Topics 2009

Research for global markets for renewable energies

Export Volume of the German Renewable Energy Sector in Billion Euros

- 0.5 billion euros in 2000
- 2.5 billion euros in 2004
- 4.6 billion euros in 2005
- 6.0 billion euros in 2006
- 9.0 billion euros in 2007
- 12.0 billion euros in 2008
Cover image:
The cover image shows the export volume of the German renewable energy sector in billions of euros (source: data from the sector • image from AEE)
Research for global markets for renewable energies

Annual conference of the Renewable Energy Research Association in cooperation with the Renewable Energy Agency

24-25 November 2009
Umweltforum Berlin

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Contents • Topics 2009

- Welcoming messages
  4 Welcoming message from the German Federal Ministry of Education and Research
  Thomas Rachel, Parliamentary State Secretary • BMBF
  7 Welcoming message from the German Federal Ministry for the Environment
  Joachim Nick-Leptin • BMU/Department of Research and Development for Renewable Energy Sources

- Renewable energies and the transformation of the global energy system
  10 Megatrends, challenges and strategies
  Prof. Dr. Frithjof Staß • ZSW
  Prof. Dr. Jürgen Schmid • Fraunhofer IWES Kassel
  18 Significance of renewable energies and of energy efficiency in various global energy scenarios
  Dr. Wolfram Krewitt (†) • DLR
  Dr. Joachim Nitsch • DLR
  Kristina Nienhaus • DLR
  24 International energy policy
  Dr. Robert Klinke • Auswärtiges Amt

- Research for global markets – International exchange of experience
  30 Welcoming message from the International Renewable Energy Agency (IRENA)
  Hélène Pelosse • International Renewable Energy Agency (IRENA)
  33 The global research market for renewable energies: Competition and technology partnerships
  Prof. Dr. Eike R. Weber • Fraunhofer ISE
  Gerhard Stryi-Hipp • Fraunhofer ISE
  39 The energy and research policy framework conditions for renewable energies in Germany
  Jörg Mayer • German Renewable Energy Agency
  44 TREE – Transfer Renewable Energy & Efficiency – The Renewables Academy’s knowledge transfer project
  Berthold Breid • Renewables Academy AG (RENAC)
  48 The CERINA Plan – An alternative to the Kyoto instrument
  Dr. Norbert Allnoch • International Economic Platform for Renewable Energies (IWR)

- Research for global markets – Technology partnerships for renewable energies
  52 The German federal government’s strategy for the internationalisation of science and research
  Karl Wollin • German Federal Ministry of Education and Research
  55 Off to new markets! – Renewable Energy Export Initiative
  Juliane Hinsch • Head of the Office of the Renewable Energy Export Initiative in the BMWi
  57 Solar construction – Climate-appropriate construction in other climates
  Prof. Dr. Andreas Holm • Fraunhofer IBP
  Dr. Michael Krause • Fraunhofer IBP
  Sebastian Herkel • Fraunhofer ISE
  Dr. Peter Schossig • Fraunhofer ISE
  Prof. Dr. Christian Schweigler • ZAE Bayern
  Dr. Norbert Henze • Fraunhofer IWES
  61 Concentrating solar collectors for process heat and electricity generation
  Anna Heimsath • Fraunhofer ISE
  Werner Platzer • Fraunhofer ISE
  Stefan Heß • Fraunhofer ISE
  Dirk Krüger • DLR
  Markus Eck • DLR
  66 Research on geothermal electricity generation – On-site laboratory at Groß Schönebeck
  Dr. Ernst Huenges • Helmholtz Centre Potsdam/German Research Centre for Geosciences
69 Storing bioenergy and renewable electricity in the natural gas grid
Dr. Michael Specht • ZSW
Frank Baumgart • ZSW
Bastian Feigl • ZSW
Volkmar Frick • ZSW
Bernd Stürmer • ZSW
Dr. Ulrich Zuberbühler • ZSW
Dr. Michael Sterner • Fraunhofer IWES
Gregor Waldstein • Solar Fuel Technology GmbH & Co. KG

79 Solar thermal power plants – Export hits without a domestic market
Prof. Dr. Robert Pitz-Paal • DLR
Dr. Henner Gladen • Solar Millennium AG
Dr. Werner Platzer • Fraunhofer ISE

85 Concentrating photovoltaics (CPV) for countries with high direct irradiation
Dr. Andreas W. Bett • Fraunhofer ISE
Dr. Bruno Burger • Fraunhofer ISE
Joachim Jaus • Fraunhofer ISE
Tobias Fellmeth • Fraunhofer ISE
Dr. Oliver Stalter • Fraunhofer ISE
Dr. Matthias Vetter • Fraunhofer ISE
Hans-Dieter Mohring • ZSW
Dr. Andreas Gombert • Concentrix Solar GmbH
Hansjörg Lerchenmüller • Concentrix Solar GmbH

90 Requirements for integration of wind energy into the grids of various countries
Dr. Kurt Rohrig • Fraunhofer IWES
Dr. Bernhard Lange • Fraunhofer IWES
Reinhard Mackensen • Fraunhofer IWES

94 Off-grid power supply and global electrification
Dr. Philipp Strauss • Fraunhofer IWES
Markus Landau • Fraunhofer IWES
Michel Vandenbergh • Fraunhofer IWES
Georg Bopp • Fraunhofer ISE
Briza Ortiz • Fraunhofer ISE
Dr. Matthias Vetter • Fraunhofer ISE
Guido Glania • Alliance for Rural Electrification
Michael Wollny • SMA Solar Technology AG

Strategic research objectives

104 Future mobility based on renewable energies
Dr. Günther Ebert • Fraunhofer ISE
Prof. Werner Tillmetz • ZSW
Dr. Michael Specht • ZSW
Dr. Michael Sterner • Fraunhofer IWES
Dr. Bernd Krautkremer • Fraunhofer IWES
Dr. Thomas Pregger • DLR
Dr. Wilhelm Kuckshinrichs • Jülich

111 Integration of renewable energies into electricity and heat supply
Prof. Dr. Jürgen Schmid • Fraunhofer IWES
Dr. Bernhard Lange • Fraunhofer IWES
Dr. David Nestle • Fraunhofer IWES
Dr. Kurt Rohrig • Fraunhofer IWES
Dr. Michael Sterner • Fraunhofer IWES
Dr. Philipp Strauss • Fraunhofer IWES
Uwe Krengel • Fraunhofer IWES

116 New strategic challenges for research and development of renewable energies
Björn Klumsmann • German Renewable Energy Federation (BEE)

122 Research for global markets – Strategic approaches of the BMU
Joachim Nick-Leptin • German Federal Ministry for the Environment

127 The area of conflict between technology transfer and intellectual property protection
Dr. Winfried Hoffmann • EPIA President and Chief Technology Officer of Applied Materials GmbH & Co. KG
Jana Lewerenz • Secretariat for Future Studies
Thomas Pelikofe • Applied Materials GmbH & Co. KG

133 Innovation structures in Germany for technological leadership – Solar Valley Central Germany
Dr. Hubert A. Aulich • Solar Valley Central Germany and PV Crystalox Solar PLC
Dr. Peter Frey • Solar Valley GmbH

Panel discussion

139 Are Germany’s economy and research in renewable energies fit for international competition?

Acknowledgement

146 Sponsors and contributors

Indexes

148 Locations of FVEE member institutes
149 Addresses of FVEE member institutes
150 Legal notice
Welcoming message from the German Federal Ministry of Education and Research

Ladies and Gentlemen,

“Our policies are shaped by the principle of sustainability. We want future generations to enjoy good living conditions. Global climate protection is the pre-eminent environmental policy challenge of our time. It will provide the basis for sustainable long-term economic and ecological development in the future. We also regard climate protection as a competitive driver for new technologies.” Words to this effect are contained in the original German text of the coalition agreement between the CDU, CSU and FDP.

The theme of your annual conference “Research for global markets for renewable energies” follows on from the strategic foundations established in the coalition agreement. One the one hand, the goal is to open up and benefit from export opportunities for our economy. On the other hand, we can help to solve critically important global energy and climate problems and act responsibly for the future by promoting the spread of environmentally friendly and climate-friendly energy technologies worldwide. I am pleased that the Renewable Energy Research Association is addressing these pressing issues at its annual conference.

The new federal government attaches extremely high importance to energy policy. After all, the issue of how we provide our energy requirements in the future in an environmentally friendly, climate-friendly and sustainable manner is one of the most important global challenges of our time. For this reason, we want to prepare for the transition to the era of regenerative energies and wish to expand our technological leadership in renewable energies. Research is a key part of the approach here. Only by conducting excellent energy research will we be able to maintain our strong international competitive position. And only through research will we be able to ensure that renewable energy sources offer solutions that are cost-effective enough to be able to play an even stronger role in strategic decisions on energy supply and climate protection.

For this reason, we will be developing a new energy research programme focussing on energy efficiency research, storage technologies, intelligent grid technology and second-generation biofuels.

The German Federal Ministry of Education and Research (BMBF) and the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) are pleased to be acting as the patrons of the Research Association’s annual conference. The responsibility for energy policy and energy research policy is spread across a number of different bodies in the new federal government too. The BMBF and BMU have already successfully coordinated their support for research on renewable energies during the previous legislative period. The fact that two federal ministries are now acting as patrons for the annual conference demonstrates that these two ministries will continue to consult with each other and closely coordinate their activities. In my view, this is essential if the energy policy goals in the coalition agreement are to be achieved.

Making climate protection affordable

Climate change is happening and is relentless. In order to keep climate change at a manageable level, we have to reverse the trend with regard to emissions.

In a few days, the World Climate Summit will begin in Copenhagen. We must ensure that this climate summit will be a success. Failure is not something we can afford. We need a legally
binding international climate protection treaty for the period after 2012, an agreement that follows on from the Kyoto Treaty. The World Climate Summit in Copenhagen must be used to put in place the preparations for the agreement of a long-term climate protection treaty in the course of 2010.

The federal government will do everything possible to ensure that all of the central points of the new climate protection treaty will be decided upon in Copenhagen, alongside the form and structure of this treaty. The cabinet was unanimous in this regard at its meeting in Meseberg. For this reason, the Federal Chancellor will be participating personally in the Climate Summit in Copenhagen. At the Summit, she will be personally active in trying to ensure that everything possible is done to achieve a binding climate protection treaty.

Climate protection measures cost money. However, this should not stop states from engaging in climate protection, as all climate protection measures not undertaken today will ultimately cost us much more in the future. One of the federal government’s main goals is thus to make climate protection affordable – for industrialised states and for developing countries too. In order to reduce CO2, we need efficient and effective technologies that make use of renewable energy sources.

This represents a major task for researchers. On the one hand, current technologies have to be further refined and the investment costs of these reduced. On the other hand, we must use new scientific findings to develop entirely new technological approaches that will serve as technology leaps and provide for much more efficient solutions to our energy and climate problems.

There is a particular need here for fundamental research organised on a long-term basis. With its “Basic Energy Research 2020+” support initiative, the German Federal Ministry of Education and Research will continue to promote this area of energy research in particular. This corresponds with the distribution of responsibilities for support for energy research among the various bodies.

Maintaining our leading position in research

Germany enjoys a leading international position in research on and production of renewable energy technologies and technologies for the efficient conversion and use of energy.

Continuous and ambitious support for research and development, accompanied by practical testing since the 1980s, has borne fruit. However, other countries have also identified the potential of renewable energies and the associated market opportunities in the same way has Germany has done. These states are investing strongly in production and research, and in photovoltaic and wind power technology in particular.

If Germany wishes to maintain its leading technological position in this competitive environment, our research will have to be excellent. We must further develop our technologies and promote innovation by intelligently combining activities in research, industry, infrastructure and the nurturing of young talent.

Research and innovation require coordination: The excellence of the individual players is an important prerequisite, but is not everything.

As well as supporting the development of individual technologies, the BMBF therefore also promotes successful and promising technology regions as “teams” with the ministry’s special programmes such as the Leading Edge Cluster competition: The goal is to develop world-class research, regional support for innovation and infrastructure, the industry and educational institutions.

These are overall concepts aimed at further improving the competitiveness of given regions in the future. For example, the goal of the “Solar Valley Central Germany” cluster of excellence is to reduce the costs of photovoltaic technology to such an extent that so-called grid parity is achieved. It is necessary to overcome the cost barrier associated with photovoltaics in order to speed up the use of this technology.

In the future, we will continue to bundle support for sophisticated technology with
regional strengths and initiatives. The second round of the Leading Edge Cluster competition has been initiated with this in mind, and the evaluation round is already in progress.

### Improving networking in international research

Research for global markets – the subject to be presented and discussed at this conference for renewable energies – means international cooperation first and foremost, and this holds in a number of regards:

International exchange opportunities for scientists and cooperation with the best research centres in the world are prerequisites for maintaining our excellent research position. Only as an attractive scientific location with international links will we be able to continue to develop leading technology and supply it to the world.

In this context, the internationalisation of the training and education of our young scientists and support for the mobility of scientists are essential.

Many of the target countries for our environmentally friendly energy technology products are developing countries. However, simply exporting technology is not enough here; we also have to prepare the ground for environmentally friendly supply and usage concepts with strategically prepared cooperation projects. This includes the fostering of expertise, specialist institutions and the training of experts.

In summary, cooperation with developing countries in matters of education, research and development must be strengthened in order for this fostering and training to take place.

These are the components of the federal government’s strategy on the internationalisation of science and research, which was approved at the start of last year and is to be continued during the present legislative period too.

### Science Year 2010 – The future of energy

Last but not least, we also have to draw public attention to the critical importance of the issue of energy in the future and the central role of research in the search for solutions.

For this reason, the BMBF has given the upcoming Science Year of 2010 the motto “The future of energy”. The BMBF will be acting together with partners from science, industry, politics and society as a whole to address the public, foster enthusiasm, encourage public debate and communicate the importance of research and science in achieving secure, environmentally sustainable and affordable energy supply in the future. The “Science Year – Energy” initiative is particularly aimed at fostering the interest of young people in the topics of energy and energy research and, as a result, in scientific and technical careers too. We hope that as many research institutes, universities and companies as possible will take part in the “Science Year – Energy”: with their own projects, by participating in the research exchange platform, exhibitions, discussion platforms and the nationwide “Energy Day” planned for the end of September 2010, which will give people an opportunity to look behind the scenes and visit facilities where the future of energy research is being shaped.

Returning to matters in hand, I would like to wish you all a stimulating exchange of information and opinions at the Research Association’s annual conference and hope you will come up with many good ideas for business with global markets.
Ladies and Gentlemen,

On behalf of the German Environment Ministry, I would like to welcome you to this international exchange of experience on the occasion of the annual meeting of the Renewable Energy Research Association. Our Parliamentary State Secretary, Ursula Heinen-Esser, had to change her plans for tonight on rather short notice. So, she asked me to apologise for this and to take over this welcome address for her. I would also like to convey the best wishes of Federal Environment Minister Norbert Röttgen.

“Global climate protection is the pre-eminent environmental policy challenge of our time.” This is one of the key statements in the Coalition Agreement of the new government. It clearly shows that climate protection will remain at the top of the German environmental policy agenda in the years to come.

In a few weeks, the eyes of the global community will be on the Copenhagen conference. People expect the countries of the world to take responsibility. Our goal is to reach a consensus on all core issues in Copenhagen. In 2010 this outcome must be translated into a detailed, internationally binding agreement.

Despite the difficulties that objectively exist, we are optimistic that a breakthrough will be achieved at the Copenhagen summit. Germany has always been a driving force in climate protection. It will continue to play this role. We stand by our climate policy goals. We are committed to the target of limiting global warming to a maximum of 2 degrees, and the target of cutting greenhouse gas emissions by 80 to 95% by 2050. By 2020, we want to achieve a 40% emissions reduction in Germany compared to 1990.

Climate policy is essentially energy policy. Two aspects are particularly important:

1. We need to expand renewable energy.
2. We need to use energy more efficiently.

Next year, the German government will present a new energy concept. Among other things, this concept will outline

- the intended development of the energy mix
- and perspectives for integrating a steadily growing share of renewable energy in the overall energy supply system.

Our goal is for renewable energy to provide the main share of energy supply. In a dynamic energy mix, they will gradually replace conventional energy sources.

Chancellor Angela Merkel reaffirmed this in her recent policy statement: “We want to pursue the path towards the age of renewable energy”. The most important instrument in this policy will be the Renewable Energy Sources Act, the EEG. The new government remains committed to the EEG – this has also been laid down in the Coalition Agreement. We are delighted that feed-in tariffs for renewables have been put in place in many countries. The EEG has become a major German export good. A number of countries have used it as a model for a successful policy to facilitate the market introduction of renewable energy.

Germany is an international leader in many renewable energy technologies. There are various reasons for this. But a decisive reason is that Germany has top research institutes and excellent scientists in the area of renewable energy. Thanks to their expertise – thanks to your expertise – renewable energy made in Germany are in great demand throughout the world.
It goes without saying that financial framework conditions have an important impact on research. Decisive impetus was already provided during the last legislative period. With the High Tech Strategy, R&D funds were stepped up considerably. This also benefitted support offered by the Federal Environment Ministry for renewable energy research. We will continue this policy. Our aim is to focus research funding on sectors that are particularly relevant for society. These include climate protection and energy.

Successful research is vital for reaching our ambitious energy policy objectives. The research institutes united in the Renewable Energy Research Association can make a major contribution to reaching these objectives. I am very pleased about the great interest in this meeting, and I am delighted to see so many young participants here. The students of today will be the researchers of tomorrow. Your ideas are needed. Germany will only be able to maintain the current standard of living if we defend our position as technology leader. This means that we need scientists and engineers.

I welcome very much that the Renewable Energy Research Association is addressing international cooperation at this meeting. Climate change does not stop at borders. We are all affected. And we can only cope with this enormous challenge if we work together.

I am therefore delighted to see so many representatives of embassies here tonight. I wish you all fruitful and informative discussions and every success for the conference.
Renewable energies and the transformation of the global energy system

- Megatrends, challenges and strategies
- Significance of renewable energies and of energy efficiency in various global energy scenarios
- International energy policy
Megatrends, challenges and strategies

Summary

Megatrends such as global population growth, the development of industrialised societies in developing and emerging countries, and the increased mobility of people, goods and knowledge are the main factors that will influence energy requirements in the future. The most important limitation on these developments is the durability of ecological systems.

A paradigm shift is necessary if a balance between growth and sustainability is to be found in the future. A wide range of challenges are associated with the transformation of the energy system and the emerging global markets for renewable energies; these challenges also have to be met by science and research policy if Germany is to retain its position as a technological leader in international comparison.

Introduction

Our world is changing at an increasing tempo. Industrialisation is proceeding in fast forward mode in certain parts of the world, and important markets are shifting from west to east and from north to south. Economic growth and the emergence of a global middle class with increasing urbanisation and uninterrupted population growth in developing countries are all resulting in a strong increase in demand for raw materials such as steel, cement and glass, and for capital items and long-life consumer goods. On the other hand, the reverse trends are taking place in western societies due to the ageing and shrinking of populations, an increasing focus on the consumption of sustainable products and, above all, the transformation of production economies into service and knowledge economies.

On an overall basis, these developments will nonetheless lead to a steep increase in energy requirements given current energy supply structures – the increase will be around 40% over the next twenty years alone [1]. The question thus arises as to how long this development can be sustained, particularly considering that a change in the trends in the fundamental data is not in sight. The availability and prices of non-renewable energies and the geopolitical risks alone demand that a decoupling of economic development and energy requirements take place. The task here is to keep the difference between energy consumption and the energy services actually needed – such as mechanical power, heat, light and communications – as low as possible. This is particularly necessary in view of the limited durability of ecological systems.

Challenges presented by climate change

The “stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system” [2] agreed at the climate conference in 1992 has now resulted in the specific requirement of limiting the increase in the average global temperature to 2 °C with respect to the pre-industrial age.

At their summit in L’Aquila, Italy, in July 2009, the G8 states recognised that it would be necessary to at least halve global greenhouse gas emissions by 2050 and reduce them by 80% in industrialised countries compared to 1990 levels in order to achieve this target [3]. Despite all the political difficulties, agreement among the international community of states on this matter appears to be a matter of “when” and “how” rather than “if” – particularly with regard to the fair distribution of burdens and opportunities between industrialised and developing countries.
After all, the reality of the progress of climate change will gradually increase the pressure to act and will ultimately force decisions to be made.

However, the risks of inaction are not the only issue here; the opportunities presented by the transformation of the global energy system are increasingly being recognised too. A paradigm shift can also clearly be identified in the World Energy Outlook 2009 from the International Energy Agency (IEA) [1]. In contrast with previous reports, which concentrated on what should be done in order to reduce greenhouse gas emissions, the focus has shifted to what will happen if we do not act decisively. In place of the business-as-usual development which has been classified as “not sustainable”, a reference scenario has now been introduced that will achieve a stabilisation of the greenhouse gas concentration in the atmosphere at 450 ppm, which corresponds to the “2 °C rise scenario”.

As shown by the investigation carried out by Fraunhofer IWES in Figure 1, it is even possible from a technical and structural viewpoint to already achieve fully CO₂-free energy supply by 2050. To do so, the potentials for saving energy (mainly in the heating sector and in transport) and improving efficiency (e.g. cogeneration) need to be systematically harnessed to ensure that energy requirements do not further increase.

In parallel, fossil fuels and nuclear energy must be gradually replaced by a wide mix of renewable energies.

The main value of this type of scenario is that it demonstrates what is theoretically possible. But how realistic is this from today’s perspective? Can renewable energies fulfil the role assigned to them in the IEA scenario and can they provide around 40% of the world’s energy requirements by 2030? Currently, the figure is only 18%, and a not insignificant fraction of this is related to the non-sustainable use of firewood in developing countries. What are the key technologies, and what opportunities do they offer from Germany’s perspective?

**Development trend: Renewable energies**

Practically all world energy scenarios assume that renewable power generation in particular needs to be expanded. After all, electricity con-
suumption is rising in industry and in households, and new applications for electricity such as electromobility are also being added.

In addition, power supply is already responsible for over 40% of global CO₂ emissions today and is burdened with high specific CO₂ emission factors because of the fuels used (coal) and the poor efficiencies of power plants.

For this reason, the goal of the IEA's 450-ppm scenario is to more than halve specific CO₂ emissions from power generation from 603 gCO₂/kWh (2007) to 283 gCO₂/kWh by as early as 2030. In this scenario, nuclear energy and the introduction of CO₂ capture and storage (carbon capture and storage, CCS) technologies are to play a role. However, by far the greatest importance is attached to renewable energies, the capacity of which is to be significantly increased to almost 2,000 GW. In total, the share of renewables in power generation will increase from 18% to 37%, which will not only fully cover the increase in power consumption but will also contribute significantly to the replacement of conventional fuels before 2030.

The 10% criterion for key technologies

As the expansion of power generation from hydropower and conventional combustion of biomass is only possible to a limited extent, wind, photovoltaics, solar thermal power plants, geothermal energy, ocean energies and new biomass conversion processes will be the main pillars of this development. Thus the central question is whether these technologies are actually capable of this. The “10% criterion” theory can be forwarded as part of the empirical search for an answer to this question – in other words: a technology is capable of developing to become a key technology when a certain share of the market volume is exceeded.

The 10% criterion is already fulfilled by wind power at the moment, as around 10% of the growth in power requirements is being met by this technology worldwide. The wind market has been growing at an average of 30% per annum for ten years now, and is thus growing fifteen times faster than overall power consumption.

It is very likely that around three times as much capacity, i.e. around 340 GW of wind capacity, will be installed by 2013 as compared to 2008 [4], and around 10% of global power generation could be met by wind in 2020 if this trend continues.

This can also be expected to apply to photovoltaics with a certain time delay. However, photovoltaics currently have an installed capacity of 16 GW (2008, [5]) and are thus of the order of tenths of a percentage point worldwide. In addition, the amount of financial support necessary for grid-connected operation means that photovoltaics are only being used to a significant extent in certain countries such as Germany, Spain and Japan. In Germany, a 1% share of overall power generation is expected to be exceeded in 2009. The growth potential of photovoltaics has often been strongly underestimated up to now, as this supposedly expensive technology has seen cost reductions in recent years at a rate that nobody expected. Solar power can thus be generated for around 10 ct/kWh at locations with lots of sunshine, and this figure is falling all the time. This means that photovoltaics are at the threshold of major market penetration, and the sector has shown in the last ten years that it can deliver high growth rates.

For example, the European Photovoltaic Industry Association’s scenarios assume that it will be possible to install photovoltaic capacity of more than one hundred gigawatts in Europe alone by as early as 2020 [6]. The IEA’s expectations are admittedly significantly lower, with a worldwide installed capacity of around 130 GW [7], but it should be noted that this is based on very conservative development as regards power generation costs; these costs are an important factor in determining the rate of market penetration and, based on current trends, these assumptions can already be regarded as outdated. Nonetheless, the IEA scenario also implies that photovoltaics will be able to meet around 10% of the world increase in power consumption before 2030.
The development for the two technologies outlined here could also be repeated by other technologies – e.g.: solar thermal power, with numerous projects currently underway around the Mediterranean; the efficient conversion of biomass using innovative processes (e.g. thermo-chemical gasification of solid biomass); geothermal energy; ocean energies.

This applies analogously to numerous other application areas for renewable energies such as: solar building design; using solar energy to provide process heating and cooling; various energy storage technologies; renewable fuels; electromobility; fuel cells; renewable hydrogen. The achievement of CO₂-free energy supply is thus feasible both technically and economically from today’s perspective.

Rate of growth of markets for renewable energies

Globalisation can already be clearly identified in various sectors. For example, Figure 2 shows the development of markets for wind turbines based on the installed capacity for the years 1990, 1995, 2000 and 2008. The pace of development in Europe in the 1990s can clearly be seen, and major markets have also emerged in Asia and North America since 2000.

The second example indicates the production capacities for solar cells and modules, which have grown exceptionally quickly in a period of just three years in China and Taiwan above all (Figure 3).

Entirely new production and supplier structures have emerged as part of the globalisation of renewable energies. In the future, large multinational companies will also play a significant role in the sector; this is in contrast with the chronology of wind power in Europe, which began with regional and national markets and later led to exporting, and which often resulted in a great number of small companies. Multinational companies fulfil the financial and organisational prerequisites necessary to harness sophisticated technologies and implement increasingly larger projects. Examples of such projects include offshore wind farms, solar thermal power plants and the various production processes for renewable fuels. They can also benefit from numerous competitive advantages which result from these companies’ comparatively high level of mobility and their international connections, for example.
Figure 3
Production capacities for photovoltaic modules and cells as well as thin-film in 2006 and 2009 [10], [11]

Germany as a technological leader

What does this development mean for Germany as a business location? The broadly recognised leading role played by Germany in the growth of renewable energies and its leading technological position in many central areas is the result of very fruitful interplay between politics, science and business over the course of two decades at this stage.

The energy policy framework conditions in place established sufficient planning security and made it possible for industry to invest in the production and development of equipment in order to improve the performance and cost-effectiveness of this equipment. For example, the feed-in tariff (an indicator for power generation costs) for electricity from wind energy has fallen by over 60% since the German Electricity Feed Act came into force in 1991 [12]. A similar cost reduction has also taken place for solar power since the introduction of so-called cost-covering remuneration in the mid-1990s [13].

While science provided the impetus for the technological development in most cases, support instruments such as the so-called “100,000 Roof Programme” and the German Renewable Energy Sources Act helped to speed up innovation, as the existing markets meant that research results were quickly transferred from the laboratory to production.

As a result, a prospering renewable energy sector developed that is competitive internationally and currently employs around 300,000 people – around twice as many as in 2004. A good example here is the German wind industry, which had turnover of 8.5 billion euros in 2008 with exports representing 82% of this figure [14]. Worldwide, almost one in every three euros invested in renewable energies is spent on German-made wind power technology. This is of benefit not just to equipment manufacturers but also to suppliers from all sectors of the economy. This particularly applies to the mechanical engineering and machinery sectors, which are heavily involved in equipping photovoltaics factories worldwide.

In the future, the target countries for renewable energies will be establishing their own industries much more than has previously been the case. They will often be benefiting here from German expertise, which they can then build upon. However, there is also the risk that trade flows will be reversed; this can currently be observed in the case of Chinese photovoltaic modules, where the cost advantages are mainly due to major state subsidies for the construction of solar factories.
Even though this type of development cannot be ruled out in the future, no country will ultimately benefit from a “subsidy race”. In the growing international competitive environment, it will be crucial for the industry in Germany that it establishes an advantage based on engineering performance in order to compensate for location-specific disadvantages such as the higher wage level. This is mainly the responsibility of the companies themselves, particularly in those areas of application where there is a sufficiently large market. However, this should not be misinterpreted as a generalisation for entire areas of technology, as engineering development is by no means already complete in wind power, photovoltaics, solar thermal energy, hydropower and the whole area of bioenergies.

Support for research and development of renewable energies

The state’s task is to support not just fundamental research but also applied research so that new technologies, processes and strategies can be harnessed for energy supply in the future. The transition to industry-financed research is gradual, and should occur in the phase between demonstration and market introduction in the technology lifecycle.

State support for research should concentrate on areas of technology that will be relevant to the market in the medium term (in around 3 to 5 years) or long term (in over 10 years). The extent to which this should occur depends mainly on the amount of potential of the technologies as regards social and economic development. This is undoubtedly very much applicable to renewable energies, as the transformation of global energy supply is a central challenge for humankind in the 21st century. For this reason, international competition for the best technology will increase rapidly. This affects industry as well as research. In particular, multinational companies are in a position to procure research and development services from the “best in the world” at all times. This is the challenge that science and research policy in Germany have to face.

When German federal government expenditure for research is examined over a longer period, it can be seen that spending as a percentage of...
Gross domestic product has always ranged between over 2% and just under 3% since the 1980s [15].

However, with a current figure of around 2.5%, Germany lies behind other industrial nations such as Japan (2005: 3.3%) or the USA (2005: 2.6%), although it should be noted for the USA in particular that its gross domestic product is almost four times greater.

