The global research market for renewable energies: Competition and technology partnerships

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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 CO_2 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 CO_2 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 CO_2-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.

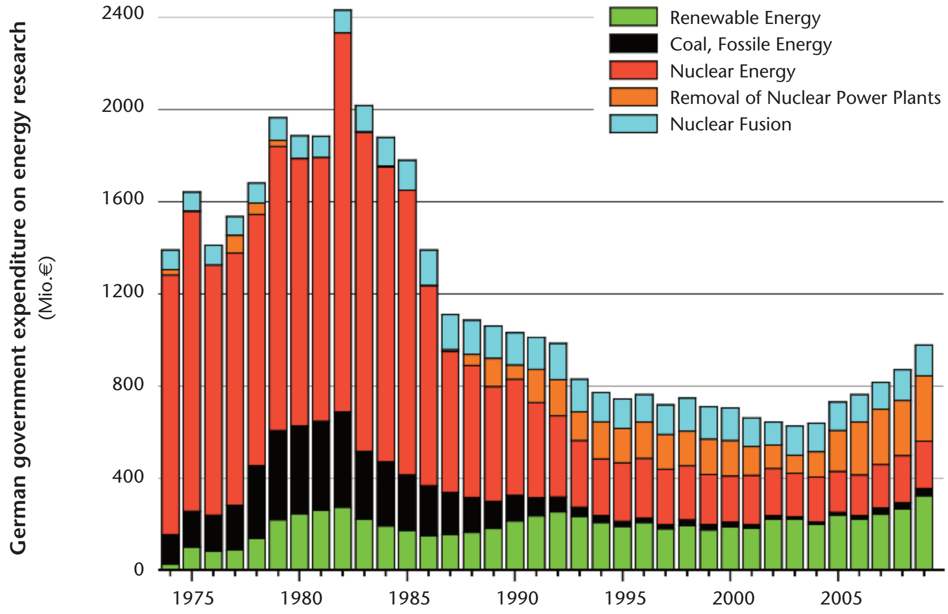
No targets have yet been established for energy efficiency, but they can easily be formulated based on current energy intensity values (kWh/k€ of gross domestic product). The aim of these calculations must be to formulate a global model that also makes it possible to achieve CO_2 goals. In the IPCC's 2007 report, it is shown that the world can afford another 750 Gt of CO_2 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.

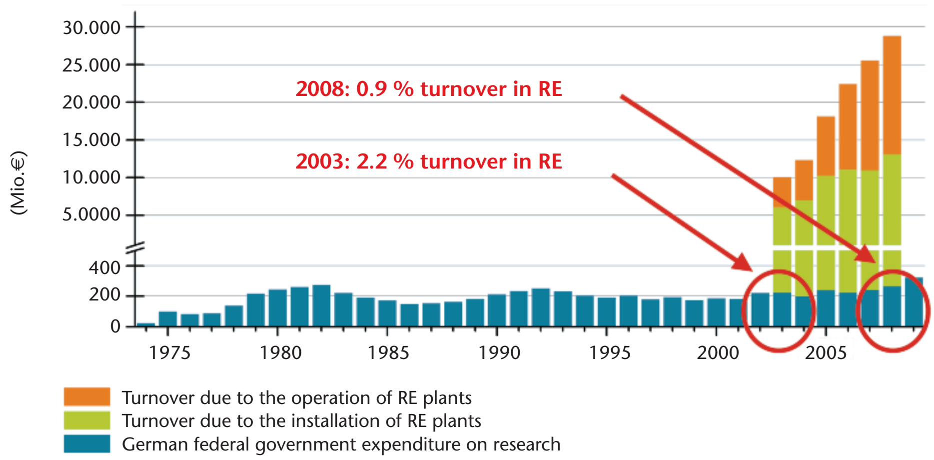
Figure 2 shows that this amount has remained approximately constant over the last 30 years; in 2003, it still corresponded to 2.2% of the turnover of the sector, but the figure was only 0.9% in 2008.

Figure 1
German federal government expenditure on energy research



2009: Energy Research: 979 Mio. €, including Nuclear Fission: 205 Mio. € + 284 Mio. € (removal) (50 %)
Nuclear Fusion: 135 Mio. € (14 %),
Renewable Energy: 323 Mio. € (33 %)

Figure 2
German federal government expenditure on research and turnover with renewable energies



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.

