

# Megatrends, challenges and strategies

Prof. Dr. Frithjof Staiß  
ZSW  
frithjof.staiss@zsw-bw.de

Prof. Dr. Jürgen  
Schmid  
Fraunhofer IWES Kassel  
juergen.schmid@  
iwes.fraunhofer.de

## 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 CO<sub>2</sub>-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)

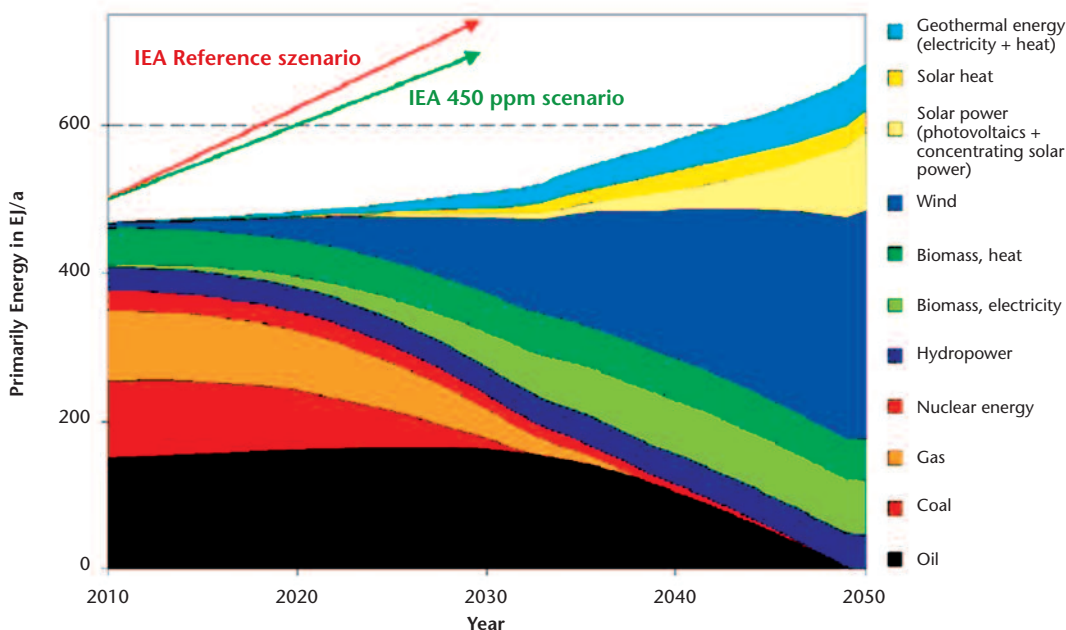
need to be systematically harnessed to ensure that energy requirements do not further increase.

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-



*Figure 1*  
The Fraunhofer IWES’s zero-emissions scenario by 2050 compared with the International Energy Agency’s scenarios

sumption 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 CO<sub>2</sub> emissions today and is burdened with high specific CO<sub>2</sub> 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 CO<sub>2</sub> emissions from power generation from 603 gCO<sub>2</sub>/kWh (2007) to 283 gCO<sub>2</sub>/kWh by as early as 2030. In this scenario, nuclear energy and the introduction of CO<sub>2</sub> 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 CO<sub>2</sub>-free energy supply is thus feasible both technically and economically from today's perspective.

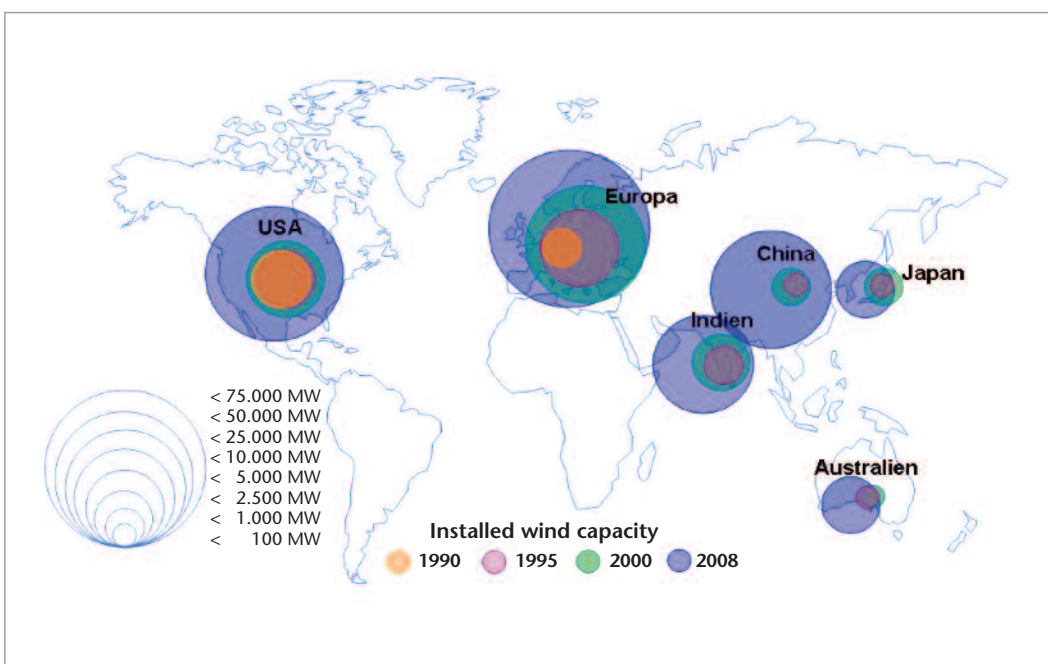
### Rate of growth of markets for renewable energies