Figure 4 shows that energy research spending in Germany in the mid-1980s was significantly above the current level [16]. Since then, the distribution of funding has shifted, but the fraction for renewable energies and energy efficiency is only around one-third in the targets for 2009 too. Germany must do much, much more in order to consolidate its position of technological leadership in this area in the light of the importance of renewable energies for global energy supply, the technological challenges and the growth that can be expected in research activities worldwide. The target markets must be kept in mind here, and technologies must be developed even if there is no or else very little potential for using them in Germany (e.g. high-temperature solar thermal energy, specialised processes for harnessing bioenergy, or the use of ocean energies). At the same time, we need more technology partnerships with industrialised countries outside of Europe and with emerging and developing countries.

It is indeed possible to identify positive trends, which are primarily associated with special programmes such as “Organic photovoltaics”, “BioEnergy 2021” or “Lithium-ion battery LIB 2015” or with the National Electromobility Development Plan, the National Hydrogen and Fuel Cell Technology Innovation Plan (NIP) and the Leading Edge Cluster competition. The doubling of the research budget of the German Federal Ministry for the Environment for renewable energies since 2004 is also a contributing factor here.

However, this trend must be speeded up and must become permanent. The Renewable Energy Research Association recommends an annual increase in state research support in the area of renewable energies of 20 percent in order to double research expenditure to around 550 million euros by the end of the current legislative period [17].

Making Germany one of the world leaders in education, science and research, and making the transition to the era of regenerative energies – these two goals are highlighted in the foreword of the new German federal government’s coalition agreement [18]. The government will have to be judged by how it meets these goals. The technological basis for achieving them is already in place. This is evidenced not least by the wide range of equipment and services represented at the Renewable Energy Research Association’s 2009 annual conference on the topic of “Research for global markets for renewable energies”.

**Literatur**


Significance of renewable energies and of energy efficiency in various global energy scenarios

When one takes stock of the progress towards more sustainable development that the global energy supply has made in the last decade, the results are disappointing. Sustainability deficits in energy supply remain evident: the global warming that this energy supply causes; the very stark difference in energy consumption between industrialised and developing countries; the scarcity and higher prices of crude oil and natural gas that can be observed; the continuing risks of nuclear energy. These deficits have not become any smaller in the last ten years, as the demand for energy has grown rapidly due to the inadequacy of efforts to improve efficiency in “high-consumption countries” (industrialised countries) and the rapid growth in many emerging countries. Although renewable energies are expanding, they currently cannot (yet) keep up with this growth and thus cannot increase their respective shares of total energy supply.

On the other hand, a large number of energy scenarios that describe possible future developments in the global energy system clearly show that only significantly more efficient use of energy combined with a major expansion of renewable energies will be able to make a comprehensive contribution to solving the problems listed above. Numerous studies have concluded that this goal can be achieved technologically and that this approach is necessary from an economic viewpoint if economies wish to continue to enjoy a stable and affordable energy supply. On a global level, it is thus expected that renewable energies will be able to provide energy amounts of the order of the total current world energy consumption by 2050 (Figure 1).

Older scenarios (examples: Shell, WBGU, IEA 2003) generally assumed significantly increasing energy demand and thus expected significant contributions to come from renewable energies. The contributions of fossil and nuclear energies were also expected to rise strongly. However, the growing urgency of drastically reducing greenhouse gases combined with the increasing scarcity of fossil fuels has made it necessary to examine global efficiency potential more systematically in recent years.

For this reason, current scenarios assume lower consumption growths (examples: IEA 2008, WETO 2006), even in their reference or baseline cases. The predicted increase in global energy consumption by 2050 will then be only 700-900 EJ/a. A particularly systematic determination of efficiency potentials was carried out in the “Energy-(R)evolution” scenario. If these potentials can be tapped at an early enough stage, the global primary energy consumption could be returned to its current level of around 500 EJ/a after passing through a maximum of almost 550 EJ/a around 2020. With the simultaneous expansion of renewable energies to around 270 EJ/a (their contribution in 2007 was 64 EJ/a), it will be possible to reduce CO₂ emissions to 10 Gt CO₂/a by 2050, meaning that the maximum CO₂ concentration could be stabilised at 450 ppm (“2 °C target”).

If potential efficiency increases are not realised to this extent, higher demand will also have to be met. The example of the BLUE-MAP scenario from the IEA quotes the following figures:

- Contribution of renewable energies 230 EJ/a
- Nuclear energy 90 EJ/a (currently 30 EJ/a)
- Fossil fuels 350 EJ/a (currently 412 EJ/a)

In order to achieve the climate protection target of 450 ppm, it is assumed that a considerable amount of CO₂ will be captured and stored underground. Assuming that efficiency improvements are very inadequate, the target of
450 ppm will not be met even if the contributions of nuclear and fossil fuels are increased considerably. For example, the WETO-CCC scenario only achieves a stabilisation of the CO₂ concentration at 550 ppm. A very significant improvement in the efficiency of the conversion and use of energy in all regions worldwide is thus essential if climate change is to be kept to a manageable level. Secondary importance with regard to the potential for minimising greenhouse gases by 2050 is attached to renewable energies and to scenarios that also depend on nuclear energy and CCS technology.

The potential of the “solar technologies” already available today is large enough to be able to meet demand such as that in the “Energy (R)evolution” scenario, which provides for an increase of a factor of 4.2 relative to the current contribution. After around 30 years of systematic research, development and market introduction, a wide variety of high-quality technologies are now available.

The current state of research progress and the market launches also makes it possible to state that further significant technological improvements can be expected in the future. This and the ongoing rapid development of the market mean that costs will continue to fall significantly, accompanied by engineering improvements to equipment. Dynamic model calculations that take these factors into account show that useful energy from renewable energies will be less costly than energy from primary sources after 2020 at the latest.

The electricity sector is of particular interest because of its highly dynamic growth and its major economic importance (Figure 2). The contribution of renewable energies is currently 18% worldwide, with the dominant share from hydropower. However, because of the dramatic growth in demand for electricity in the last ten years, the share of renewables has fallen by one percent. In the IEA’s “baseline” development, electricity demand will increase by a factor of 2.5 by 2050 relative to the 2007 level. Even in the case of significant improvements in efficiency of between 7,000 and 12,000 TWh/a of reduced electricity demand compared to the “baseline” development, electricity demand should still be between 1.8 and 2 times the current level, as shown in the two 450-ppm scenarios (Figure 2).
This growth will demand considerable efforts be made to promote power generation from renewable energies. In the “Energy-(R)evolution” scenario, their contribution increases from 3,600 TWh/a currently to around 29,000 TWh/a by 2050, which would then correspond to a share of 77%. In the BLUE-MAP scenario, it would increase to around 19,000 TWh/a (45%). As the additional contribution from hydropower – and also from biomass – is limited, this growth will mainly be provided by wind and solar energy. Lower rates of growth for these technologies in the BLUE-MAP scenario make a major expansion of nuclear power to almost 10,000 TWh/a necessary (currently 2,800 TWh/a). In this scenario, fossil fuels will even be used at around the same levels as today. The BLUE-MAP scenario assumes that CCS power plants are used for almost 85% of this amount of energy, corresponding to a total of 11,500 TWh/a of power.

Wind power currently has a capacity of 121 GW worldwide. The “Energy-(R)evolution” scenario assumes an increase to 2,700 GW by 2050, meaning that the annual market volume, currently at 27 GW/a, would “only” have to increase by a factor of five.

At the same time, the average electricity costs will sink by another 40%. In comparison, growth by a factor of 180 in photovoltaic capacity is necessary (currently 16 GW), and the annual market volume would have to increase by a factor of 35 to around 170 GW/a. In parallel, electricity costs would fall to around a quarter of today’s levels on average. The market expansion of solar thermal power plants is only beginning. Their power share would be around 800 GW in 2050 according to the “Energy-(R)evolution” scenario, which corresponds to a market volume of approximately 40 GW/a. The generation costs should fall by around 60% compared to current power plants.

The market development proposed in the “Energy-(R)evolution” scenario shows that renewable energies will almost completely replace fossil fuel power plants in the marketplace over the next 40 years (Figure 3). At the moment, around 220 GW/a of new power plant capacity is being installed per annum, with over 65 GW/a of this coming from renewable energies (including 28 GW/a of hydropower and 27 GW/a of wind power). These technologies – supplemented by biomass, geothermal energy and, in the long term, wave energy and other sources –
will lead to a continuous growth in the market volume to around 260 GW/a in 2030 and 430 GW/a in 2050.

In total, the capacity to be installed annually will thus approximately double – due to the increasing demand for electricity and to the significantly lower numbers of full-load hours that apply to renewable energies.

Similar growth trends, which cannot be described in detail here, will also have to take place in the heating sector, with strong growth required in the solar collector market in particular.

By combining the resultant market volumes with the assumed cost trend for the individual technologies, the expected investment volumes for a growing global renewable energies market can then be derived (Figure 4). Around €170 billion per annum is already being invested in renewable energy technologies currently. However, (large-scale) hydropower is responsible for €65 billion per annum of this amount, with the wind industry accounting for a further €30 billion per annum. In the “Energy-(R)evolution” scenario, the annual investment volume will rise to almost €600 billion per annum by 2030 and almost €900 billion by 2050, with investments in hydropower remaining approximately constant.

Solar technologies will be responsible for a significant fraction of this with 55%, followed in turn by wind power. The considerable growth by a factor of almost five in the investment volume for renewable energies is a sign of the shift away from today’s fuel-dependent energy supply with its totally uncertain price trends.

This shift is already well underway in the case of wind power, photovoltaics and the harnessing of biomass. Solar thermal power plants are currently undergoing something of a rebirth in southern Europe, northern Africa and the USA. Further technologies such as power generation from deep geothermal energy and wave energy are “in the starting blocks”.

In the case of heat provision technologies, the existing market trends for the technologies already available need to be strengthened by
means of suitable support instruments. The variety of energy sources to be harnessed, the demanding technical standards with regard to efficient and cost-effective systems and the generally decentralised nature of renewable energy technologies result in a wide variety in terms of sectors and companies – ranging from large-scale series production with a global dimension through to regional and craft-industry structures.

These characteristics combined with the high level of public acceptance make it easier to raise capital and have also led to the involvement of a wide range of players.

In addition, the use of domestic renewable energy sources coupled with more efficient use of energy will make many countries less dependent on energy imports. Thanks to this combination of climate-related and economic advantages, stronger expansion of renewable energies (combined with improved efficiency of use) has all of the typical characteristics of a “win-win” strategy. All of these factors, when considered together, should be sufficient to ensure stable support from energy policy and to give rise to long-term growth.

Germany is at the forefront among industrialised nations in terms of the development, market growth and energy policy support for renewable energies. Investments of around €12 billion per annum are currently being made in the German domestic market (2008).

Based on the favourable initial conditions for German companies (current foreign turnover is around €8 billion per annum, which accounts for around 20% of the world market volume), foreign markets with a size of around €60-80 billion per annum should be created by 2030. According to the “Energy-(R)evolution” scenario, turnover of between €80 billion and €100 billion per annum is possible for the German renewable energy sector by 2050, which would correspond to an average share of between 12% and 15% of the world market.

Major stimuli for new sectors of the economy and for jobs will result from the widespread application of a large number of new energy
technologies. By 2030, the gross number of jobs in the renewable energy sector could thus rise to between 500,000 and 600,000. A figure of the same order of magnitude can be expected for the increased use of technologies to improve energy efficiency.

However, to achieve these goals, ongoing and increasingly intensive efforts to maintain and consolidate the current favourable initial position on the world renewable energy market are necessary by the German renewable energy industry and also from the accompanying energy policy.

With a more pessimistic scenario that assumes that these efforts are not maintained, the turnover to be expected for the German renewable energy sector will not exceed €40 billion per annum, even with significant growth in the world markets.

Increased international cooperation will be necessary to provide the foundation for effective climate protection combined with global energy supply that is largely based on renewable energy sources. This trend is very much compatible with the liberalisation and globalisation of the energy markets, and it offers many opportunities for constructive political cooperation. The world’s very great potential for renewable energies can only be harnessed to the extent necessary to meet the global demand for sustainable energy if joint international projects are implemented. This type of international “solar energy partnership” offers important geopolitical advantages. They are an ideal opportunity to reduce economic inequality between north and south and to create global markets for future-oriented energy technologies without the risk of conflicts for scarce resources.

For example, the significance for global energy policy of the harnessing of the major potential of solar and wind power around the Mediterranean should not be underestimated in the context of the economic development and political stabilisation of this region and of its relationship with Europe.

There is no lack of solution approaches for the pressing problems of energy supply and climate protection. However, it is necessary that the efforts which have been successful up to now be expanded quickly and comprehensively and that the approach taken by just a few countries so far be expanded and implemented even more intensively. National egos should take a back seat here. The European Union, which rightly sees itself as having a leading role in the advancement of climate protection, can act to set an example here and would be economically and politically successful in doing so.
Ladies and Gentlemen,

I would like to start by thanking the Renewable Energy Research Association for inviting me to this annual conference.

I am sure that most of you will be familiar from your day-to-day work with the German Federal Ministry of Economics, the Federal Ministry for the Environment and the Federal Ministry of Transport, Building and Urban Development as the main bodies that implement the federal government’s energy policy. However, one thing is clear: Energy policy is no longer a national affair. It is very much a current issue that is debated very intensively both bilaterally between states and also in multilateral forums. The international political arena is increasingly getting involved; after all, the economic prosperity of humankind is dependent on this issue. In addition, this is an area of politics where individual states acting alone can achieve little. Only coordinated international efforts will lead to success. For this reason, German Federal Foreign Office provides intensive support for international debate on energy policy in close cooperation with other organs of the federal government.

After all, one thing is certain: Our national strategy for secure and climate-friendly energy supply can only be successful if we coordinate it with our international partners. In the areas of energy and climate protection, we cannot act alone. CO₂ emissions change the climate worldwide regardless of whether they come from a car in Germany or from a coal-fired power plant in China. German oil consumption influences the world market price via the oil markets and thus also affects consumption in other regions of the world. German investments in renewable energies and progress in research can reduce the prices for equipment – as can be currently observed in the case of photovoltaics – and thus stimulate further investment in sustainable energies worldwide. Successes and failures in energy research today will decisively shape the global energy system of tomorrow.

We have to think and act in an increasingly global manner as regards energy policy. Of course, we must also not lose sight of the development issues that are closely associated with the energy issue. There are still 1.6 billion people worldwide who have no electricity. They are waiting for energy supply methods that are decentralised and affordable. In order to create fair opportunities for development, we must structure access to energy reserves in a transparent manner and take new approaches to energy supply that do not threaten the common foundations for human life. The main issue here is to significantly reduce dependence on fossil fuels and, in turn, the emissions of greenhouse gases.

We are faced with a three-pronged challenge both nationally and internationally. We have to:
1. Prevent a climate catastrophe
2. Achieve a secure energy supply
3. Keep development opportunities open

If we fail to meet this triple challenge, the consequences for the international community and for German foreign-policy interests will be disastrous. On the other hand, if we succeed in finding the correct responses to these three challenges, this will contribute positively to our foreign-policy goal of achieving a stable and peaceful world order. This is why the success of renewable energies worldwide is so important for our foreign policy. Renewable energies are the only answer to all three of these questions at the same time. There are certain energy technologies that represent a partial response to one or two of these three challenges. The attraction of renewable energy sources is that a breakthrough for renewables will simultaneously prevent a climate catastrophe, create a long-term, secure energy supply and open up opportunities for development to all.

Based on this consideration, it is self-evident that responsible foreign policy must support and promote the breakthrough for these technologies in every way it can.
Coal and oil fuelled the first and second industrial revolutions, and the breakthrough for renewable energies will now spark off a veritable third industrial revolution. Germany has already undertaken major steps in starting off this revolution. We must now ensure that other states follow our lead. After all, Germany will not be able to achieve this energy revolution alone. I regard this as a central task for our foreign policy. We must explain the advantages of a switchover to renewable energy sources to our partners worldwide, and we have to show them the approaches necessary to implement this switchover. We also have to give them a helping hand so that we can all travel this path together.

We Germans are particularly credible partners for many states around the world because of the success of our policy up to now and because of our leading position in research.

Just how successful our support mechanisms in Germany have been is shown by a study by the International Energy Agency (IEA). It confirms that Germany and other states, including Denmark, Spain and Portugal, provide the most effective support for renewable energies. The IEA also notes that the certainty with regard to framework conditions provided by feed-in systems with fixed remuneration creates a stronger investment incentive than the amount of the tariffs alone.

The positive experience we have had with the German Renewable Energy Sources Act is one of our most convincing arguments. So far, over 40 states worldwide have passed similar acts or been guided by the German act in their promotion of renewable energies. Countless other states are interested in applying the act too. The Renewable Energy Sources Act is a German-made success story, and is also a stroke of luck for our foreign policy. In this way, we can actively offer our experience to other states. Flagship projects in Germany – I am thinking here of the second-biggest solar farm in the world in Lieberose and of the solar tower power plant in Jülich, which were both opened recently – also ensure that we continue to be prominent pioneers for renewable energies.

Our leading role in the area of renewables represents both an opportunity and a responsibility at the same time. It is a major opportunity for the German economy and for renewable energy technologies with the “Made in Germany” brand. However, it also leads to certain obligations: If we don’t drum up enthusiasm for renewable energies on the international stage, who else will do so? For this reason, we are using our good reputation to promote renewable energies worldwide.

IRENA, Mediterranean Solar Plan and Desertec

Probably the greatest success of this policy so far has been the founding of IRENA, the new international organisation for renewable energies, in Bonn on 26 January 2009. The idea for IRENA originated in Germany, and Germany was also the driving force behind the process of setting up IRENA. IRENA will give renewable energies a voice worldwide and will advise governments how they can switch their national energy supply over to renewable energy sources as quickly as possible. IRENA, which probably would not exist without Germany’s involvement, already has over 130 member states today and will help to pave the way for renewable energies in its role as one of many global institutions. Germany will continue to retain an important role in IRENA: The IRENA Innovation Centre in Bonn is to be the source of important stimuli for the ongoing development of renewable energies.

IRENA will contribute to the progress of the expansion of renewable energies worldwide. As Europeans, we have a particular interest in the progress of renewables in our own region and in our vicinity in particular. For example, there are major opportunities in the Mediterranean region for the harnessing of energy from renewable sources. Within the context of the Union for the Mediterranean, we are working together with our partners on the “Solar Plan”, a solar energy programme for the Mediterranean region. Our main aim here is that the potential of renewable energies around the Mediterranean be harnessed.
We are also providing extensive accompanying support to the new “Desertec Industrial Initiative” consortium.

This consortium could provide new expertise and implementation opportunities for our solar energy programme. Within the context of German foreign policy, we wish to help in the creation of instruments and a framework that will allow this consortium to be successful.

One example here is that the German Federal Foreign Office is currently helping to pave the way for renewable energies in North Africa by financing the “UniSolar” programme being implemented by the DLR, which will support the expansion of solar power in North Africa.

What we need for the next step with the “Mediterranean Solar Plan” and – depending on the feasibility study yet to be completed – also for Desertec are equipment and grids. I do not regard direct investment as the task of the state. Our job is to create the political framework so that the existing potential for economic cooperation can be harnessed in a systematic manner. We are working to provide security for the necessary investments and to put in place sensible rules so that these investments can provide the best results for all participants.

Strategic energy partnerships

In addition to these specific initiatives, the Federal Foreign Office is also working on the integration of climate protection and energy policy issues into all areas of foreign policy, security policy, foreign trade policy and development policy. Nowadays, diplomacy also includes energy and climate diplomacy.

On the one hand, we will have to deal with governance issues in the future to a greater extent. We aim to create an international framework for energy relations that will provide dependability and thus greater security. Financing, production, trading and the respective shares of gas, oil and renewable energies in overall energy consumption are largely determined by a system of institutions and rules.

On the other hand, we will be building on strategic partnerships with individual countries. Here too, politics can open doors for business and vice versa.

We take advantage here of the opportunities offered by bilateral dialogue in all issues relating to energy relations, such as joint research or the exchanging of best practices. Dialogue on the matter of renewable energies also plays an important role in our strategic partnerships.

We have already set up a forum for dialogue on energy and climate matters with the USA in the form of the “Transatlantic Climate Bridge”. We aim to further intensify this dialogue in the coming months, particularly in the area of energy research. We have established energy partnerships not only with the west, but also with the north and south: I would like to highlight here our energy partnerships with Norway and Nigeria, and an energy partnership with Angola is currently being planned.

We are also working to increase the importance of energy issues in our foreign relations in a European context too. Russia will remain an important strategic partner in our external energy relations. I am convinced that we can integrate Russia even more strongly into European economic structures with a wide-based modernisation partnership. By doing so, we would also be improving European energy security significantly.

The role of energy research

What role does energy research play in these efforts by the Federal Foreign Office? One can do so much promotional work for a given product, but the product will only be successful if the quality is right. Germany enjoys a lot of credibility based on its successes with renewable energies up to now in terms of research, energy management and policy. However, we cannot allow ourselves to rest on our laurels in this regard. We must consolidate our credibility anew every day by continuing to push forward. We want to continue to increase renewable energies’ share in the energy supply. We want to expand electricity grids in order to ensure
supply security in the context of increased input from renewable energy sources and decentralised power plant structures. We want to increase our energy efficiency.

We want to find and implement better solutions for energy storage in order to be able to better integrate renewable energies into the grid. We need fossil-fuelled power plants that can be controlled more flexibly, along with energy storage systems and better load management.

Energy research plays a crucial role in all these challenges. After all, it determines the feasibility, security and costs of these measures and thus the degree to which they can be implemented politically, both nationally and worldwide. We must retain our position of world leadership in energy research and renewable energy technologies in order to remain credible as a promoter of renewable energies.

Partners that have followed our example also expect support from Germany in pressing matters such as the grid integration of renewable energies. The more German research makes us able to provide this support, the more credible our efforts will become.

German energy research and German foreign energy policy thus form a symbiotic relationship with one another. Each can benefit from the other. Excellent achievements in national energy research, productive international research cooperation and tangible results in renewable energy research are extremely strong arguments in the context of political dialogue with our partners. The growing political interest in issues relating to energy supply and renewable energies can and will in turn open up better framework conditions and new opportunities for research cooperation.

International research cooperation is also an area which is becoming more and more important in foreign policy. On the one hand, this is because a large fraction of global knowledge is of course not generated in Germany. Networking with science locations worldwide is in our interest so that we can benefit from this knowledge too. On the other hand, the major challenges facing the world can only be solved by acting together.

For this reason, the Federal Foreign Office strongly supports international research cooperation. I would like to mention just two examples here.

Around 20 German diplomatic missions abroad in locations with high potential for innovation have scientific officers. These include Moscow and Washington, along with Beijing, Tokyo and Brasilia. They maintain contact with the research ministries and institutions of their host countries, keep themselves informed of the latest developments in these countries and report on these. They also support politicians in the area of science, companies active in research, and scientists and researchers from Germany in their work abroad. The Federal Foreign Office intends to further expand this network of science officers next year.

Secondly, the Federal Foreign Office provided the impetus this year for the creation of “German Houses of Science and Innovation”. A whole range of German research and science organisations are active abroad. They have excellent projects, offer very good stipends and contribute to Germany’s good reputation. However, their contribution to our good reputation could be even stronger if they presented themselves in a joint, coordinated manner. For this reason, we have begun to establish “houses of science and innovation” in five pilot locations – São Paulo, Moscow, Tokyo, New Delhi and New York. The organisations will now present themselves under this single umbrella and provide their services in a coordinated manner. We intend to include further important locations after the pilot phase that will last around another two years. We would be delighted if the Renewable Energy Research Association were to show interest and participate in the “German Houses of Science and Innovation” initiative.

As you can see, diplomats and energy researchers can do a lot to help either in their work. With this in mind, I hope that this event will help to strengthen dialogue between the fields of diplomacy and energy research and that it will open up further opportunities for cooperation.
Research for global markets – International exchange of experience

- Welcoming message from the International Renewable Energy Agency (IRENA)
- The global research market for renewable energies: Competition and technology partnerships
- The energy and research policy framework conditions for renewable energies in Germany
- TREE – Transfer Renewable Energy & Efficiency – The Renewables Academy’s knowledge transfer project
- The CERINA Plan – An alternative to the Kyoto instrument
Welcoming message from the International Renewable Energy Agency (IRENA)

Ladies and Gentlemen,

Allow me to begin by thanking the Renewable Energy Research Association for organising this conference and for their kind invitation. I am delighted to be able to discuss research developments and technologies related to renewable energies with you today.

It is true to say that 2009 marks a turning point in the development and spread of renewable energies. 52 years after the foundation of the International Atomic Energy Agency and 36 years after the foundation of the International Energy Agency, the International Renewable Energy Agency (IRENA) was founded in Bonn in January 2009. IRENA, the first international organisation that will concentrate solely on the promotion of renewable energies, is to become a voice for renewable energies that will be heard all over the world.

It is a pleasure to speak to you today as the first Interim Director-General of IRENA. Allow me to say a few words about our still very young organisation.

Locations and members

In June 2009, the members of IRENA selected the United Arab Emirates as the location of the IRENA secretariat. In addition, a Technology and Innovation Centre will be established in Bonn and a Liaison Office to interact with international organisations will be set up in Vienna.

The interim headquarters in Abu Dhabi will soon move to Masdar City – the first almost completely CO₂-free city, which will exclusively use renewable energy sources to meet its energy requirements. The fact that the sixth-biggest producer of oil in the world has committed itself to renewable energies shows that we have achieved global agreement on the need for an energy revolution – away from carbon-based energy supply that impacts negatively on the environment, and towards sustainable and clean harnessing of energy.

Just this morning, the EU Commission became the 138th member to join IRENA. The high number of members achieved within such a short time demonstrates just how important the issue of renewable energies has become to member states. They are a must for developing, emerging and industrialised countries, regardless of whether states are rich or poor in raw materials. With renewable energies, dependencies on fossil fuels can be reduced and the various targets that have been set for climate protection can be achieved. Renewable energies are a “must” if climate change is to be kept in check.

IRENA’s tasks

The expansion and growth of renewable energies in recent years has been considerable. Worldwide investments in clean energy technologies amounted to the considerable sum of 120 billion US dollars in 2008.¹ As a further example, solar energy capacities were increased by a factor of six between 2004 and 2008 to reach 16 gigawatts, and those of wind power were increased by 250% to 121 gigawatts. In addition, numerous states have now created the necessary political framework conditions, such as feed-in acts, in order to support renewable energies.²

Despite the sometimes positive trends in the worldwide use of renewable energies, there are still currently serious barriers to the spread of clean fuels in place. These include long permission procedures, import duties and technical barriers, uncertain financing for renewable energy projects, centralised infrastructure, and insufficient awareness of the possible applications of renewable energies.

IRENA will help to dismantle these barriers. In order to promote the expansion and sustainable use of renewable energies worldwide, IRENA will be offering its members practical help. This will include the provision of relevant information on the subject of renewable energies, including analyses of potential and scenarios, best-practice examples and effective financing mechanisms. The Agency will also be providing capacity building, training, workshops and policy advice. It will be facilitating the transfer of knowledge and technology, and will be providing help with the improvement of political framework conditions.

Initial activities

IRENA is currently in the process of establishing itself. We are working tirelessly to recruit qualified staff and complete the organisational and structural infrastructure at our headquarters. Despite these start-up steps, the Agency has already begun its initial activities. For example, it has set up a working group under the leadership of the DLR that will consider the potential of and scenarios for renewable energies. Among its other tasks, the working group will prepare an appraisal of the current global potential of all renewable energy sources. In addition, scenarios are to be developed that show how a changeover from the current energy supply system to an energy system based on renewable energies can be implemented.

The sudden death of the project leader Wolfram Krewitt came as a shock to us. I would like to take this opportunity to express my sincere condolences to his colleagues and, in particular, to his family and friends.

As an additional activity, IRENA is advising the Kingdom of Tonga with regard to the electrification of its outer islands using renewable energy sources.

IRENA has also conducted workshops on the topics of capacity building and knowledge management. These workshops analysed tried-and-tested methods and identified needs and knowledge gaps.

Another focus was the dialogue with a large number of stakeholders and other international organisations in the field of energy (e.g. UNIDO, IEA, UNFCCC, IPCC), NGOs and networks in the renewables sector in order to investigate the possibility of cooperations and partnerships.

IRENA will be cooperating with Ren 21, EREC/Greenpeace and the IEA to organise a side event at the UNFCCC Conference of the Parties in Copenhagen on 15 December. Under the motto “Renewable Energy – Our Chance to Mitigate Climate Change”, IRENA and its partners will be presenting renewable energy scenarios and showing how renewables can contribute to achieving CO₂-reduction goals and placing energy supply on a secure basis.

Activities in the area of research

In future, IRENA will be focussing increasingly on the area of research. In the light of increasing trade volumes worldwide and strong increases in the numbers of automobiles, IRENA will be promoting research on electrical drive systems in the transport sector in particular. Overall, IRENA will be working towards a gradual reduction in the production costs of renewable energies so that they become competitive on the market as quickly as possible and are no longer dependent on subventions.

A major amount of research continues to be necessary, particularly in the area of technologies that are not yet competitive or are not yet ready for the market. These needs must be addressed quickly.
In order to further support our work, our long-term aim is that IRENA be advised by a scientific advisory board. We are working to establish contacts with the leading research institutions. All research institutes represented here are also cordially invited to work with us. Alongside its e-learning programmes, IRENA will also be offering stipends for academics who wish to work on renewable energies in order to promote young talent in this area.

IRENA will be expanding its activities in the research sector by actively influencing the direction of further research. In its role as a global voice for renewable energies, IRENA will be distributing the latest research findings, communicating them to the relevant stakeholders and basing its ongoing activities on these findings.

With the study of potentials, IRENA wishes to give every country the opportunity to calculate its own renewables technology mix that offers the most promise. In this way, every country should be put in a position to create its own “technological roadmap” on the path to more renewable energies.

