billion tons of CO_2 equivalents were pumped out of German stacks and exhaust pipes into the earth's atmosphere. Up to 2004, annual emissions of climate gases fell by just under 215 million tons or 17.4%. It must be said, however, that the major part of this reduction can be attributed to the modernisation of the east German economy. The next phase will be considerably more challenging without this "perestroika effect". Under the Kyoto Protocol, Germany has committed to a 21% reduction by 2012. The remaining 19% would then have to be achieved within the space of 8 years.

This represents a huge challenge for the German economy – yet this tour de force is relatively insignificant for the global climate overall. Every three years, electricity consumption in China alone grows by the amount that is currently consumed in the whole of Germany. Even if power consumption in Germany was reduced to zero, it would be more than offset within an extremely short space of time by the worldwide growth of energy consumption. However, Germany is the EU's biggest emitter of CO_2 ahead of the UK, and, according to the Germanwatch organisation, it is in 6th place worldwide in the league table of carbon dioxide sinners, behind the USA (21.44%), China (18.8%), Russia (5.69%), Japan (4.47%) and India (4.23%): Germany – with its 3.97% share of global GDP and 1.28% of the world's population – is responsible for 3% of worldwide energy-related CO_2 emissions.

Pioneering role: leading the way to keep up

So what are the reasons for the ambitious programme? The first argument is a political one: within the context of the EU, Germany's strong industry makes the country a big energy consumer and a large-scale emitter. It will only be possible to force through an effective emission reduction strategy in EU if Germany leads the way. Or to put it another way: if Germany fails to act, then no one else will do anything either. The EU in turn plays a key role as an ice-breaker for international climate negotiations. No one else of comparable weight is in sight who would be willing to take on a leadership role. These are the standard political arguments in Berlin and Brussels.

The second argument is connected to the NICs like China, India and Brazil: only if a key industrialised country leads the way as a role model, showing that it is possible to reconcile climate protection and economic success will the NICs be willing to tread the path of climate protection. And, in the long term, this will decide whether successful global protection of the earth's atmosphere is feasible at all.

The third argument has to do with industrial policy: it is important that Germany develops the technologies, processes, planning instruments and services that ensure a reduction in greenhouse gas emissions worldwide. The countries who are leaders in this area will have an edge in the global competitive arena in the medium and long term, and this means jobs and prosperity. The market strategists call this the "first mover advantage". Massive investment in research and development is needed to obtain this status – as well as a hard-and-fast political framework that promotes climate-friendly economic activity.

These considerations only carry weight, however, if the effects of climate policy are simultaneously "cushioned" for energy-intensive companies. Above all for those whose production processes offer little scope for reduced energy consumption. Otherwise, we run the risk of ending up with a double zero-sum game: firstly in the employment market, if more jobs are lost in the classic industrial segments than can be created in the pioneering sectors – and secondly on the climate protection front, if energy-intensive companies simply migrate to countries that don't take the protection of the earth's atmosphere quite as seriously.

We will only be able to reap the fruits of early and determined action in national economic terms if the same regulatory conditions prevail for industry worldwide in the medium term, thereby creating a global market for climate protection technologies. If the "avant garde" gets too far ahead of the others, it risks losing its way in treacherous terrain. Leading the way to keep up – this will be the benchmark for the assessment of German climate policy.

The precondition for this is the ability to integrate climate protection with cost efficiency and energy supply reliability. In this context, cost efficiency means focusing on measures that avoid greenhouse gases at the lowest cost. Energy supply reliability means reducing dependence on energy imports and banking on a wide range of measures in order to spread the associated risk.

Catalogue of measures: Integrated Energy and Climate Programme

On December 5, 2007, the German cabinet approved the "Integrated Energy and Climate Programme" (IEKP). A total of 49 measures, including 15 laws and regulations, are in the pipeline with the aim of reducing CO_2 emissions by around 36% by 2020 and therefore avoiding 220 million tons of CO_2 equivalents. The question of how the remaining 4% are to be achieved so that Germany meets its target has not yet been answered. The programme is focused on three sectors:

› Energy efficiency – the sparing use of energy in industry, commerce and private households.
› Renewables: the aim is to increase their share in the generation of electricity and heating energy as well as in the area of transport.
› Fossil fuels: low-CO_2 technologies should be employed to make the use of coal, oil and gas more climate-friendly.

Energy efficiency: aims of the German government

By 2020, the German government plans to double energy productivity compared to 1990 levels. In concrete terms, this means that only half as much energy should be needed to generate one unit of GDP than was the case 30 years previously. However, energy productivity increased by just 1.6% a year between 1990 and 2005, despite the fact that this was the same period during which the highly inefficient GDR economy collapsed. In order to achieve the aforementioned target, we would need to see a 3% increase in energy efficiency every year for the remaining period accompanied by economic growth of 1.8% per annum.

Electricity consumption: upward trend

The Federal Environment Agency (UBA) in Germany believes it will be necessary to reduce electricity consumption by 11% by the year 2020 in order to meet the 40% target for greenhouse gas emissions. Here again, the trends point in a different direction. In 2007, electricity consumption in Germany rose by 0.3% while the economy grew by 2.5%. In the preceding years, the growth in energy consumption was even more marked: between 2000 and 2005, electricity consumption by industry, households and commerce increased from 571 TWh to 612 TWh. In the segment

of private households, the trend towards one-person homes, bigger apartments and a wider range of consumer electronics appliances accompanied by ever-larger TV screens suggests that the road to the "energy efficiency nirvana" will be a rocky one. According to the German Energy and Water Association (BDEW), consumer electronics meanwhile account for 12% of total electricity consumption in private households. The in-

creasing number of private PCs is also fuelling a massive rise in household electricity consumption. This also applies to the infrastructure in the background. According to a recent study by the Federal Environment Agency in Germany, the country's 50,000 computing centres use 8.67 TWh of electricity a year. Worldwide, the Internet accounts for a surprisingly high 5.3% of energy consumption, says Internet guru Kevin Kelly in his Technium IT diary. A single Google search lasting seconds uses the same amount of energy needed to light a room for a full hour using an energy-saving lamp.

There is the added possibility of totally new "energy consumers". One issue currently being debated is electric mobility in connection with transport. So-called plug-in hybrid vehicles with a combined combustion engine/electric drive might be hooked up to a power socket when they are parked, for example. If a lot of surplus wind energy happens to be available in the network, they could use this energy to charge their batteries. This could also work the other way around: the batteries could be used as reserve accumulators when needed and act as mini power supply units. This is good news for the storage of volatile forms of energy from sources like the wind and the sun – as well as for the climate-friendliness of the transport sector. But one thing it will certainly not do is reduce electricity consumption.

Against this backdrop, the VDE electrical engineering association is extremely pessimistic with regard to the development of electricity consumption. In a study published in January 2008, the VDE estimates that, in the event of "business as usual", the demand for electrical energy resulting from new applications and the growth of the equipment park up to 2025 could grow by as much as a massive 60%. Even if major progress is made on the efficiency front, the VDE still forecasts a 30% growth in demand. When the study was presented, VDE expert Prof. Wolfgang Schröppel said that electricity consumption can only decline if there is a rapid and radical change in technology. The VDE sees the greatest economy potentials in electric motors in industry and the household. Today, the small motors that drive household appliances ranging from hairdryers to washing machines possess electrical efficiency rates of between 40 and 75%. This figure could be increased to 85%, albeit at considerably higher production costs, and would alone save 8.2 TWh a year. The economy potential for the stand-by mode of electrical appliances is of a similar order. The electricity consumed by stand-by could be reduced by between 5 and 10 TWh a year – equivalent to between 1 and 2% of total electricity consumption in Germany.

Soft measures: strategy of the German government

The measures laid out by the German government in the electricity sector to meet the reduction targets are relatively "soft". It is hoped that deregulation of metering operations will promote the spread of intelligent meters so that households and commerce can obtain a more accurate picture of their energy consumption and therefore identify power eaters. The idea is that precise consumption information available online will encourage more energy-efficient behaviour. In addition, the energy advisory services provided for households by bodies such as consumer advice agencies are to be improved. Subsidies are to be made available for professional energy-saving advisory services in commerce and industry as well as for investments in effective energy-saving technologies. A voluntary system of energy consumption labelling for electrical appliances is to be agreed with the manufacturers, and discussions are still ongoing on a market launch programme for highly energy-efficient appliances. This also applies to modern energy management systems in German companies. The plans of the German Environment Ministry include making the energy tax benefits for the manufacturing industry and complete tax exception for energy-intensive companies dependent on the requirement that the energy consumption of these companies is reviewed in depth by external experts to pinpoint economy potential. No final decision has yet been made on this measure, however.

Whether industry and commerce decide to make any significant investment in energy efficiency ultimately depends on the cost efficiency of such measures. Although investments in efficiency are generally profitable as the costs are recouped via the saved energy over time, investment funds are limited, and this means that companies will tend to invest in areas where this is most urgent or where they can achieve the highest level of profitability. As a rule, investments in energy-saving measures do not belong in this category. In view of rising energy costs, it remains to be seen whether this situation will change in the future.

