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

DLR
Dr. Wolfram Krewitt (†)

Dr. Joachim Nitsch
jo.nitsch@t-online.de

Kristina Nienhaus
kristina.nienhaus@dlr.de

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 CO_2 emissions to 10 Gt CO_2/a by 2050, meaning that the maximum CO_2 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 CO_2 will be captured and stored underground. Assuming that efficiency improvements are very inadequate, the target of

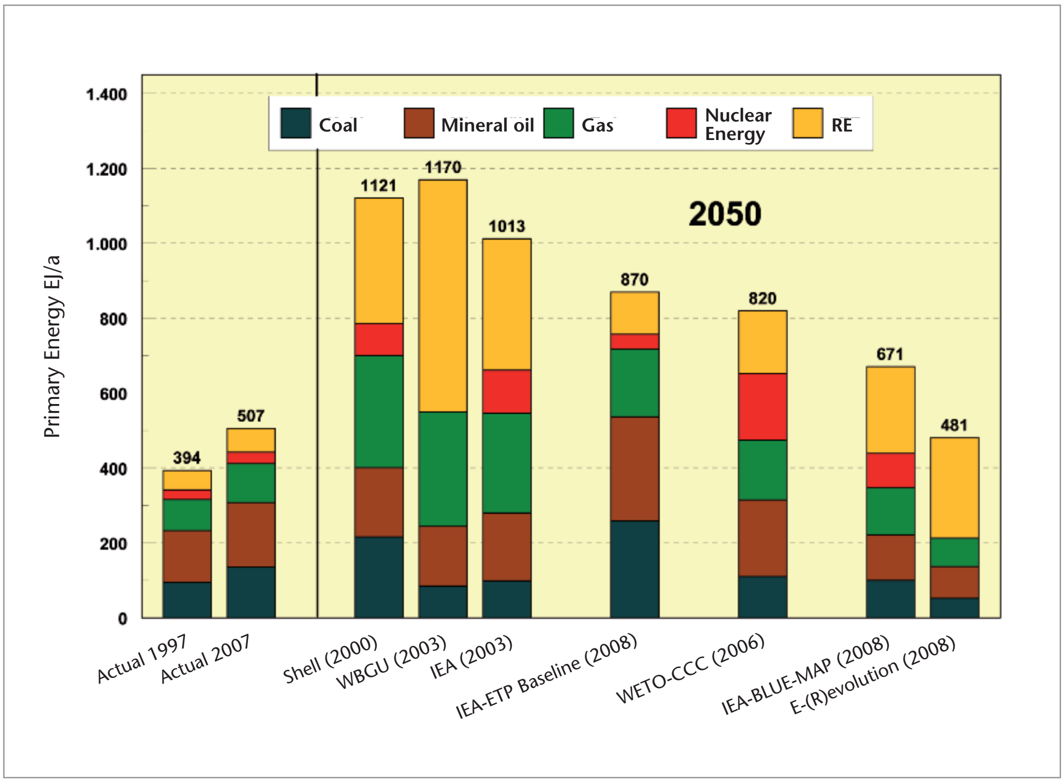


Figure 1

Selected scenarios for global energy supply in 2050