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.

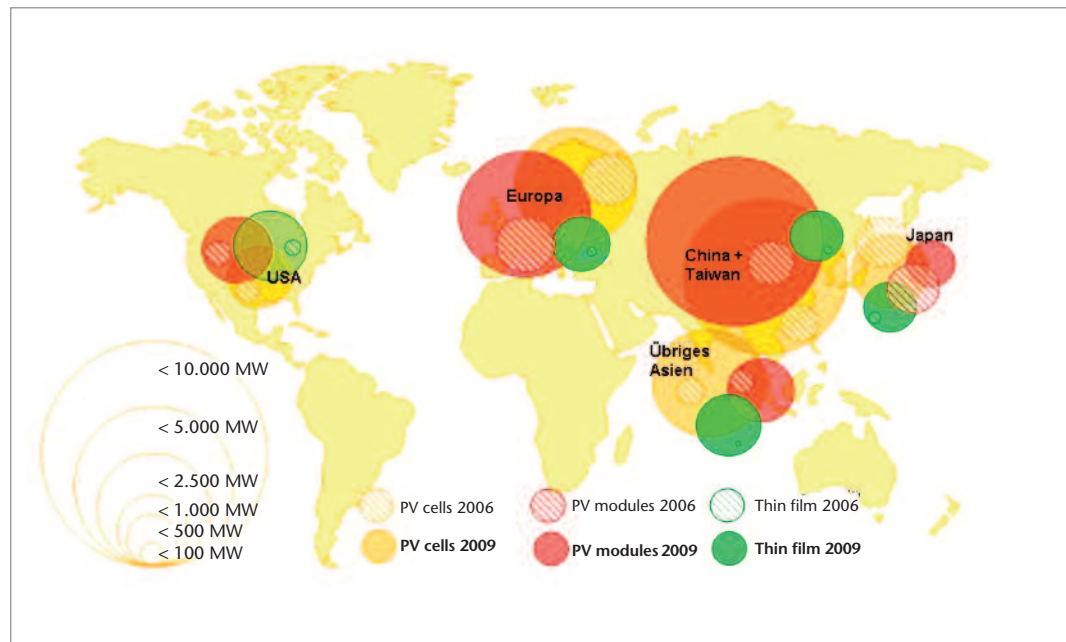
The second example indicates the production capacities for solar cells and modules, which have grown exceptionally quickly in a period of just three years in China and Taiwan above all (*Figure 3*).

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 off-shore 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 2*  
Development of installed wind capacity 1990-2008 [8], [9]

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 21<sup>st</sup> 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