It is my own personal aim to help the poorest of the poor. For this reason, IRENA will initiate the development of an affordable PV application. Already today, there are Solar Home Systems (SHS) that start at $300. Our goal is to reduce this price by 50% in the near future, to begin series production of these SHS, and to identify suitable distribution channels for them. There is already a competition for this organised by the Fraunhofer ISE in Freiburg.

I am pleased that the conference programme is dealing with the investigation and further development of renewables technologies. The plenary session – which consists of players from politics, excellent research institutes and the private sector – gathers together highly qualified experts, investors and decision-makers. I am certain that only effective cooperation between these players will result in progress in development and thus contribute to solving the world’s climate and energy supply problems.

We must ensure that international research cooperation is expanded so that the opportunity to develop technologies on a global scale and adapt them regionally, as mentioned by Prof. Staiß in the invitation, can be realised. IRENA will be happy to participate in these efforts and invites all involved to work together closely.

To close, allow me to make another “personal” appeal to everyone present. I call upon everyone – and in particular on women – who shares IRENA’s goals and is interested in working with IRENA to apply to the secretariat in Abu Dhabi. It is my explicit goal to employ at least 50% women at IRENA.

I thank the organisers for the opportunity to speak to you today. I wish you all a successful conference.
The global research market for renewable energies: Competition and technology partnerships

Humankind is faced with a double global challenge from the scarcity of fossil fuels, which has already begun, and from the risks to the basis for human life due to the increase in CO₂ in the atmosphere to values that our planet has not seen for a million years.

This challenge can still be met today, but the “window of opportunity” for avoiding drastic negative effects on the world’s economies – due to the steep rise in energy prices and the consequences of an unstable climate with droughts and storms of unprecedented strength – will probably only remain open for another 10-15 years. For this reason, urgent and decisive action is the order of the day.

The world was concentrating in vain on achieving agreement on the values for the targeted reduction in national CO₂ emissions at the failed COP 15 Climate Conference in Copenhagen in 2009, but an alternative positive target would appear to be easier to implement politically and thus ultimately more effective. This reorientation of global climate policy could concentrate on two goals:

- Increasing the share of renewable energies in the national and global energy mix
- Increasing energy efficiency, e.g. as expressed by the ratio of energy consumption to the value created nationally

Even though CO₂-reduction targets are difficult to achieve in countries such as the USA or emerging countries such as China or India, these types of positive goals are readily understood and even contribute to the creation of jobs in sophisticated technology sectors. The European 20-20-20 scenario already contains the goal of 20% of renewable energy in final energy consumption by 2020, which should certainly be extended to a goal of 80-100% by 2050.

No targets have yet been established for energy efficiency, but they can easily be formulated based on current energy intensity values (kWh/€ of gross domestic product). The aim of these calculations must be to formulate a global model that also makes it possible to achieve CO₂ goals. In the IPCC’s 2007 report, it is shown that the world can afford another 750 Gt of CO₂ emissions if global warming of over 2 °C is to be avoided; this is not a large amount in the light of the current annual emissions level of around 30-35 Gt.

A rapid increase in the share of renewable energies in the energy mix and improvements in energy efficiency both require active research and development in these technology-related fields. There is still much research needed, both nationally in Germany and globally.

Figure 1 shows German expenditure on energy research in the last 35 years. The maximum was € 2.4 billion in 1982, spent mostly on nuclear fission research and research on coal and other fossil fuels. Current research expenditure is only around one-third of this maximum, and of this amount, only a third again, i.e. around € 200 million, is directly associated with renewable energies.

Figure 2 shows that this amount has remained approximately constant over the last 30 years; in 2003, it still corresponded to 2.2% of the turnover of the sector, but the figure was only 0.9% in 2008.
An improvement to over €300 million appears likely for 2009, also due in particular to investments in offshore wind. However, it remains to be seen if the research budget for renewable energies that was recently increased in 2009 will continue at the present level.

It can thus be observed that the global challenges outlined above have not yet resulted in long-term increases in budgets for the research necessary to develop new, more efficient and more cost-effective energy technologies.

The impressive growth in this sector, which was stimulated to a significant extent by the financially attractive feed-in tariffs for renewable energies specified in the German Renewable Energy Sources Act (EEG), even led to a significantly reducing percentage for state research expenditure as a fraction of the turnover of the sector.
Figure 3 shows that photovoltaics grew particularly quickly – from a 0.9% share of renewable energies in 2000 to as much as 8.9% in 2006 – in the context of the rapidly increasing power capacities for renewables that tripled between 2000 and 2006 in Germany to reach 30 GW. This is not surprising when you consider that photovoltaic technology is a semiconductor technology which is experiencing a continuous increase in performance accompanied by price reductions, in a manner similar to the development of microelectronics over the last 50 years.

The learning curve for photovoltaics over the last 25 years (Figure 4) shows a continuous reduction in prices of approximately 20% for every doubling of the installed amount. A special development in photovoltaic technology has taken place in recent years: Global demand for PV modules was so strong in the years between 2003 and 2008 that system suppliers could essentially pick and choose the clients that they wished to supply. Despite huge rationalisation gains at manufacturing companies, the prices remained constant and the rapidly increasing profits were mainly invested in quickly expanding capacity, which was necessary and also politically desired. The economic
The global research market

Prof. Weber, Stryi-Hipp

The crisis of the last 18 months has led to a significant cooling-off in the market, and it is interesting to note that the extrapolated learning curve of the last 30 years now applies again thanks to significant price reductions in 2009.

The continuation of this learning curve or even acceleration along it is possible, but this would require funding for application-oriented research and development to increase in line with sector turnover. In parallel, expenditure on fundamental research and development would also have to increase as unexpected breakthroughs are always possible – e.g. in the area of organic solar cells.

In principle, research on all types of renewable energies and on energy efficiency for buildings, transport and production should be supported. However, certain areas are worthy of particular attention: photovoltaics; the conversion of solar thermal energy; wind energy; energy optimisation of buildings; electromobility and the closely related development of electrical storage devices. This should be accompanied by the development of new, intelligent energy-distribution grids which will allow for bi-directional feed-in and storage of electricity.

Photovoltaics have the potential to supply a very significant fraction of electricity generation in a renewable manner and with negligible operating costs in the long term. To achieve this goal, more cost-effective production methods and continuously improving conversion efficiencies are necessary. With system prices below €3/Wp, this technology can already compete with other renewable technologies such as concentrating solar thermal technology or offshore wind.

At the moment, thin-film technology and, in particular, cadmium telluride (CdTe) technology – as supplied by First Solar and others – offer a cost advantage, with module costs of less than €1/Wp being quoted. However, this cost advantage comes at the cost of significant disadvantages in conversion efficiency: While PV modules made from crystalline silicon currently have efficiencies of between 16% and 21%, thin-film modules only achieve between 8% and 11%, i.e. half as much.

Thin-film equipment offers advantages for large-scale systems on cheaply acquired land. However, if the area available is limited, as in the case of roof-mounted systems, good efficiency becomes more important. A keen price war is currently in progress. In particular, manufacturers of solar cells made of crystalline silicon in Germany have to regard the prices of thin-film technology as the target.

The advantage still enjoyed today by German and European technology is under serious threat, and a rapid increase in R&D expenditure in this area is essential for this reason.

The third significant PV technology is concentrating PV, which uses high-efficiency solar cells with conversion efficiencies of up to 41% and degrees of concentration of up to 500; this technology is still in its initial stages, but has the potential to achieve significant market shares in sunny regions.

Solar thermal technology provides hot water without using electricity generation as an intermediate step. There is further potential for improvement here in operations management and in the manufacture of the vacuum collectors that are particularly necessary in zones with cooler climates.

Concentrating solar thermal technology is being used increasingly for electricity generation in sunny regions. This technology is particularly attractive in combination with heat storage, as melted salt solutions make it possible to use heat stored during the day to generate electricity at night too. In one of the latest developments, work is being done on combining this technology with concentrating PV.

The harnessing of onshore wind is one of the most cost-effective renewable methods of power generation. However, good locations are limited in both number and availability, meaning that significant growth is possible at these locations only by repowering existing wind turbines with larger rotors.

Offshore wind presents a completely different situation: We are still faced with major technological challenges here that demand intensive
research work – e.g. on large-scale equipment extending into the 20-MW range, or in the area of corrosion resistance.

The energy optimisation of existing buildings and the development of innovative strategies for new buildings – right through to the Masdar City project for a city that is completely self-sufficient as regards energy – offer huge potential for increasing energy efficiencies, as more than one-third of our energy consumption is used in buildings. The refurbishment of old buildings presents particular challenges, as the development of suitable technologies must be accompanied by support from aids to market introduction here. These should make it possible to distribute the short-term costs over the many years of energy use.

The increase in the use of renewable energies in the transport sector has led to the birth of the field of electromobility. Taking the lead from developments in Japan and China and with the support of significant state support programmes, the German automobile industry is beginning to tackle this challenge. It remains to be seen how and when hydrogen fuel-cell technology will make a breakthrough in the transport sector.

The capacity of battery systems is already sufficient to drive plug-in hybrids with limited electric range and a combustion motor to increase range. With improved battery technology, purely electric vehicles with sufficient range will also become available. There is still need for major research here, both on the batteries themselves and on the energy management necessary for these systems.

The last item that should be mentioned here is the transition required from the conventional unidirectional electricity grid to a bi-directional grid with locally distributed intelligence. With this grid of the future, power consumers will be able to adapt to fluctuating electricity prices and will switch on significant loads when the price is the lowest – e.g. when sufficient wind power is being fed in. At the same time, consumers will also be able to feed in power from wind or solar systems or from the batteries of electric cars, which of course only need to be fully charged when the customer actually wants to use their car. The power grid of the future will also require transmission technology for long distances in the form of high-voltage direct current transmission in order to connect sunny regions in the south, windy and water-rich regions in the north, and the customers.

- Renewable energies only accounted for 13% of the total energy research budgets of IEA states in 2008.
- In international comparison, Germany has the highest share of the energy research budget, but this still amounts to only 33%, while nuclear energy research (including fusion and waste) has 64%.
- Germany is responsible for only 5% of the energy research spending of the IEA countries, Japan 28%, USA 31%.
- When related to gross domestic product, Germany spends €0.20 per €1,000 of GDP (USA €0.25, Japan €0.72).
This brief outline of an energy system of the future shows up many areas where considerable research is necessary. In order to achieve the climate protection targets in time, it is essential that technology expertise be developed more intensively worldwide. However, this can only happen successfully if funding for this research area increases significantly.

Figure 5 shows that research on renewable energies is only responsible for 13% of the energy research budget of all countries in the International Energy Agency (IEA). When related to gross domestic product, Germany spends €0.20 per €1,000 of GDP on research and is thus behind the USA (€0.25) and far behind Japan (€0.72). In the USA, spending on PV research alone was almost doubled from $135 million in 2008 to $260 million in 2009, and this figure is set to rise to $320 million in 2010. In addition, around $800 million is to be spent on 46 Energy Frontier Centers in the next five years, with eleven of these concentrating on PV.

In Europe, close technology partnerships have already been initiated in the area of silicon PV technology by European programmes such as Crystal Clear. Unfortunately, the opportunity has been missed to establish a Knowledge and Innovation Center (KIC) for renewable energies as part of the European Institute of Technology. Nonetheless, it can be expected that further relevant programmes will be part of the 8th EU Framework Programme at the latest. Transatlantic technology partnership will also be strengthened. The Fraunhofer-Gesellschaft has already established the rapidly developing Center for Sustainable Energy Systems (CSE) at MIT in Boston, and the German Federal Research Minister Annette Schavan has signed the first transatlantic agreement on technological cooperation, particularly in the area of renewable energies.

The challenge to humankind is a clearly global one, and for this reason technology expertise must also be bundled globally. The countries that tackle this process the most effectively – and Germany is clearly one of the leaders here – will reap the greatest economic benefits.

On the other hand, growing interest – in Asia, in particular – will result in keener competition. If Germany does not respond to this competition with the necessary level of effort in the area of research and development, it is possible that we will lose our position of technological leadership – something that has already been observed in the past with other key technologies such as microelectronics.
The energy and research policy framework conditions for renewable energies in Germany

For 20 years now, Germany has been expanding renewable energies with the support of state incentive instruments. What is the reasoning behind the systematic retention and refinement of these instruments over this period with the aim of creating a reliable basis for the successful development of renewable energies?

Reasons for the promotion of renewable energies in Germany

Germany is dependent on energy imports to a considerable degree. Almost three-quarters of the total energy consumed must be imported from abroad. The dependence on a small number of supplier countries – e.g. Russia – is increasing. The risk of political dependencies due to the increasing importance of energy is thus also increasing. Reducing the dependency on imports is thus an important aim of German energy policy.

With a share of around 10% for renewable energies in the German energy mix (2008), Germany has indeed made good progress, as renewable energy sources are largely domestic. However, the high share of 90% for fossil fuels provides motivation to further speed up the shifting of energy production in favour of renewable energy sources.

Another reason for supporting renewable energies is the inability of the free market to integrate the high consequential costs of climate change into current energy prices. The costs of environmental damage, damage to health, the disposal of waste from nuclear and coal-fired power plants, and the costs of security measures and of conflicts for energy raw materials are not yet reflected in our energy prices to an appropriate degree. Support for renewable energies, which would avoid the majority of the consequential costs described in the first place, thus helps avoid financial burdens on future generations.

Figure 1
Targets for the expansion of renewable energies in Germany up to 2020
Source: German Federal Ministry for the Environment (2009)
The European Union has set binding targets for the expansion of renewable energies by the year 2020. Member states must achieve a total of 20% of their energy supply from renewable energy sources. Germany, with 18%, is slightly below the average. The German figure is made up of a share of at least 30% of power generation, 14% of heat provision and 12% of fuel supply.

However, the main reason for the promotion of renewable energies in Germany is the economic-technological factor. With the introduction of Germany’s Electricity Feed-in Act in 1990 and its development into the Renewable Energy Sources Act (EEG) that came into force in April 2000, a strong new industry gradually established itself. The fact that renewable energy technologies have been able to compete on the market has led to economies of scale and increases in efficiency. State support has meant that German companies have been able to establish a technological advantage that will become increasingly important in the light of future climate protection agreements. In 2008, German companies achieved turnover of almost €29 billion from the installation and operation of equipment and another €12 billion from exports.

The innovations that have resulted are now available to the whole world in order to reduce CO₂ or help even the smallest units in developing countries to achieve self-sufficiency of energy supply.

Technologies that are close to being market-ready are supported by incentive systems such as electricity feed-in tariffs, premium models or fuel quotas; other technologies that are not yet ready for the market require fundamental research that is mainly conducted by scientific institutes and universities.

### Development of research support

Since 1973, the German federal government has been preparing energy research programmes. The currently applicable, fifth energy research programme is entitled “Innovation and new technologies”. It was initially intended to cover the period 2005 to 2008, and was then extended to 31/12/2010.

In the initial period up to 2008, the programme was given a support budget for fundamental research of €1.7 billion. Although support for renewable energies and energy efficiency grew – at a low level – up to 2008, most of Germany’s research funding is still spent on nuclear technologies, including the decommissioning of plants and research on nuclear fusion.

The four federal ministries responsible for energy issues – i.e. the Ministries of Research, the Environment, Economics and Agriculture – spent a total of €161.2 million in 2008 on institutional support and support for specific renew-
able energies projects. This funding was used for the following purposes:

1. Reduction of costs by increasing efficiency and achieving economies of scales by optimising production processes and improving product lifecycles
2. Development of new technologies
3. Sustainable expansion of renewable energies by investigating ecological and social effects

Technologies for system integration and wind power are becoming more important as part of the project support. Photovoltaics had a 44.1% share of the budget in the 2005-2008 support period, but this figure dropped to 26.3% for project support approved in 2008. On the other hand, the area of system integration has now grown from around 0% to 18.7%, while the wind power area has increased from 21% to 26.6% driven mainly by offshore wind power. This development shows that the processing of large amounts of energy, the storage associated with this, and the intelligent control of energy consumption are becoming increasingly important.

Conversely, less support is being provided for fundamental research as the various technologies become more competitive on the market. In this phase, market incentive instruments become technology and innovation drivers. The German Renewable Energy Sources Act (EEG), which provides for defined tariffs over a period of 20 years for electricity fed in from renewable sources, has proven one of the most successful support measures worldwide.

How the feed-in tariff works

The five core elements of the EEG were defined after a ten-year learning period (1990-2000) with the Electricity Feed-in Act, which was the predecessor of the EEG, and they continue to apply today:

- **Priority for EEG electricity**: Every system for the generation of electricity from renewable sources must be connected to the electricity grid by grid operators. Every kWh of electricity may be fed into the grid and is transmitted to consumers.
- **Defined remuneration**: Every kWh of electricity from renewable energy sources receives a guaranteed tariff, which in turn makes it possible to calculate the payback period for the investment in equipment.
- **Long period of applicability**: The remuneration applies for a 20-year period, which gives investors a high degree of yield security. During this period, operators are free to opt out of EEG tariffs or opt back in again, depending on whether higher prices can be obtained on the open market.
- **Technology-specific support**: Each technology offers different advantages that cannot only be measured in terms of current economic performance. The other factors include the maturity of the technology, the technology’s potential for the future, the suitability for the location, and issues relating to landscape and nature conservation. The principle is thus to support each technology (PV, wind, biomass, ...) with its own different tariffs in order to cover the respective costs of each technology.
- **Degression**: In order to speed up learning effects and avoid windfall gains, an annual reduction of the initial tariff has been specified. This innovation pressure helps all technologies to gradually approach grid parity, i.e. a price level which reflects that paid by end users.

A significant factor in the EEG’s success has been and continues to be the fact that it is independent of the government’s current budgetary policy. As the feed-in tariffs are fully financed by a levy system between producers, grid operators and consumers, there is no “EEG budget”
that is subject to the whims of overall budgetary decisions.

This situation also helps provide the financial security desired by investors for the development of larger projects. This independence must continue as it is.

Costs and benefits of the EEG

Additional costs for society as a whole are of course also associated with the EEG, as it compensates for the difference between the lower market price for conventional energies and the costs for renewable energies. If the entire EEG levy of €4.5 billion for 2008 is considered per kWh unit of electricity, every consumer had to pay an extra 1.1 cents, which represents around 5% of the average consumer electricity price. When this figure is considered per average household in Germany, additional costs of around €3 per month arose.

On the other hand, the support for renewable energies has led to a remarkable boom for the industry. Alongside the €40 billion in turnover thanks to investments, operation and exports, the sector has also created 280,000 jobs so far.

Equipment efficiencies have increased significantly. For example, modern wind turbines now produce 50 times more electricity than turbines in 1990 did, thanks to innovative technology, larger rotor diameters and greater hub heights.

The CO₂ emissions avoided by renewable energies in 2008 amount to around 72 million tonnes for the electricity sector alone. If the CO₂ emissions avoided by the heating and fuel sectors are also included, around 110 million tonnes of CO₂ in the atmosphere have been avoided. No other climate protection instrument apart from support for renewables can boast similarly high levels of CO₂ savings. The specific costs of the savings per tonne of CO₂ differ and are higher than for other measures in certain cases; however, the potential for development and cost reductions for these technologies is great, and the demand envisaged on the world markets is immense too.

Germany’s systematic support for research is indeed showing the way: Technologies that are

**Average Consumer Electricity Price 2009**

Support for RE generates only a very small share of the average electricity price.

- contribution to cogeneration of heat and power: 0.2 ct (1%)
- sales and distribution: 0.8 ct (3%)
- measuring: 0.8 ct (3%)
- support for RE by EEG: 1.1 ct (5%)
- concession levy: 1.8 ct (8%)
- electricity tax: 2.0 ct (9%)
- grid fee: 5.9 ct (26%)
- VAT: 3.7 ct (16%)
- generation: 6.9 ct (29%)
not market-ready are developed by means of fundamental research, and technologies close to market maturity are launched with the help of incentives and are then subject to innovation cycles.

However, two weaknesses can be identified: With current funding of €161 million, fundamental research is not receiving the same level of financial support as in the USA or Japan, which are investing more heavily in their research capacity in the area of renewable energies. In addition, more effective research incentives must be developed in the areas of heat and fuels, which could potentially make major contributions to climate protection, in order to make progress here more quickly.
More and more governments worldwide are setting ambitious targets for the expansion of renewable energies. The diversification of the energy mix by increasing the share of renewable energy sources is not only critical for the reduction of CO₂ emissions, but also offers an opportunity to harness new economic potential, particularly for numerous developing and emerging countries as these countries often have significant natural resources. Renewable energies offer secure energy supply and can stabilise electricity grids, even with a continuously growing energy demand. In subsidised energy markets, falling energy imports give the exchequer greater room for financial manoeuvre.

One difficulty with the practical implementation of expansion targets is that specialist knowledge is required for the successful and, above all, speedy development of the renewable energy sector.

Ministries have to develop laws and regulations, decision-makers from the private sector are in demand for the financing of equipment, the analysis of viability and the management of complex project processes, and engineers and technicians are needed for engineering design and for installation and maintenance. A lack of expertise at one of the bodies involved can quickly lead to a bottleneck in the value-added chain.

The TREE project (Transfer Renewable Energy & Efficiency) initiated by the Renewables Academy is implementing international knowledge transfer where all key participants are involved. Seminars on capacity building, which are available for various levels, provide decision-makers on policy and economic matters from developing countries, emerging countries and transition countries with the expertise necessary to implement renewable energy technologies in a fast and sustainable manner.

Other countries should benefit from Germany’s experience in the last 20 years with the creation of suitable policy framework conditions and economic incentive mechanisms, the harnessing of financing methods, the establishment of commercial expertise and the implementation of technologies.

TREE is being supported by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) as part of the International Climate Protection Initiative, as decided by the German Bundestag. Income from the sale of CO₂ certificates for emissions trading is invested in national and international climate protection measures.

In 2008 and 2009, a total of 170 projects were initiated in developing, emerging and transition countries. TREE is one of these projects that aim to make cost-effective use of existing potential for the reduction of emissions and also to demonstrate the technological feasibility of innovative model projects for climate protection. Increasing energy efficiency, expanding renewable energies and the transfer of knowledge are all supported in a targeted manner.

RENAC offers seminar stipends for participation in TREE seminars on solar energy, wind power, bioenergy and energy efficiency technologies. The most important selection criterion is that the applicants be able to apply the knowledge they acquire in their everyday work as directly as possible and that they pass on this knowledge as widely as possible.
However, other factors such as motivation, level of qualification and English-language skills also play a role.

In order to teach the principles of clean energy supply in the long term, the educational concept behind TREE is structured in a multi-dimensional manner. With the one-week introductory seminars in Berlin, every target group can learn about the technology aspects relevant to them: After an introduction to technology issues, decision-makers on policy and economic issues can learn more about the structuring of framework conditions, about project financing and management, and about economic viability, market entry, legal and insurance matters related to renewable energies. For engineers, the focus is on planning, installation, maintenance and quality management for equipment. Individual issues can be dealt with in more detail in later specialised seminars that build on the introductory seminars. Certain courses are also conducted in the target countries.

These seminars are then followed by an e-learning phase. In cooperation with the Beuth University of Applied Sciences in Berlin, RENAC has set up an online learning portal that participants can use to complete specialised seminars. In addition, participants can also use the online advice facilities to obtain suggestions and tips from lecturers on practical projects. Further services are also available in addition to the learning services – e.g. a series of publications for ministry staff regarding legal aspects of renewable energies or a mobile exhibition that offers a closer look at various technologies.

TREE was started in November 2008. In the first year, the 560 participants in total came from 14 countries in South America, Africa and Asia. This year, the states that have signed the IRENA (International Renewable Energy Agency) statute and those from the MENA region can also participate, i.e. a total of almost 100 countries.

The thematic focus this year is the training of project developers from industry and private sector service-providers, as the economic strength of a given country is increased when the prerequisites for investments are created and new areas of activity in energy efficiency and renewable energies are established. Since suitable policy framework conditions are the prerequisite for this, there is also a focus on courses for decision-makers on policy and representatives from specialist committees in the legislature area.

The training offered as part of TREE supports participants in expanding capacities in their own participating countries. The crucial element here is not only the transfer of knowledge, but also the initiation of international dialogue.
The TREE seminars in Berlin represent an opportunity for participants from various continents to meet and exchange their experience. And they can stay in contact with the help of the TREE Community, and can discuss current problems or projects and thus ultimately contribute to the progress of the expansion of renewable energies in their own country thanks to the support of a worldwide network.

The project is being supported by the German Federal Ministry for the Environment:

Additional information:

Weitere Informationen:
www.tree-project.de
www.renac.de

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**Country | Applicants | Total participants | Engineers | Decision-makers | Specialised seminars | Regional CSP seminars**
---|---|---|---|---|---|---
Argentina | 5 | 3 | 1 | 2 | 0 | 0
Brazil | 72 | 100 | 48 | 7 | 9 | 3
Chile | 62 | 80 | 13 | 10 | 13 | 2
China | 106 | 13 | 4 | 6 | 3 | 0
India | 66 | 22 | 8 | 9 | 5 | 0
Indonesia | 59 | 19 | 3 | 3 | 8 | 0
Jordan | 56 | 80 | 8 | 13 | 1 | 62
Malaysia | 82 | 26 | 9 | 8 | 9 | 0
Mexico | 68 | 34 | 9 | 13 | 0 | 42
Namibia | 47 | 54 | 9 | 13 | 0 | 42
Peru | 35 | 88 | 2 | 10 | 2 | 81
Philippines | 42 | 18 | 6 | 3 | 0 | 4
South Africa | 57 | 70 | 18 | 8 | 2 | 47
Thailand | 77 | 20 | 10 | 7 | 0 | 3
Total | 834 | 558 | 107 | 116 | 56 | 315*

Total participants in seminars in Berlin and regional CSP seminars: 558

Participants in CSP seminars are not taken into account in the “Applicants” category, and some have also taken part in seminars for engineers and decision-makers.
## Overview seminars for policy decision-makers

**Brief description:** Participants in these courses will receive a comprehensive overview of the most important technologies, how they work, and their possible applications. Strategies for the development of suitable framework conditions will be identified and financing instruments will be explained. Participants will be able to create important stimuli for the use of renewables and energy efficiency technologies in their own countries.

**Topics**
- Renewables (grid-connected) and energy efficiency: technologies, framework conditions, financing
- Rural electrification: technologies, framework conditions, financing

**Number of seminars:** 4  
**Duration:** 5 days  
**Location:** Berlin

## Technology-specific specialised seminars for policy decision-makers

**Brief description:** In these seminars, the lifecycle of renewables and energy efficiency applications will be highlighted in various project phases and from the perspective of various participants such as financiers, project developers, legal specialists and operators. Existing systems will be compared and analysed. Participants will be given specialist knowledge on technology, costs, financing, legal aspects, quality assurance and the necessary framework conditions.

**Topics**
- Grid-connected photovoltaics
- Photovoltaic stand-alone systems (including examples of applications in water management)
- Biogas and biofuels
- Wind power (large-scale and small-scale)
- Solar thermal energy (large-scale and small-scale)
- Energy efficiency in industry and commerce, in the building sector and in the water sector
- Hybrid systems

**Number of seminars:** 7  
**Duration:** 5 days  
**Location:** Berlin

## CSP seminars for engineers and decision-makers from the areas of policy and business

**Brief description:** The participants will acquire knowledge about the CSP technologies currently available, the state of the art in technology, and about possible applications. They will develop an understanding of the most important implementation steps and the main factors influencing the success of a CSP project.

**Topics**
- Prerequisites, technologies, project management, costs, financing, local value creation, grid connection and operation of solar thermal power plants

**Number of seminars:** 3  
**Duration:** 3 days  
**Location:** Abu Dhabi, Mexico, India

## Seminars for financiers and project developers

**Brief description:** The seminars aim to support investments in renewables and energy efficiency projects by providing training for financiers and project developers. Economic analyses of various technologies and of various application conditions are presented, and viability analyses, financing mechanisms and examples are introduced.

**Topics**
- Financing for renewables and energy efficiency with technical introduction, cost calculations, examples of financing

**Number of seminars:** 4  
**Duration:** 2 days  
**Location:** Malaysia, Abu Dhabi, South Africa, Mexico
The CERINA Plan – An alternative to the Kyoto instrument

1. Introduction

International negotiations on a follow-up agreement for the Kyoto Protocol, which will expire in 2012, have stalled to a significant extent and it is currently not expected that agreement will be reached in Copenhagen. The Kyoto instrument is essentially based on the approach of limiting the CO₂ emissions of individual countries, with the amounts ideally agreed upon by the international community. An alternative instrument, the CERINA Plan (CO₂ Emissions and Renewable Investment Action Plan), will be presented here. Its model approach is based on investments rather than setting limits.

2. Worldwide CO₂ emissions – the status quo

Global carbon dioxide emissions in 2008 rose to a new record value of 31.5 billion tonnes and are thus 40% above the level of 1990 (IWR 2009). The goal of the Kyoto Protocol was to reduce emissions in Kyoto countries by 5.2% by 2012 relative to the reference year of 1990 (UNFCCC 1998). However, emissions have risen considerably worldwide because of economic development in numerous emerging countries. This outcome is evidence that the Kyoto limit mechanism does not work. One cause that can be identified is the fact that political representatives cannot or do not wish to accept economic limitations for their own countries in negotiations in connection with climate protection. Resistance in their home countries to upper limits and emissions trading with the threat of
companies moving abroad to new locations all lead to mistrust among politicians in the context of global competition for industrial investment.

This results in low levels of willingness to make voluntary commitments. These are the reasons why it is not expected that a new climate protection treaty will be agreed in Copenhagen. Even in the case of agreements between countries, the issues of whether and when CO₂ reductions will actually be implemented and what sanctions apply if targets are not reached are still open. The example of the Kyoto Protocol is evidence that these problems still remain.

