SRU Sachverständigenrat für Umweltfragen

Setting the Course for a Sustainable Electricity System

Five Propositions

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Contents

Introduction

The German Advisory Council on the Environment (SRU) is in the process of compiling a special report on the future of electricity supply in Germany for the period up to 2050. The Council considers one of the greatest challenges to be the transition to sustainable forms of electricity generation that largely avoid greenhouse gas emissions. The focus both in the coming special report and in this summary paper is on electricity generation, as this accounts for a large proportion of German greenhouse gas emissions today. The electricity sector has extremely long investment cycles in power stations and transmission networks. Investment decisions made in the next ten years therefore have implications for the emissions situation to 2060 and beyond. The German electricity supply system must also be considered in the European context.

In this summary paper, the German Advisory Council on the Environment puts forward for debate a number of key propositions and issues. The energy sector faces some far-reaching decisions whose medium-term consequences have yet to be adequately explored. The Council therefore sees a need for timely and broad-based public debate on this topic. With this position paper, the Council aims to provide the impetus for such debate.

Generally speaking, there are four options for the future of Germany's electricity supply:

Option 1: Rapid replacement of existing (mostly coal) power stations, without carbon capture and storage (CCS)

Option 2: Later replacement of existing (mostly coal) power stations, using CCS, from approximately 2020

Option 3: Prolonging the service life of and expanding existing nuclear power stations, and building new nuclear power stations

Option 4: Expanding renewable energy

Which of these options represents the best route to sustainable and secure electricity supply has been a subject of heated debate in Germany for years. It also remains to be seen whether and to what extent they are mutually compatible. To this end, the German Council on the Environment has compiled five propositions for debate. These are set out in detail in the sections that follow.

Proposition 1 **Industrialised countries must cut greenhouse gas emissions by at least 80 percent by 2050.**

This is necessary to prevent harmful climate change and enable a fair sharing of the burden between industrialised and developing countries.

Proposition 2 **The decisions made today affect emissions in 2050.**

The time horizon of the current energy policy debate needs to be extended to take account of the fact that many types of power station have a service life of several decades. Investment decisions made today cannot be allowed to obstruct emission reductions needed in the long term. It is no longer a matter of how we attain our climate change policy targets for 2020 or 2030, but of how we lay the groundwork for successful climate change mitigation through to 2050. The current plans for new conventional *base load* power stations (see glossary) without CCS (Option 1) are therefore incompatible with the climate change policy targets for 2050.

Proposition 3 **Electricity demand can be met in full with renewable energy.**

Achieving this requires a restructuring of the system, notably including expansion of electricity *transmission networks* (see glossary), efficient long-distance transmission lines, and the provision of storage capacity. As converting transmission networks and adding storage capacity take time, decisions as to the direction to be taken must be made on a timely basis. Such restructuring is possible but requires strong political will.

Proposition 4 **Having large amounts of base load generating capacity is incompatible with the expansion of renewable energy.**

As the renewables share grows, the usefulness of base load power stations falls and demand for quick-start generating capacity to provide *balancing power* (see glossary) rises. Options 1, 2 and 3 (base load generation) are not compatible with Option 4 (expanding renewable energy); it is necessary to make a system choice. Going down both roads at the same time is neither technically nor economically feasible.

Proposition 5 **The system choice should go in favour of renewables.**

Coal and nuclear energy are not capable of delivering a sustainable and future-proof supply of electricity. Nuclear energy is not sustainable because of unresolved final disposal problems and other risks. Knowledge of the opportunities and risks of carbon capture and storage – a precondition for the ongoing use of coal – is not yet far enough advanced. As carbon storage capacity and uranium deposits are limited, Options 2 and 3 could only put off the transition to renewables by a few decades.

Proposition 1 The challenge: Industrialised countries must cut greenhouse gas emissions by at least 80 percent by 2050

For climate change policy to be successful, industrialised countries need to cut greenhouse gas emissions by at least 80 percent by 2050 compared with their level in 2000.