When it comes to electrical appliances, the EU in Brussels is the body with the most power to introduce measures in the area of energy efficiency. This applies both to binding consumption regulations along the lines of the Japanese Top Runner model (where the most energy-efficient appliances are the market benchmark) and to systematic labelling. In years to come, the public sector intends to act as a role model for the procurement of energy-saving appliances.

On the whole and on closer inspection, the measures adopted by the German government betray a lack of imagination as to how to promote a trend reversal in the field of electricity consumption.

Concrete approach: energy efficiency on the heating front

Expectations on the heating front are more concrete: around 40% of final energy in Germany is used for heating, in other words for warm rooms and hot water. The aim of the German government is to ensure new buildings are more or less no longer dependent on fossil fuels from 2020. To this end, the energy efficiency targets for new buildings are being increased by 30% from 2009 and by the same percentage from 2013. The EnEV energy efficiency regulations were amended to this end in June 2008.

Existing buildings offer even more potential, however. Around three in four of Germany's residential properties were built before 1979. Extended financial subsidies have therefore been made available for improved insulation and the modernisation of heating systems. The jury is still out on the effectiveness of these subsidies, however, as homeowners still need to invest a lot of their own money in these modernisation measures and as these investments take a long time to pay for themselves. In order to achieve the desired target consumption of seven litres of heating oil per square metre and year, it would be necessary to invest around 100,000 euros in a single-family house with a living space of 120 square metres which had not been modernised since 1975. According to the "CO_2 building report" of the German Construction Ministry, only 3% of owners and tenants are willing to invest in heat insulation or new heating systems or to accept a premium on the rent if the costs are refinanced over more than 12 years – which is the norm today.

There are also pitfalls in the rent laws, as the landlord has to bear the costs while the tenant is the one who profits due to the lower heating costs; yet it is generally not possible to pass on the cost of modernisation to the tenant in the form of higher rent. The German government also intends to eliminate some of the legal obstacles in this area.

What is needed is a great leap forward. Currently only 2.2% of old buildings are being completely modernised for energy efficiency every year. There are special assistance schemes for the energy modernisation of schools, child nurseries and state-owned properties. Electric night-storage heating systems, which are responsible for 8% of all electricity consumption in Germany, are to be gradually replaced with the help of a subsidy programme, and the first batch should have been phased out by 2020.

Renewables by decree: heating energy

6% of heating energy in Germany is generated from renewables. Primarily in the form of the good, old-fashioned wood-fired hearth or traditional tiled stove. The German government wants to considerably increase the share of renewables used for heating, cooling and water heating purposes and has set a target of 14% for 2020. Oil, gas and electricity are to increasingly make way for solar heating (solar thermal systems), geothermal energy (heat pumps), wood pellets and wood chips. To step up this substitution process, the German government recently amended the Renewables Heating Act. This legislation stipulates the use of renewables from 2009 in new buildings and as part of comprehensive modernisation measures – such as the replacement of the heating system. This obligation will be deemed to have been fulfilled if more than half the heat is provided by renewables. If solar collectors are used, a certain collector area per square metre of total net area will be required. There will be exceptions for houses with particularly good insulation or in cases where a miniature power plant in the cellar supplies combined heating and electricity, or where the house is connected to a heating network. However, these systems must also primarily obtain their heating energy from renewables or cogeneration sources.

Subsidies under the market incentive programme are designed to encourage owners of old buildings to replace their heating systems with new efficient alternative concepts that are partly operated using "eco-heat". In 2009, a total of half a billion euros in subsidies will be made available for this purpose, and owners will also be able to take advantage of low-interest loans.

Success story: renewables in the electricity sector

Water, wind, sun, biomass and geothermal energy – these are the renewable sources of energy. The generation of electricity from these – with the exception of biomass – inexhaustible sources of energy has been booming since the introduction of the German Renewables Act (EEG) in 2000. The EEG ensures that the operators of the electricity networks accept the electricity from renewables (priority feed-in) and remunerate this input in line with the statutory regulations (remuneration obligation). The remuneration rates differ based on source; they are lowest for

electricity from large-scale hydroelectric power plants and highest for solar electricity from photovoltaic systems. The additional costs resulting from the EEG laws are evenly distributed among all electricity customers. Exceptions are made for energy-intensive companies, who pay a fixed surcharge of 0.05 cents per kilowatt hour of electricity . The German government has calculated that the EEG created additional costs totalling 3.3 billion euros in 2006. These calculations were based on the so-called "differential costs": the exchange value of the generated electricity is deducted from the costs of the renewables themselves.

Since the EEG legislation was enacted, the share of renewables in overall electricity consumption has increased from 5.5% in 1999 to over 14% in 2007. The original 12.5% target set by the German government for 2010 was therefore achieved and even exceeded last year, although it should be noted that the wind and water conditions were highly favourable in 2007.

Renewables meanwhile play an important role in combating the greenhouse effect. According to the German government, around 100 million tons of carbon dioxide emissions were avoided through the use of renewables in 2006. Had it not been for renewable forms of energy, carbon dioxide emissions in Germany would not have fallen but increased since 2000. Moreover, new industrial sectors are sprouting up in Germany in the slipstream of this legislation. Some of the new companies, particularly those active in the fields of wind energy and photovoltaics, are players in the world market.

Wind, water, biomass: which sources are most promising?

The expansion of wind energy is the primary motor behind the renewables uptrend in Germany. Around 5% of total electricity meanwhile comes from wind towers; the total volume in 2006 was 31 TWh, and estimates based on preliminary figures indicate a volume of 39.5 TWh for 2007. Hydroelectric power is still in second place, and hydropower plants contributed 21 TWh to overall generation in 2006, equivalent to 3.5%. The major part of this electricity comes from large-scale run-of-river power plants. Almost 80% of hydropower is supplied by a few dozen plants with capacities in excess of 5 MW. The remainder is generated by over 5,000 small hydropower plants. Hydroelectric power is being expanded only gradually and has only limited future potential. With the new construction of Europe's oldest run-of-river power plant in Rheinfelden on the High Rhine in southern Baden, EnBW is responsible for one of the biggest projects in the field of renewables. EnBW is also continuing to invest in hydroelectric power at other locations on the Upper Rhine and on the Neckar.

Electricity from biogas is hot on the heels of hydropower, accounting for around 3% or 18 TWh of German electricity production in 2006. Conversion of biogas from energy-producing plants into electricity is the cornerstone of this supply concept and these activities have grown rapidly in recent years.

Expansion of photovoltaics is also progressing apace, and the bluish solar cells meanwhile adorn more and more roofs in Germany. There are also considerably more big outdoor systems than there were a few years ago. The share of photovolatics in overall electricity supply is still extremely low, however, and was in the order of 0.4% or around 2 TWh in 2006. The fact that many solar installations produce relatively little electricity is

system-inherent. Not only do solar cells logically not produce any energy at night; the conversion rate of solar radiation energy into electricity is still also extremely low.

Geothermal energy – the production of electricity and heating power from the heat of the earth – currently plays only a negligible role in the electricity market. The EEG legislation is currently being amended to ensure the continued promotion of expansion in the area of renewables. There is great optimism in many quarters: the German government has, for example, upgraded its targets for 2020, when it hopes that renewables will account for between 25 and 30% of electricity consumption – provided, of course, that electricity consumption falls in line with government predictions. The central study on the expansion of renewables conducted by the German Environment Ministry in 2007 estimates that gross electricity consumption will be in the region of 570 TWh in 2020, with renewables accounting for 156 TWh of this total.

No. 1 hope: offshore wind energy

Wind power continues to play a key role in the plans of the German government. By 2020, it is to supply 82 TWh, equivalent to just under 15% of gross electricity generation and more than 50% of all energy from renewables – almost three times today's production output. However, many of the new wind towers are to be built off the coast in offshore wind farms in the ocean: wind energy plants with a capacity of around 10,000 megawatts should be operating there in 12 years time and producing around 35 TWh of electricity a year – according to the central study conducted by the German Ministry of Environmental Affairs in 2007. The time frame for the original and far more ambitious plans of the German government has been extended to 2030, when the rated capacity of the offshore farms should be in the order of 25,000 MW.

But these expectations are still not based on any hard-and-fast data; although there are offshore wind farms off the coast of Denmark, Sweden, the UK or Ireland, there aren't any off the German coast – because the Germans are planning something on a totally different scale. In Germany, the big offshore installations with capacities of between 3 and 7 megawatts per wind tower will not be situated near the coast but 30 to 40 kilometres offshore in water depths of up to 40 metres. This strategy is designed to take account of the various needs of tourism, nature conservation, shipping and fishing. But it poses far greater challenges in terms of the construction and operation of the power plants as well as with regard to the connection of power cables to the inland network. So it comes as no surprise to learn that the original offshore plans are already way behind schedule. The first wind yield at sea was supposed to have been "harvested" a full 5 years ago. Instead, the only things that are currently in operation are two test towers, one in Rostock port and another one 100 metres off Emden. The first German offshore wind farm is now to be built during 2008 and scheduled for full operation before the end of 2009 – if everything goes according to plan: the farm will be the "Alpha Ventus" test section, 45 kilometres off the island of Borkum.