3. The Cerina Plan – An alternative investment approach

The IWR approach is based on investments rather than setting limits. The basic principle of the CERINA Plan is to directly link CO₂ emissions of individual countries to investments in renewable energy. The higher a country’s CO₂ emissions, the higher the investments they must make in renewable energy technologies. Every country emits CO₂, which means that every country is obliged to take responsibility and make a proportional contribution. The annual global increase in CO₂ is known (in millions of tonnes), which means that the necessary investments in renewable energy generation systems (electricity, heat, fuels) required to at least compensate, and thus slow down the global CO₂ increase, can be calculated retroactively.

In 2008, global investments in renewable energy systems totalled €120 billion. In order to stabilise the CO₂ emissions, the investments would have to be increased fourfold, to at least €500 billion per year, according to IWR calculations.

The most important aspect of the CERINA Plan is the distribution of the investments to the various countries, as determined by the CO₂ emission quantity in each country. The more CO₂ a country emits, the higher the investments required in the country. With total global CO₂ emissions of 31.5 billion tonnes, and investments totalling 500 billion euros required per year for renewable energies, this results in a theoretical CO₂ offset price of €16 per tonne. The specific investments in renewable energy technologies can be calculated for each country according to the country-specific CO₂ emissions. IWR calculated the investments in renewable plant technology required based on the individual CO₂ emissions for a total of 65 countries.

Sample calculations

According to the CERINA Plan, China, which currently has the world’s highest CO₂ emissions at 6.8 billion tonnes (2008), would have to initiate annual investments in renewable energy technologies of 109 billion euros by means of political framework conditions to build wind, solar, hydroelectric or biomass-powered plants. India – with emissions of 1.4 billion tonnes of CO₂ – requires investments totalling 22.5 billion euros, while Germany would have to invest 13.7 billion euros, for emissions of 860 million tonnes. The CERINA Plan also takes smaller countries with lower emissions into account. For example, Hungary, with emissions of 60 million tonnes (2008), would have to organise investments of one billion euros, and New Zealand would require investments of 600 million euros.

4. Outlook

Copenhagen is unlikely to produce a binding climate protection treaty. As an alternative to the Kyoto instrument, the CERINA Plan offers an opportunity to establish a transparent, verifiable and clear system for the reduction of emissions.

The advantage of the CERINA model approach is that the direct linking mechanism gives each country two types of action to take to fulfil their obligations: They can either reduce emissions or increase investments in renewable energies. Accordingly, countries with lower emission values make lower contributions than countries with higher emissions. Each country can select the option suitable for them. In the end, the increasing proportion of renewable energies or the reduction of CO₂ emissions via savings or
increased efficiency will result in a reduction of global emissions.

Further information and contact options:

www.cerina.org
www.iwr.de
www.renewable-energy-industry.com

Bibliographie


Research for global markets – Technology partnerships for renewable energies

- The German federal government’s strategy for the internationalisation of science and research
- Off to new markets! – Renewable Energy Export Initiative
- Solar construction – Climate-appropriate construction in other climates
- Concentrating solar collectors for process heat and electricity generation
- Research on geothermal electricity generation – On-site laboratory at Groß Schönebeck
- Storing bioenergy and renewable electricity in the natural gas grid
- Solar thermal power plants – Export hits without a domestic market
- Concentrating photovoltaics (CPV) for countries with high direct irradiation
- Requirements for integration of wind energy into the grids of various countries
- Off-grid power supply and global electrification
The German federal government’s strategy for the internationalisation of science and research

In addition to the opportunities, the globalisation process also presents us with great challenges: Germany must maintain its international technological competitiveness; at the same time, it shares the responsibility for preserving global stability and sustainable living conditions. Science and research are essential for both tasks.

Against this background, the federal government developed its strategy for the internationalisation of science and research, which was passed in February 2008 and is being continued under the current government. The strategy pursues four main objectives:

- Enhancing cooperation in research with the world’s best.
- Availing of innovation potential internationally:
  This includes German companies establishing partnerships with leading international high-tech locations and R&D centres.
- Enhancing long-term collaboration with developing countries in education, research and development.

Germany and the European Union have set a target of investing 3% of their gross domestic product in research and development by 2010. We can only remain competitive in a world with an increasing number of competitors if we consistently work on the 3% target. In addition to the USA and Japan, China, India and Korea, as well as other former developing and emerging nations, are becoming new partners and competitors.
Using the German research and innovation potential to take on international responsibility and contribute to solving global challenges.

Meeting the globally increasing energy demand with a sustainable and affordable energy supply, which protects the environment and climate, is one of the most important tasks in this context. Germany is an international leader in research and production of technologies for renewable energies and efficient use of energy. The goal of internationally-focused research must be to contribute to strengthening this leadership position and preparing the way for global use of these technologies.

However: Other countries have also identified the potential and market opportunities offered by renewable energy and are making significant investments in production and research, in particular in the photovoltaics and wind power technologies. If Germany wants to be successful in this competition, we must be better than others through our research, develop our technologies and work strategically in promoting research and the next generation of scientists, industry and infrastructure.

„Research for global markets“, as in the title of the 2009 FVEE annual conference, primarily means collaborating internationally, and doing so in a variety of ways:

- Academic exchanges and collaboration with the best research centres in the world are essential if we are to retain our excellent position in research. We will only be able to continue to develop top technologies and offer them worldwide if we remain an attractive, internationally networking scientific location.

- Up and coming scientists must be educated internationally and the mobility of scientists must be promoted if we are to succeed in this context.

In order to support this, opportunities for international research cooperation should be improved, internationally-focused research infrastructures should be expanded further and the presence of German universities and research institutes overseas should be enhanced.

Synergies with measures and funding instruments of the European Union should be used for this purpose.

Figure
International mobility of scientists and researchers from and to Germany
Many of the target countries for our environmentally friendly energy technology products are developing countries. However, simply exporting technology is not enough here; we also have to prepare the ground for environmentally friendly supply and usage concepts with strategically prepared cooperation projects. This includes the fostering of expertise, specialist institutions and the training of experts. This can only succeed if collaboration with developing countries in education, research and development is enhanced. Scientific and technological collaboration must complement development policy collaboration if this target is to be achieved. Important tasks in this context include initiating dialogue in international education and research, supporting research in humanities and social sciences and further developing European and multilateral instruments.
Off to new markets! – Renewable Energy Export Initiative

Renewable energy is becoming more and more important for the global energy supply. German companies in this industry have a leading position in the international competition, and their technologies are highly esteemed and in demand overseas.

The Renewable Energy Export Initiative was established in 2003 based on a decision by the German Bundestag to make an active contribution to global climate protection by distributing German technologies, and to support German companies in positioning themselves on international markets.

Since then, the initiative has been managed, coordinated and financed by the German Federal Ministry of Economics and Technology (BMWi). It is supported by Deutsche Energie-Agentur GmbH (German Energy Agency, dena), the Association of German Chambers of Commerce and Industry (DIHK) and the affiliated German Chamber Network (AHKn), Germany Trade and Invest (GTAI) and the German Society for Technical Cooperation (GTZ).

With a wide range of measures, specially tailored for the requirements of small and medium-sized companies, the Export Initiative supports the German renewable energy industry in opening new sales markets overseas:

1. Market information

At events in Germany on selected target countries, entrepreneurs can learn about potential sales markets.

In addition to this, numerous publications offer compact industry profiles and comprehensive country and market analyses. A weekly newsletter reports on the latest industry news and trends in the target markets.

2. Business development

In order to support German companies in business development worldwide, the Export Initiative offers the so-called AHK business travel programme. It involves individual travel for German entrepreneurs to potential cooperation partners and a central presentation event in the target country.

The Export Initiative organises travel for foreign potential customers or decision-makers from the fields of business and politics in the target country to Germany with the purchaser or multiplier programme. This allows them to learn about German technology on-site, and do business with German providers of products directly.

3. Programme for developing countries

By providing market information and developing contacts to local experts, business partners and decision-makers on-site, the
Project Development Programme (PEP) assists German companies in positioning themselves in developing countries. In addition to this, the programme also supports local private-sector structures in these countries via knowledge and technology transfers.

4. Marketing support

The Export Initiative offers support for successful overseas marketing. This includes joint stands at trade fairs overseas and presentation of German renewable energy companies in the Internet or in multilingual marketing and exhibition material under the image label “renewables – Made in Germany”. In addition to this, the Export Initiative also supports the image-enhancing installation of solar energy systems on representative institutions as flagship projects overseas. The virtual marketplace www.renewablesb2b.com allows companies to make contacts around the world quickly and easily and market their products.

The economic dynamics of companies who have availed of the services of the Export Initiative have developed particularly successfully. They can save a lot of time and money when entering the market.

See www.exportinitiative.bmwi.de for further information on the services of the Export Initiative and current events.
Solar construction – Climate-appropriate construction in other climates

If the climatic conditions in a region permanently or temporarily deviate from the range considered comfortable by users, measures must be taken to condition the interior climate to make the living environment pleasant. The task of climate-appropriate construction consists in ensuring comfortable interior conditions all year round with constructive means only, with a minimum use of fossil fuels and a maximum percentage of renewable energy.

Modern designs often ignore the fundamental climate-appropriate principles and then attempt to use high-tech systems (generally with significant consumption of fossil fuels, and sometimes with air conditioning systems which are found unpleasant) to compensate for incorrect construction physics decisions. In many countries, buildings are designed and built based on western models, even though they may already have led to construction physics problems in their countries of origin. In locations with warm external climates, the energy consumption of buildings considered unfavourable in European or American conditions increases significantly, as much of the energy must be used to cool the building. However, especially in countries in the sun belt, use of solar thermal cooling and air conditioning processes is a promising alternative to electrically powered chillers. Climate-appropriate construction, which fulfils the criteria of summer-time heat protection, can guarantee a more pleasant interior climate and save a lot of energy.

Unfortunately, architectural designs are transferred from one climatic region to another without a second thought, even if they are completely unsuitable there. The main reasons for these violations of the principles of climate-appropriate construction are historical and social:

- Historically, the inappropriate building styles were initially imposed by the colonial powers. They took possession of overseas territories and forced the construction style of their home countries on the inhabitants of the colonies against their will. For example, the building types appropriate and adapted for the climate in Holland are absolutely unsuitable for the former Dutch colony of Indonesia.
- Today, emerging countries manufacture and install technical systems in buildings which do not suit the local climate due to a naive belief in progress and a lack of knowledge of construction physics. The same applies for the uncritical application of European construction standards. Regulations which may be appropriate in Europe are not necessarily suitable for China or Taiwan. Local architecture, which grew organically over centuries in the respective climatic regions, is not appreciated or is disregarded by domestic architects. They want to be “modern” and imitate the designs considered so (e.g. glass and steel facades as built in America).

Principles of climate-appropriate construction

Depending on the climatic conditions in a region, the interior climate of a building must be adjusted in a way that pleasant conditions are provided for its users. Different comfort criteria and different measures are key for conditioning, depending on whether it is too cold or too hot outside. Figure 1 shows the step-by-step procedure for minimising the energy requirement. Step-by-step optimisation makes evaluation and prioritisation of the individual measures easier, and facilitates cost-benefit analysis.
In order to achieve the project target of minimum use of fossil fuels and maximum use of renewable energy, the following procedure is recommended:

First, the climatic conditions and the conditions due to the planned use are analysed on site. Adjusted for these conditions, the technical equipment of the buildings should be designed such that as little energy as possible is required for internal conditioning and any other requirements. While a solution optimised specifically for the local climate must be developed during planning of a building, the same potential savings may be utilised for the use-specific energy requirements as in Europe. Based on the concepts developed and taking the requirement figures of comparable premises into account, the expected overall energy requirements are determined.

In a further step, the renewable energy sources available at the project location are analysed and their suitability and economic feasibility for this project are evaluated. As a result, a recommendation of suitable systems and equipment and a mathematical estimate of the proportion of the overall energy requirement which can be supplied from renewable sources are drawn up. Any remaining energy requirements are covered with conventional processes, whereby an environmentally sensible and economic combination with the renewable systems is the goal. This results in an optimal or multiple equivalent overall concepts for energy supply.

1st step: Climate factors and climatic conditions

A precise analysis of the climatic conditions on site is essential in determining the feasibility of a project in terms of energy and construction physics. Key external climatic factors which influence the energy requirements of a building are as follows:

- Temperature and relative humidity of the exterior air
- Irradiation intensity
- Wind and rain may be important if the external air or evaporation cooling are to be used to improve the indoor climate.

For apposite planning and construction, the factors arising from the local climatic conditions must be taken into account. The influences on the user’s comfort, the safety of the buildings and the premature aging of construction materials must also be analysed.
2nd step: Energy optimisation of buildings

The main adjustments and construction physics influences are shown in Figure 2.

Accordingly, for a climate-appropriate building design, e.g. for a location in the United Arab Emirates, where climatic conditions require cooling but no heating, the following measures must be ensured:

- Favourable ratio of external surface to building volume (i.e. where possible, multi-storey, larger units)
- Preferable orientation of buildings from east to west as this results in the lowest irradiation effect (due to the extremely high sun)
- Minimise window surfaces, use double and triple glazing, avoid windows facing east or west due to the strong irradiation
- Preferably automatic shading, low SHGC (Solar Heat Gain Coefficient) values of windows reduce heating by the sun
- Good thermal insulation of the roof surfaces in particular
- Lightest possible colours for the external surfaces, to reflect more of the solar irradiation and absorb less
- Decrease the exchange of air in warm periods to prevent excessive heating of the building, ventilation system with heat recovery
- Avail in full of options for nocturnal ventilation (care is needed in high humidity areas)

- Where possible, urban developments should be planned such that streets are narrow and the buildings opposite one another provide shade.

3rd step: Efficient building conditioning and technical systems

According to the project targets, renewable energy should be used to cover as much of the energy demand as possible. The potential natural or renewable energy sources must be taken into consideration and their availability and respective possible energy supply potential must be evaluated based on technical and economic criteria.

As already stated in the introduction, as much of the energy required to generate cooling as possible should be provided from regenerative energy sources. As a result of the high solar potential which is available in many cases, the use of solar energy for conditioning buildings and open spaces should be investigated first. Use of photovoltaic systems for direct conversion of solar irradiation to energy makes sense in countries in the sun belt, due to the high availability of solar irradiation. For example, the annual total irradiation in Dubai is 2000 kWh/a m². That means that standard modules can produce yields of 100 MWh per annum on a surface area of approx. 500 m². The only problematic or limiting factor for use on site is soiling via sand and dust.

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Figure 2
Construction physics influences and adjustment options for cooling energy of buildings
There is a variety of different thermally driven processes for generating cooling and providing fresh air conditioning using (solar) heat. In general, two types must be distinguished:

- Closed systems which provide cooling for comfort air conditioning in the form of cold water
- Open processes used to condition fresh air

Which of these processes is suitable for a particular application depends in particular on the climatic conditions (irradiation, external temperature, external air humidity) on site, in addition to the building design, building use and comfort requirements. High irradiation leads to great system loads, while high external temperatures and air humidity limit the performance of the systems due to the recooling required.

Conclusion

Climate-appropriate construction largely depends on constant consideration of the prevailing climate parameters during the building design phase.

The energy required for indoor climate conditioning can be significantly reduced via simple building measures. Studies show that the potential savings in building energy requirements can reach up to 75%. To achieve this, the various measures must already be taken into consideration as part of planning:

- Climate-appropriate building design
- Use of new energy-saving technologies
- Combination of high-efficiency systems for supplying power and cooling

Constructive measures in particular can only be changed to a minor extent after the fact. The design and combination of the system technology also requires comprehensive planning, as over or undersizing leads to a significant increase in the primary energy requirement or to a lack of conditioning in the interiors. Therefore: First, build appropriately for the climate, then install air conditioning appropriate for the building!
Concentrating solar collectors for process heat and electricity generation

Concentrating solar thermal collectors for global markets

Concentrating collectors are particularly suitable for generating process heat and electricity in climatic regions with high direct solar irradiation potential around the world. The earth’s so-called sun belt extends to the left and right of the equator, incorporating Southern Europe, North Africa, and the great deserts of our planet.

Collectors in the temperature range from approx. 250 ° – 450 ° are suitable for use in solar thermal power plants, such as those planned for the Desertec project. To date, thermal oil has primarily been used as the heat transfer medium in parabolic trough power plants. A future alternative is direct evaporation of water for parabolic troughs and linear Fresnel collectors, a cost-effective and environmentally friendly heat transfer medium. Smaller concentrating collectors, which generate process heat at temperatures between 150 °C and 300 °C, are suitable for solar cooling and for combined heat and power generation. This allows direct supply of industrial companies with heat/cooling and electricity. That is particularly interesting for regions with unstable electricity grids or grid-remote regions. In India alone, the off-grid electricity generation in the power range below 1 MWel accounts for 12% of the overall electricity consumption.

In Europe, approx. 27% of the overall final energy requirement is accounted for by industrial process heat. Approx. 30% of this requirement occurs at temperatures below 100 °C and a further 27% occurs in a range between 100 and 400°C [1].

Figure 1
Overview of concentrating collectors, applications and corresponding operating temperatures
A majority of process heat can be generated via solar energy. Processes with great potential for integration of low-temperature process heat up to 150 °C and medium-temperature process heat up to 400 °C are used in the foodstuffs and textile industries, for example, as well as in laundries, the metal and paper industries.

**Stationary collectors for generating low-temperature process heat**

One approach to utilising the great potential in the area of low-temperature process heat is the development of low-concentration stationary (i.e. do not track the sun) collectors. Compared with focusing collectors, they have the advantage that much of the diffuse solar irradiation can also be used for energy conversion. Compared with standard flat-plate collectors, they generally have significantly lower thermal losses. Therefore, these collectors are suitable for the temperature range between 80 °C and 150 °C [2]. An example for this kind of collector concept is shown in Figure 2 – the RefleC collector, developed by Wagner & Co. Solartechnik in cooperation with Fraunhofer ISE as part of a project funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety.

Based on the technology of standard flat-plate collectors the following goals are pursued:

- Reduction of thermal losses by using a second transparent collector cover and concentrating reflectors
- Lower costs and better draining in the event of stagnation than evacuated tube collectors
- Adaptation of the maximum collector output to the load profile of the application to be supported (via the shape of the reflectors)

Simulation results in Würzburg for the version shown in Figure 2 indicate that at a constant input temperature of 120 °C, the annual energy yield is 40% higher than for a double covered flat-plate collector due to the use of reflectors.
Direct evaporation for power plants

In generating electricity in solar thermal power plants, the system efficiency is primarily determined by the upper process temperature. Currently, a synthetic heat transfer oil stable up to approx. 400 °C is used in parabolic trough fields. A further increase of the process temperature, and thus the system efficiency, is not possible with this approach.

However, if water is evaporated directly in the collector arrays and overheated, the upper process temperature can be increased significantly. Direct evaporation of the water in the collector array is far more complex than the current technology from a process technology point of view, due to the two phase flow and the great difference in density between water and steam. The fundamental controllability of the direct solar evaporation was demonstrated successfully in the DISS test system at the Plataforma Solar de Almería (PSA) during over 10,000 operating hours.

Current development targets consist in improving key components of the collector array so that they can be used at temperatures of up to 500 °C and pressures of up to approx. 130 bar. The research efforts in this area focus on

- Absorber tubes, in which the temperature stability of the selective coating must be increased,
- Flexible pipelines, which must remain flexible at significantly higher process pressures, and
- The storage system in which economic solutions are developed for storing the latent evaporation heat.

The development work has now reached a level of maturity which encouraged German and Spanish consortia to produce initial demonstration systems. At the beginning of 2009, Novatec-Biosol commissioned the first solar thermal power plant with direct solar evaporation near Murcia (Spain). The power plant has an electricity output of 1.2 MW and uses linear Fresnel collectors (Figure 3).

Industrial process heat and combined heat, cooling and power generation

Steam is often used in industrial companies and hotels to supply heat to various consumers.

Figure 3
Collector array of the first solar thermal power plant with direct solar evaporation near Murcia
(Image: Novatec-Biosol)
Small heat transfer surfaces and rapid heating of the connected processes are key advantages. Solar collectors can provide steam for this purpose; however, so far only a few systems have been built which use this principle. Steam is generated indirectly, oil or pressurised water is heated in the solar array and then routed to a steam generator or a pressure release. However, direct evaporation in the solar array can increase the efficiency and possibly decrease the system costs [3].

The direct evaporation is currently being demonstrated in the “Pilot solar process heat generation system with parabolic trough collectors” project. For this, 100 m² of Solitem PTC1800 collectors were installed on the roof of a production hall of the Alanod company with funding by the BMU [4]. The solar array is operated in recirculation mode, i.e. only part of the water is evaporated. The water/steam mixture is then routed to a steam drum and separated there. The saturated steam is routed to the production steam mains, as soon as a pressure of over 4 bar (abs), equivalent to a temperature of 143 °C, is reached. The water in the steam drum is pumped back into the solar array (recirculated). The evaporated water quantity is routed back to the solar array from the condensate line (Figure 4).

The combined generation of electricity and heat was studied thoroughly at Fraunhofer ISE in the “Medifres” project funded by BMU. Case studies showed that under favourable conditions in high irradiation countries, replacing diesel generators with combined solar heat, cooling and power is already worthwhile. Companies and research institutes can network on the topic of „Medium and Small Scale CSP“ via the www.mss-csp.info homepage.

Summary and outlook

Concentrating collectors can make an important contribution to future solar heat and electricity supply. Concentrating collectors support the industry in decreasing their dependency on fossil fuels.

Decentralised combined heat, cooling and power can be an interesting future option. In order to establish these technologies globally, further demonstration projects are required, as well as research and development in the field of small-scale thermal engines, system integration and collector development customised for target markets, to develop concentrating collectors as an important component in future.
Literatur


Research on geothermal electricity generation – On-site laboratory at Groß Schönebeck

In Germany, geothermal heat can be provided from deeper reservoirs from depths of 400 m or more (deep geothermal energy) for large-scale heat grids and for electricity generation – combinations are also possible.

The technologies for use in deep geothermal energy generally require at least one production borehole and one reinjection borehole, which access water with sufficient temperature from a deep geothermal reservoir as required. The thermal water circuit is closed above ground, the energy is generally transferred to the respective consumer via a heat exchanger, and the cooled water is returned to the reservoir via the reinjection borehole (Figure 1).

The geothermal resources available in Germany consist of deep hot water (hydrothermal systems) to a lesser extent, and to a far greater extent of thermal energy stored in plutonic rock (petrothermal systems).

Hydrothermal systems are deep strata which carry water (aquifers) with sufficient natural hydraulic conductivity (permeability). In addition to the temperature of the aquifer, the key for economic operation of hydrothermal systems is the pump rate which can be achieved. For reasons of economy, hot water production of at least 100 m³/h is often required. While a specific temperature can always be reached at a corresponding depth, the second condition considerably restricts the number of possible locations.

Figure 1
Accessing a geothermal reservoir
Accessing these hot aquifers primarily involves a discovery risk. While the reservoir depth and temperature can be predicted relatively precisely, the main risk is insufficient aquifer permeability and thus insufficient thermal water production.

In petrothermal systems, geothermal energy is collected from plutonic rock strata irrespective of the hydraulic properties of the geothermal conductor. While the temperature distribution in the earth’s crust is prescribed by nature, petrothermal systems can improve the flow conditions to the borehole via engineering processing with engineered geothermal systems (EGS) technologies. Figure 2 shows the result of such a treatment based on the example of the on-site geothermal laboratory in Groß Schönebeck. In special cases, such treatments can be used to generate an artificial heat exchanger underground, from which the deep geothermal energy is withdrawn with surface water. In this way, petrothermal systems can increase the economy of geothermal energy generation. For example, the hydraulic fracturing or acid treatment methods can artificially increase the hydraulic conductivity even in low permeability rock. In Germany, approx. 95% of the geothermal potential can only be accessed using this technology. All system components required for this are available, but only a few projects have implemented this technology to access a deep geothermal heat source.

Access to deep geothermal energy via boreholes and the subsequent provision of energy are largely dependent on two conditions: First of all, the temperature should significantly exceed 40 °C for heating or 100 °C for electricity generation.

On the other hand, a sufficient flow rate per borehole or pair of boreholes must be attainable.

These and other basic conditions generally cannot be proven until the project development is already underway, which means that a series of decisions must be made on the way to
geothermal energy provision. Much research is still needed. The need for research for the corresponding project phases is shown by the fields with green backgrounds.

Systems for supplying heat to many or large-scale consumers, e.g. for feeding into large-scale heating grids of up to 40 MW (commerce, apartment buildings), use deep geothermal energy from boreholes approx. 2-3 km deep and feed the thermal energy into heating grids. In Germany, they currently have a total capacity of approx. 150 MW and a broader market introduction is imminent. The expansion of low-temperature heating grids would significantly expedite the market launch. Compared to smaller systems with shallow geothermal energy, these systems are more suitable for dense development.

To generate electricity, hot water is pumped from boreholes at depths of up to 4-5 km. In general, subterranean engineering work on the geothermal reservoir is required in Germany to achieve the flow rate required for economic use. Above ground, the thermal energy of the pumped hot water is converted to electricity via secondary circuits (ORC or Kalina). The first systems of this type connected to the grid in Germany, with roughly 7 MW of installed electric capacity, prove the fundamental feasibility of this type of electricity generation.
1. Storing renewable energy for fluctuation compensation, supply security and grid stability

The goal of future energy systems is a sustainable complete supply based on renewable resources. The final energy sources electricity, heat and fuel should be available at all times without usage restrictions. However, many renewable energy sources, such as wind power and solar energy, provide energy in a fluctuating manner. Energy storage is the solution. Thus, even in times when renewable energy is in short supply (e.g. no wind), the demand can be met.

This paper presents a new approach for seasonal storage of renewable energy. The storage medium in question is SNG – Substitute Natural Gas –, which can be generated via the conversion route “Biogas-to-SNG”, “BioSyngas-to-SNG” and the new “Wind-to-SNG” concept.

Generation of substitute natural gas (“biogas” from biogas is state-of-the-art. Manufacturing processes from biosynthesis gas via biomass gasification are currently in the demonstration phase. The process of generating substitute natural gas from CO₂ and H₂ is new. Fluctuating electricity from renewable energy sources (e.g. from wind power) is used for electrolytic generation of hydrogen, which is converted to methane with CO₂ (e.g. from biogas) or with CO/CO₂ compounds (e.g. from the product gas of the thermo-chemical conversion of biomass) in a synthesis reactor in the wind-to-SNG concept.

Using the existing natural gas infrastructure, the renewably produced, chemical energy source methane is stored efficiently, distributed and made available for use as required. Bidirectional convertability of electricity and gas facilitates energy storage and electricity grid stabilisation, by providing negative balancing energy if there is surplus electricity by feeding substitute natural gas or by providing positive balancing energy if there is a demand for electricity via conversion of substitute natural gas into electricity.

2. Energy storage: A key component in a sustainable energy system

Of all the renewable energy sources, biomass is the easiest to store, as this exists in material form as fuel. It can be stored seasonally, and is available when required for generating heat, electricity and fuel and therefore suitable for base load coverage. Biomass currently covers approx. 10% of the global energy demand. However, the contribution to global energy consumption could increase to max. approx. 20%. Geothermal energy and run-of-river hyroelectricity, other sources with limited supplies, are also suitable for covering the base load. The great potential of renewable energy sources lies in virtually unlimited solar radiation and in wind energy, although both occur in a highly fluctuating manner and can only be controlled to a limited extent, and therefore require storage.

Only sufficient energy storage can ensure a secure complete supply based on renewable energy sources. The potential and the possible fields of application of the various storage systems depend on the required storage capacity and storage duration, as well as the conversion losses and the costs. Only the expansion of the electricity grids, the bundling of different
electricity generators together with consumers and new storage concepts, along with clever management of generation, loads and storage, allow an energy system based on renewable energy sources to be created which can guarantee complete supply at all times.

2.1 Storage options for renewable energy

Most renewable energy is converted to electricity in a transportable form. However, electricity can only be stored directly to a limited extent (e.g. in capacitors). Electricity storage technologies therefore use the following forms of energy:

- Electric energy (supercapacitors)
- Potential energy (hydropower, pumped storage power plant)
- Mechanical energy (compressed air reservoirs, flywheel energy storage systems)
- Electrochemical energy (batteries)
- Chemical energy (fuels)

Pumped storage power plants are generally used for storing electricity for periods ranging from several hours to several days. In the energy industry, such hydroelectric power plants have for decades been the storage medium of choice for intermediate storage of excess electricity and for feeding these capacities back into the electricity grid when needed (peak load coverage). As their existing capacity and expansion potential are strictly limited by geographical factors and environmental conditions in Germany, they will only be able to contribute to the future integration of renewable energy into the electricity grid to a limited extent.

Compressed air reservoirs operate with output ranges similar to those of pumped storage power plants. However, there are as yet only two systems in operation worldwide.

Storage in flywheel energy storage systems or supercapacitors is limited, particularly with regard to duration and capacity. Therefore, they are primarily used for short-term (< 1 hour) provision of power to compensate for fluctuations.

Stationary and mobile batteries represent a medium-term (< 1 day) power reserve, although their use is limited by their very low energy and power density and lifetime. The integration of future electric vehicles’ mobile batteries into the electricity grid as part of a so-called „vehicle-to-grid“ concept makes it possible to charge vehicles’ batteries (energy storage) and systematically feed the energy back into the power grid. This creates large-scale “virtual battery storage”. However, its use is restricted by the availability period of the vehicles and the capacity provided by the vehicle owner. Also, intelligent management of the charging and discharging processes is required (smart grid).

For long-term storage and seasonal balancing of renewable energy sources, currently only chemical secondary energy carriers can be used, such as hydrogen and carbon-based fuels (e.g. substitute natural gas), which can be created from various renewable energy sources. The withdrawal capacities of underground gas storage including conversion to electricity extend into the 10-GW range, with cycle times ranging from days to months (see Figure 1). They therefore represent the only conceivable option for seasonally storing renewable energy with a capacity in the TWh range and converting it back into electricity when required. In addition, the chemical secondary energy carriers can be used in other application areas, such as in transport.