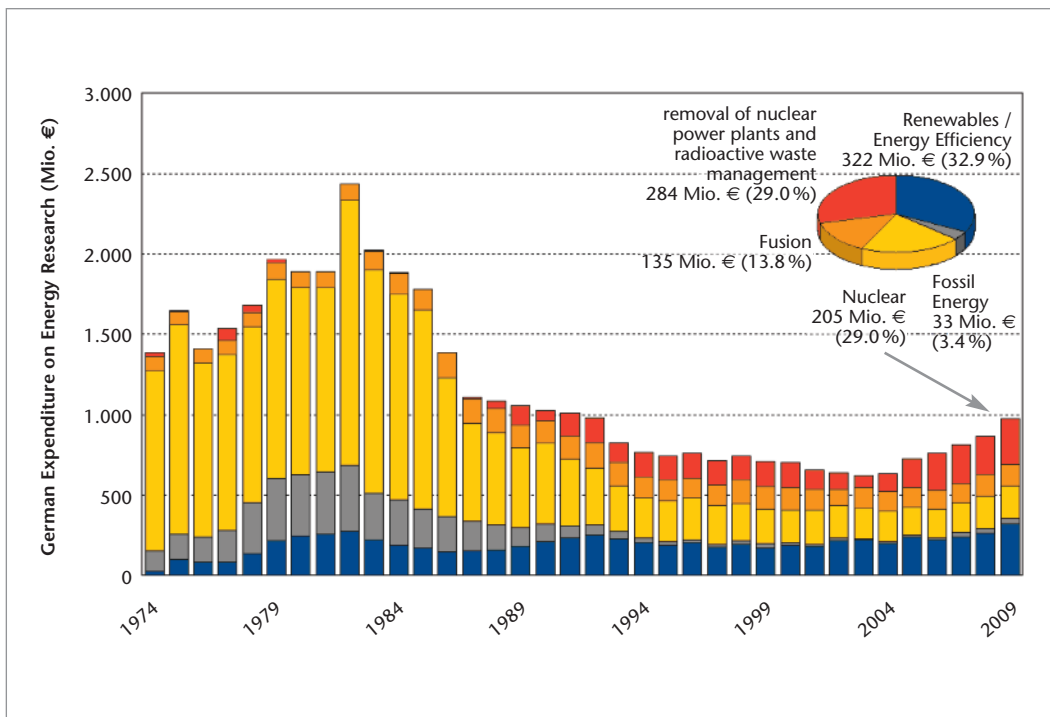


Figure 4  
Amounts and structure of German federal government expenditure on energy research between 1974 and 2009 [16]

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

- [1] International Energy Agency (IEA): World Energy Outlook 2009. IEA, Paris 2009.
- [2] Rahmenübereinkommen der Vereinten Nationen über Klimaänderungen.
- [3] G8 Summit 2009: Chair’s Summary, L’Aquila, Italy, 10 July 2009.
- [4] BTM Consult ApS: World Market Update 2008 (Forecast 2009-2013). Ringkøbing, Denmark 2009 ([www.btm.dk](http://www.btm.dk)).
- [5] Renewable Energy Policy Network for the 21st Century (REN21): Renewables Global Status Report: 2009 Update. REN21 Secretariat, Paris 2009 ([www.ren21.net](http://www.ren21.net)).
- [6] European Photovoltaic Industry Association (EPIA): SET FOR 2020. EPIA, 2009 ([www.epia.org](http://www.epia.org)).
- [7] International Energy Agency: Energy Technology Perspectives 2008 – Scenarios and Strategies to 2050. International Energy Agency, Paris 2008.

- [8] Earth Policy Institute: Cumulative Installed Wind Power Capacity by Selected Country and World, 1980-2007, ([www.earth-policy.org](http://www.earth-policy.org)).
- [9] European Wind Energy Association (EWEA): Wind energy development in the EU 1998 to 2009 ([www.ewea.org](http://www.ewea.org)).
- [10] Sonne Wind & Wärme (Hrsg.): Weltkarte der PV-Industrie – 124 Produktionsstandorte in 31 Ländern, in: Sonne Wind & Wärme, 2/2006, S. 38-39.
- [11] Sonne Wind & Wärme (Hrsg.): Weltkarte der PV-Industrie – Zell-, Modul- und Dünnschichtfertigung – 355 Hersteller in 42 Ländern, in: Sonne Wind & Wärme, 16/2009, S. 93-94.
- [12] Vorbereitung und Begleitung der Erstellung des Erfahrungsberichtes 2007 gemäß § 20 EEG-Forschungsbericht. Projektleitung: Prof. Dr. Frithjof Staiß, Maike Schmidt, Dr. Frank Musiol, Zentrum für Sonnenenergie- und Wasserstoff-Forschung Baden-Württemberg (ZSW). Stuttgart November 2007 ([www.bmu.de](http://www.bmu.de)).
- [13] Das Aachener Modell der kostendeckenden Einspeisevergütung ([www.aachen-hat-energie.de](http://www.aachen-hat-energie.de)).
- [14] Bundesverband Windenergie e. V.: Mit Windenergie aus der Konjunkturlaute. Pressemitteilung vom 21. April 2009.
- [15] Bundesministerium für Bildung und Forschung (Hrsg.): Bundesbericht Forschung und Innovation 2008/2008. Berlin 2008.
- [16] Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (Hrsg.): Innovation durch Forschung – Jahresbericht 2008 zur Forschungsförderung im Bereich der erneuerbaren Energien. Berlin 2009.
- [17] ForschungsVerbund Erneuerbare Energien: Verdopplung der Forschungsförderung für erneuerbare Energien und Energieeffizienz im Koalitionsvertrag verankern. Presseinformation, Berlin, 16.10.2009.
- [18] Wachstum, Bildung, Zusammenhalt. Der Koalitionsvertrag zwischen CDU, CSU und FDP. 17. Legislaturperiode, Oktober 2009.