Further expansion will be postponed until the necessary insights have been gained from the operation of this trial farm. To date, the Federal Shipping and Hydrography Agency (BSH), the body responsible for approval procedures, has approved 20 farms with around 1,400 towers in the North Sea and the Baltic. Applications for more than 30 further wind farms are currently pending at the BSH.

Still unclear: costs and risks

If the expansion of wind energy is to pick up speed as planned, the framework conditions will have to be dramatically improved. Back at the end of 2006, an amendment to the "Acceleration Act for Planning Procedures for Infrastructure Measures" placed the network operators under an obligation to arrange for the connection of offshore farms at their own cost. In this way, the burden of providing a "plug socket" at sea was lifted from the plant operators. Connection costs can account for as much as 25% of total investment costs. The connection of four planned offshore wind farms in the North Sea alone cost Düsseldorf-based energy supplier E.on around 400 million euros. The costs are passed on to all electricity customers via the network utilisation fees.

The amended EEG legislation on renewables will lead to an increase in remuneration levels for electricity from offshore wind farms –

from the current figure of 9.6 cents to between 13 and 15 cents per kilowatt hour. Whether this will be sufficient to unleash a new wave of growth at sea remains to be seen. There are still a whole series of technical issues that need to be resolved, and the cost situation is still far from transparent. What is clear is that offshore operations are far more complex and costly. Due to weather risks, troubleshooting off the coast is far more difficult than on land. This is why the use of high-

maintenance components is avoided wherever possible; and also why all key auxiliary assemblies and sensors are present in duplicate, ensuring that failure does not automatically result in standstill. Together with the need for highly durable foundations in the deep water and high-level corrosion protection to counter the effects of the salt air, this drastically increases the cost of producing these kinds of installations. At the same time, however, the electricity yield at sea is far superior, as the wind blows stronger and more evenly.

When it comes to the expansion of offshore wind energy facilities, the proverbial "eye of the needle" is the limited capacity of producers and suppliers: very few producers are willing to shoulder the risk of offshore ventures. There are also bottlenecks in the infrastructure for the construction of offshore facilities – the availability of the required special vessels being one example.

Danish wind energy world market leader Vestas found out to its considerable cost just how great the risks associated with offshore installations can be – most recently at its 100 million euro project at Scroby Sands off the British coast. The main bearings in the multiton gear units of all 30 wind towers had to be replaced, which is nothing short of a catastrophe at sea, as the repairs cost around ten times the amount they would have cost on land: an estimated 30 million euros all told. Two years previously, Vestas had to replace the machine buildings in all 80 offshore wind towers at its Horns Rev wind farm – due to corrosion damage.

Onshore wind energy: stimuli from repowering?

The formerly dynamic development of wind energy on land is losing momentum. In 2007, new wind tower construction in Germany was 25% down on the 2006 figure. According to the German Wind Energy Institute (DEWI), 883 new wind energy installations with a rated capacity of 1,677 megawatts went into operation in Germany last year – compared to 1,208 installations with an output of 2,233 megawatts in 2006. The forecasts for 2008 indicate a further decline in new facilities. It is becoming increasingly difficult to find good locations for new installations. Moreover, the wind energy industry says the profitability of these installations is under pressure due to the rising cost of raw materials like steel and bottlenecks in the engineering sector. This also restricts the locational options to areas with high wind availability. Even if this in no way means that the construction of new wind towers will come to a standstill, the real future of onshore wind energy lies in so-called "repowering" – the replacement of older, smaller installations with new, more powerful ones. The potential is promising, particularly in the better locations.

All in all, the rotors of just under 20,000 wind towers are currently turning in the wind. Modern installations have a capacity of 2 to 3 MW. However, most of the existing towers were built back in the nineties and take up some of the most favourable wind locations. 17.3 % of wind energy installations are over ten years old. In 2004, the average output of all installed wind energy facilities was 1 MW; in contrast, the new installations commissioned this year have an average rated capacity of just under 1.8 MW. If the old turbines with their typical capacity of 200 to 600 kW were replaced by new multi-megawatt turbines, a smaller number of installations would be able to generate a far higher overall volume of electricity: "Bigger installations can greatly reduce airborne noise while doubling output and even tripling yield", says Hermann Albers, President of the German Wind Energy Association.

According to calculations of the DEWI, repowering could, under ideal conditions, increase the electricity yield from the areas already being used for wind energy installations to 90 TWh a year. This figure only represents a theoretical potential, however. One of the major obstacles in practice is the approval procedure. The success of repowering depends primarily on the approved hub height of the rotor and the stipulated distance from residential areas. The planning laws have, if anything, become more restrictive since the pioneering days of wind energy; there are many wind energy locations where no towers would be approved if the same decision had to be made today. The state of Lower Saxony, for example, stipulates that a new wind tower must be at least one kilometre away from the nearest residential building. In many places, the maximum height is set at 100 metres – but the new models which often boast many times the yield of older towers need to be taller than 100 metres. The upshot is that the old installations continue to operate because no approval is granted for new installations at the same location.

According to a study conducted by the German Environment Ministry, the potential useful capacity of repowering would be in excess of 26,000 MW (the BWE calculates an even higher 28,000 MW), which could be used to produce 49 TWh of electricity a year – if approval were to be given for hub heights of up to 130 metres. Alongside offshore strategies, repowering is therefore the second factor on which hopes for the future of wind energy are being pinned – and thus the hopes for the key contribution that renewables might make to the central goal of climate protection.

It is uncertain whether repowering will pick up speed. The approval issues are extremely complex. Responsibility mainly lies with the municipalities, with the regional states also stipulating some of the important regulations. A repowering breakthrough is currently not in sight. In 2007, only 108 old installations were replaced (by 45 modern plants). As this is not part of its official remit, the German government can only provide indirect support. The German Construction and Environmental Affairs Ministries have prepared a joint study on how repowering models can be promoted in the area of planning approval. This information is designed to support the corresponding modernisation strategies of the planning bodies in the regional states and the municipalities.

No. 2 hope: biomass

Alongside wind energy, biomass is the other renewable source of energy that will have to shoulder the main burden of further expansion on the renewables front. According to a central study conducted by the German Environment Ministry in 2007, the volume of electricity generated from biomass should triple by 2020 compared to 2005 levels, ultimately supplying an annual energy volume of 36 TWh. This would be equivalent to around 6.2% of gross electricity generation based on the government's forecasts for the electricity market. More than half of this is to come from biogas, the remainder from solid biomass, in other words wood.

The German government has realised, however, that biomass has been used extremely inefficiently to date. Only a very small percentage of electricity is generated from biogenic substances in cogeneration plants, and in most facilities, the heat is given off to the atmosphere unused. The government therefore intends to include a provision in the amendment to the EEG laws to the effect that large-scale plants will only receive remuneration if they are operated in cogeneration mode. A regulation on the feed-in of biogas into the natural gas network is also in the pipelines. This will promote the increasing use of biogas in conurbations along with the options for utilising the heating energy.

Limited: arable land for energy-producing plants

The use of biomass for energy producing purposes cannot be increased indefinitely. The limiting factor is the availability of space. At a conference in Berlin, State Secretary for Agricultural Affairs Gert Lindemann said that cultivation of energy-producing plants had reached a new record last year with a total 1.75 million hectares – more than 14 percent of Germany's total arable land volume. He added that it is conceivable that around one third of all farmland will be used for this purpose in the long term.

Competition with the cultivation of food crops is increasing all the time, however, resulting in higher prices for both food and for the "energy farmers". At the end of 2007, the German Biogas Association pointed out that the price of input materials for biogas plants like corn and cereals have more than doubled. Input material costs account for more than 40% of the overall costs of a biogas plant. The Association is therefore calling for higher remuneration levels for electricity from biogas. However, this would also increase the risk of creating an endless price spiral.

Against this backdrop, BayWa, Europe's biggest agricultural trading group, is concerned about bankruptcies in the biogas sector. "If raw material prices do not fall soon, there is an increasing probability that farmers with biogas plants will be facing problems that pose a risk to their very survival", said BayWa boss Wolfgang Deml, adding that prices are not, however, expected to fall in the long term. Deml warned of a worldwide cereal shortage, citing a growing global population, rising standards of living and the massive subsidisation of renewable raw materials as the key contributing factors.