![Figure 1](discharge_time_and_storage_capacity_of_different_electricity_storage_systems)

**Figure 1**
Discharge time and storage capacity of different electricity storage systems
2.2 Storage capacities in today’s energy system and when expanding electromobility

In today’s energy system, energy reserves are provided via the storage of fossil fuels (coal, crude oil and natural gas). The amount of energy thus stored is typically enough to cover several months’ consumption. However, this does not apply to electricity. Supply and demand must always be precisely balanced. If supply is largely provided from renewable energy sources, the principal question is: Which storage systems can take the place of fossil fuel reserves?

The figures in Table 1 illustrate the problems with storing electricity: Generation and consumption must be simultaneous. The available electricity storage capacity adds up to just 0.04 TWh, i.e. the available storage facilities could theoretically satisfy Germany’s entire electricity demand for less than 1 hour.

If electric vehicles’ batteries are bidirectionally integrated into the grid and coupled with intelligent energy management, both the charging and the withdrawal of energy are possible (vehicle to grid). Batteries have the advantage of a very rapid response time and can thus be activated and deactivated flexibly. Therefore, these mobile energy storage systems offer the option of providing system services for grid stabilisation, e.g. balancing energy or load balancing. In peak load periods, this energy is available via discharging the traction batteries, which are then charged again during low load periods. This smoothes the electricity load curve and reduces the load on the energy generators, as well as on the grid, depending on the spatial distribution of the storage systems. Assuming that 40 million vehicles are all simultaneously connected to the electricity grid and that each vehicle feeds in 10 kWh, the storage coverage amounts to around 6 hours and is thus many times higher than the capacity installed to date in the form of pumped storage power plants (Table 2).

By incorporating traction batteries, electromobility can thus make a contribution to electricity storage and electricity grid stabilisation. Therefore, in the future it will be possible to use electric vehicles primarily as short-term energy storage systems in order to support grid operation and to bridge short-term fluctuations. However, the existing system does not permit multi-day, let alone seasonal electricity storage, even under the assumption that all current vehicles were replaced by electric vehicles.

### Table 1
<table>
<thead>
<tr>
<th>Consumption</th>
<th>Electricity [TWh/a]</th>
<th>Natural gas</th>
<th>Liquid fuels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average output</td>
<td>615</td>
<td>930</td>
<td>707</td>
</tr>
<tr>
<td>Storage capacity</td>
<td>0.04</td>
<td>217</td>
<td>250</td>
</tr>
<tr>
<td>Mathematical storage coverage</td>
<td>0.6</td>
<td>2000</td>
<td>3100</td>
</tr>
</tbody>
</table>

1) Petrol, diesel, kerosene
2) Fluctuates greatly seasonally
3) Pumped storage power plants
4) 47 underground gas storage systems (plus 79 TWh under construction/in the planning stage) [1]
5) Stock of petrol, diesel, kerosene und extra light heating oil
6) Relative to the average output

### Table 2
<table>
<thead>
<tr>
<th>Consumption</th>
<th>1 million electric vehicles</th>
<th>40 million electric vehicles</th>
</tr>
</thead>
<tbody>
<tr>
<td>Percentage of electricity consumption</td>
<td>0.3</td>
<td>0.4</td>
</tr>
<tr>
<td>Storage capacity</td>
<td>0.01</td>
<td>0.4</td>
</tr>
<tr>
<td>Mathematical storage coverage</td>
<td>0.15</td>
<td>0.6</td>
</tr>
</tbody>
</table>

1) Reference year 2008
2) 0.16 kWh/km; 12,000 km/a
3) Available storage capacity per vehicle: 10 kWh
4) Relative to the average output of 70 GW (cf. Tab. 1)
Current knowledge suggests that the production of secondary energy carriers is a necessary prerequisite for seasonal energy storage. Liquid and gaseous fuels, unlike electricity, can be stored directly and in large quantities. In the fuel market, petrol and diesel are stored for months at a time. The gas storage capacities in Germany are around 5000 times higher than the capacities of pumped storage power plants (Table 1). As natural gas can be converted into electricity in modern power plants with an efficiency of almost 60%, the obvious solution is to use gas storage capacity for the storage of renewable energy.

2.3 Capacity requirements for seasonal storage systems

One key question in the event of 100% supply based entirely on renewable energy sources is: How much storage output and storage capacity is required in the German electricity grid, to bridge longer wind lulls for example? Renewable energies used for generating electricity and suitable for covering the base load include bio-energy, geothermal energy, run-of-river hydro-electricity and approx. 10% of the wind power capacity installed. Of this total approx. 18 GW of forecast output in 2050, bioenergy will account for 5 GW, geothermal energy for 4 GW, run-of-river hydroelectricity for 3 GW and the part of the wind energy output which is suitable for covering the base load will be 6 GW, calculated in accordance with [2]. At an average load of 70 GW (see Table 1) almost 20 TWh of storage capacity remains, if the remaining output of approx. 50 GW is drawn over a period of 2 weeks. However, only 0.04 TWh are currently available in Germany for electricity in pumped storage power plants. For complete supply based on renewable electricity, storage capacities would have to be increased by a factor of around 500!

The only viable option in Germany for the required capacities of around 20 TWh would be chemical energy carriers, which can be stored underground in caverns as gas, for example. In comparison, a reservoir cavern with hydrogen as the chemical storage medium has around 10 to 100 times the storage capacity of the compressed air variant; with renewably generated substitute natural gas, the storage capacity is even around 30 to 300 times as high (depending on the storage pressure). A comparison with existing and planned natural gas storage facilities shows that these storage capacities are already in place in the existing infrastructure (Table 1). From a purely theoretical point of view, 217 TWh of natural gas stored in caverns can be converted into 130 TWh of electricity with gas and steam power plants on a flexible timescale. There are no other storage technologies with capacities in the region of > 10 TWh on the horizon.

Nevertheless, a conflict is arising with regard to the storage of renewable energy in underground storage facilities: the technologies of compressed air reservoirs and gas storage facilities (natural gas, substitute natural gas or hydrogen) are competing with the so-called „storage“ technology CCS (carbon capture and storage), which actually refers to disposal of CO$_2$ and not storage of energy itself. If the large-scale conversion of fossil fuels into electricity were to involve the dumping of CO$_2$ in empty natural gas underground storage facilities, the corresponding reservoirs would thus no longer be available for seasonally storing renewable energy.

3. Solution: Substitute natural gas (SNG) as a storage medium for renewable energy

The renewable energy carrier SNG can be produced in a variety of ways. Primary resources include

- „Wet“ biomass for anaerobic fermentation (biogas to SNG)
- „Dry“ biomass for thermochemical gasification (biosyngas to SNG)
- Renewably generated electricity for electro-lytic production of hydrogen in combination with carbon (di)oxide from various biogenic and non-biogenic sources (wind to SNG)
- Combination of the abovementioned methods

The individual paths are explained below.
3.1 Biogas to SNG

In anaerobic fermentation of biomass, raw biogas with the main components CH4 (50 – 70 vol.%) and CO2 (30 – 50 vol.%) is produced. It also contains steam, minor components H2S, NH3, and depending on the type of pre-desulphurisation, also N2 and O2. Treatment of the raw biogas to SNG is implemented by removing water, the minor components and the main component CO2, until it reaches the quality required for feeding (substitute gas quality) for the maximum concentration of the gas components and the combustion properties. CO2 is removed in existing plants via pressure swing adsorption or various scrubber systems. The residual gas created in treatment is generally used to generate heat for the fermenter in a burner or in a gas motor for combined electricity/heat generation.

3.2 BioSyngas to SNG

If solid fuels are not burned but gasified, the result is a combustible gas which can be used for a variety of purposes. The fuel reacts with air, oxygen and/or steam, and the raw gas required is created. Its composition depends on the gasification method, the process conditions and the materials used. Ideally, the gas is not diluted with nitrogen, an inert component (gasification with air). Main components include H2, CO, CO2, H2O and (depending on the gasification temperature) CH4. Minor components such as sulphur compounds, ammonia, tars and dust loads must be removed from the gas.

To create SNG via biomass gasification, the AER (Absorption Enhanced Reforming) process developed at ZSW has ideal properties for downstream methanation due to its high H2-content of > 60 vol.%. In this reaction, CO and CO2 are converted to methane via the hydrogen present in the gas (Equation 1 – 3). This requires a defined H2/CO/CO2 ratio, provided no gas conditioning/gas separation is required. Thanks to its configurable stoichiometry [3], its components and the CH4 part already present, the AER product gas is ideal for creating SNG, as no other process steps are required after primarily quantitative conversion and after separation of reaction water. If synthesis gases from gasification with non-adjusted H2-content are used, downstream CO2 separation is absolutely necessary.

3.3 Wind to SNG

The „Production of C-based fuels from CO2 and H2“ topic has been the subject of research at ZSW since the end of the 1980s with the objective of storing renewable energy [4 – 6]. New aspects of the wind to SNG concept are the use of existing gas grid infrastructures for storing and converting the generated fuel to electricity, and in particular the use of wind-generated electricity, the further expansion of which is currently restricted by the capacity of the electricity grids. However, solar electricity or any other type of renewable electricity can be used for the process.

The basic principle of the wind to SNG concept is the bidirectional linking of the existing infrastructure units (the electricity grid and the gas grid) with the goal of establishing a new way of managing loads and generation, which enables high proportions of fluctuating electricity generation from renewable energy sources to be accommodated in the energy system. To date, this link only exists in terms of generating electricity from natural gas (gas to power), but not vice versa (power to gas). The new concept is based on storing electricity which cannot be fed into the grid for reasons of grid stability, or
cheaply available electricity (e.g. at times when a large amount of wind power is available), in the form of substitute natural gas. One key goal is to enable the planning and control of the feed from wind farms. The principle is shown in Figure 2.

The concept envisages firstly using electrolysis to convert „excess‟ electricity from fluctuating sources into hydrogen, then into substitute natural gas in a subsequent synthesis step with CO₂ (and/or CO). The energy efficiency for this is > 60 % (kWh\textsubscript{SNG}/kWh\textsubscript{el}).

A wind to SNG system can accommodate excess wind power by initiating electrolysis and can store it temporarily as SNG in the natural gas grid. In times when less wind power is available, or when the demand for electricity is higher, the electrolysis level can be reduced by means of systematic reduction or deactivation of the electrolysis. In order to ensure that there is sufficient electricity generation power – even during periods of low to no wind – a combination of the wind to SNG system with a gas or combined heat and power plant is a suitable concept, whereby conversion to electricity does not have to be implemented at the location of the wind to SNG system.

The wind to SNG concept is also easy to integrate in the existing energy system. A particular advantage compared to other options is the use of the natural gas grid with its high storage and transport capacity. While a high voltage direct current transmission is restricted to outputs < 7 GW, gas pipelines can reach up to 70 GW. High wind power yields can be stored both seasonally and transported long distances with high energy transmission levels. For conversion to electricity, gas power stations with electric efficiencies of up to 60% are ideal. With an increasing amount of renewable energy in the electricity grid, Germany requires the construction of these high-efficiency power stations to be able to react rapidly to load fluctuations. By contrast to nuclear and coal-fired power plants, gas power stations can be regulated quickly and easily.
Also worthy of note, is the particular degree of flexibility regarding use options of the stored energy, because not only can SNG be converted back into electricity, it can also be used in the heating market or the fuel market. The latter is of particular interest in the context of the planned increase in the proportion of renewable fuels in transport area.

The wind to SNG concept has various interfaces to the mobility area (“wind to tank” in Figure 2), as three regenerative energy carriers for vehicles can be provided:

- (Stored) electricity for battery-powered electric vehicles (BEV)
- H₂ for fuel cell vehicles (FCEV)
- SNG for natural gas vehicles (CNG-V)

The chemical energy carriers H₂ and SNG are also suitable for plug-in hybrid vehicles (plug-in HEV), with which short distances can be traveled purely electrically – H₂ or SNG are only used for longer distances via conversion to electricity in a “Range extender”.

Hydrogen from electrolysis of wind to SNG systems can be distributed via H₂ grids and be made available for mobility. On the other hand, hydrogen can also be provided via decentralised generation at petrol stations by reforming SNG using the existing infrastructure, without requiring a large-scale distribution infrastructure for hydrogen.

### 3.4 Biogas/Wind to SNG

The carbon dioxide required for methanation can be provided from a variety of sources (CO₂ separation on conversion of fossil fuels to electricity, lime/cement production, chemicals industry processes etc.). As an “off gas”, CO₂ is created when converting biogas to biomethane (CO₂ separation). As this biogenic CO₂ is not associated with climate-relevant emissions, it is particularly suitable as an educt for methanation (Figure 3.1). Alternatively, CO₂ from biogas can also be used directly without previous separation, by feeding the biogas directly to a methanation unit (Figure 3.2). The connection of a wind farm/biogas/wind to SNG system to locations where bottlenecks in the electricity grid cause delays in adding wind power is an optimal combination (e.g. in coastal areas where a lot of new offshore wind power is installed).

---

**Figure 3**

Increasing the methane yield from biogas systems by adding H₂ and subsequent methanation.
In an initial technical implementation phase, the installation of a 10 MW wind to SNG system in conjunction with a biogas plant is planned, in which the biogas is methanated to SNG without CO2 separation by adding H2. The system is to be commissioned in 2012.

3.5 BioSyngas/Wind to SNG

In a further version, biogenic gases from thermochemical gasification should be used, whose stoichiometry is not adapted to the subsequent SNG generation. Addition of H2 to the gasification gas allows virtually complete conversion of the biogenic carbon to fuel carbon. This facilitates significantly more efficient use of biogenic resources for the fuel yield. Another aspect is the use of the oxygen produced during electrolysis for biomass gasification.

4. Experimental results

At ZSW, a variety of fixed bed reactors for SNG generation up to a power class of 50 kW was built and tested. Due to the exothermic energy from methanation and the quality requirements for the gas properties for feeding into the gas grid (H2 < 5 vol. %, CO2 < 6 vol. %), there are special requirements for the reaction management and the reactor concept. This is taken into account in the reactor geometry, the reactor cooling concept and the activity profiles set for the catalyst packing beds.
The target is a maximum conversion level in a single-phase reactor system without requiring downstream gas conditioning. As an alternative, reactor concepts with intermediate condensation/water separation are being investigated.

A complete container-integrated wind to SNG system in the 30 kW power class was developed as commissioned by the Solar Fuel Technology company. It contains electrolysis, methanation and control electronics including a filling module for natural gas vehicles (Figure 4). The system is used to study load profiles for grid control. After completion of the test phase, the wind to SNG system will be operated at a biogas plant. The biogas will be methanated directly (without previous CO2 separation) according to process version 2 in Figure 3.

The results of SNG generation from educt gases AER syngas, CO2/H2 and biogas/H2 are shown in Figure 5. The reactor was operated with comparable operating parameters in all three cases. After a single reactor run, the concentrations remain below limit concentrations for H2 and CO2 in the generated SNG for the educt gases AER syngas and biogas/H2 after drying without further gas conditioning. For the CO2/H2 educt gas, these limit concentrations are slightly too high, but can be complied with via reduction of the gas load and/or pressure increase.

The fundamental suitability of the wind to SNG concept for energy storage and grid control was proven. With a far less complex process compared to Fischer-Tropsch or methanol synthesis, SNG can also be produced in decentralised applications, distributed via the natural gas grid, stored and used in accordance with demand.

5. Conclusion

The various methods for producing SNG from renewable energy and the use options in different consumption sectors offer opportunities for a merging of the electricity grid, gas grid and mobility energy sectors. Electricity and SNG can be converted to one another bidirectionally and have a fully-established infrastructure with seasonal gas storage capacity. Also, H2 can be created decentrally from both energy carriers, without having to rely on a widespread H2 distribution system with high infrastructure costs. The concept presented possesses the following outstanding features:

- SNG generation permits seasonal storage of renewable energy. While the storage capacity of the electricity grid is currently only approx. 0.04 TWh – with a storage coverage of less than one hour –, the storage capacity of the gas grid in Germany is over 200 TWh with a storage coverage of months.

- The wind to SNG concept can provide positive and negative balancing energy to stabilise the electricity grid (conversion of SNG to electricity and increasing/decreasing electrolysis).

- By expanding wind energy (in particular offshore), in future, high wind power levels will be available more and more often, which cannot be absorbed fully by the electricity grid, but as SNGs in the existing gas grid.

- SNG generation from CO2 and H2 is, unlike bio-SNG, not subject to surface limitation due to the cultivation of biomass.

- SNG can be produced from various forms of renewable energy (biomass, wind/solar electricity, etc.).

- Combining the resources of biomass and electricity from renewable energy allows biomass carbon to be transferred almost completely into fuel carbon, thus increasing the coverage of fuels from biomass significantly (e.g. doubling the methane yield from a biogas plant).
Literature


Solar thermal power plants – Export hits without a domestic market

Solar thermal power plants only use the direct solar irradiation, and are therefore hardly usable in Germany. Nevertheless, German companies and research institutes are among the global technology leaders. This can only be achieved via suitable international partnerships. This presentation provides details of the major international networks in this area. Examples will be used to show how German technologies and research results can be positioned on the international market.

1. Introduction

Parabolic trough collectors, which generate electricity in a conventional power plant via high-temperature heat, have been used in the Mojave Desert in California for over 20 years. For a long time, no-one emulated this success story. However, the global challenge presented by the climate change and the oil prices shock have highlighted the advantages of this technology and have led to a veritable construction boom, initially encouraged by an electricity feed-in act in Spain. Now, construction is underway throughout the earth’s sun belt.

Two different systems for large-scale solar thermal electricity generation in sunny countries are currently available:

- **Line-focusing systems**, which direct the concentrated radiation in their caustic line to an absorber tube with a selective coating, reaching temperatures of up to 400 °C in the heat transfer medium circulating there.
- **Point-focusing systems**, in which three-dimensionally curved, sun-tracking individual mirrors (heliostats) direct the solar radiation to a heat exchanger (receiver), which is located at the top of a tower. These systems can reach higher temperatures than the line-focusing systems.

Both technologies aim to replace the heat generated by fossil fuels in conventional power plants fully or partially. Their attraction is that the high-temperature heat generated can be stored very cost-effective (compared with electricity) and efficiently, to allow continued operation as clouds pass or after sunset. If low quantities (<15%) of additional fossil combustion in the power plant are possible, this concept can be used to provide electricity as required with great reliability, to replace fossil fuel-fired power plant capacities fully.

### Table 1

<table>
<thead>
<tr>
<th>Year</th>
<th>Event</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td>Initiation of the SSPS (IEA) and CESA projects (Spain)</td>
</tr>
<tr>
<td>1979</td>
<td>Seven countries combine to build SSPS in Almería (DLR for Germany)</td>
</tr>
<tr>
<td>1985</td>
<td>CESA and SSPS systems merge to become PSA test centre</td>
</tr>
<tr>
<td>1981</td>
<td>First solar thermal electricity generation in Europe</td>
</tr>
<tr>
<td>1987</td>
<td>Spanish-German cooperation agreement on 50:50 basis (DLR/CIEMAT)</td>
</tr>
<tr>
<td>1990</td>
<td>PSA qualifies as a large-scale European system</td>
</tr>
<tr>
<td>1994</td>
<td>First joint EU projects (DLR/CIEMAT)</td>
</tr>
<tr>
<td>1998</td>
<td>Change of the cooperation model to project-specific cooperation</td>
</tr>
<tr>
<td>2004</td>
<td>Start of cooperation between DLR/Fraunhofer on Fresnel collectors</td>
</tr>
<tr>
<td>2006</td>
<td>PSA celebrates 25th anniversary</td>
</tr>
<tr>
<td>2007</td>
<td>First commercial electricity generation in Spain</td>
</tr>
</tbody>
</table>

SSPS = Small Solar Power System
CESA = Central Electro-Solar de Almería (solar tower)
2. International cooperation as a basis for technological development

The development of this technology was initiated as early as the late 1970s by the International Energy Agency (IEA) (Table 1).

Even that far back, Germany already played a leading role when DLR was commissioned to coordinate the project of building the SSPS demonstration system in Almería, Spain. After it had successfully proven that solar thermal electricity generation in Europe was possible in 1981, operation of the plant was continued as a test centre under the name “Plataforma Solar de Almería (PSA)” (Figure 1) by a partnership of the Spanish CIEMAT and DLR.

PSA developed into the European test centre where key commercial systems which were subsequently introduced on the market, were developed and tested. This benefitted Spanish and German companies in particular. At the end of the 1990s, when it became clear that the technology had not succeeded in specific market penetration, the German side had to step back its influence due to decreasing funding and since then, it has had a guest role at PSA. In the early 2000s, the indications of market penetration of the technology in Spain increased and the development was intensified again. Other German research partners, e.g. Fraunhofer ISE became involved in these activities in 2004. The Spanish feed-in act passed in 2004 led to the construction of commercial solar thermal plants in Spain, which fed electricity into the grid in 2007 for the first time.

In order to further decrease costs, however, further research and development work is required in this area. As this has always been associated with very large and expensive test infrastructure, four major European research institutes pooled their expertise and infrastructure in 2003 to form the Sollab association, which features the Swiss Paul Scherer Institute (together with ETH Zurich) and the French CNRS in addition to the DLR and CIEMAT. This facilitated improved access to the test infrastructure for German companies.

Another key to the spread of this technology to other countries in the sun belt was the IEA’s SolarPACES cooperation, which was based on the previous activities in Almería, and now comprises 16 member states (Figure 2). In this network, in which DLR performs major coordination activities, new markets, in particular in the USA, Egypt, Algeria, Australia, Italy, Israel, UAE and South Africa, were opened, which are now largely supplied by German countries.
3. Market situation and the role of the German industry

Worldwide, approx. 0.6 GW of solar thermal power plants are operated, while approximately the same capacity is currently under construction, most of it in Spain and the USA. Other projects in the 6 – 8 GW range are in development around the world (Figure 3).

In particular, German and Spanish manufacturers are dominant. In addition to the project development and turnkey delivery of solar arrays and power station blocks, German companies are leaders in production of key components such as mirrors, absorber tubes and steam turbines. In addition to this, major German energy suppliers act as investors and, in the medium-term, probably also as operators of solar thermal power plants.
4. Competitive advantages through research and development

As solar thermal power plants have no domestic market in Germany, the industry competes on international markets. Its key to success is in the delivery of superior high-tech components and the ability to provide system solutions from one source. All technical and financial risks are covered. The major German companies from the energy industry are well positioned.

The key remains that they deliver top technology and are therefore technologically always one step ahead of competitors. This is where the German research landscape and, in particular, the Renewable Energy Research Association (FVEE) come into play, which can prepare technological development and assist in industrial implementation. Four examples of this are listed below.

4.1 Direct evaporation

DLR, in cooperation with German and Spanish partners, has led the development of solar steam generation technology, in which the thermal oil in a parabolic trough collector is replaced by water or steam, since the mid-1990s. It saves investment in the expensive special oil and the corresponding heat transfer mediums, allows higher process temperatures and thus better system efficiencies.

On the DISS test system (Direct Solar Steam) at PSA, processes were identified as safely technically controllable, comprehensive component tests were performed, and simulation models and control concepts were developed and validated. Also, the most recent investigations confirmed the economic relevance of this technology.

As the next step before market introduction, the demonstration of the overall system with multiple parallel evaporation trains in the power plant-relevant scale (approx. 5 MWe) is imminent. For this purpose, it is planned to implement a corresponding pilot system with German industrial partners in the vicinity of the planned ANDA-

SOL III power plant in Southern Spain (Figure 4), which consists of one collector array of roughly 2-3 collector strings. On one hand, this collector array must be operated continuously to evaluate and demonstrate the long-term stability of the components and the every-day operability of the system. On the other hand, it will be designed so flexibly that it will permit the investigation of various operation strategies. A 5 – 15 MWh innovative heat storage system is to be integrated in this test system, and be subjected to extended operation in the power plant, to demonstrate feasibility in real operation. In the demonstration system of a Fresnel collector with the involvement of DLR and Fraunhofer ISE at PSA, direct evaporation was used and tested successfully in the last two years.

4.2 Component development and qualification

High-temperature stable efficient receiver systems are a key component for the parabolic trough and the Fresnel technology and are required by various collector companies worldwide.

With the assistance of Fraunhofer ISE and DLR, the Schott CSP Solar company developed the evacuated receiver PTR-70. With the aid of this technology, heat losses of the absorber tubes through which the heat transfer fluid flows are minimised. At an operating temperature of 380 °C, an emission level of under 7% is reached in the newest coatings. The problem of hydrogen diffusion from the thermal oil has been solved via barrier coatings and getter materials. In addition to the receivers for thermal oil, pipes with reinforced steel walls are offered for direct evaporation.
The parabolic mirrors and collector design for the SKAL-ET collector were developed by a German company, Flagsol. The curved special mirrors consist of white glass coated with silver which has a thickness of 4 to 5 mm. The mirrors are 2 to 2.8 square metres in size. The company also supplies the control systems for the solar array, a key component for operating the overall system. In linear Fresnel collectors, high-temperature stable absorber tubes are also used, which are stable up to 450 °C in air. The secondary concentrators, which consist of borosilicate mirrors coated on the front by Fraunhofer ISE, can also withstand elevated temperature loads.

With concentrating primary mirrors and parabolic trough, Fresnel and tower heliostats, the optimal focusing of the sun on the respective receiver structure is important. With highly-developed characterisation and qualification methods for the mirror components, both FVEE institutes contribute to quality assurance in power plant construction. Important elements include ensuring the mirror shape, spectral reflectivity and the endurance of the components. The question of measurement and in particular the degradation of complete collector arrays requires further development of the methods used to date. Standardisation of the methods is advanced worldwide as part of the IEA Solar-Paces programme.

4.3 Operation optimisation via forecasts
The system developed in the CSP FoSyS project will serve to predict electricity production of an individual power plant. Currently, no such integrated systems are available. Therefore, CSP power plants only operate with restrictions on the day-ahead and intraday electricity market, which means that they lose out on major economic advantages.

The project distinguishes three applications for this type of a prediction system:
1. Participation in the Spanish electricity market
2. The application for the license for grid access
3. The optimisation of power plant operation with the aspects of maintenance, solar array control, production planning and safety

The prototype resulting from the project is to be integrated in the parabolic trough power plant Andasol 3. However, the prototype is to be modular, which means that only a part, the power plant model, is specialised for the technology of a parabolic trough power plant. Thus, a product derived from the prototype can be used for all concentrating technologies, which use direct radiation as an energy source. For this purpose, only the power plant modelling must be adapted to other technologies.

Even the legal conditions which are analysed in this study, generally do not depend on the selected technology. That means that the same legal conditions can be used in nearly all cases, both for parabolic trough technology and in the other concentrating technologies.

4.4 UniSolar
Currently, massive expansion of solar thermal power plant capacity in the states of North Africa is being discussed intensively. An example of this is the DESERTEC concept co-developed by DLR. This power plant expansion aims to produce electricity at low cost in North Africa in solar thermal power plants, and to transport it to Europe and Germany in particular via high voltage direct current lines. In the medium term, it is planned to source 15% of European electricity requirements from these sources. In order to implement this massive expansion, political, technical, economic and socio-political priorities must be set at an early stage. The implementation of the DESERTEC concept thus also supports the heightened cooperation between the EU member states and countries of the Southern Mediterranean as part of the Union for the Mediterranean. UniSolar, funded by the German Federal Foreign Office, is based on this concept and can be viewed as a first step to practical implementation.

The objective of the project is the technological cooperation and targeted support of those countries in North Africa, which just started implementing the first solar thermal power plants. Technical optimisation options for commissioning and operation are to be used specifically and contribute to increasing the efficiency of the solar power plant section and the overall
electricity generation. The local capacities are to be expanded via educational programmes, training courses, workshops and technology transfer, and a specific cooperation with the German industry is to be made possible. The distribution of the technology is to be guaranteed via correspondingly trained and supported local contacts and networking with one another. They can competently accompany and support project developments and technology developments in the target countries. These measures are intended to promote sustainable implementation of solar power plants and the development is to be speeded up via multiplier effects.

Target groups for the expansion of capacities and distribution of the technology on the North African side are research institutes, universities, industrial companies, experts, engineering firms, decision-makers and power supply companies in Egypt, Algeria, Tunisia and Morocco. Other states in Africa are to be added during the course of the project.

The Renewable Academy Berlin, with the support of Fraunhofer ISE, also offers workshops on solar thermal power plants around the world for decision-makers and engineers as part of the TREE project (Transfer Renewable Energy & Efficiency) funded by BMU.

5. Summary and outlook

A technologically leading role is the requirement for participating successfully in the rapidly growing market for solar thermal power plants.

The lack of a domestic market requires global operating companies and an internationally well-networked research and access to test facilities in the sun belt. Both is currently the case; however, rapidly increasing research budgets, in particular in the USA, China and the Gulf states, can lead to a shift in the market in the medium term. Therefore, public research and development budgets adjusted for the increasing turnover of the companies and their own research expenditure must be added to maintain a leading role in Germany.
Concentrating photovoltaics (CPV) for countries with high direct irradiation

1. Introduction

The ultimate objective of all research work in the area of photovoltaics (PV) is to reduce the costs for PV-generated energy and thus to provide a sustainable energy supply.

The current market is dominated by Si modules. Technologies on a thin-film basis (a-Si, CIGS, CdTe) reached industrial mass production in the last two years.

Concentrator photovoltaics are an alternative approach to reduce the costs per PV-generated kWh. The underlying idea is easy to understand: This technology reduces the need for comparatively expensive solar cell area, by focusing the sunlight via a low-cost optical concentrator. A small cell which converts the high irradiance efficiently is the target for the focused light. In order to concentrate the sunlight sufficiently, the system must track the sun’s path. Therefore, the concentrator systems are particularly suitable for countries with a high direct irradiation.

Concentrator systems are preferred as PV power plants in the kW-MW power range. The interest in this technology increased significantly in recent years, as the costs were reduced and system efficiencies of over 25% were reached in the field [1].