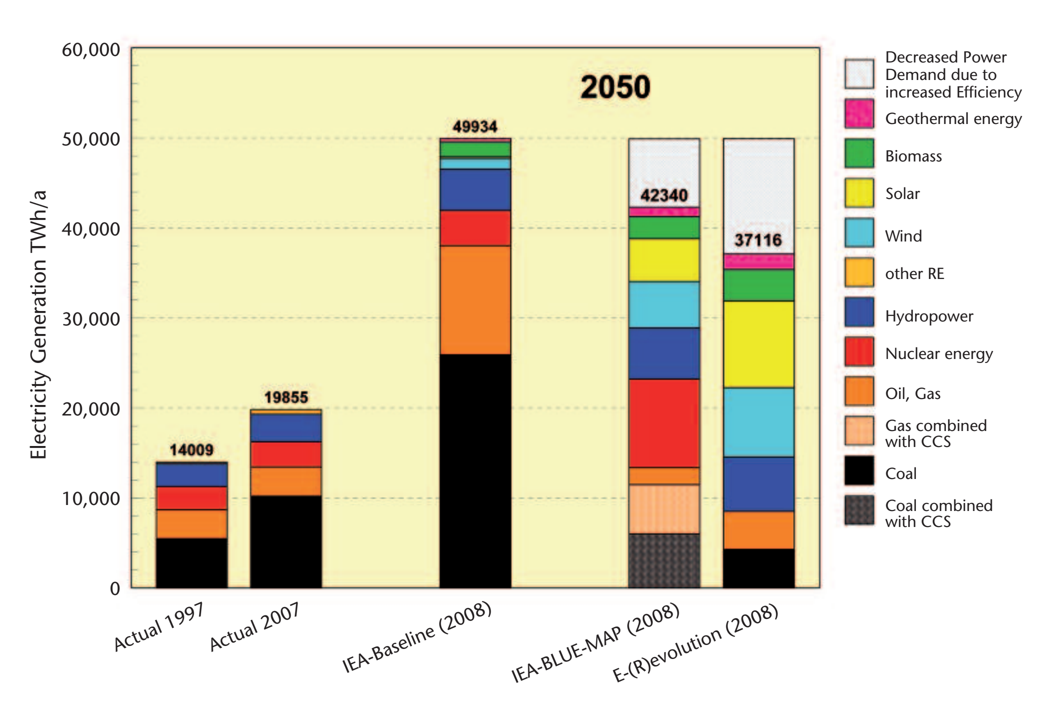
450 ppm will not be met even if the contributions of nuclear and fossil fuels are increased considerably. For example, the WETO-CCC scenario only achieves a stabilisation of the CO_2 concentration at 550 ppm. A very significant improvement in the efficiency of the conversion and use of energy in all 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*).

Figure 2
Structure of electricity supply in 2050 in two 450-ppm scenarios



This growth will demand that 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