Imported raw materials: social and ecological problems

The boom in energy-producing plants is not just a German but a worldwide phenomenon. As a result, countless unit-type heating and power plants in small towns throughout Germany are fired using palm oil from plants grown in developing countries and NICs, above all in Indonesia. According to the calculations of the Leipzig Institute for Energy, palm oil was used in German unit-type heating and power plants to generate around 1.3 billion kilowatt hours (TWh) of electricity in 2007. The Catholic charity organisation Misereor warns that the growing demand for plants like sugarcane, palm oil, soybean or corn to generate energy poses a threat to the poor and primarily urban populations of the world's developing countries. In Indonesia, for example, the price of vegetable oil used to prepare meals has increased by almost 30 percent. Misereor says palm oil producers can earn more by exporting the oil than in the local market, making a basic foodstuff almost unaffordable for the poor. "Full tank and empty plate" is therefore the chief criticism of the aid organisations when it comes to creating a worldwide market for bioenergy. Jean Ziegler, the UN Special Rapporteur on the Right to Food, also warns of the far-reaching consequences of the increased use of energy-producing plants grown in developing countries. "The effects of biofuels on the food situation give great cause for concern with regard to the (human) right to food", says Ziegler in his report to the UN Human Rights Council. He illustrates this with a simple sum: 200 kilograms of corn can be converted into enough biofuel to fill a 50-litre tank – or it can be feed someone for a whole year.

The climate profile of these imported raw materials can also be extremely negative. According to the German "Bread for the World" charity, for example, virgin forests are being razed in Indonesia as well as in Colombia, Brazil and New Guinea to make way for the cultivation of energy-producing plants. Indonesia has set a bleak world record in this regard – nowhere else is virgin forest being destroyed as mercilessly as in the island state. An area of around 1.8 million hectares of forest has been lost every year since 2000 – five soccer pitches every minute. The result is the destruction of biodiversity and an additional major burden on the world's climate. The greenhouse gas profile is absurd, however, when forests growing on peatland are felled. This practice releases the carbon dioxide stored in the soil. Intact peatland, something of a rarity worldwide, stores up to 1,400 tons of CO_2 per hectare. The World Wildlife Fund has calculated that the destruction of forests and swampland to build paper and oil plantations on Sumatra alone causes more greenhouse gases every year than are emitted by the Netherlands.

Discourse: biofuels as climate killers

The consequences are particularly drastic when biomass from these sources is used for the production of fuels. This is underlined by a study conducted by Joseph Fargione from "The Nature Conservancy". If rainforests, peatland, savannas, grassland or abandoned farmland are converted into plantations for oil palm trees, soybeans, sugarcane or corn, this creates a considerable "carbon debt": due to forest clearing and the slow decomposition processes in the soil, between 17 and 420 times the amount of CO_2 is released as could be avoided each year if the biofuels obtained from this land were used to replace fossil fuels. This means it will take 17 to 420 years before emissions are back to zero.

According to a further study chaired by Chemistry Nobel Prize Winner Paul Crutzen, the use of fertilisers emits three to five times more laughing gas (nitrous oxide, a particularly potent greenhouse gas) than originally thought. On its own, this finding could negate or even reverse the supposed advantages of standard biofuels.

Biofuels only possess a positive environmental profile is they are produced from waste biomass or plants that need little or no fertiliser and do not reduce the level of CO_2 storage in the soil. This is, for example, the case with special perennial grasses or certain tree species. A further criterion for a positive environmental profile is that these plants are only cultivated on arable areas that are not required for food production. According to David Tilman, a co-author in the study conducted by Joseph Fargione, there is sufficient degraded or abandoned farmland to cover around 10 to 20 percent of global energy requirements for mobility needs.

Under pressure: the climate protection strategy of the German government

In view of this debate, the use of biomass in the fuel segment – a key element in the climate protection strategy of the German government – is coming under increasing pressure. In this area, the government has great hopes for the admixture of so-called biofuels in diesel and petrol. Only last year, a decision was made to introduce considerably stricter regulations in this segment: by the year 2020, energy-producing plants were to account for 20 volume percent of fuel content. The current figures are roughly 5% for diesel and 2% for 2-star petrol. This admixture strategy is unrealistic, however, and German Environment Minister Gabriel was recently forced to revise the biofuel stance of the German government.

The admixture of bioethanol in gasoline will now not be increased as planned from the current level of 5% (so-called "E-5" regulation) to 10% ("E-10" regulation). The reason? The Federation of Importers of Foreign Cars had put the number of cars that would not run on E-10 and would therefore have to switch to more expensive Super Plus fuel at over 3 million. Based on the figures provided by the manufacturers, the government had originally believed this would only affect around 375,000 cars. The aim of the E-10 regulation was to make it easier for the automotive industry to comply with the EU stipulation of a limitation of CO emissions per car to 120 g/km by 2012. If the German Environment Minister has his way, the car manufacturers are to meet this target by technical means alone, even if this would be more expensive than the planned E-10 regulation.

Numerous experts believe that the confusion over biofuel regulations increases the pressure on the German government to adopt a more balanced energy and climate policy. One short and medium-term option might be to increase the subsidies for other renewables like wind energy.

There are still hopes that second-generation biofuels will solve many of the problems in the long term. Unlike current biofuels, the new versions use the entire plant for fuel production rather than just the fruits. But the large-scale application of the technology for these new biofuels is still a long way off.

Solutions: what the German government is planning

The German government is planning two measures in response to the criticism:

› From 2015, the further expansion in the use of biofuels is to be geared more systematically to actually reducing the level of greenhouse gas emissions by amending the German Biofuel Quota Act. Harmful emissions occurring in the production and use of biofuel will have to be minimised step by step. This applies both to the cultivation of the biomass in question as well as the technology used for fuel production. The increase in the biofuel content is expected to cut the greenhouse gas emission from the fuels by up to 10%.

› A further regulation is designed to ensure that the biomass used as a raw material for petrol and diesel is grown renewably. This applies to the land on which it is grown as well as the cultivation methods and their impact on soil, water and air.

While the debate over the fuel strategy of the German government is becoming increasingly heated, the use of biomass for the production of electricity and heat is generally free of such controversy. This is due to the fact that the production of biogas is far more efficient than the production of fuels, provided that the occurring heat is put to good use. But here as well, there is ongoing debate over growing methods and raw material imports. This is why there are plans to introduce regulations in this sector stipulating minimum requirements for energy-producing plants. These regulations will apply to growing methods in farming and forestry on the one hand and to their contribution to the reduction of greenhouse gases on the other.

This will only work, however, if there is a globally effective, reliable and transparent certification system for biogenic raw materials – but there are so indications at all that such a system is in the pipeline. In other words, the road ahead of us is long and rocky.

On an uptrend: solar energy

Photovoltaics has been on the up in Germany for a number of years now, and this boom is becoming stronger all the time: in 2007, new installations with a peak capacity of more than 1,100 megawatts went on stream, a 30% increase on 2006. All in all, Germany now has installations with a peak output of 3,800 megawatts, equivalent to the capacity of four large-scale coal-fired power plants. The electricity yield of photovoltaic plants is far lower, however, as the sun only shines during the day and shines longer and more strongly in summer than in winter. Depending on the location, a photovoltaic installation in Germany supplies 750 to 1,000 full-load hours, and this figure can be as high as 1,300 in selected cities in southern Germany with particularly high sunshine levels. The "full-load hour" is a measure of how many hours the installation would have operated in one year if the output it supplied had always been utilised 100%. For comparison purposes, base-load power plants operating on lignite or uranium supply around 7,240 full-load hours, with figures of 5,620 for run-of-river power plants and an average 1,800 for wind power plants – with more recent designs sometimes achieving figures of between 2,000 and 3,000.

The 2007 study conducted by the German Environment Ministry predicts a peak photovoltaic capacity of 10,000 megawatts in 2020. It is already safe to say that the actual figure will be far higher if the government does not drastically reduce the subsidies for photovoltaic systems. But where there is light, there is also shadow.

A hot potato: costs of photovoltaic systems

No form of electricity is remunerated as generously as solar energy from photovoltaic systems: the EEG laws currently stipulate a sum of over 46 cents per kilowatt hour for a solar installation on the roof, guaranteed for a period of 20 years. The exchange price for one kilowatt hour of electricity is around 5 cents, while 9.1 cents is the maximum amount paid for wind energy. This high remuneration means that the avoidance of carbon dioxide costs an enormous amount of money: the Rhine-Westphalia Institute for Economic Research (RWI) in Essen puts the figure at 900 euros per ton. In contrast, emission trading values the price of one ton of carbon dioxide at between 20 and 30 euros. The RWI also made waves with another figure. The institute's researchers extrapolated the feed-in remuneration for the photovoltaic systems installed up to the end of 2007 and guaranteed for a period of 20 years and arrived at a figure of around 31 billion euros. If we subtract the value of the produced electricity, this leaves us with follow-up costs in the order of 23 billion euros. If this is divided by the number of employees, this means that each and every job in the photovoltaic industry is subsidised to the tune of around 153,000 euros. This even puts the subsidies in the coal-mining industry to shame, where each workplace was funded to the tune of "just" 78,000 euros. And as the dynamic growth of new solar cell installations is ongoing – and expected to peak at 1,500 to 2,000 megawatts in 2008 – the huge costs will develop just as dynamically. Even if the current subsidy system only remained in place in until 2010, the RWI calculates that this would still result in gross feed-in remuneration payments of 73.5 billion euros.

Photovoltaics casts long shadows. In reality, both the German government and industry anticipate the payment of subsidies for far longer periods. The central study published by the German Environment Ministry even predicts the continuation of solar subsidies far beyond the year 2020. If the guaranteed promotion period of 20 years is still in place at that time, the subsidies for photovoltaics would have to paid right up to the middle of the 21st century. Today, the "solar debt" – the subsidies that still have to be paid in the future for existing plants – already totals 112 euros per capita.