2. The technological basis of concentrator photovoltaics

Concentrator photovoltaics are characterised by the fact that the individual components such as cells, cooling, concentrator optics and tracking are highly interdependent and therefore must be optimised as a whole. Concentrator photovoltaics must therefore be viewed as an integrative technological approach. For example, the tracking precision requirements for the mechanics can be reduced if the optical concentrator is designed accordingly by using a second stage. This in turn can result in increased complexity during the assembly process. This example shows the concatenation of technologies and the complexity in the development of a concentrator system. Therefore, there is no one concentrator system – each system must be developed and analysed individually. As a result, there is a variety of possible system implementations.

The true evaluation of a concentrator system is not revealed until in the application, and is specified via the costs per generated kilowatt-hour (€/kWh). Of course, this evaluation value depends on the irradiation conditions, and thus on the location.

The variety of concentrator system approaches is easiest to explain by applying the concentration factor. The concentration factor of current systems ranges from 2 to 1000. Figure 1 shows two examples of system components: On the left, the low-concentrating ARCHIMEDES system developed at the ZSW in Stuttgart. It uses Si concentrator cells and has a single-axis tracking system. On the right, the high-concentrating FLATCON system developed at the Fraunhofer ISE in Freiburg, and prepared for market introduction by Concentrix Solar, Freiburg. This
system uses III-V semiconductor multiple solar cells and has a two-axis tracking system and a concentration factor of 380.

The following section discusses the main components of a concentrator system briefly:

**The optical concentrator**

As optical concentrators, either lenses or mirrors are used. A second optical stage which is generally mounted directly on the solar cell is often used. Fresnel lenses are often used instead of heavy solid lenses. They require less material and can be produced more cost effectively. Where lenses are used, imaging errors, in particular chromatic aberrations, must be taken into account when designing the system. Mirror systems have advantages in such cases. The challenge for the mirrors is to produce highly-reflective coatings with long-term warranties cost-effectively. Figure 2 is a schematic representation of various optical concentration concepts as currently used in systems.

**The concentrator cell**

The cells used in concentrator systems must deal with the high irradiance and the resulting high currents. Therefore, there is no one best concentrator solar cell. The solar cell technology must be adapted for the concentration factor.

Resistance losses scale quadratically with the current densities, which requires a higher degree of metallisation of the solar cells, which in turn increases shading losses. Also, the solar cell is not lit homogenously, depending on the optical concentrator, which can be taken into account by designing the front contact grid.
accordingly. Therefore, the “optimal” solar cell design is highly dependent on the system design. In general, it can be said that only slightly modified industrial silicon solar cells are used, in particular for low concentration ranges (Figure 1, left). Figure 3 shows an example of cell development at Fraunhofer ISE [2]. Here, the metal wrap trough (MWT) solar cell was modified such that it can be used for concentration factors of up to 20 depending on the design.

Multiple solar cells, in which different III-V semiconductor materials are deposited above one another, allow extremely high efficiencies to be reached. This cell type is used in high-concentrating systems. Figure 4 shows the coating structure and characteristic curve of the Fraunhofer ISE record solar cell which reaches an efficiency of 41.1% at a concentration factor of 454 suns [3].

Trackers

Tracking systems have been utilised to an increasing extent for flat modules, as tracking can be expected to increase the yield by between 20-35% [4]. As a result of this development, there are now multiple providers of tracking systems on the market, which benefits concentrator photovoltaics. However, the precision and stability requirements for concentrator systems are significantly higher. The required precision depends on the concentration factor and on the optics used in the system. As a guideline value, a concentrating system with a factor of 500 aims for and reaches mechanical precision of 0.1 °.

A good control system is important to reach this goal. At Fraunhofer ISE in recent years, a development has been pursued, which integrates the tracker control into the inverter electronics:
The resulting tracker inverter reduces the costs of the concentrator system. For low-concentrating photovoltaics, a single-axis tracking system with a mechanical precision in the degree range is often sufficient. In general it can be stated that the reliability of the tracking system is not a problem and that the power consumption for the drive on average is significantly lower than 100 W [5], which is negligible with system sizes in the kW range.

3. Concentrator systems in operation

Concentrix Solar manufactures high-concentrating FLATCON concentrator modules. Since autumn 2008, a production line with a capacity of 25 MW has been available. This fully-automated production line is used to produce modules with efficiencies of 27%. The modules are mounted on two-axis tracking units. The nominal system capacity is 6 kW. Figure 5 shows a photo of a Concentrix concentrator system and a measured DC characteristic curve of the system. With favourable irradiation conditions, DC system efficiencies of over 26% have been reached.

Figure 5
Left: FLATCON concentrator system by Concentrix Solar. The aperture area is 28.8 m². On the right, the measured DC characteristic curve of the system is shown. An efficiency of 26% was measured.

Figure 6
Left: Photos of the 100 kW systems in Seville (top) and Puertollano (bottom) in Spain. On the right, the maximum AC power plant efficiency of the two systems from May to September 2009 is shown.
Figure 6 shows the maximum AC efficiency from May to September 2009 for two 100 kW power plants at the sites in Seville and Puertollano in Spain. The efficiencies remained constantly significantly above 20%, and peak values of up to 24% were reached.

4. Summary and conclusion

Concentrating photovoltaics have now reached a development level at which the transition from laboratory to industrial manufacturing has been made. This technology can now penetrate the market. The cost and yield analyses lead us to expect that CPV systems on sites with high direct irradiation can reach electricity generation costs which are significantly lower than those for classic PV technology. If these forecasts are proven true in the coming two years, this technology will grow rapidly.

Literature


Requirements for integration of wind energy into the grids of various countries

Introduction

In Europe and around the world, wind energy is developing at an incredible growth rate. Countries such as Denmark, Germany and Spain have created a major foundation for integrating wind energy with their pioneering work. In 2030, wind energy is to provide more than 25% of the electricity requirement in Europe [1]. This high percentage of wind energy generation presents an enormous challenge for reliable and safe integration of wind energy in supply grids. As a consequence, the need to manage wind farms like conventional power plants in terms of predictability and grid compatibility is increasing in order to guarantee a reliable and safe integration of wind energy in supply grids. The country-specific regulations and requirements for the energy market and electricity grids are framework conditions which must be taken into account when developing system technology and the tools for planning, monitoring and management.

The term “power plant properties for wind farms” indicates that wind energy generation must be controllable and reliable in accordance with the system requirements, and that wind turbines must support the electric grid in the event of disturbances. These capabilities are based on management of active and reactive power of the wind farms and their reactions in the event of grid disturbances such as fault ride through [2] capability, an ability with which wind turbines can survive temporary voltage drops and thus contribute to grid stability.

Grid integration status

One of the largest barriers to further development of wind energy technology is the restricted capacity of the transmission grids. Large-scale balancing of wind energy feeding by transporting energy long distances decreases major fluctuations to a great extent [3]. This requires an efficient and sustainable expansion and strengthening of the European transmission grid and, in particular, of the connection points, in conjunction with detailed planning and early detection of grid bottlenecks at a European level.

Future reliable and economic grid planning and safe grid operation also require reliable monitoring, better understanding and precise predictability of the respective grid status. This results in the need for improved monitoring, simulation and prediction tools, in conjunction with dynamic analysis and evaluation of the joint European system.

The development status of wind energy use in Europe is very different in the individual countries. For example, the installed capacity in Germany and Spain is at a double-figure gigawatt level, followed by Italy, France, Great Britain, Denmark and Portugal.

Worldwide, currently approx. 130,000 MW of wind capacity are installed, and the growth rate is immense. In some countries, wind power generation at times covers more than half of the entire load (Denmark, Spain). The challenges for an electric energy supply system with a very high proportion of wind energy are

- The variability of wind energy feeds,
- Forecast errors for wind feeds,
- The electric grid for absorbing and transporting wind energy.
The grid integration status quo in these countries is such that the grid can largely absorb and transport the energy from the turbines which exist today. However, the grids in some countries are rapidly approaching their capacity limits. When comparing the requirements for grid integration in various countries, it is not sufficient to use the installed wind capacity as a measurement variable. The impact of wind power feeding on grid operation also depends on the following factors:

- The percentage of wind power in the grid (% min, % avg, % max)
- The variability of the load
- The flexibility of the conventional power plant infrastructure
- Ways of increasing the flexibility of generation and load
- The structure of the grid (wind locations – load centres)

The degree of penetration can be measured by the energy or power Wind energy penetration in European countries.

In the IEA Wind Annex 25 [4], the penetration was also measured based on the minimum load and the grid capacity. This representation shows

<table>
<thead>
<tr>
<th>Region/case study</th>
<th>Peak MW</th>
<th>Min MW</th>
<th>TWh/a</th>
<th>MW</th>
<th>MW</th>
<th>MW</th>
<th>TWh/a</th>
<th>%</th>
<th>%</th>
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<tr>
<td></td>
<td>Peak load</td>
<td>Cons.</td>
<td>(Min load+ interconn)</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>West Denmark real</td>
<td>3700</td>
<td>1300</td>
<td>21</td>
<td>2830</td>
<td>2380</td>
<td>5,00</td>
<td>65%</td>
<td>24%</td>
<td>58%</td>
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<tr>
<td>Denmark 2025</td>
<td>7200</td>
<td>2600</td>
<td>38</td>
<td>5190/6790</td>
<td>3125</td>
<td>6500</td>
<td>20,20</td>
<td>35%</td>
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<tr>
<td>Ireland 2020</td>
<td>8800</td>
<td>4560</td>
<td>49,2</td>
<td>1000</td>
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<td>5100</td>
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<td>24</td>
<td>427</td>
<td>2000</td>
<td>2389</td>
<td>38000</td>
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<td>552,3</td>
<td>10000</td>
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<td>246,2</td>
<td>2400</td>
<td>15145</td>
<td>17500</td>
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<td>788</td>
<td>8000</td>
<td>20,00</td>
<td>31%</td>
<td>14%</td>
</tr>
</tbody>
</table>

Table 1: Wind capacity installed worldwide.
Diagram: Fraunhofer IWES

Table 2: Wind energy penetration in European countries
the challenges at high wind feed rates in low load periods. It also illustrates the special features of stand-alone systems compared with well-connected areas.

Table 2 shows the current and expected penetration of wind energy in some countries in Europe. For example, in Germany it is expected to reach 14% of peak load and 71% of the minimal load by 2015. With this high penetration rate, wind capacity will soon significantly exceed the load in many countries. The wind power generated must therefore be transported long distances to facilitate an exchange. One of the main tasks for research and the industry is to develop future grid planning tools for designing a sustainable, powerful European grid infrastructure. In particular, the new international offshore connections and an offshore super-grid must be designed.

Future challenges

Grouping multiple large-scale offshore wind farms and other distributed wind turbine groups to wind farm clusters [5] opens up new ways of optimally integrating yield-dependent generation into electric supply systems. The Wind farm Cluster Management System (WCMS) developed by Fraunhofer IWES is responsible for grouping the geographically distributed wind farms for optimal grid operation management and minimisation of the reserve and balancing capacity requirement, and mapping and managing it as a single large-scale power plant feeding into multiple extra-high voltage nodes. With the aid of new operating management concepts for active and reactive power control, higher levels of wind power can be integrated in supply systems.

As a result of the system topology, the following system levels must be considered:

- Individual wind turbine
- Individual wind farm
- Geographical, grid-topology and control-technical grouping of multiple wind farms to a wind farm cluster

For modern wind farms and with corresponding wind farm controllers, the following control and operation management strategies are currently state-of-the-art or achievable:

- Feeding reactive power based on setpoint specifications
- Maximum value restriction based on setpoint specifications
- Compliance with maximum gradients based on setpoint specifications
- Power restriction in the event of excess frequency

The following advanced strategies can also be implemented using the options above:
• Scheduled specifications (time-variable specification of maximum values)
• Voltage control in high/extra-high voltage grids
• Rapid voltage control in medium-voltage grids
• Provision of balancing capacity

Based on these options, future control and operation management strategies can be derived for wind farms:
• Reactive power feed
• Generation management
• Scheduled specifications
• Voltage control at high and extra-high voltage levels
• Provision of balancing capacity
• Primary control capacity

**Literature**

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[2] dena Netzstudie I


Off-grid power supply and global electrification

Introduction

The electrification of off-grid rural regions plays an essential role for a basic level of supply, in particular for economic development. Depending on the local framework conditions, different technical system concepts and business models are suitable for sustainable provision of a reliable and cost-effective supply of electricity. From small solar home systems, hybrid systems with photovoltaics, biomass, wind and hydro-power, to multi-megawatt stand-alone grids which can be integrated in integrated grid structures, FVEE member institutes, together with industrial companies, develop technical solutions, test systems and components and run trials in realistic conditions.

Solar home systems (SHS)

A simple solar home system (SHS) for basic electrification consists of the following components: a solar generator, battery and charge controller, as well as the directly connected DC consumers. An optional inverter can also be used to supply AC consumers (Figure 1).

Such systems are used to supply energy-saving lamps, an increasing number of LED lamps, and some radios, televisions and refrigerators. The SHS charge controller connects the solar module (15..150 Wp) to the battery and the electricity consumers. It protects the battery against overcharging and deep discharge. As storage device, lead batteries with liquid electrolyte, bound in gel or fleece in a few systems, with a storage capacity of 3 to 5 days, are used almost thanks to the suitable system technology, are often competitive with standard diesel stations or conventional grid expansion.
exclusively. All components must satisfy demanding requirements – in terms of efficiency, reliability and ease of operation. This is why Fraunhofer ISE develops and tests SHS components in the laboratory.

Worldwide, there are currently major programmes for widespread distribution of SHS, such as in Argentina, Bangladesh, Bolivia, China, India, Morocco or South Africa. The possibility of supplying remote households decentrally, simply and independently with electricity using SHS is considered a particular advantage of this technology. By contrast to central plants, these systems can be the property of the end users. However, even if the system is operated by a RESCO (Rural Energy Supply Company) and does not belong to the user, there is always a direct correlation for the user between their personal consumption and the status of the system. This reduces the coordination work compared with concepts featuring central supply.

In Ecuador for example, PV systems are subsidised by the state with the aid of a rural electrification fund (FERUM). Every year, new projects can apply for this funding. The PV systems for basic electrification consist of a 100 Wp solar generator and a 105 Ah battery for supplying DC consumers (three energy-saving lamps, one radio and a black and white television). In addition to this, PV systems with inverters in two sizes up to 200 Wp and over 200 Wp have been subsidised since 2007/2008. Now, systems with up to 800 Wp are installed at end customers’ locations.

Funding is US$3,200 or US$3,500 per household. The size and configuration of the individual systems are specified according to the requirements of the applicants or end users. As some areas are difficult to reach, the funding also takes transport costs into account.

Standardisation of components reduces costs. The local operator model, in which technical training by RESCOS and funding play an important role, is an important success of the PV project in Ecuador. End users must make monthly payments. As part of the DOSBE EU project [1a,b], Fraunhofer ISE was involved in the development of this operator model.

Hybrid systems

Supplying electric consumers in off-grid locations is challenging if it must be guaranteed continuously all year-round. Seasonal fluctuations of the energy from the sun, wind and water in particular mean that supply solutions which rely solely on one energy source require significant investments for electricity storage. Systems with different electricity sources are known as hybrid systems. Common combinations include PV-diesel or wind-diesel systems. Combinations of photovoltaic generators, wind turbines and diesel motors are also widespread.

Figure 2
Hybrid system with DC-AC connection
(Source: SMA)
Hybrid systems can be designed as DC systems, mixed DC/AC systems or pure AC systems. DC/AC systems are often used in farms or other small companies. When designing systems, planners must take into account that the inverter power must match the overall maximum consumer power. **Mixed DC/AC systems** are particularly suitable for combining medium AC loads with DC generators. At the same time, this also allows the battery on the DC side to be charged via a combustion generator (Figure 2).

Pure **AC hybrid systems** can be set up flexibly with modular components (Figure 3). Depending on the application and the available energy sources, renewable and conventional energy carriers can be incorporated. If the power converters and combustion generators are intended for the purpose, they can also be connected to the public grid.

The system is easy to expand via additional components or electricity generators to cope with increasing energy requirements. A mass-produced modular system for AC connected hybrid systems was built and tested for the first time in the European „Hybrix“ project [2] by BP-Solar, SMA and Fraunhofer IWES (Figure 4). It is now in use worldwide. This type of system can be used to supply all standard electric AC devices.
From an economic perspective, stand-alone systems with battery storage in the kilowatt power range are far less expensive than systems which use diesel generators only. Even larger hybrid systems which additionally use a diesel generator to avoid long-term battery storage can be operated at lower costs than stations in which diesel motors alone are used. The reasons for this are the high maintenance work required, the short service life and the very poor partial load efficiency of diesel generators.

In power supply systems away from the integrated grids, it is primarily the expandability and the type of connection of the individual components which play an important part. The AC connection with battery inverters which can be connected in parallel (Sunny Island™) can connect almost any kind of power generators and all standard consumers to the hybrid system. Figure 5 shows typical generators which can be combined easily using the SELFsync® control technology patented by Fraunhofer IWES. The system is easy to expand on the consumer side and on the generator side.

**Stand-alone grids and micro-grids**

Stand-alone grids can be used for several remote houses or loads outside the integrated grid. Grid interconnection levels the load profile and increases the supply security. Stand-alone grids can be fed from a central power plant, a hybrid system or multiple decentralised electricity sources. In the integrated grid, the number of consumer-related independent generation systems, e.g. photovoltaic systems and combined heat and power plants, has increased significantly in recent decades. This technology can also be used for stand-alone grids. However, high decentralised power inputs may not endanger the stability of the grid.

Feed-in tariffs could be used to create incentives for investments and for sustainable operation of the remote generators in the stand-alone grid. In this way, grid participants with more financial clout could help to finance the overall system and would thus also ensure that it runs smoothly.

In principle, a collectively supported feed-in tariff could be used for such systems, similar to the German Renewable Energy Sources Act (EEG). The WG 4 – Rural Electrification working group of the European PV technology platform developed a proposal for this [3]. The technical feasibility of such stand-alone systems was demonstrated on the Greek island of Kythnos (Figure 6). This is similar to independent generation in the integrated grid, but research is still required for organisational implementation.
Stand-alone grids can be connected to one another or to the integrated grid using suitable, i.e. grid compatible control technology. This allows so-called micro-grids to be formed temporarily, which can then continue to operate without problems even if the main grid fails (Figure 7).

It was proven [5] that a variation of the grid frequency – imperceptible to the user – is suitable to derate excess solar power fairly (Figure 8).

A continuous decentralised derating of PV systems becomes necessary when the batteries are fully charged and electricity is in relatively low demand. It is crucial that the PV systems installed in houses are derated in a fair manner. This is achieved automatically by increasing the grid frequency. Figure 9 demonstrates this for houses on the island of Kythnos.
Financing and business models

The best-known financing model for SHS worldwide is via micro-loans, which also enables poor rural population strata to purchase small systems. Financial scope for paying down the loan is provided by the dropped costs for kerosene. In its basic form, this business model works without government subsidies. It is widely recognised as being highly successful and is increasingly supported by development institutions.

The Grameen Shakti Bank in Bangladesh is an internationally recognised pioneer. It offers the customer not only financing but also guarantees professional installation and maintenance by certified and specially trained contractors. To date, Grameen Shakti has financed more than 200,000 systems.

Common business models for solar home systems also include leases (e.g. SolarLuz), the „Fee for Service Model“ (e.g. the Moroccan PERG-Programme, based on a Public Private Partnership) and subsidies for the acquisition costs [6].

Given the very low income levels, mini-grids in rural areas of developing countries are generally not economically self-supporting. A common form of financing that allows independent electricity generators to make profit is a subsidy on the investment combined with tariffs covering operating costs for end customers [7].

This model, for example, is often used by African “Rural Electrification Agencies”. In practice, however, it has often been shown that the users’ low capacity or willingness to pay causes the cash flow of these projects to remain below expectations.

The moment the batteries need replacing is therefore generally regarded as critical to the sustainability of this financing model.

Following the feed-in tariff, the Joint Research Centre of the European Commission (JRC) developed a tariff concept tailored to mini-grids in cooperation with the EU PV technology platform named Regulated Purchase Tariff (RPT), which is a strong incentive for independent electricity producers to continuously operate the system while giving financial leeway for required repairs and replacements of system

Figure 8
Derating the decentralised feeding PV generators. The power inputs of the PV generators before and during the derating. [5]
components. Depending on the actual electricity generation, compensation guaranteed by the government will be granted, which will ensure the sustained operation of the system in combination with the user fees. This model has yet to be tested in practice. The RPT corresponds to the development policies of output based aid, which is becoming increasingly important.

Summary

In order to electrify off-grid regions, systems in the range of under 50 watts to systems of several megawatts were developed that are fed with renewable energy.

Very small systems which are privately owned by the electricity consumers are already operated sustainably worldwide. There are also appropriate financing and operator models.

An even greater challenge are the so-called mini-grids that can be successfully operated as stand-alone grids but which impose significantly higher requirements to the organisational framework. The advantage of grid interconnection is both the equalisation of generation and load and the higher energy yield as less power has to be stored or derated.

The goal is to build power supply grids for densely populated areas which offer a secure supply and a high grid quality and can possibly later operate in an integrated grid. The challenge now is to develop financing and support models and to provide incentives for investors and the sustainable operation of the power supply systems that can be used in the respective regional socio-cultural environments. The “Renewable Energy Regulated Purchase Tariff” [3] is a viable model especially for stand-alone grids which, however, still needs to be tested in practice.

The development of grid-compatible stand-alone systems, which has been promoted in Germany since the nineties, has also allowed for a technological edge for the next generation in grid technology of integrated grids. The systematic introduction of modern information and communication technology at the distribution grid level, promoted under the slogan “Smart Grids”, also benefits from this preliminary work. An example is the so-called micro-grid that can work as a distribution grid in an integrated grid and, in the case of a blackout, can ensure supply as a stand-alone system.

Acknowledgement

The research upon which this article is based would not have been possible without the support of the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) and the European Commission.
Literaturliste


Strategic research objectives

- Future mobility based on renewable energies
- Integration of renewable energies into electricity and heat supply
- New strategic challenges for research and development of renewable energies
- Research for global markets – Strategic approaches of the BMU
- The area of conflict between technology transfer and intellectual property protection
- Innovation structures in Germany for technological leadership – Solar Valley Central Germany
- Panel discussion: Are Germany’s economy and research in renewable energies fit for international competition?
Future mobility based on renewable energies

In Germany, traffic accounts for about 20% of all CO₂ emissions. The main pollutant is individual traffic, i.e. cars and lorries, with about 80%. The average consumption of fossil fuel per vehicle has fallen in recent years but worldwide the total number of vehicles is continuing to increase beyond the current 900 million and therefore also the consumption of fossil energies and CO₂ emissions along with it. High CO₂ emissions that acutely threaten our environment and the finite reserves of fossil fuels such as oil and gas are therefore, in addition to the increasing air pollution in urban areas, the main reasons almost all major vehicle manufacturers are working intensively on alternative vehicle concepts.

The German federal government has recognised the problem and supports the development of technologies for battery and fuel-cell assisted electric vehicles with its „National Electromobility Development Plan”. Both share the extremely energy-efficient electric drives and the option of using renewable sources such as solar or wind energy for their energy supply. Another promising approach is supply based on biofuels. The ecological potential and the characteristics of all three vehicle concepts will hereinafter be briefly described and compared (Figure 1).

Battery electric vehicles (BEV)

Vehicles powered by electricity alone have an electric motor that draws its power from an onboard battery, in contrast to conventional combustion engines that are powered by petrol or diesel. The battery is regularly charged with power from the stationary grid. Electric motors are very efficient with energy. Petrol or diesel vehicles convert the bulk of the chemically bound energy within the fuel into heat. Electric drive systems, on the other hand, use the electrical energy stored in the battery almost entirely for the drive system. Therefore, they only need about ¼ of the energy that a combustion engine needs (Figure 2).

However, there is still a significant disadvantage: Batteries can store only a relatively small amount of energy per volume or weight, which is more than an order of magnitude lower than that of liquid fuels. The result is that the range of these electric vehicles is still limited to around 150-200 km. However, these vehicles still suffice for many tasks because most of our daily journeys are relatively short, such as the drive to work or to the supermarket. They are therefore suitable as vehicles for commuters, as second family cars or as an urban vehicle.

<table>
<thead>
<tr>
<th>Drive system</th>
<th>(Mobile) energy carrier</th>
<th>Energy source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric motor</td>
<td>Battery</td>
<td>Electricity from renewable energy sources</td>
</tr>
<tr>
<td>Electric motor</td>
<td>Fuel cell</td>
<td>H₂ from renewable energy sources</td>
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<td>Combustion engine</td>
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<td>Biomass</td>
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Figure 1
Vehicle concepts based on renewable energies

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Drivers who have to travel longer distances sometimes should opt for a so-called plug-in hybrid electric vehicle (PHEV). In addition to an electric drive, these vehicles also have a combustion engine that is used when the battery is empty. In extreme cases, the combustion engine only serves to generate electricity for charging the battery. This allows for very simple vehicle designs without any kind of mechanical connection between combustion engine and wheels. Such plug-in hybrid electric vehicles are ideal for the transitional phase from conventional combustion-driven vehicles to electric vehicles. They are mostly electrically driven but since they do not abruptly stop when the battery is empty, which is what drivers might fear, they have great market potential as universal vehicles. Electric vehicles show virtually no local CO₂ emissions. For the total balance, however, the source of the electricity is crucial. If it is from a coal-fired power plant, which also transforms a high proportion of primary energy into heat instead of electricity, the emissions turn out to be about 160 g of CO₂-equivalent for a small car – more than petrol and diesel vehicles. In this case, nothing would be gained.

With the current German electricity mix, things are already looking better. With just under 110 g, there is already a modest improvement over conventional vehicles.

However, electric vehicles only really make sense if the electricity is largely generated with renewable energy sources, in which case negligible CO₂ emissions are achievable. Therefore, the introduction of electric vehicles has to be inextricably bound to rapid increases in the share of renewables in our electricity generation (Figure 3).
Electric vehicles require infrastructures. They account for about 16% of electricity generation today. According to the pilot study of the federal government, this percentage should increase to 30% by 2020, 50% by 2030 and 80% by 2050. As the change-over to an electric vehicle fleet should take place in similar time frames, the supply of electric vehicles with renewable energies would be guaranteed in the medium term.

Electric vehicles primarily draw their energy from the electricity grid. Thanks to the economical electric drive, this kind of supply can be managed without any further problems. If, following the objective of the federal government, one million electric cars were driving on German roads by 2020, our total electricity consumption would increase by less than 0.5% and even if in a few decades all 45 million cars were to be electrically powered, electricity consumption would increase by only 20-25%. However, temporal concentrations of recharging processes could lead to undesirable load peaks. If all vehicle owners were to recharge their cars at night, it could very well lead to grid overload assuming a strong market penetration of electric vehicles. These effects can be avoided with modern control technologies and flexible tariffs, made possible with the introduction of electronic meters: Battery electric vehicles still have to be recharged at regular intervals but the exact timing is somewhat flexible.

This will often make it possible to recharge the vehicles selectively during favourable generation and consumption periods (Figure 4).

Imbalances in energy generation and consumption can be offset within certain limits by choosing the time for recharging the vehicle. In addition to these temporal load shifts, it is even possible to feed back the electrical energy from the vehicle batteries into the electricity grid and thus compensate, or at least mitigate, deficits caused by a high consumption or a momentary lull in the output of wind power plants. This is possible because the vehicles are stationary more than 90% of the time and are available to be connected to the grid. With a high proportion of electrical vehicles, a huge electrical energy storage can be realised that can effectively dampen the fluctuations of wind and solar energy, thus facilitating the further expansion of renewable energy.

**R&D requirements:**
In addition to the further development in lightweight vehicle construction, which is especially important for electric vehicles, battery technology in particular needs to be advanced.
Storage capacity, durability, cost, safety and recharging times are all still not really sufficient for a wide acceptance of electric vehicles.

The introduction of electric vehicles also requires the creation of a recharging infrastructure. As electric vehicles only have a limited range, they should always be connected to the grid while stationary. In addition to domestic sockets that can be used for basic requirements, recharging possibilities at work, in front of supermarkets, in car parks or public parking areas have to be implemented in the future. Individual charging stations as they are already installed today on hand-selected sites are not sufficient and above all, too expensive in order to achieve a sufficient density. A universal, affordable, user-friendly charging and billing process is required that allays the consumer’s fear of searching for recharging options.

Fuel cell vehicles

For many years, a number of major vehicle manufacturers have been working on electric vehicles with fuel cells as an energy source. Worldwide, there is a lot of practical experience with cars, lorries and buses. Currently, the vehicles on the road are in their second and third generation. In 2010, Daimler are planning a further development of their B-Class fuel cell technology during test operation. For 2015, a general market launch is planned. Compared to the previous versions, improvements in the lifetime of the fuel cell stack (> 2000 h), its performance (65 kW to 100 kW), range (from 160 km to over 400 km), reliability and cold start ability were achieved.
Fuel cell vehicles also have an electric motor that draws its energy from a fuel cell. The fuel cell runs on pure hydrogen, which is usually stored compressed in a tank. As is the case with battery electric vehicles, virtually no CO₂ is emitted while driving. Of greater importance to the environment, however, are the total emissions of the system. These depend on how the hydrogen was produced and processed. Conventional production from natural gas leads to emission values similar to those of battery electric vehicles that run on the current German electricity mix, which means they are only moderately more favourable than conventional diesel and petrol vehicles. CO₂ emissions can only be reduced to very low levels if the hydrogen is produced using renewable energy, such as via electrolysis (Figure 9). The prerequisite here is that the electricity is to be supplied from renewable energy sources as well.

One difference to battery electric vehicles still remains: Compared to battery electric vehicles, the energy loss in the entire process from supplying power for electrolysis up to filling the pressure tank is several times as high, leading to a significant cost disadvantage for fuel cell vehicles in the future.

The higher energy density (Figure 5) of hydrogen allows for perfectly acceptable ranges of 400 km and more (Figure 6).

That means that the application of fuel cells in buses and lorries remains viable. There is still much room for improvement of fuel cell technology, however. Above all, this includes the high costs, which are expected to be significantly reduced along with further technical progress but above all, by the start of mass production.