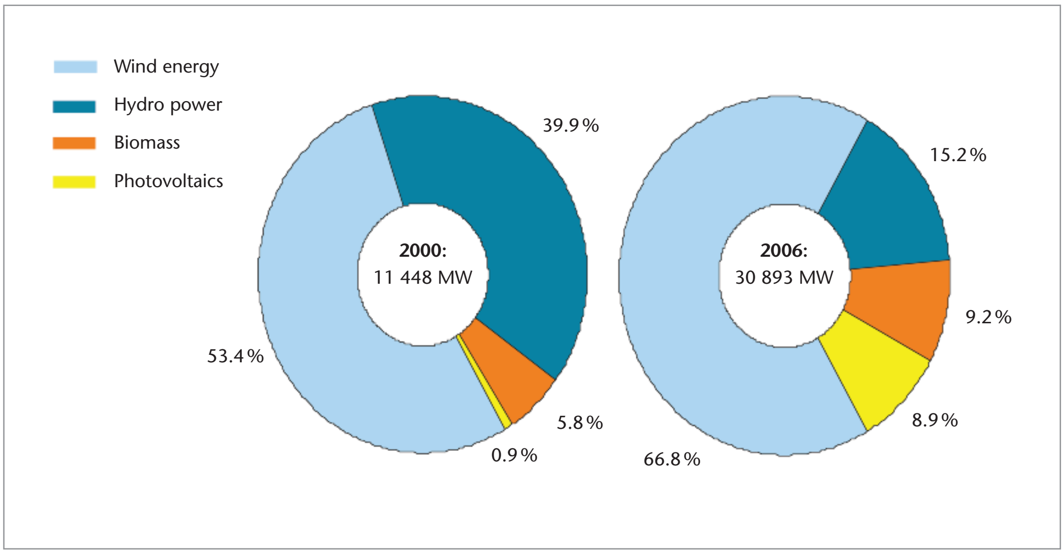


Figure 3
German federal government expenditure on research and turnover with renewable energies

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 semi-conductor 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

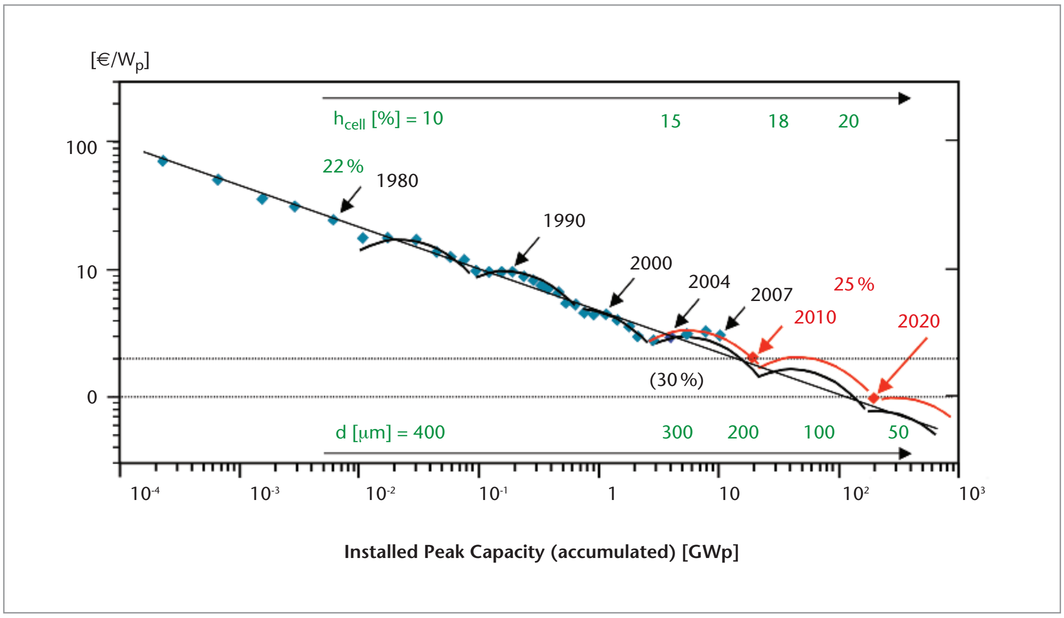


Figure 4
Price learning curve for PV modules made from crystalline silicon

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).

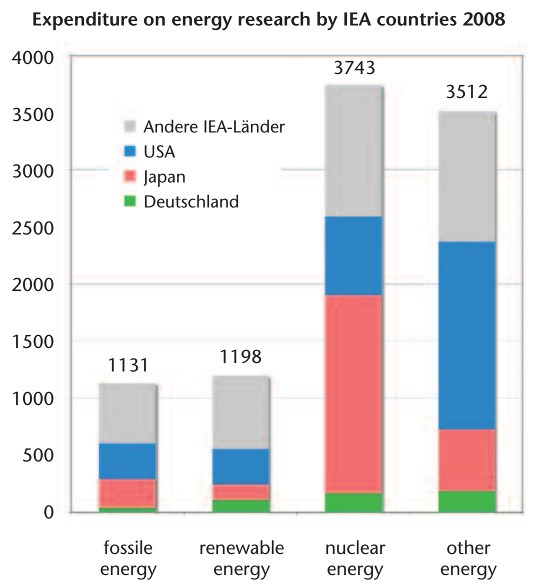


Figure 5
Energy research budgets worldwide

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. Trans-atlantic 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 Minster Annette Schavan has signed the first transatlantic agreement on technological cooperation, particularly in the area of renew-able 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.