The consequences are serious, as photovoltaics eats up the cost-cutting successes of the other renewables. In 2003, one kilowatt hour of so-called "EEG electricity" (the electricity promoted by the German Renewables Act) cost an average 9.16 cents. By 2006, this figure had risen to 10.88 cents and is estimated to have been in the order of 11.66 cents for 2007 according to the Association of German Network Operators. This is equivalent to an increase of 27 percent within a period of five years, an increase mainly due to solar energy. The greater the volume of solar energy in the network, the greater the impact of high solar energy production costs on the overall system. We were originally promised the opposite: electricity was supposed to become cheaper year by year.

It should be noted that the German subsidy system not only finances the expansion of the solar industry in Germany. The Photon trade journal estimates that half of all the solar modules installed in Germany are meanwhile imported, primarily from Asia. Germany is the world market leader in the field of photovoltaics. 55% of worldwide photovoltaic capacity is installed in Germany! A European comparison underlines the unique status of Germany in the area of solar energy. In 2006, PV plants with a total output capacity of 1,246 MW were installed in the EU. Germany accounted for over 92% of this figure. The trend in other European markets was meagre at best: additional capacity of 60.5 MW was installed in Spain, Europe's second-largest market, followed by Italy with 11.6 MW and France with 6.4 MW of new capacity. This was reported by the Observatoire des energies renouvelables (Observer), an association of leading European organisations in the field of renewables.

Photovoltaics: plans of the German government

The industry is profiting from these developments and posting high earnings. In 2006, total sales of the PV industry were in the region of 3.8 billion euros. A recent Handelsblatt survey lists 2 solar companies among the 10 German companies with the highest returns: Q-Cells in first place and Solarworld in fourth.

In the event that everything stays as it is, the success of photovoltaics could quite conceivably become a failure. The exploding costs not only pose a risk to public acceptance levels for the solar industry but damage the reputation of renewables as a whole.

The German government has reacted to this risk by amending the EEG renewables legislation to counter this risk and intends to gradually reduce the remuneration payments for photovoltaics. This is more or less automatic under the EEG laws, as the remuneration rates are reduced by a certain percentage each year. In the case of photovoltaics, the annual degression rate is set to increase from the current figure of 5 to 8% in 2010 and then to 9% in 2011. The Photon trade journal says this is not enough and recommends that the amendment to the current laws should include a one-off degression leap of 30%, followed by a further 7.5% reduction in subsidy rates each year. Even if this happens, Photon calculates that PV subsidy costs will still total 150 billion euros in the period up to 2019.

What is certain is that the future of solar electricity generation by photovoltaic means depends on the extent to which the costs per kilowatt hour of electricity can be reduced. Solar energy plays an important role in the scenarios for the future of electricity supplies, particularly in the long term. Part of this strategy is the vision of generating large volumes of electricity at low cost in solar thermal power plants in Southern Europe and North Africa and transporting it to Central Europe via a new supernetwork.

It would be a mistake, however, to believe that photovoltaics have no greenhouse-like effect at all. A great deal of energy is needed to produce the systems, with the result that around 100 grams of carbon dioxide occur for every kilowatt hour of electricity from a photovoltaic installation. The corresponding figures for other sources are 40 for hydropower, 32 for nuclear energy and 24 grams for wind energy.

Bottleneck: the transmission network

One of the biggest problems relating to the expansion of renewables is the situation in the electricity networks. The traditional power plant locations were mainly in the western and southern parts of Germany – in the coal-mining regions and the major industrial centres. Due to the rise of wind energy and the replacement of domestic coal by imported coal delivered by ship, there has been a shift in the main generating locations to the north and north-east of Germany. This means the generated electricity has to be transported to the consumption hotspots. The deregulation of the electricity markets and the system of European electricity trading also create a need for greater transmission network capacity.

In order to achieve this, the transport networks need to be massively expanded. But the expansion tempo of the networks cannot keep up with the expansion of renewables. Due to the lead time in terms of planning and administration, but above all due to local opposition to new construction projects, it takes 8 to 10 years until a new high-voltage transmission line is in place. There are meanwhile increasingly frequent regional bottlenecks in the electricity network, and the output of wind energy plants needs to be throttled, which means they cannot exploit their full electricity generation potential. In economic terms, the electricity is more or less thrown away.

This is no longer a rare occurrence. In 2006, Vattenfall Europe Transmission GmbH still recorded 80 days with critical situations as defined by the German Energy Industry Act. Last year, this figure had risen to 155 days. During the first 29 days of 2008, an amazing 28 days were critical.

The Federal Network Agency in Germany is also raising the alarm, saying that the duration of approval procedures leads to unforeseeable delays in many expansion measures that are of European significance. According to the President of the Agency, Matthias Kurth, this is why "the possibility of bottlenecks in the electricity network cannot be ruled out in some regions of Germany in the medium term. Bottlenecks within Germany could have serious consequences for the German wholesale electricity market – with unforeseeable effects on prices overall".

According to the power industry, 40 billion euros will need to be invested in the expansion and maintenance of the electricity networks up to the year 2020. dena, the German Energy Agency, estimates that 850 kilometres of new high-voltage network need to be built to cater to the expansion of wind energy alone. If these new networks are not built, then the growth plans for renewables may soon become pie in the sky.

In order to solve the problem, the German government has decided on legislation to accelerate the expansion of the high-voltage networks as part of the IEKP programme. The aim is to standardise the different approval procedures in the various German states and streamline the legal procedures.

Fossil energies: the combined generation of heating energy and electricity

When power is generated from coal, gas and oil, electricity isn't the only product – heat is also generated. In conventional power plants, this heat is lost as it is simply routed out of the chimney stack. In contrast, plants operated in line with the power-heat cogeneration principle use both sources of energy. The precondition for this is that there are customers for the heat, ideally an industrial or commercial company that has the same high heating requirements 24 hours a day, 365 days a year. Households only need heating energy pumped into the house via district or local heating networks during the heating season.

This negatively impacts the profitability of cogeneration plants. These plants are mostly "heat-driven" – electricity is basically a waste product of heat production. The advantage of cogeneration technology is its high efficiency; it can use up to 90% of the energy contained in the fuel. There are plants of all sizes: from unit-type heating and power plants that supply a single property or a small number of buildings to a large-scale cogeneration plant that can supply heating power to many city districts spread over a large area.

The German government intends to double the share of cogeneration in overall electricity generation to 25%. Today, combined heat and power plants generate 70 TWh of electricity, and the target for 2020 has been set at 140 TWh in the recently amended German Cogeneration Act. This legislation has been in force since 2002 and promotes cogeneration activities through bonus payments based on the size of the plant in question. When the Act was first introduced, the aim was also to double the cogeneration share – but the sector recorded just 2% growth, falling way short of the target figure of 10%.

The remuneration payments for the electricity producers are now to be increased once again and there will be subsidies for the expansion of district and local heating networks. To date, there have been far too few customers for heating and process heat. There are also plans to support installations in the industrial sector that produce energy for the internal requirements of the company only.

All this is supposed to cost a maximum of 750 million euros a year, which will then be distributed among all power customers in line with the current practice. This figure is no higher than the sum earmarked for the promotion of cogeneration concepts during the last two years. This limitation gives rise to scepticism over whether a big success is in the pipeline this time around. "A major wave of new construction of the kind needed is not in sight", Adi Golbach, Director of the German Cogeneration Association, told the Frankfurter Rundschau newspaper, for example.

Many question marks: CO_2 capture and storage

Without fossil fuels, it will impossible to satisfy the hunger for energy for any long periods in the future. This applies not only to Germany but also and even more so to the global economy. Coal and lignite will play a key role, and the coal deposits will last for centuries. They are geographically spread and there is no sign of any kind of all-powerful "coal OPEC". In their respective economic booms, India and China in particular are banking on electricity from coal, a raw material they possess in abundance.

The drawback of coal is its high carbon content. The incineration of coal produces the greenhouse gas carbon dioxide, which in turn fuels global warming. Coal incineration causes 750 grams of CO_2 per kilowatt hour of electricity, with figures of 950 grams for lignite and 430 grams for natural gas. There are therefore widespread hopes for the development of technologies that remove the carbon dioxide from the flue gas of the power plants so that it can be stored in gas-tight underground caverns. The collective term for these kinds of technology is CCS (carbon capture and storage).