Further improvements in the durability, robustness and in the storage capacity of hydrogen are desirable. Another major hurdle to market introduction of fuel cell vehicles is the lack of a hydrogen supply infrastructure. A sufficiently dense network of hydrogen filling stations is a prerequisite for consumer acceptance but it also requires large investments. Nevertheless, an industrial consortium consisting of car manufacturers and energy suppliers have recently declared they want to establish a dense filling station network by 2015.

### Biofuels

In addition to battery electric and fuel cell vehicles, vehicles running on biofuels also offer a high ecological potential. Biofuels either are a part of a closed cycle and the related plants absorb similar amounts of CO₂ during their growth phases as are emitted by the vehicles during operation or they are produced with already existing biomass. CO₂ emissions range from low to significant when compared to fossil fuels and depend both on the method and the individual design.

First-generation biofuels such as biodiesel from rape or ethanol from sugar cane that only use a certain part of the plant are considered moderately ecologically effective. In contrast, second-generation biofuels use the whole plant, resulting in a significantly higher CO₂ reduction.

Today, biofuel has found widespread use in some countries as diesel additive or as ethanol. Worldwide however, only about 2.4% of fossil fuels are substituted by this. In general, biofuel is a limited resource. If one were to use the entire potential area of 3.2 million hectares for cultivating biofuel crops in Germany, a maximum of 20% of today’s fuel requirements could be covered.
However, competing alongside normal traffic, there is also air traffic for which biofuels possibly represent the only viable alternative to fossil fuels, as well as the stationary sector with combined heat and power plants in which biofuel can be used to an even greater advantage. For example, 6 t of wood is enough to produce 1 t of diesel but it can also substitute 2 t of heating oil. The application of biofuel should therefore mainly take place where its advantages are fully realised. One such an area of application is the plug-in hybrid vehicle or vehicles for which an electrification will be much more difficult to realise.

A disadvantage is the high demand for land that biofuels have when compared to wind or solar energy. In order to generate the annual electricity demand of a small car running on biofuel, an area of about 5000 m² of arable land is required. For an electric vehicle with the same annual mileage, the roof of a single-family house with about 20 m² would suffice (Figure 7).

A relatively new approach relies on the production of substitute natural gas called SNG. Hydrogen, produced via electrolysis powered either by wind or solar energy, is methanated in the presence of CO₂ (see Figure 6 on p. 118). This methane can then be distributed via conventional natural gas pipelines and used for local electricity and heat generation and for the operation of natural gas cars. The advantage of this approach is basing the vehicle’s supply on renewable energies, the uncomplicated long-term storage, the presence of a distribution infrastructure and the universal useability of the energy carrier methane. In addition, methane produced from biomass can be included. A disadvantage, however, are the high energy losses in the process chain.

Summary

It is safe to assume that vehicles with battery and/or fuel cell aided electric drives will successively replace our conventional, primarily fossil-powered, vehicles in the private transport sector in the decades to come because of their potential environmental advantages.

Prerequisite, however, is a consistent focus on research and development to improve on the still existing weaknesses such as insufficient energy density, durability, safety, road capability and cost-effectiveness. Furthermore, the rapid creation of a corresponding filling or recharging infrastructure is called for.
Regarding biofuel technology, especially the CO₂ emissions from production have to be reduced. The current processes for producing biodiesel can only be a beginning. In general, biofuels will remain a limited resource and should therefore mainly be used in those niches that do not offer any other solutions.

Luckily, the federal government is supporting all target areas with subsidy funds. This responsibility is shared by five ministries responsible for research and development, economy, the environment, transport and agriculture.
Integration of renewable energies into electricity and heat supply

The challenge of today’s global primary energy demand and its expected increase can be met by renewable energy sources, which are known to have a sufficient potential (Figure 1). In terms of quantity, the sun and the wind could even meet the demands alone but they are subject to great fluctuations and their availability depends on the geographical location. The task is thus essentially defined as the technical and economical development of renewable energy sources, their integration into the supply structures and the transformation of energy systems.

Where are renewables today?

Photovoltaics presently have a global share of only one-tenth of a percent but their learning curve shows a decrease in costs by 20% for each doubling of installed capacity. The global share of wind energy is already at around 1.5%. In recent years, wind energy had annual growth rates of 30-40%.

The coming years will be slightly lower, although the learning curve here shows a decrease in costs by 10% for each doubling of installed capacity.

Looking at the costs plotted against the generated energy is a feasible economic comparison (Figure 2). One can see that all renewables become competitive with conventional fossil fuels when their share is at approximately 20%. This applies to them all equally; cost-effectiveness is not a fundamental but rather a temporal question.

Any sole supply with renewable energies should be based on several pillars due to fluctuations in the availability of the wind and the sun. These include, for example:

- Use of energy stored in biomass
- Demand side management
- Appropriate integration of large pumped storages for medium to long-term compensation
- New storage approaches for short-term grid support as they may arise, for example, with electromobility
How can we significantly increase the efficiency of our energy supply?

Two-thirds of the primary energy stored in the energy source are lost as waste heat in conventional power plants.

For every kilowatt-hour generated directly from renewable energy sources, three kilowatt-hours are replaced on the primary side of conventional power plants (Figure 3). On the other hand, we have to utilise the heat losses for our own thermal demands via a rapid and widespread application of combined heat and power generation.

Another important component is the electrically powered heat pump. It utilises 75 percent environmental heat from the air or the ground and 25 percent operating energy to power heating and water heating. The higher the portion of renewable electricity used, the better the heat pump’s efficiency and environmental balance (Figure 4).

The third major portion of primary energy is used for our mobility needs in the transport sector, with current average efficiencies
around 20%. Here, electromobility powered by regenerative energy is the most efficient alternative (Figure 5).

Transformation of energy systems

As is already becoming apparent today, the increasing shares of renewable energies from wind and the sun in the energy mix will see the current load supply types – base, intermediate and peak load – disappear.

With an increasing share of fluctuating electricity sources, Europe needs a new, highly efficient electricity transmission system that on one hand compensates the fluctuations resulting from local generation on a large scale (the wind will always blow somewhere in Europe) and on the other allows for the integration of the enormous storage power plant capacities, especially of those in Norway.
If the expansion of this trans-European supergrid takes too long or is incomplete, so-called residual-load power plants would have to compensate on a national level. In contrast to previously employed base and intermediate load power plants, these would include the fast-reacting gas power plants with combined heat and power and virtually connectable small-scale systems such as CHP stations, microturbines and fuel cells. Electrical energy storage as it is often proposed could, in principle, also provide for this compensation but it is not competitive with strong grids or residual-load power plants, at least not in the foreseeable future.

Today’s large-scale power plants are not suitable for any kind of fluctuation compensation because they do not adapt quickly enough to power fluctuations. Suitable power plant types would include: gas power plants and combined heat and power plants (engine generators, microturbines, fuel cells) that can be controlled via the appropriate communications facilities.

The expansion of natural gas-based power plants and combined heat and power could be started immediately. The initially growing demand for fossil natural gas is compensated in the medium term by the dropping demand for natural gas heating systems (with increasing combined heat and power and electric heat pumps). The long-term natural gas demand will eventually drop to zero due to its substitution with sustainably produced biomethane and synthesised methane from electrical surpluses (Figure 6). This methane supply also implies that the future natural gas grid – just like the future electricity grid – must be able to handle varying directions of flow. To this end, new management strategies are required (smart grids). The current expansion rate of liquid gas terminals should be upheld in order to allow for an adequate capacity of, for example, methane produced by wind energy surpluses from particularly high-yield locations.

To offset the sharp increase in future fluctuations in solar and wind energy production, the following instruments are available:

- High-performance, high-voltage direct current transmission networks in Germany and Europe for coping with optimally located energy sources from wind and sun, for the large-scale horizontal compensation of power fluctuations and for the connection to large storage power plant capacities, for example to those in Norway.

![Figure 6](image)

**Figure 6**

Conversion of wind, sun and biomass into SNG for storing renewables and distributing them with the existing infrastructure by coupling the electricity and gas grid (Sources: Sterner, Fraunhofer IWES and Specht, ZSW)
• Responsive, decentralised power plants (preferably combined heat and power plants or gas power plants) that are supplied via natural gas grids from biomass and waste-gasification plants with CCS or renewable methane produced from electricity surpluses.

• Interactive grids for electricity and gas (smart grids) in conjunction with load and feed-in management (combined power plants).

The environmental friendliness of electric heat pumps and electric vehicles, including trains, trams and buses, is improved with an increasing portion of renewable energies in the electricity mix.

A consistent implementation of this strategy does not require additional storage capacities for stabilising the electricity grids. However, this is true only for a pan-European concept. Close coordination on the one hand between all European member states and on the other by, for example, the European Commission is key for successful implementation.
New strategic challenges for research and development of renewable energies

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Context

Renewable energy sources have increased considerably in all sectors in recent years. This is especially true for the electricity sector: While 10 years ago, less than 5 percent of the German electricity consumption came from renewable energies, their share has tripled to more than 15 percent today. In 2008, they already generated about 93 billion kilowatt-hours.

This development was primarily the result of the successful and efficient German Renewable Energy Sources Act (EEG). On the one hand, it has enabled private investments to build renewable power plant capacities and on the other, it has served as a strong incentive for technological developments. Regarding renewables, there was an extremely productive relationship between German innovation and research and the young emerging industry.

To date, the heating sector lacks a similarly effective instrument like the EEG, so developments in this area have moved on at a far slower pace and have been less continuous. The Renewable Energies Heat Act, which entered into force at the beginning of this year, now sets out a fixed portion of renewable energies for new buildings. However, the larger segment of the existing buildings is still slow to be upgraded to higher energy efficiencies and renewable energies. In the heating sector, the share of renewables therefore only doubled from 3.5 to 7.4 percent in the same time period. Expressed in absolute numbers, however, this is a similar order of magnitude as seen in the electricity sector. For example, a total of about 104 billion kilowatt-hours of renewable heat was generated in Germany in 2008.

In the transport sector, development was erratic. This is due to the lack of reliability on the part of the political framework. Initially, the Red-Green government supported the rapid expansion of the biofuel industry and created a strong investment incentive for the sector with the tax exemption for pure fuels. In 2006, the grand coalition then decided to terminate the tax exemption for pure fuels and to start to gradually fully tax them instead. To compensate for the expected capacity crunch in the industry, the same government then introduced a quota system for biofuels. Nevertheless, this system change massively slowed down the dynamic development of the market. Added to that, the overall quota was lowered to 5.25 from initially 6.25 percent at the end of the grand coalition government in 2009. The share of biofuels in fuel consumption, which had started from almost zero percent in 1998 and had increased to 7.2 percent in 2007, fell sharply in 2008. Today, the share of biofuels is only about 6 percent. This is equivalent to an energy supply of around 37 billion kilowatt-hours.

Industry forecast 2020

What is going to happen with renewable energies? The industry has set itself ambitious goals. The BEE member companies want to significantly exceed the requirements of the EU and the federal government for 2020. In order to succeed, we need the right political framework conditions. This means, for one, a successful mix of administrative law and market incentives for the rapid expansion of renewable energies in all three sectors – electricity, heat and transport. By 2020, we could then cover 28% of the total final energy consumption in Germany with renewable sources.
It also means appropriate research promotion. This is a matter of supplying the excellent capacities of the German Renewable Energy Research Association and others in Germany with adequate resources and appropriate targets so that we can lay the foundations for further growth and continued technological development to 2020 and beyond.

Electricity generation forecast

We still expect a continuation of the dynamic developments in the electricity sector. With sufficient efforts targeted to efficiency and with a slight decline in consumption of 620 billion kWh in 2007 to 595 billion kWh in 2020, renewables will already cover 47 percent of the German electricity demand in 2020. This corresponds to about 280 billion kWh of generated electricity. Slightly more than one half of this is wind energy (149 billion kWh), followed by bioenergy (54 billion kWh), photovoltaics (40 bil-
lion kWh), regenerative hydropower (32 billion kWh) and geothermal energy (4 billion kWh).

As of yet uncertain remain the effects of the life extension for nuclear power plants as announced by the new federal government, a decision we consider to be wrong. It unsettles investors, impedes competition on the electricity market, reduces pressure for innovation in the energy industry and hinders developments in research and, ultimately, progress in the field of renewables. Depending on the final formulation of the life extension, its negative effect on the expansion of renewable energies will be weaker or stronger. From the industry’s point of view, the decisive factor is that the priority for electricity supply remains on renewables and is not undermined in practice.

**Heat generation forecast**

There need to be more causes for renovation in the heating sector as the biggest potential lies in the insufficient energetic quality of heating systems in Germany; only 12 percent of German heating systems are state of the art. We therefore are in favour of a new instrument. It could be an energetic quality standard that is raised at fixed intervals and requires renovation in all buildings that fail to meet this new standard.

In a second step, renewables should then be a binding part of these renovations. In addition to this regulatory approach, especially financial incentives are still required to promote a faster transition to renewables. To this end, the market incentive programme requires at least 1 billion euro a year and has to be independent from the financial situation of the federal budget. This instrument is a very effective stimulus programme. After all, one euro from public funds triggers private investments eight to ten times that amount. As a result, renewables could achieve a share of 25 percent of the heat supply in Germany by 2020.

**Biofuels forecast**

In the transport sector, only biofuels are available to any significant extent as to limit the use of fossil fuels and replace them. Therefore, a funding re-start of this sector is necessary. The new federal government has taken the first steps towards this goal within the framework of its Growth Acceleration Act. It contains a change in taxation which is to help rehabilitate the pure fuel market for biofuels.

The increase in the overall rate, the next important step, is still pending. The proposed suspension of the planned tax bracket is not sufficient either. The tax rate for biodiesel and vegetable oil should be limited to a maximum of 10 cents per litre.
If the promotion of electromobility is backed by concrete actions – namely, in the field of battery research and during market introduction – the aim of the federal government of putting one million electric vehicles on German roads by 2020 can be achieved in the opinion of the BEE. Overall, the share of renewables in the transport sector’s energy consumption could then rise to 19 percent.

A share of 100 percent renewables is only possible with R&D. But the year 2020 only represents an intermediate step in transforming our energy supply. The long-term goal must be switching to 100 percent renewable energy. Only then can we engage in economic activities in an environmentally friendly way while escaping ever rising fossil raw material prices. So after 2020, we will still need a dynamic growth of renewables in all areas. Here, the great importance of research comes into play again. While we are mostly familiar with, and dispose of, the means to promote the expansion of renewables for the next ten years, we still need significant technological and social advances for the years after.

The consequences restructuring our energy supply has on research and development in renewables can be roughly divided into two categories. In the broadest sense, one concerns “technical” and the other “social” issues.

**Technical aspects of research**

We still require major progresses in our efficiency of energy use. This applies to the entire energy sector, as well as to plant production and the plants themselves in the field of renewable energies. After all, there are also limiting factors in this area, such as the extent of usable land. Regarding plant manufacture, material and energy use have an impact on the remaining balance of CO₂ emissions from renewables.

The main technological challenge, and thus the most important research task, can be described with the term “system integration of renewable energies”. This mainly pertains to the electricity sector, but not only. The higher the share of renewable energies in our electricity system, the lower the remaining fossil capacities.

With this, however, there are less capacities initially remaining to compensate fluctuations in solar and wind energy. New and more powerful storage media, technologies and structures are called for. We also need intelligent control systems that on the one hand help balance power generation and demand, and on the other efficiently coordinate several decentralised power plants.
This concerns not only electricity but also the heat sector in which major advances are needed to optimally connect generation, storage and supply to an ever-increasing share of renewables. Here, the major focus is primarily on heat storage, local heating networks and modern efficiency technologies in private and industrial use.

Combining electricity, heat and mobility is becoming ever more important because the utilisation of renewable technologies is increasingly cross-sectoral in nature. Prototypes such as the hybrid plant in Prenzlau (Brandenburg) that combines electricity, heat and fuel production, point in the right direction. The important thing in the relatively young field of renewable energies is research that is diverse and open to new technologies because setting course too early towards a certain goal would hinder promising developments in other sectors. The best technologies and concepts can only be proven in practice. In addition, different technologies also have different time horizons in which they mature and become fully effective.

In the field of electricity supply, smart grids and smart metering will play an important role in the future. There are a number of problems that research has yet to solve to allow for their extensive and successful application. In the future, the electricity infrastructure must therefore allow for both an increased decentralisation of power generation and improved networking over longer distances in order to make power plants feasible for regional supply on the one hand, and on the other to redirect large amounts of power from, for example, offshore wind farms to more remote consumption centres.

A key strategic issue for the energy supply of the future are the regenerative combined power plants. They link various regenerative production units and combine the specific strengths of the individual applications. In order to ensure that the operators of, for example, wind turbines and biogas plants cooperate on a large scale in the future, an appropriate stimulus for regenerative combined power plants has to be integrated into the EEG as soon as possible. In the past, valuable impetus for such an instrument also came from the Renewable Energy Research Association. The increasing proliferation of regenerative combined power plants will then have to be accompanied by research that is in step with actual practice. The therein employed IT components have to be optimised and the communication between plant and grid operators has to be improved.

**Sociological and economic aspects of research**

Now to the socio-political aspects. In this case, too, will the restructuring of our energy supply entail a considerable demand for research. First, there are the business sciences: Existing value-added models have to be advanced and refined for the area of energy generation and supply with regard to renewable energy sources. This is the only way to establish precise distinctions within the production chains and to provide reliable information on business costs and the economic effects of renewables. In this context, new models for technology assessment and evaluation of specific funding instruments are required.

An important research field – also beyond the interests of the renewable energy sources industry – is the question of monetising external effects of energy supply.

Only someone who knows how high the costs of coal and nuclear power are for climate, environment, health and for the availability of resources can properly value the benefits and advantages of expanding renewable energies. Scientific assessment and mathematical models are prerequisites for politicians if they are to develop and apply effective management instruments, thereby promoting the transformation of our industrial society into a sustainable economy.

In social sciences, the expansion of renewable energies opens up new fields in acceptance research. Phenomena such as the contradiction „Renewables yes – but please not on my lawn”
call for scientific investigation. Using the results, appropriate communication and action strategies can be derived, allowing for an expansion of renewables that is in line with the involved locals. Here, it could be possible to develop new public participation models and evaluate the effects of various methods and communication strategies.

Renewable energies depend on an effective legal framework while its formulation is significantly influenced by jurisprudence. This raises the question of how to proceed adjusting legal instruments to promote renewable energies and illuminating hidden obstacles in existing statutory provisions hindering their further advancement. As science, in the field of energy law, has been previously dominated by the perspective of traditional energy production from fossil and nuclear sources, it is now required to increasingly incorporate renewables’ point of view into this area and to close the strategic gap by establishing think-tanks promoting the advancement of renewables.

Conclusion

Overall, renewables have grown steadily since their introduction and have long left their niche. With continued growth, they will become an increasingly dominant factor in our energy supply – with significant consequences for the whole power generation infrastructure, the grids, and ultimately the consumers.

Research has a central role in ensuring a smooth transition towards a new, safe and sustainable energy supply with the goal of 100 percent renewable energy.

German research and development has a top position in the field of renewable energies. So far, the excellent results have been quickly implemented and efficiently applied to technology. A globally leading industrial sector with a high export potential has formed in Germany that is also able to contribute successfully to job and value creation. Despite the previous achievements, research and development in this sector continues to be necessary at a high level in order to increase the considerable potential for innovation and to enable the rapid and complete transformation of our energy supply.

This requires constant impetus from an active research community which rapidly transfers innovative technological developments to the mainly medium-sized companies of the industry. The required research capacity has to correspond to the growth of the markets and has to be guaranteed by an increasing flow of research funds. Research and development of a renewable energy mix must therefore be given priority in energy research.

FVEE and BEE recommend raising funds for research and development of renewable energies and energy efficiency by 20 percent annually, as done so in the last three years, in order to achieve at least a doubling in the medium term. This is the only way Germany can keep up with global market dynamics and meet requirements of the EU as well as its own energy policy objectives for 2020 and beyond. This is the only way the German industry can maintain its leading position in the face of the rapidly increasing international competition.
Research for global markets – Strategic approaches of the BMU

Strategic approaches of the BMU

Energy research is part of our energy and climate policy. The key objectives of energy research in the BMU are:

1. Reducing greenhouse gas emissions
   - Increasing energy efficiency
   - Expanding renewable energies – reducing costs
   - Improving quality and efficiency (e.g. efficiency rates)
     – System integration (e.g. storage, smart grids)
     – Opening up new fields of application (e.g. process heat in the solar thermal field) – Environmental and ecological compatibility, acceptance

2. Creating options for the future
   - Institutional support of the BMBF
   - BMBF research programme “Basic Energy Research 2020+”
   - BMU projects for preliminary research, e.g. at the Fraunhofer ISE, ISFH and ZSW (PV) and the DLR (Concentrated Solar Power – CSP)

3. Jobs in Germany
   - Promotion of technologies lacking potential applications in Germany (e.g. CSP, and to a lesser extent ocean energy)

All of this ultimately serves competitiveness on the world markets!

Who is funding what?

Institutional funding (basic research)
   - BMBF and BMWi: HZB, FZ Jülich, Fraunhofer Institute
   - Federal states: HGF, Fraunhofer, ISFH, ZSW, ZAE, universities

Project funding: basic and applied research
   - BMBF:
     – Basic research – Applied research in multidisciplinary programmes
   - BMU (renewable energies), BMELV (biomass only):
     – Applied research – As well as preliminary research
   - Federal states:

RE research funding overview
   - Project funding of the BMU and the BMELV
   - Institutional support of the BMBF and the BMWi
   - BMBF: “Basic Energy Research 2020+”
   - Multidisciplinary programmes of the BMBF: PV cluster of excellence, PVcomB in Berlin
   - Project funding of the BMWi (shallow geothermal energy, integration/grids/storage)
   - Federal states (The Fraunhofer Centre for Silicon Photovoltaics in Halle, Competence Centre Thin-Film- and Nanotechnology for Photovoltaics Berlin)
   - German Environment Foundation
Figure 1
RE research funding by the various ministries in 2008

Figure 2
Energy research (actual) by German government

Figure 3
International RE research
Export successes of renewables

- PV export quota: 48%
- Wind energy export quota: 82%

Germany plays a technologically leading role in almost all renewable energies worldwide.

Research expenditure for PV in 2008

![Figure 4: PV research expenditure in 2008](image)

Private research expenditure

- R&D expenditure of companies for RE increased by 80% in 2008 (source: EU Commission)
- 5 of the 6 “top-spending green energy firms” were from Germany (source: EU Commission)
- Companies have their own research centres or research organisations (e.g. q-Cells, SolarWorld, Würth Solar, Enercon)

![Figure 5: Private research expenditure](image)
The German Renewable Energy Sources Act (EEG) as an innovation driver

- Private R&D expenditure is ultimately based on the EEG, thus being “induced by the government”.
- The degression of the feed-in tariff provides incentives for innovation.
- The technology bonus provides for additional incentives for innovation in some selected areas.
- The market incentive programme (MAP) also provides incentives for innovation.

Research funding of the BMU in the area of renewables

Figure 6
BMU budget estimates for R&D in the area of RE

Figure 7
Newly approved projects of the BMU in 2009 (118.44 million euros)

Figure 8
New grants of the BMU from 2004 to 2009
Conclusions

- Public RE research funding is well-positioned in Germany.
- EEG and MAP are the innovation drivers.
- Excellent research landscape: HGF, FhG and other institutes, universities and private research centres.
- Germany is the technological leader in almost all RE.
- But: there are new developments in other countries, notably the USA and China.

Further information

  bmu@broschuerenversand.de
- Newsletter of the BMU
- Homepage: “Research” at www.erneuerbare-energien.de
- Research year-book and CD with a brief description of all funded projects (available from PTJ and BINE)
The area of conflict between technology transfer and intellectual property protection

1. Introduction

Against the backdrop of a changing climate, the transfer of clean technologies to emerging and developing countries is urgently called for. At the same time, there is also the legitimate interest of protecting the intellectual property for these technologies. To answer the question whether this area of conflict affects the mitigation of or the adaptation to climate change, the framework of technology transfer and the herein existing obstacles shall be explained.

2. Transfer of clean technologies essential for climate protection

Mainly due to the demands of developing countries, global energy consumption is set to rise; these countries will be responsible for two thirds to three quarters of the total increase in energy-related emissions. In 2004, developing countries caused 40% of all emissions from fossil fuels but will probably replace the OECD countries as the main emitters by the beginning of the next decade.

In this scenario, China will soon replace the USA as the No. 1 emitter (Figure 1).

Consequently, it is not enough that individual countries or groups of countries implement climate protection programmes. Only if all countries participate, will we be able to stop climate change.

The extent of the required economic transformation can be equated to that of the industrial revolution, except that it has to be three times as fast and encompass the whole world. Not only industrial greenhouse gas emissions must be reduced quickly and dramatically but also the outdated and therefore greenhouse gas intensive technologies used for everyday purposes, which are an important factor in respect to climate change due to their high numbers [1].

The UNFCCC, the Kyoto Protocol and the Bali Action Plan encourage developed countries to take all possible measures to facilitate the transfer of clean technologies. Different views and positions have crystallised and those pointing to intellectual property rights are hindering the transfer of clean technologies.

Figure 1
Reference scenario: energy-related CO₂ emissions by region
Source: OECD/IEA World Energy Outlook 2006

China overhauls the U.S. as the world’s biggest emitter already before 2010. Even though China’s per capita emission will reach only 60% of the average per capita emission of OECD countries in 2030.
3. The relationship between technology transfer and intellectual property

Intellectual property rights are basically understood as a privilege granted to the inventor and developer as a compensation for research and development expenditure. It is supposed to be an incentive for further innovations. Intellectual property rights include an exclusive right of exploitation for a limited period, by virtue of which the holder can set a higher price than he could in a competitive situation. This right was added to the General Agreement on Tariffs and Trade (GATT), a pillar of the World Trade Organisation, within the framework of the Trade Related Intellectual Property Rights (TRIPS) in 1994. The agreement strengthens intellectual property rights, its implementation is mandatory and it includes an enforcement mechanism.

Against the backdrop of climate change, technology transfer refers to the requirement of introducing clean technologies to mitigate and/or adapt to climate change in regions where such technology is not yet generally available [2] (Figure 2). Successfully transferring technology includes learning, understanding, using and copying technology with the ability to choose the technology, adapt it to regional conditions and combine it with indigenous technologies [3]. These factors form the so-called technological “hardware and software”, where hardware mainly includes devices and software consists of training, education and management.

Intellectual property rights shape technology transfer: There are two kinds of paths along which such technologies can be transferred: horizontally and vertically.

- **Vertical technology transfer** implies relocation or sale of a technology without sharing the underlying intellectual property rights, usually by selling finished products to end users or by transferring all production rights to an investor [2].

- **Horizontal technology transfer**, on the other hand, implies the exchange of intellectual property, mostly in the context of joint ventures or between a foreign direct investor and a native company located in the target countries [2].

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**Figure 2**
Relationship between technology transfer and intellectual property

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<thead>
<tr>
<th>Intellectual property</th>
<th>Requirements analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exclusive right of exploitation for a certain period as a compensation for research and development expenses</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Technology transfer</th>
<th>Technology choice</th>
</tr>
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<tbody>
<tr>
<td>Technology transfer involves learning, understanding, using and copying a technology with the ability to choose the technology and adapt it to local conditions but to also combine it with indigenous technologies.</td>
<td>Paths differ greatly from sector to sector, technology, maturity and national circumstances</td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Reproducibility</th>
<th>Considerations of the transfer conditions, agreement and implementation</th>
</tr>
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<tbody>
<tr>
<td>Evaluation and adaptation to local conditions</td>
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Dr. Hoffmann, Lewerenz et al. • Technology transfer and intellectual property protection
4. Causes for stagnation of the transfer process

Certainly, a manufacturer and developer of clean technologies does not „lose“ know-how if he makes it available to emerging and developing nations at no costs, however third parties may now benefit without consideration of costs and efforts of developing said new technologies; undercutting and the resulting market displacement imperil the company’s economic survival. Intellectual property rights are based on these considerations and they serve to protect from exactly these losses, but at the price of complicating technology transfer [1].

In order to ensure that intellectual property rights do not hinder the transfer of clean technologies, an extensive transformation, or even re-establishment, of administrative and legal institutions is necessary (Figure 3). Most developing countries, however, lack the required means. On top of that, the necessary skills and expertise need to be acquired. So instead of directly using their resources to reduce poverty and stop climate change, developing countries would first have to establish an extensive bureaucratic and legal apparatus for the protection of intellectual property rights of developed countries, and even that would not guarantee a quick and widespread implementation of clean technologies. Of course these countries will be reluctant to adjust a part of their public institutions to cater to the specific interests of foreign companies. They would then be in a situation in which they would be allowed to use technologies they cannot use due to lack of resources and know-how [1]. Intellectual property rights play a role in technology transfer but only regarding emerging and developing countries’ access to advanced technologies, not to common technologies [4]. So the question is: Who is responsible for capacity building? And so one side pushes this responsibility to the other.

5. The area of conflict

The problem with so many industrialising countries is that they cannot jeopardise their economic growth aiming towards a higher quality of life for the population and that they have to avoid an energy-intensive, unsustainable and environmentally harmful industrialisation process at the same time.

Vertical technology transfer unfortunately ignores this dilemma. It may be entirely possible to spread the technology for solar cells, for example, by selling them in developing countries...
From an environmental perspective, this might even be satisfactory but the interests of developing countries in capacity building and application expertise, for example, would be undermined [5].

To date, almost all organisations mainly follow a project-oriented approach, which lacks a strategic dimension with regard to the integration of renewable energies into the energy supply systems. Coordination is informal, meaning that there are no evaluation reports for assessments, lessons learned and experience gained from the projects. Another risk of lacking networking lies in the fact that projects are carried out independently or in competition with one another, and in occurring redundancies [6].

In short: The problem is characterised by heated and biased questions of responsibilities and operating primarily without a solid empirical foundation.