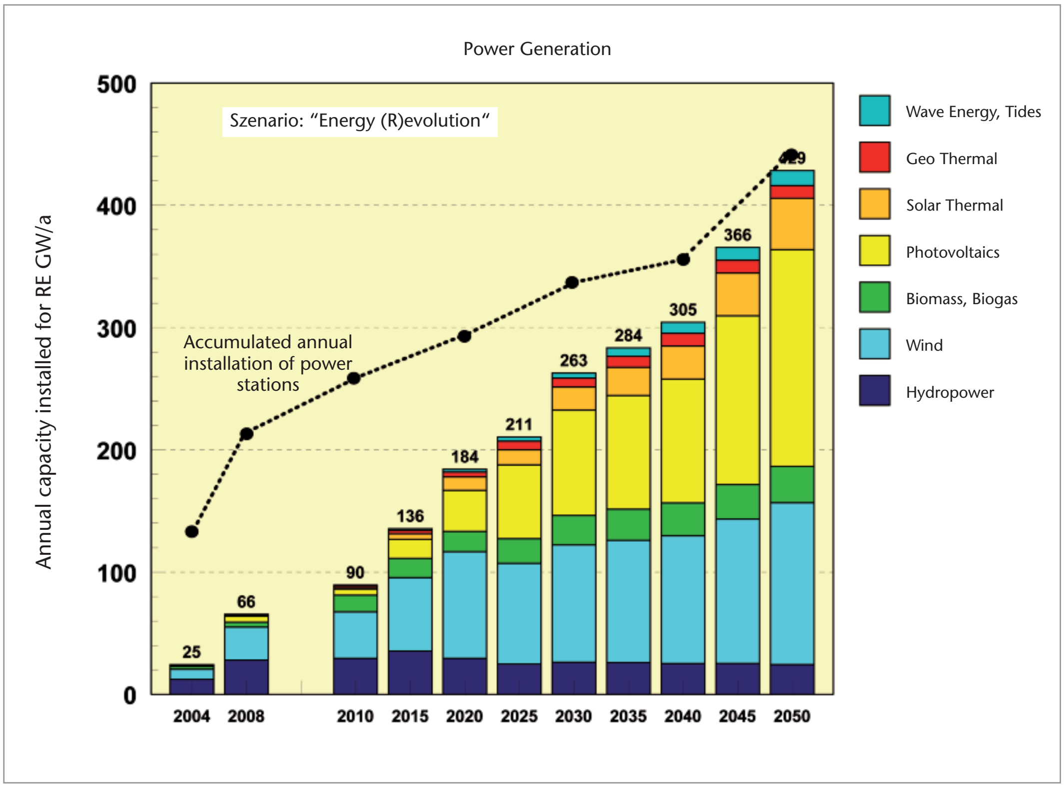
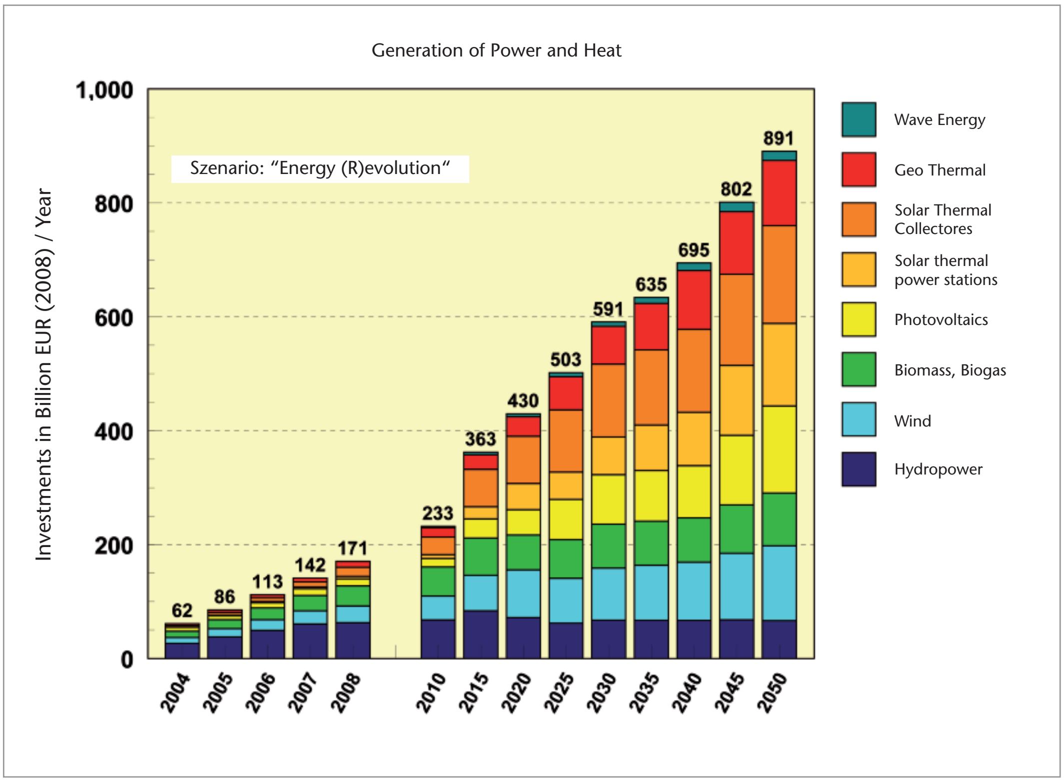


Figure 3
Annual capacity installed for renewable energies in the electricity sector

Figure 4
Global investments in renewable energies for electricity and heat by energy type



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 by 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.