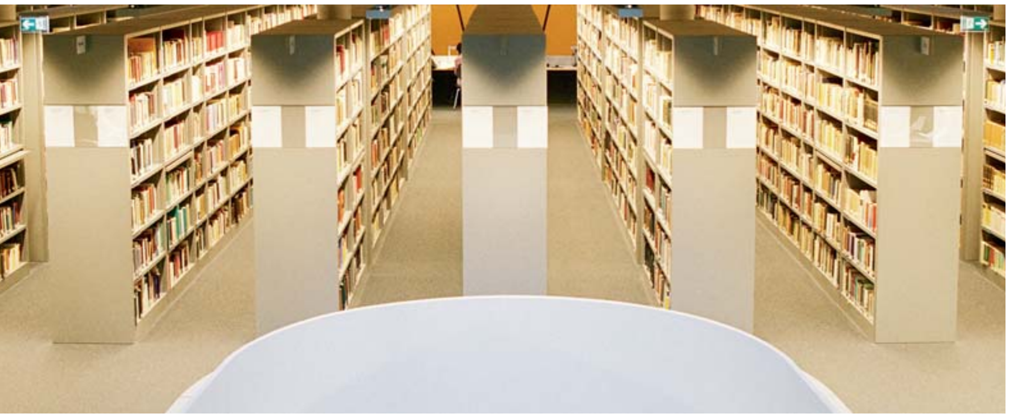
However, they are still at the R&D stage in a transitional phase to trial operation. The German government is therefore focusing on the development of the legal framework that will be necessary for the approval of separation technology and storage as well as on stepping up research into and the development of demonstration facilities. CCS technology will not help us to achieve climate protection targets before 2020, but there are many who have great hopes for this technology in the period after 2020.

But the question marks are just as big – on the technological front, for example, although there is great optimism that the technology can be made to work. There are also question marks with regard to acceptance levels: how will local residents react to this kind of final carbon dioxide storage facility? The biggest uncertainties, however, are in the area of cost efficiency: what will it cost to capture, transport and store a ton of CO_2?

RWE provides a good example of this: the first large-scale demonstration power plant is scheduled to go into operation in 2014 with an output of 450 MW and CO_2 capture technology. The cost of the project has meanwhile increased to 1.7 billion euros, 700 million more than originally planned. In short, CCS would result in additional costs of 6.5 to 7 cents per kilowatt hour of electricity.

As concerns the costs of avoiding CO_2 emissions, only the biggest optimists believe in a figure of 20 euros per ton. The pessimists believe 70 euros per ton is a more realistic price. This is a long way from the anticipated certificate costs in the field of European emission trading. Hardly anyone will be willing to pay much more than 30 to 40 euros per ton of CO_2 even in the long term. In other words, CCS would only have a chance if the costs of the technology were in this corridor.

The first projects have already fallen at this hurdle. In summer 2007, Norwegian energy company Statoil and oil multi Shell announced their intention to shelve plans for CO_2-free energy supply from two offshore platforms. The availability of storage facilities also presents a problem. In Germany, the only suitable caverns are in the north. Power plants in the south of the country would have to transport their carbon dioxide along hundreds of kilometres of pipeline. And it goes without saying that all storage facilities are finite. This means CCS is a stop-gap technology that provides one thing above all: breathing space, 73 years of it. An expert opinion prepared by the Wuppertal Institute estimates that this is how long the storage facilities that exist worldwide are good for – based on the assumption of constant coal consumption. 73 years is equivalent to two power plant generations, after which alternative forms of energy would have to shoulder the entire burden of energy supplies.



Summary: the stance of EnBW

From the point of view of EnBW Energie Baden-Württemberg AG, the following can be said with regard to the climate protection plans of the German government:

› EnBW supports a committed policy to protect the earth's atmosphere. In his opening address at the 2nd German Climate Congress, Hans-Peter Vilis, the CEO of EnBW, emphasised that climate protection is increasingly a focal point of corporate policy. The EnBW chief announced the intention of his company to play a committed role in the field of energy efficiency, renewables forms or energy and the efficient, decentral supply of electricity and heating.
› To achieve this, it is necessary to fully reconcile climate protection, cost efficiency and supply reliability.
› The German government has set itself the extremely ambitious goal of cutting climate gas emissions by 40% by the year 2020.
› According to the calculations of the German government, the IEKP integrated energy and climate protection programme adopted by the cabinet in 2007 will reduce emissions by 36%, which means they will not be sufficient to meet the target on their own. There are, however, other, more pessimistic calculations. Greenpeace, for example, forecasts that these measures will only reduce emissions by 30%.
› In actual numbers, the IEKP is designed to reduce emissions of carbon dioxide equivalents by around 220 million tons a year.
› But this is only half the truth, as the German government is currently also sticking to its plans to exit nuclear energy generation by 2023. The operation of the nuclear power plants in Germany prevents 160 million tons of carbon dioxide from entering the atmosphere each year. If the operating times of the reactors really are shortened as planned, then this volume of energy would also have to be replaced by the IEKP.
› In other words, what the German government has to do in reality is to reduce greenhouse emissions by over 50% compared to 1990 levels.
› The IEKP entails a number of serious risks. If just one of these risks materialises in a central field of action, the programme will fail to achieve its objective. This applies in particular to the measures in the areas of cogeneration, wind energy and energy efficiency. There is no plan B and no safety reserve.
› The targets defined for the expansion of cogeneration and the saving of energy are unrealistic, as the planned measures are in no way adequate to achieve the desired effect.
› EnBW therefore urges the powers-that-be to revoke the decision to reduce the operating times of the nuclear power plants and to thereby retain one of the cornerstones of climate-friendly energy generation. These plants do not need to be built; they are already in place and all we need to do is keep on using them.
› Nuclear energy makes a reliable contribution towards the achievement of climate protection targets – and one which does not require any high-level investment. On the contrary, the energy industry has already offered to negotiate several times now on making part of the income from the continued operation of nuclear power plants available for the funding of other climate protection measures.
› The German nuclear power plants therefore not only help to protect the earth's atmosphere and ensure the reliability of energy supplies but also make climate protection policy more economical. The existing nuclear power plants produce electricity at an unmatchable price. They can reduce the macroeconomic burden of climate protection – with the corresponding positive effect on the competitiveness of German companies and the security of many people's jobs.
› Without nuclear energy, it will not be possible to meet the climate protection targets, power supplies will be less reliable and the macroeconomic cost of climate protection policy will continue to increase.
› Renewables are continuing to enjoy rapid growth. But the environmental associations need to decide what is more important: would they like renewables to primarily serve as a replacement for electricity from fossil fuels or for electricity from nuclear power plants? Those who take climate protection seriously know that nuclear energy and renewables are not opposites but that they ideally complement one another.

Discourse: nuclear energy in Germany

In Germany, the gradual exit from nuclear energy generation was pushed through by the Red-Green coalition government in an amendment to the German Atomic Energy Act. The key points of the amended legislation that came into force in April 2002 include the ban on the construction of new atomic power plants and the reduction of the rated operating life of existing nuclear power plants to an average 32 years since commissioning. The Act stipulates that a maximum 2.62 million gigawatt hours (GWh) of electricity may be generated in German nuclear power plants after January 1, 2000. This figure represents the cumulative residual electricity volume allocated to the individual plants based on their age.

The German plans to exit nuclear power generation have not been taken up by other nations. More and more countries have decided to build new plants or to extend the operating periods of existing nuclear facilities. The EU Commission and the European Parliament have also spoken out in favour of continued nuclear power generation – on the grounds of supply reliability and climate protection. As a result, electricity from nuclear power plants will continue to flow through German transmission networks even if it is no longer produced in the country itself. It will simply be "imported" across the border.

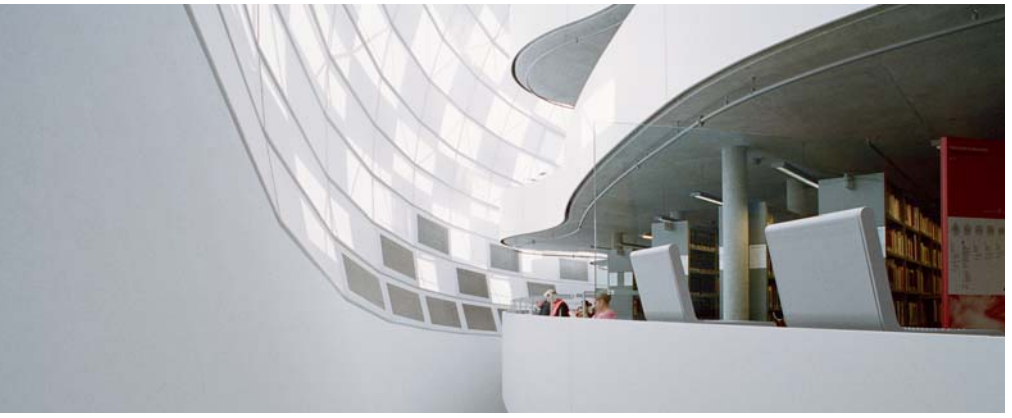
Baden-Württemberg is a CO_2 role model for the rest of Germany. While an average 550 grams of CO_2 are emitted per produced kilowatt hour in Germany overall, the figure for Baden-Württemberg is just 300 grams. 51% of the electricity generated in Baden-Württemberg comes from nuclear power plants. If the four nuclear power plant units in Neckarwestheim and Philippsburg had to go offline, Baden-Württemberg's CO_2 profile would be far worse than it is at present. It would not be possible to replace the 4,624 MW that would be taken out of the network with renewable forms of energy. There are only two ways to replace nuclear energy as a low-cost source of baseload supply: by building coal-fired power plants and/or importing electricity. It is easy to calculate the impact of such measures: the CO_2 profile will be less favourable, prices will rise – and the south of Germany will become a "high-price region". Baden-Württemberg will become more dependent on outside support, and the value added processes in the production of energy will take place outside our home state – with all the disadvantages this entails.