6. A step-by-step approach based on economic criteria

Technology transfer usually starts with local development projects. This is mostly about improving the living conditions of the locals and building their confidence in the new technology. Even if this can be accomplished, the following steps will have to be taken to ensure a successful technology transfer (Figure 5):

A) Pilot project

In addition to the objectives of a project, the potential of a further technology transfer should be analysed, too. Here, one quickly comes across criteria of economic efficiency, in addition to political and/or environmental aspects, which should be evaluated in a structured analysis. When selecting the pilot projects, the subsequent spreading to the larger region ought to be an important selection criterion.

B) Service and maintenance

Securing an active and operating system includes two aspects:

- Storing spare parts on site, in order to start repairs quickly and avoid lengthy and costly ordering processes.
Experience from previous projects has shown that complete system failures were often caused by apparently small problems. For example, the lack of a suitable fuse costing just a few cents resulted in failure and even ruined the whole system in a short time.

• Equally important is a more thorough understanding of the products in order to maintain an adequate quality level of service and operation.

C) Installation of products

This requires furthering one’s understanding of existing technologies and products significantly. At the same time, entrepreneurial structures have to be established, including project management, logistics, quality management and after-sales service.

D) Production

This will usually only be useful if the market volume of the specific region is large enough for an adequate sales volume.

It is also necessary to build a working network with suppliers, customers and universities to develop own processes and patents and thus limit licensing costs. It is suggested that from steps A to D, the plant sizes increase from the sub-kW into the MW-range and thus the extent of the intellectual property (IP) to be transferred. By step C or D the latest, companies will usually only agree to a transfer if the economic exploitation of IP rights is clearly regulated.

Technology transfer to emerging and developing countries should not only be a matter of economic criteria but also of environmental and developmental goals. Only with the role of a “central coordinating body” that controls this area of conflict, that considers IP an economic good and does not lose sight of the steps A to D will it be possible to ensure transfer of technology to these regions to the necessary extent and with long-term success.
Literature


See also:
Innovation structures in Germany for technological leadership – Solar Valley Central Germany

Summary

The federal states of Saxony-Anhalt, Thuringia and Saxony have developed into a region with the highest photovoltaic industry density in Europe. In the regional cluster “Solar Valley Central Germany”, a comprehensive innovation concept was launched, made possible by a cooperation between the industry, research, education and politics, allowing for the implementation of the latest solar technologies in the industry and which aims to create additional jobs in the region, beyond today’s 11,000 up to 40,000 by 2020. This concept allows solar power to reach competitiveness with electricity from conventional fuels.

1. Introduction

In the cluster “Solar Valley Central Germany”, winner of the Cluster of Excellence innovation competition held by the German Federal Ministry of Research in 2008, this international leadership is further expanded upon with an alliance of industry, silicon photovoltaics research and educational institutions. With appropriate cooperation and topical coordination, solar power is to reach competitiveness with electricity from conventional fuels. With the planned investments by industry partners and with public funding, “grid parity” can be achieved within a few years. This would mean that solar power would cost less than “electricity from the socket”. This is the crucial milestone.

2. The world’s leading photovoltaic region

The region – consisting of the three federal states of Saxony, Saxony-Anhalt and Thuringia – has Europe’s highest density of photovoltaics companies (Figure 1). In 2009, 11,000 workers were already employed in this area. The industry-specific growth rate in recent years was over 35 percent; a similar average growth rate is expected for the coming years.

The leading manufacturers in the region – representing 43% of the German PV industry turnover – are the motor of the innovation concept “Solar Valley Central Germany”.

3. The innovation strategy in the “Solar Valley Central Germany”

Currently, 29 global companies, 9 research institutes and 4 universities are cooperating to pursue three interrelated goals in a jointly adopted strategy:

• Technology development
• Education and
• Cluster management

The strategy is being implemented in 98 individual projects with a total budget of €150 million over a period of five years. The public sector – the Federal Ministry of Research and the state ministries – are funding 50% of the expenditure. The cluster is managed by the industry, which is responsible for work themes, partner selection and financing the equity ratio.
This tightly coupled approach to development is effectively supported by the regional network of stakeholders. Technological development is forced within the framework of a long-term innovation strategy incorporating all steps of the value chain in order to promote solar power system efficiency, product reliability, service life and reduction of production costs. All innovations share the ultimate goal of reducing the costs per kilowatt-hour of energy. The development concept extends from basic research to applications in innovative production technologies.

Of particular importance to achieving the ambitious goals is the adaptability of the respective development results to the interface of the following value-added step.

The cost targets for these innovation goals are based on past experiences: When the installed PV capacity doubled, the price dropped by 20%. The Solar Valley concept will ensure that this price-learning curve (Figure 2) will be carried forward into the future – while maintaining margins for the manufacturers. It will thus make a major contribution towards achieving the grid parity milestone.
With the prevailing solar irradiation in this region, this will already be achieved well before the year 2015.

The field of education includes the specific measures to meet the needs of this rapidly growing industry with regard to professionals and managers on all levels of qualification. An integrated education system for all steps of the value-added chain and for comprehensive strategic tasks is to be established in a coordinated effort of the federal states.

Cluster management supports the professionalisation and expansion of the network as well as the coordination along the value-added chain of the regional PV industry.

Of particular importance are measures for increasing the attractiveness of the region for national and international investors, supporting the foundation of spin-offs and the coordination of joint appearances for international industry representatives, expert panels and political authorities. For the operational implementation, a management platform with regional offices has been established in the three participating federal states, cooperating as an umbrella organisation with the industry representatives on site.

4. Technologies and products for grid parity

The research and development programme for grid parity is being realised in a system of 12 joint projects that are coordinated in terms of content and schedules.

In the key activity area of the crystalline silicon (c-Si) technology line, the objective is to produce a maximum of electricity with a minimum of silicon. This means decreasing the thickness of silicon wafers from today’s 180 micrometres to about 100 micrometres and increasing the efficiency rates of solar cells and solar modules. To reach the ultimate goal of reducing the cost per generated kWh of energy, we need new solutions both at the level of the product and of the manufacturing technology.
In addition, product reliability and a service life of over 30 years have to be guaranteed to the end user.

The milestones on the way to grid parity are agreed upon, what now counts for the year 2011 is:

- More than 30% material savings
- Increasing efficiency to 20% module efficiency for c-Si and 10% for thin-film solar modules
- Increasing reliability and service life of the module to over 30 years

5. Education and research for a future technology

The high-tech photovoltaics industry has an extraordinary demand for highly qualified specialists and managers. In addition to the purely quantitative number of required staff for the rapidly growing industry, the challenge lies in meeting the quality demands of an industry that wants to remain competitive especially in the international high-end segment.

The achievement of cost targets is closely linked to the growth scenarios of the industry. By the year 2020, 40,000 jobs have to be filled, corresponding to 50% of all jobs in the PV industry and its suppliers in Germany.

An integral, cross-state education system is to meet this demand. As an immediate measure, four new bachelor and master degree programmes were launched, six endowed chairs were established and a competence centre for vocational education and training was built.

For the 2011 milestone, the following targets are to be realised:

- Qualification of 5,000 skilled workers in the region
- Recruitment of 2,000 professionals from the region
- Academic education network with 400 bachelor/master degrees per year
- Expansion of PhD positions for 40 graduates per year

6. High-tech region highly attractive to economy and society

With the innovation concept of the Solar Valley Central Germany, structures for technological leadership in international competition are created. This results in new opportunities:

- Environmental policy – CO$_2$ reduction with solar power
- Economic policy – solar power as a driver for clean energy
- Regional policy – Central Germany is developing into a leading high-tech region highly attractive to investors
- Corporate policy – accelerating the innovation process to consolidate the technological lead

An interdisciplinary cooperation of manufacturers and users, planners and architects allows for innovative solar power system solutions that meet technological and economical demands as well as those of architectural designing, landscaping and urban landscaping. These model solutions can affect the manufacturer’s product range and secure unique selling points in the booming buyers’ market. An example is the newly established international conference series BauhausSolar in Erfurt. Bauhaus tradition – with its roots in Weimar and Dessau – and the regional industry see the development of new system solutions and the future paths for an “energy culture”.

In the “Solar Valley Central Germany” cluster, the stage is being set for a change in the energy strategy – in addition to excellence of product and technology suppliers, the announced 40,000 jobs and the qualitative development of the region all being on the agenda.
Are Germany’s economy and research in renewable energies fit for international competition?

Panel discussion with representatives from research, politics and business

Shorter innovation cycles require more research and development

Aulich: In photovoltaics, prices have fallen dramatically, the competition is very strong. The Spanish market declined strongly in 2008, leading to a build-up of high excess capacities and manufacturers were pressured into disposing their products. In addition, the production technologies for renewables, developed mainly by German plant constructors, spread rapidly and become internationalised. This means that the cycle from the good idea in a research institute leading to production is not 7-8 years like it used to be, but only two years now. The only chance we have is to increase the pace of innovation and thus increase R&D expenditure even further. Otherwise, Germany will lose its leading position. It also requires greater willingness on behalf of the industry to implement new ideas to reduce costs. This is a prerequisite to keeping the jobs in Germany.

Competition from Asia puts pressure on industry and research

Stadermann (FVEE): My question is somewhat provocative: Research funds have increased slightly and the industry itself is also engaged in research. Why are Chinese solar cells as good as ours? Why have we lost the lead?

Aulich: Germany has been working on the subject for a long time and did all the preliminary work. Other countries, such as China, did not. But if you want to build a solar manufacturing facility in Asia today, because it is a future technology that generates profit and jobs, then you will be able to find a general contractor who will build the facility using the latest technologies, guarantee efficiency rates and even show you how it is done. That was not the case 7 or 8 years ago. If you go to China or Malaysia, you will see German plants that have been built by German plant constructors. These German plant constructors have strong links to the German research landscape. This landscape continues to supply good ideas for further developments. This should indeed be the case but the rate of know-how transfer has increased enormously. If you want to maintain the lead as a solar cell or wafer manufacturer, you already need to have the next technology in store in addition to the one used for constructing the plant. And you should also try to ensure that not all of the know-how remains with the plant constructor; a part of it should be kept to yourself so it is not as easy to resell the technology. But we should not fool ourselves. China is putting a tremendous effort into making its own developments with many engineers and scientists. It is not like they only plagiarise and nothing else is happening. In this respect, there is enormous pressure not only on the German industry but also on German research.
Hoffmann: I would like to mention another factor regarding the competitiveness of German companies: A few months ago, the Landesbank Baden Württemberg (LBBW) published a study demonstrating that there is a 40 percent cost disadvantage for German manufacturers. To my knowledge, there is an investment assistance in China for production facilities of 20, 30 or 40 percent – it depends on the region – until the end of the first quarter. The Chinese manufacturer is provided the rest of the money by the Chinese state bank at a low percentage for 15 years. Added to this is the 10-year tax holiday. And when you add the dollar/euro currency factor to this, it is the “last nail in the coffin”. For these reasons, there are heavy investments in new production facilities in China despite excess capacities. When German or European companies go to their banks, however, there will be long debates whether they get the money at all and on which terms. In other countries, people openly talk about the importance of domestic value creation when public market development programmes are being discussed. I am not suggesting to erect trade barriers to keep out foreign products but we have to react to these international challenges with our framework to be able to maintain Germany and Europe as a centre of technological innovation. So far, I have found no answer as to what exactly this is to look like. We need to consult with colleagues from all ministries and the EU and find out which measures are suitable for preparing us for the future.

International comparison of economic promotion

Kaiser: Yes, the Chinese are subsidising their PV production. But so did we: European structures provide grants to countries, there is support for municipalities, the KFW and funds from federal programmes. Germany, too, used its instruments to promote the domestic PV industry. Now it is a bit more difficult but nevertheless there are still investments in that area. Mr Asbeck is currently expanding his production. And that we now have competition in the market, that module suppliers are having difficulties with the new prices, is normal – it is, after all, a free market economy. We have allowed profit margins of 30-40 percent in the production of PV modules. With this continuing for several years, it does not come as a surprise that we now have a bandwagon effect in this area that is building up excess capacities. The answer can only be: when the Chinese are coming, you have simply got to be better! First, you need innovation to stay ahead in production and cost structures. Secondly, you have got to be better in customer care. Advertise the fact that you manufacture in Germany and treat your customers well. I would like to give an example of what I mean with customer care. The magazine Photon asked a few people to get offers for a photovoltaic roof system with 6 KW. After one month and 30 inquiries, there were 5 more or less serious offers. This is the situation on the market. You really need to take better care of your customers before you step up to politics and demand protection or import restrictions!

European research policy

Hoffmann: I am not at all satisfied with the recent research policy on the European level. Mr Nick-Leptin from the BMU had shown in his presentation that more than 50% of the energy sector research expenditure in Germany is for nuclear energy and significantly less than 50 percent for the renewable sector. Matters regarding distribution are even worse in the seventh EU Research Framework Programme – the eighth is currently underway. This inadequacy in resource allocation should be made more public! We should point out clearly that renewables have already proven what they are capable of – in contrast to the promises we heard in the last 50 years, for example from nuclear fusion. We already know it will be cheaper to generate electricity with renewables in 10 years than any of those systems will ever be able to – if at all. The title to decommission nuclear facilities is a necessity, which is bad enough. But as of now, we are not investing enough in technologies that are supposed to supply us in the future. I therefore have to admit that I am highly dissatisfied with the priorities set by our research policy.
Aulich: When the EU reveal their research and development funding, you can see that those funds are often spent at the national level but presented as part of the EU budget. I would consider it reasonable for the EU to draw up their own budget, handle topics themselves and focus more on renewables than they did in the past. As of now, the R&D budget for hardware, system development and grids is dominated by interests that are not consistent with promoting renewables. From the perspective of the manufacturing industry, the main demand on the national and European level especially is that the funds are not only extended, but granted sooner and more specifically.

Kaiser: Of course we welcome the fact that the EU are supporting research efforts. It is also very fine when they introduce their own programmes. However, they should be oriented towards the politically set priorities. These include climate protection, energy efficiency and, above all, renewables. 20 percent renewables by 2020 is the mandatory target set by the EU. A meaningful way to back this is with increased research efforts.

Weber: I would like to defend the way Germany promotes research in the area of photovoltaics. I believe that we are as strong as we are because we use our relatively small budget to support projects in a very sensible manner. For example in comparison to the NREL in the U.S., a huge institution with a strong institutional funding which is used to little effect in the industry in relation to their resources. In my opinion, the PV industry is well-suited to project-oriented funding in which you propose innovative projects which then should, of course, have at least a 50 percent chance to succeed. Regardless of the allocation procedure, we definitely need the doubling of funds as proposed by the FVEE.

Kaiser: In Germany, research funding is adequate and purposeful. Our next evaluation of our research programme will be in 2011. You are welcome to forward us your suggestions. This is also about more money of course. For example, the approval rate for PV has decreased substantially. That is not because the applications have gotten worse but because there is simply more work to be done in this area. A market has developed there and the pace of innovation has increased. Therefore, there is actually more room for applications. Instead, however, the research budget for PV was frozen. Albeit at a high level – which was politically highly controversial, so the BMU was proud of being able to maintain this level – but frozen nonetheless. We had to grant other areas an increase in research funds. Result: declining approval rate for PV – a very bad situation for German research, very bad for the prices in this area.

Hoffmann: The extension of funds is an important issue. In order to maintain the industry in Germany, it is absolutely necessary to make even more use of existing collaborations between research institutes and the industry in the future. We must work together to achieve an increase of the research budget for renewables and that good applications can be successfully approved with a rate of at least 60 percent. This will require a budget three times as high. It is also to help the German industry remain internationally competitive. The means to this end are certainly not sufficient.

More funding for research into renewables required

Two-track funding approach: Preliminary research and applied research

Staß: Every innovation starts with a fundamental invention. Then there is the pioneer market such as we have today for solar thermal power plants. Then there is the market introduction, as now in photovoltaics. Market penetration comes next, such as for onshore turbines. This is followed by market saturation, now seen with hydroelectric power plants. The question is: Do we engage in research for the next 2 years to maintain a delta of technological advantage? Yes! But we also need preliminary research to discover revolutionary innovations for new applications which may only come about in 10 years time. This is the art of balancing, both of PV but also of other areas such as solar thermal
power plants, geothermal energy, ocean energy and energy storage. A healthy balance has to be found.

Rau (Roth und Rau AG): My comment regarding the BMU: Of course it is important to do preliminary and strategic research here in the Renewable Energy Research Association. But when we file an application as an industry, it is usually for projects that really need a fast implementation for reasons of competitive advantage. When we engage in a specific technology, we need it to be ready for the market by the year after next the latest. The application phases are too long in many cases. After all, the innovation advantage of German companies is the rapid realisation of these projects.

Competitors in Asia or wherever need 2 years as well. They do not necessarily rely on our work but conduct their own R&D. Our research environment is in direct competition to them, too. You have to consider that when you are thinking about deadlines.

Kaiser: To me, it seems a bit too hectic to say “If we do not make it in two years, then it is over”. The bureaucratic response: We are talking about the federal budget 2010 at the moment. It will come into effect in April 2010. Then you can apply for funding in May and it is decided on in September.

Now the research policy response: If the Americans put a lot of money into renewable research now, it will not terribly surprise us at the Ministry. Americans are quick to put a lot of money into an area but two years later, they also withdraw it just as quickly. The strength of Germany was and is continuity. The combination of short-term and long-term projects and the persistent pursuit of many different paths.

We also view the fact that there are several ministries active in research funding as a strength because it provides for a plurality of approaches. There simply are several decision-makers, all of which are important and related in a very interesting way. This is a good structure as long as we work together and not against each other, as long as we share and avoid overlapping research, utilise synergies and encourage plurality.

Not underestimating competition from the U.S.

Staib: At this point, I would like to disagree quite strongly with Mr Kaiser because this American in-and-out policy has now taken on a wholly different quality. The Solar Energy Technology Programme rules that the solar research budget will be doubled for 2010, so another added 100 million euros. Of this amount, nearly 70 million goes to the National Renewables Energy Lab, and they work at a high level. Indeed, we are also competing for research leadership in several other fields. We have to be careful here, and there are also some industrial policy arguments. The U.S. would be so stupid if they would let their market for renewables, as it is visible today, be taken away from them. They are extremely professional and when they start something, they see it to the end. Underestimating the Americans would be fatal. This is why the FVEE recommends increasing funding significantly. The 20 percent per year we suggested is an enforceable compromise in politics but in fact, research needs considerably more.

Kaiser: What was NREL’s problem in the USA? Their financing was secured via institutional funding but for whom were they supposed to do research? They had a buyer market which was hinged on tax concessions that had to be passed through congress every year – or sometimes not. You will not find a continuous partner there. In Germany, we have a solid research landscape based on continuously developed project funding. We have an excellent research landscape and we have an attractive domestic market on which you can put your research products and where you can find industrial partners. And we have a broad political consensus through all parties in the Bundestag, without any exception – this is a fantastic constellation. Now it is important that we, after having invested a lot in the past to develop this potential, put it to use. We cannot allow ourselves to make mistakes at this point.

We have to keep on improving. So my appeal to you is: Let us fight together, and not as competitors in the various renewable energy source fields, to ensure that we all make progress. We
must pull together and clearly show the
decision-makers that this is not for amusement
but rather for our medium-term future.

Research funding as an industrial policy?

Oberzig: There is the expectation that research
policy increases competitiveness and creates
jobs. Is research policy also an industrial policy?

Kaiser: Of course we have an interest in the
continued development of our research land-
scape, in its stability, networking and good line
to industrial applications. Our impression is that
this works quite well. During the presentation
by Mr Nick-Leptin (BMU), you heard that of the
research titles of the Federal Ministry for the
Environment for photovoltaics, about half of the
funds go to the Renewable Energy Research
Association but a good third goes to industrial
projects. I think this distribution is very reason-
able. We should continue to carefully pursue
this transfer from research to practical applica-
tions. In this sense, research policy is indeed in-
dustrial policy with a strong scientific backdrop.

Staß: Science is not an end in itself. The effects
of 20 years of Research Association demonstrate
this. Today’s companies would certainly not be
as successful as they are if they had not received
the technological input. This is also a question
of cycles. Public research funding heavily
invested in photovoltaics in the beginning; the
institutes – also those of the Research Associa-
tion – took part in the technology transfer.
There are very close partnerships with the
companies in which we conduct joint R&D.

In the meantime, the sum of research invest-
ments from the PV industry is four times the
public research funding, and that is only right
and fitting. It is a stated objective and mandate
of the Research Association to support the
industry, but also to work out new scientific
ideas that may only become important at a later
time.

Industrial policy: Clusters of excellence

Oberzig: Is the Solar Valley in Saxony, Saxony-
Anhalt and Thuringia a concept with which one
can improve efficiency in research and which
could also be part of an industrial policy?

Aulich: We have an excellent research and
development landscape in Germany, we have
outstanding people, we have scientists who
enter into the field of solar energy – a very
attractive subject – and want to work hard. On
the subject of clusters of excellence, it is still too
early for a final evaluation because it is only a
year old. I think the approach is very good, it
could be implemented very quickly but also
proved quite complex here and there, a fact
that should not be overlooked. In Solar Valley,
there is a total of more than 98 individual pro-
jects in the various programmes that all need to
be coordinated. Given the international compe-
tition, I think it is very fortunate that there are
companies of many stages of the value-added
chain located there, all within a radius of 100
km. You can even work together with your
competitors because the problem is perhaps
3-4 years ahead. It is a good thing when more
people come to the region – whether they are
suppliers or investors. A cluster of excellence is
like a boiling pot with the lid pressed onto it:
pressure builds up faster and new ideas will
bubble up. I think it is a very good approach.
Research and development as an industrial policy

Schiel: The German Engineering Association VDMA represents manufacturers who offer products for all kinds of energy technologies, not just for renewables. We have had difficulties in the VDMA, for example regarding the integration of photovoltaics on the manufacturer side because we do not want to politically support the high PV remunerations. However, we recognised early that there is a strong group of manufacturers within the VDMA that is engaged in exploring photovoltaic production facilities. This group receives far too little attention in German discussions. The photovoltaics industry is often spoken about as if it lacks sufficient export quotas. Indeed, production technologies in Germany achieve a turnover of over 2 billion euros and 80% of this is exported. In this respect, we have a very strong photovoltaic production facility industry in Germany – in addition to the well-known end-product manufacturers.

The photovoltaic and wind industry provide good examples of a successful industrial policy encompassing basic research, demonstration projects and market introduction back-up. With the aid of energy policy instruments, an entire industry has been established. This holds especially true for the wind energy industry with the 100 and 250 MW Programme. We are attempting something similar in the area of fuel cell technologies with the National Innovation Programme. Something like that sometimes goes well and sometimes it does not. Back when the 100,000 Roofs Programme was discussed and implemented, I was working for a Member of Parliament and still vividly remember the difficulties of this process. We are now experiencing something similar with the market introduction of fuel cells, and electromobility powered by batteries will probably face the same problems. It seems very important to me that the various industrial policy tools – and R&D funding is, in my view, such an industrial policy tool – go hand in hand and ensure there are no gaps between research, development, demonstration and market introduction, or else the industry will fall into a recession.

If you have found an industry to be innovative with a promising export potential, then you have to engage in R&D even if it is ready for the market. There are research papers, such as that of the Helmholtz Association, that regard the wind industry as a market-ready technology no longer as worthy of research funding as other industries. I think that R&D has to remain an instrument of industrial policy – even if a technology is relatively close to the market or even ready for market launch.

Research for other climate regions

Uh (GTZ): I would also like to address some sectors other than PV for emerging and developing countries. An example from Morocco: Solar thermal systems are mainly used in combination with thermosiphons there. Such a system has a size of 2 m², produces 200 litres of warm water and costs about 1,000 euros. The mean per capita income in Morocco is 1,000 euros a year as well. So you can roughly estimate the proportion of the population that could afford it. And who needs 200 litres of hot water per head and day in Morocco? Storage collectors are, I am convinced of that, a fast seller for the whole MENA region. To do this, you need partners and possibly a trans-national research programme with a university in Morocco or in another country. This is just one example, but you always have to look very carefully as to what the markets beyond the developed countries actually need.

The same with medium wind power: This technology fully evolved in developed countries and was subsequently never optimised to meet the demands of the countries where it was newly deployed. Actually, it would have had just the right size for many electricity grids in developing countries but technically, it is still stuck in 1985. The demand for optimisation has to be looked at.

The same with grid integration. But – and this important point is addressed to Mr Wollin from the BMBF and Mr Kaiser from the BMU – you cannot achieve all that from here. That is, we actually have to

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think about getting the products from German manufacturers to the right place. What drives us is the climate problem and that is a global one.

Shortage of skilled workers – promotion of young talent

Schneider (University of Applied Sciences Berlin, HTW): We have talked a lot about development and growth now. To what extent do you consider the limits of available technical staff? Some graphs show an almost exponential growth for renewables but the universities do not provide this kind of output. How do you respond to this fact?

Schmid: The promotion of young talent is an extremely important issue and I think that academic and institutional research is suitable for this in order to add to the educational and training spectrum. We have a massive shortage of engineers in the entire machine and plant construction sector, even so during the economic crisis. We have a demand for additional experts especially in the rapidly growing renewable energy industry. This is particularly true for the wind industry. The graphs for Germany shown to us by the German Renewable Energy Federation may yet be accommodated somehow. But when installation is ready and done with in Europe, then there will be a lack of experts to manufacture to capacity. This is one of the key tasks for the next few years and it is not only specific to renewable energies. The manufacturer of a bearing or a gear box does not necessarily have to have special training as a “renewable energies engineer”, but has simply to be a good mechanic or mechatronics engineer.

Aulich: I would like to differ from Mr Schmid on this. Photovoltaics have a huge demand for junior staff as skilled workers and in the bachelor’s and master area. There are many approaches that can be supported by joint campaigns, allowing you to exercise some pressure on politics.

This is one of the advantages of a cluster formation such as the Solar Valley Central Germany. In Erfurt, for example, a training centre for photovoltaics and advanced technology is being built in which several hundred apprentices will be trained in the coming years. There are also endowed chairs ensuring that the subject of photovoltaics is taught at universities.

Staß: I think young people are in a position to properly assess their future prospects – perhaps the 130 students at this meeting are a good example. Regarding renewable energies, we do not necessarily need specialists but generalists in certain sectors such as process engineering, mechanical engineering, electrical engineering, chemistry and physics that focus on renewables. Asking actively teaching colleagues of the institutes in the Research Association, I learned that the number of students quadrupled in the last 2 to 3 years. I think that the students themselves make a statement with their participation, and universities will listen to this statement. There are now a one and a half dozen interdisciplinary master’s and bachelor’s programmes. So I am quite confident regarding the future. The one and a half million employees in the green industry give cause for a positive outlook.

Kaiser: The courses at the universities and universities of applied sciences are the federal states’ responsibility. As the federal government, we cannot do much for the promotion of skilled workers except help by forming opinions. But the decisions made on the federal state level have longer-term effects. If you fully develop a course, it will have consequences on the labour market 4 to 6 years later. This only makes sense if you find a stable environment, when you can plausibly say that those people you are now attracting to the courses are needed in 5 to 7 years time. Therefore it presupposes that we, in the federal government, pursue a policy that has a long-term orientation.

Do you understand what I am talking about? We have to create a remuneration structure in the area of photovoltaics that enables people to do good business not only in 2010 and perhaps in the first half of 2011. We have to set down a stable political foundation that can bear the load up to 10 years in advance.
International cooperation

Staß: We heard many presentations at the annual conference regarding the adaptation of technology to local conditions in other countries, to the regional climates, to grid integration, but also to the respective societies and cultures. To these ends, we require specific knowledge from the user countries. In this respect, an ideal research partner for global markets should offer competencies that complement our own. We can learn much from one another and especially from developing countries. So it does not always have to be an East-West partnership, it can also be a South-North partnership. There are many good examples in the Research Association. For example, when it comes to solar construction it is a wholly different story for Asia than it is for Central Europe. In this respect, it is obvious that you are going to look for a partner that can provide a lot of input based on experience with the climatic requirements.

Our deficit lies in non-European research collaborations. Americans and Europeans mainly engage in science in a competitive way. This leads to a healthy competition. But on the other hand, we are not utilising synergies and have duplications of effort. There is practically no budget provided jointly that allows to increase the attractiveness of international and non-European research by offering a budget that can be applied to together. In Europe, we have the advantage of being strongly networked in scientific efforts. This is missing at the international level and is urgently required for global markets.

Kaiser: Yes, we do have budgets for international cooperation, allowing for joint applications. We have an agreement with Israel. My suggestion would be a reverse approach: If you find a meaningful level of cooperation, then file a request to the BMU or the BMBF for a joint project. The ministries would like to support such non-European cooperations because we perceive this deficit in the same way as you do. But we believe that this ought to grow from the bottom up, from the initiative of specific agreements between the institutes, rather than us developing a framework agreement and then desperately searching for participants.
Public relations for renewables

Hoffmann: This mix of measures still requires a key element: communication! There is not enough publicity to generate the necessary pressure. At this conference, we have heard a lot about price learning curves. We, as an industry, believe that it will continue to hold true for the next 10-15-20 years due to technology-driven products. But it is an important task to communicate this fact to the general population. The renewables industry – and I include research – has to create a very different understanding of the necessity of renewables in the general public to carry it successfully into the future.

Of course, this includes inspiring young people to enter into these professions. The topic of renewables, especially photovoltaics, suffered an almost exclusively negative reporting in the media in the last three months: the discussion of the energy feed-in act, quotations from the RWI Essen and the Photon magazine, reports in Zeit, Handelsblatt, Financial Times Germany and Der Spiegel.

At the weekend preceding the coalition consultation, we placed a half-page ad in the Frankfurter Allgemeine with Mr Weber from the Fraunhofer ISE to counter the bad press with a few positive facts about photovoltaics.

I think we are all prompted to put things into perspective here. Positive communication will hopefully also encourage more young people to start scientific studies and achieve something in this great environment. I hope that we can get more people involved across the entire value-added chain. Generally speaking, we need mechatronic engineers, solar engineers and people skilled in individual technologies such as wind energy or fuel cells. We need more young people in all of these fields if we are to realise the goal of 100 percent renewables.
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