Fuel change: share of gas up to 30%?

How does the German government intend to achieve the 40% target despite the exit from nuclear energy? The Federal Environmental Agency (UBA) in Germany has done the sums. The central element is a massive changeover in the fuels used for electricity generation, specifically the substitution of natural gas for coal. Today, natural gas accounts for 11% of total electricity generation, equivalent to an electricity volume of 70 terrawatt hours (TWh). By the year 2020, the volume of electricity generated from natural gas would have to be doubled to 165 TWh. As a result, power from natural gas would account for around 30% of total electricity consumption as forecast by the UBA.

The Federal Environmental Agency is naturally aware of the weaknesses of such a strategy: Germany relies on a small number of importers for its natural gas, and most of the gas used in Germany comes from Russia. This supply strategy entails a whole series of political and price risks. The UBA therefore recommends the discontinuation of the use of natural gas for the heating of buildings and water, which account for over 90% of the natural gas currently used. This would mean that natural gas consumption in Germany would only have to increase by 3% up to the year 2020. However, the UBA has no apparent strategy for the achievement of this goal. The gas industry has invested many billions of euros in the infrastructure for the heating of buildings, and it is clear that it will not withdraw from these activities without a fight – firstly to ensure that it does not have to write off its investments prematurely, and secondly because it is generally the case that more money can be earned in the heating market than through the generation of electricity.

The situation has changed fundamentally anyway since the oil prices rose to their record highs. As gas prices are also on the up in the slipstream of oil, the risks of producing electricity from natural gas have increased enormously, putting a question mark over the cost efficiency of many projects. The logical consequence is that many of these projects have already been shelved.



Nuclear energy exit: the economic consequences

But even it this changeover is successful, it will have its price. For all the debate over the pros and cons of nuclear energy, it is clear that the climate protection strategies will cost far more than was originally the case if the German government simultaneously stands by the nuclear exit policy. This was impressively confirmed once again by the McKinsey study commissioned by the Federation of German Industries (BDI). The study calculated the costs and potentials of more than 300 individual technological levers to avoid greenhouse gas emissions. Overall, the study considers a 26% reduction in greenhouse emissions by 2020 compared to 1990 levels to be economically feasible in four sectors: buildings, industry, energy and transport – without any detrimental effects on economic growth or quality of life and while retaining the plans to exit nuclear energy generation. The average avoidance costs were calculated as being up to 20 euros per ton of CO_2 equivalents. Many of these measures – such as the improved insulation of buildings – have "negative" avoidance costs. In other words, they also pay dividends in financial terms.

There are also various other avoidance levers, but the implementation of these levers would entail far higher levels of investment. A reduction of just 31% would involve far higher average avoidance costs of between 32 and 175 euros per ton of CO_2 equivalents – again, assuming the exit from the nuclear power sector. Based on the data supplied by the study, the BDI draws the conclusion that a reduction in greenhouse gas emissions beyond the 31% mark would not be economically viable without the continued generation of electricity in nuclear power plants. And, on closer inspection, there are also a number of question marks over the figure of 31% itself.

Despite its optimistic underlying assumptions in the area of energy efficiency, a study conducted by the Prognos Institute and the EWI (the Institute of Energy Economics at the University of Cologne) in May 2007 for the energy summit staged by the German government also comes to the conclusion that the continued operation of the 17 nuclear power plants in Germany is the most reliable and cheapest way of meeting the set climate protection goals. This strategy would be cheaper both in macroeconomic terms and in terms of the cost of electricity for the end consumer. The authors of the study claim that the price difference would be in the order of 2 cents per kilowatt hour in favour of nuclear energy.

Electricity shortage: question mark over supply capability?

Experts are also increasingly questioning whether the gap left by the exit from nuclear energy generation can be filled at all. In a study conducted in autumn 2007 by the Hamburg Institute of International Economics (HWWI) on behalf of HypoVereinsbank (HVB), for example, the authors came to the conclusion that renewables cannot replace nuclear energy. Based on an assumed annual increase in electricity consumption in the order of 0.5 percent, this translates into a "supply gap" of around 16 percent of total electricity consumption by the year 2020. The shortfall would have to made up by imports or generated using fossil fuels. HypoVereinsbank is one of the leading financers of renewables in Germany.

In its study on power plant and network planning up to 2020 (with an outlook to 2030), even the pro-government German Energy Agency (dena) came up with alarming results. In view of the anticipated demand for electricity in 2020, says the dena study, the power pant capacities in Germany will no longer be sufficient to fully cover the annual peak load. These calculations include the current plans for the construction of new fossil fuel power plants – where a high probability exists that these plans will be implemented. These fears are not allayed either by the committed exploitation of energy efficiency potentials or the achievement of targets for the expansion of renewables (to 30%) and cogeneration (to 25%). Even complete implementation of the energy programme of the German government accompanied by a strong reduction in energy consumption will not be enough to avert the risk of a steadily growing "electricity gap" between annual peak load and secured power plant capacity from 2012 onwards. In 2020, even if electricity consumption falls, this gap could grow to an enormous 11,700 MW. If the demand for electricity remains constant – as many participants in the energy industry debate anticipate – this would result in an electricity shortfall of as much as 15,800 MW by the year 2020. According to the dena, even imported electricity is not a long-term solution, as there will also be shortage of power plant capacity on European level.

In addition, opposition to new coal-fired power plants is increasing all the time. Several projects have already failed to overcome this opposition or have been indefinitely shelved due to the explosion of plant engineering and construction costs. The price of turnkey coal-fired power plants has almost doubled during the last four years. Power plant projects for a total output volume of 6,500 megawatts were abandoned last year alone. In Ensdorf in the Saarland region, for example, the opposition of the local population prompted RWE to drop its plans for the construction of a coal-fired power plant.

This could result in a situation where even fossil fuels are no longer able to offset the effects of the politically driven exit from nuclear power generation. According to the most recent study conducted by the Trend-Research market research company, Germany, which currently still exports electricity to neighbouring countries, could be permanently dependent on power imports from as early as 2015.

The energy industry in German currently has plans to build 60 new large-scale power plants, many of them fired by coal or lignite. According to Trend-Research, around half of these projects are being seriously pursued. Experts calculate a replacement need of around 45,000 megawatts for outdated plants, equivalent to an investment volume of roughly 50 billion euros. These figures do not include the more than 20,000 megawatts of power plant capacity that are to go offline step by step up to around 2023 due to the exit from nuclear energy generation.

The Trend-Research study divides the current power plant projects into four categories based on the probability of their actually being built and then computes various power supply scenarios for Germany. The conclusion of the study? if the decision to exit nuclear energy generation remains in place, Germany will only be able to avoid a electricity supply deficit if new plants are built with a total capacity of 36,000 megawatts. The planned marked increase in the share of energy generated from renewables by 2020 is already factored into the calculations for this scenario. If only projects rated as "highly probable" are in fact implemented (scenario number two), then Germany will no longer produce enough electricity to meet its own requirements by 2015.

Conclusion

There must be further debate over the future of nuclear energy and the contribution it can make to energy supply operations in Germany. A topic that requires no further debate is the importance of effective climate policy. There is also wide-ranging agreement on the key fields of action: energy efficiency, renewables and highly effective fossil fuels with low carbon dioxide emissions.

And what is also clear is that climate protection is only possible if it is driven by high-level and wide-ranging research and development efforts. This is key to success in the reduction of climate gases and is also an important precondition for the economic success of Germany companies both at home and on the world market. What this will also require is an intelligent innovation policy to transform the inventions and insights of researchers into marketable products and services.

Glossary

› Bali roadmap

The Bali roadmap adopted at the 13th Conference of the Parties to the UN Framework Convention on Climate Change and the Kyoto Protocol in Bali, Indonesia, in December 2007 represents an official negotiating mandate for a comprehensive international climate protection treaty for the period after 2012. In the time up to the 15th Framework Convention Conference in Copenhagen in December 2009, the 192 member states of the Convention will be discussing and conducting negotiations on the topics of containment, adjustment, technology and financing.

Carbon capture and storage (CCS)

CCS is the abbreviation used to describe the technology for carbon dioxide capture and storage. Various different techniques are already undergoing small-scale trials. They should be available for technical application on a large scale by 2020 and allow low-CO_2 utilisation of fossil fuels for the generation of electricity. No final decision has yet been made on transport systems or storage locations. According to the EU, however, all coal-fired power plants must be CCS-ready by 2020 – in other words, they must permit retrofitting of this technology.

Clean Development Mechanism (CDM)

CDM, the mechanism for environmentally compatible development, is one of the flexible instruments defined by the Kyoto Protocol. CDM projects are climate protection projects implemented in developing countries by industrialised states. These projects must be sustainable and must be implemented in addition to existing projects. The emissions avoided by the projects are reviewed and certified by independent institutions. Industrialised countries and companies can then claim credits for the CDM emission certificates to help them to meet their own emission targets.

CO_2 equivalents

The global warming potential (GWP) of a greenhouse gas, extrapolated over a certain period of time (generally 100 years), allows the comparison of the impact of difference greenhouse gases. Based on their differing impact on the climate and their lifespan in the atmosphere, the IPCC has calculated the greenhouse gas potential of the greenhouse gases defined by the Kyoto Protocol. In other words, it has defined the contribution of a specified volume of greenhouse gases to the greenhouse effect. The benchmark used in this process is carbon dioxide. A reduction of 25 tons in CO_2 emissions, for example, is equivalent to one ton of methane emissions.

COMTES 700

Within the framework of the European "COMTES 700" research initiative (Component Test Facility for a 700°C Power Plant), electricity producers and plant manufacturers are working on innovations to boost the efficiency of conventional power plants and reduce CO_2 emissions from these plants. By increasing the steam parameters to 700°C and 350 bar, it is hoped that COMTES 700 will lead to the creation of a new power plant generation with efficiency rates of over 50%. The precondition for this is the development of new state-of-the-art materials that can withstand the added strain.

Emissions

Emissions are the gaseous, liquid or solid substances released into the atmosphere or other parts of the environment from an installation or other technical process; they also take the form of noise, vibrations, radiation and heat. The source of the emissions is known as the "emitter". Emissions are not only caused by human activity. There are also natural emitters: cattle and swampland emit methane (CH_4), for example, while plants emit pollen as well as volatile organic compounds (VOC) and volcanoes emit sulphur dioxide (SO_2).

Flue gases

Flue gas is the term used to describe the waste gas occurring during combustion processes in power plants, waste incineration plants, production processes etc. (Post combustion).

German Renewables Act (EEG)

The "EEG", the German Renewables Act, is designed to ensure the priority of electricity from all renewable energy sources like sun, wind, water, biomass and geothermal energy as well as sewage, pit and landfill gas. The legislation came into effect in 2000 with the aim of significantly increasing the share of renewables in overall electricity generation in Germany in line with the objectives formulated by the EU.

Gigawatt (GW)

One gigawatt equals one billion watts or one million kilowatts (kW).

Greenhouse gases

Greenhouse gases (GHG) caused by human activity influence the natural greenhouse effect. The increasing concentration of greenhouse gases in the atmosphere results in less heat being radiated back into space from the earth's surface, and this in turn leads to a rise in the average temperature on earth. The Kyoto Protocol defines the following relevant greenhouse gases: carbon dioxide (CO_2), methane (CH_4), dinitrogen oxide (N_2O), partially halogenated hydrofluorocarbons (HFCs), perfluorocarbons (PCFs) and sulphur hexafluoride (SF_6).

High-voltage direct current and supraconductive lines

The electrical energy supply system in Europe uses alternating current, in other words current that changes its polarity periodically and regularly. One of the key issues in the debate on the future of renewables is the transport of electricity – solar electricity generated in places like Southern Europe and North Africa, for example – across large distances. The supporters of this idea favour the construction of very high-voltage lines for direct current as a means of transporting this electricity. The use of direct current is designed to minimise energy losses over these long distances. Direct current is a form of current with a constant strength and direction. Storage batteries and normal batteries, things we use every day, supply direct current. Supraconductors are materials whose electrical resistance drops to a level so low it is virtually zero if the temperature falls below a certain level. This makes it possible to increase the current density during transport. Cooling is performed using substances like liquid nitrogen (- 197°C).

Immissions

Immissions are the effects of the emitted pollutants on plants, animals and humans as well as buildings once they have spread in the air, water or soil or have been chemically or physically transformed.

International Atomic Energy Agency (IAEA)

The International Atomic Energy Agency IAEA was founded in 1957. It is an organisation belonging to the United Nations (UN) and has its headquarters in Vienna. The IAEA currently has 144 member states. It acts as a research and technology based forum for the peaceful use of nuclear energy and the monitoring of nuclear weapons grade material. On behalf of the UN, the IAEA also monitors compliance with resolutions and international treaties relating to atomic energy and nuclear weapons.

International Energy Agency (IEA)

The International Energy Agency IEA was founded in 1973 with the aim of promoting cooperation on the research, development, market introduction and application of energy technologies. 27 industrialised nations belong to the Paris-based organisation. The IEA publishes a comprehensive World Energy Report each year.

Integrated Energy and Climate Programme (IEKP)

At its policy meeting in Meseberg in August 2007, the German government decided on the key elements of an Integrated Energy and Climate Programme IEKP. The programme jointly drawn up by the Federal Ministry of Economics and Technology and the Federal Ministry of Environmental Affairs, Nature Conservation and Reactor Safety took on concrete form in December 2007. It is a combination of promotion measures, economic instruments and regulatory measures covering energy production, energy efficiency, transport and private households. The 29 individual measures in the IEKP are geared towards a sustainable climate and energy policy.

Intergovernmental Panel on Climate Change (IPCC)

The decision to create the IPCC was made by the United Nations in 1988. The United Nations Environmental Programme (UNEP) and the World Meterological Organisation (WMO) then called the IPCC in being. All countries who are members of these organisations can nominate scientists for the IPCC. The main remit of the IPCC is to assess the risks of climate change and to document avoidance strategies. The IPCC does not conduct its own research but collects the findings of research in the various disciplines, including in particular the field of climatology. It provides a coherent overview of this material in the IPCC Assessment Reports. These reports are prepared in working groups and approved in plenary session. All this takes place within the framework of a complex, multi-phase procedure involving lead authors and co-authors for individual articles, coordinators and lead authors for the overall report and inde pendent experts for the individual sections and the report as a whole. These independent opinions are provided not only by the nominated and selected scientists but also by representatives of the governments of the member states.

Glossary

Kilowatt (kW)
One kilowatt equals 1,000 watts.

Kyoto Protocol
The Kyoto Protocol is based on the United Nations Framework Convention on Climate Change (UNFCCC) and is a binding treaty under international law in which 38 industrialised countries (OECD members and Eastern European transformation states) have pledged to reduce their anthropogenic CO_2 emissions. The Protocol permits the use of "flexible" mechanisms which enable these states to meet a part of their commitments in the period from 2008 to 2012 at as low a cost as possible. As the commitments outlined in the Kyoto Protocol do not make any key contribution to the achievement of the goal of the UNFCCC, agreement on a follow-up treaty to Kyoto is of particular importance.

Megawatt (MW)
One megawatt equals one million watts or 1,000 kilowatts (kW).

Monoethanolamine (MEA)
Monoethanolamine is a colourless, caustic liquid that is used as a base material in the chemical industry – as an organic solvent, for example, or as an absorption agent for carbon dioxide and hydrogen sulphide in an amine wash, in which acidic gases are removed from gaseous mixtures.

OLED technology
Abbreviation for organic light emitting diode. An OLED is a thin-film light emitting component made of organic semiconductive materials. OLEDs are cheaper to produce than LEDs but their current density and luminance are lower. OLEDs are mainly used in screens and displays.

OSART missions
OSART missions are a service provided by the International Atomic Energy Agency (IAEA) and are considered to be the most in-depth form of evaluation for nuclear power plants. A team of international experts (Operational SAfety Review Team, OSART) reviews management procedures, organisation and administration, training and qualification, operation, maintenance, technical support, operating experience, radiation protection, chemical aspects, emergency planning, preventive and precautionary measures as well as the safety culture in nuclear power plants. The findings are subsequently published by the IAEA.

Rigid polystyrene foam
Polystyrene (PS) is a common thermoplastic material used in many areas ranging from electrical engineering to packaging.

Terrawatt (TW)
One terrawatt equals one trillion watts or one billion kilowatts (kW).

Thin-film transistors (TFT)
Thin-film transistors (TFT) are used to make large-scale electronic circuits. LCD flat screens are a common application of these transistors.

United Nations Framework Convention on Climate Change (UNFCCC)
The United Nations Framework Convention on Climate Change (UNFCCC) was signed at the Earth Summit in Rio in 1992. It has meanwhile been ratified by 192 states and therefore enjoys quasi-universal validity. The aim of the Convention is to prevent hazardous anthropogenic effects on the climate system. The states must document comprehensive data on their emissions to facilitate comparability. The industrialised nations have undertaken to provide financial support to the developing countries during this process. One of the central principles of the Framework Convention is "Common but differentiated responsibility" of the various states for the fight against climate change.

The production of this Innovation Report was climate-neutral.

The production of this Report inevitably resulted in greenhouse gas emissions. EnBW Energie Baden-Württemberg AG commissioned the "my climate" company to ensure that the production of the report was climate-neutral. This means that the emissions are offset by climate protection projects in other locations – in this case, by EnBW funding for a TÜV-certified bio-mass project in India that meets the "Gold-Standard" criteria. The project makes a provable positive contribution to sustainable development; it is not only socially and ecologically meaningful but also creates new jobs and helps to improve the quality of air in the region.

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