On several occasions since 1996, the Council of the European Union has reaffirmed its target of limiting the global temperature rise to 2° C. According to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), extraordinary efforts are needed if this target is still to be achieved. The EU has committed to cutting greenhouse gas emissions by 30 percent of 1990 levels by 2020 provided that other developed countries undertake to achieve comparable emission reductions and economically more advanced developing countries make an appropriate contribution. The German government target is a 40 percent cut in national greenhouse emissions below 1990 levels by 2020. German energy policy must of course be considered here in its European and international context. A key part is played in this connection by the Kyoto Protocol and the successor agreement expected to come out of the Copenhagen conference, and by the EU Emission Trading Scheme.

There is broad consensus in the EU that industrialised countries should cut greenhouse gas emissions by at least 60 to 80 percent by 2050. In the technical part of its report, the IPCC even considers it necessary to reduce global CO_2 emissions by 50 to 85 percent below 2000 levels to bring the 2° C target within reach. For industrialised countries, this implies cuts of 80 to 95 percent compared with 1990. Repeated reference has been made to these reductions at international climate change conferences since Bali. The European Commission has now also gone over to this target range in its communication in preparation for the climate change conference in Copenhagen. Mainly for cost and efficiency reasons, the electricity sector will have to make a disproportionately large contribution in achieving these targets.

Reduction targets of this kind for industrialised nations are not only essential in climate policy terms, they are also a basic condition and requirement for fair burden sharing between industrialised and developing countries and hence for international climate change agreements to be capable of achieving their aims. The idea of contraction and convergence of per capita emissions as recommended by the scientific advisory councils to the German government has now been adopted as a guiding principle in the government’s Sustainability Strategy: “Ethically, every human being has the same right to make use of resources, as long as these resources are not overexploited.”

Proposition 2 The decisions made today affect emissions in 2050

The policy framework put into place in the next few years will be critical in determining the energy development path to 2050. Investment choices made today must not be allowed to obstruct emission reductions necessary in the long term. It is no longer a matter of whether we attain our climate policy targets by 2020 or 2030, but how to lay the foundations today for successful climate change policy up to 2050. Because its time horizon is far too short, the EU Emission Trading Scheme in its current form is unable to take the place of serious and critical reflection about the medium-term impacts of today's investment decisions.

The German power station fleet is about to undergo a major overhaul. It is estimated that between 2.4 and 33 GW of fossil fuel generating capacity will go out of service in the period 2007 to 2020, and an estimated 50 to 80 GW is estimated to need replacing across the entire power station fleet between now and 2030. The large estimation range in these figures relates to flexibility reserves. The technical lifetime even of somewhat older conventional power stations can be considerably extended by investing in modernisation and upgrading. In some cases, service lives can be as long as 60 years. Large amounts of generating capacity also need replacing across the EU. In contrast to Germany, replacement spending over the last decade has mainly related to renewable energy and gas-fired power stations, with barely any new coal-fired capacity. A service life of 40 years is generally assumed for capital-intensive nuclear and coal-fired power stations and in the range of 20 to 25 years for wind turbines and gas-fired power stations. Investment decisions made in the next 10 to 20 years will therefore shape the power station fleet and the energy mix well into the current century. This is especially the case if the replacement capacity consists of capital-intensive base load power stations.

An 80 percent CO_2 reduction target for Germany would be compatible with only a very limited number of new coal-fired power stations without CCS. The Lead Study 2008 compiled for the German Environment Ministry computes that there is scope to build new coal-fired power stations with a capacity of 9 GW. At a targeted 95 percent reduction for the electricity sector, the scope for building new conventional coal-fired power stations would be even smaller. In comparison, new coal-fired power stations with an output of nearly 28 GW are currently under construction or at an advanced planning stage. Germany thus risks blocking its own chances of taking a climate-compatible development path and – merely considering the size of its coal-heavy power station fleet – of joining some Eastern European Countries to play a negative special role for the EU climate policy agenda. Whether this problem could be solved after the fact by retrofitting CCS is not yet clear; it is therefore not currently possible to justify building large numbers of new coal-fired power stations (see Proposition 5).

So far, while 2050 does receive mention as a time horizon in many programmatic documents from the German government and the EU, it by no means has the binding force as a target date that would be needed for long-term investment decisions. For the emission trading sector, the officially adopted reduction path only goes as far as 2025. However, making short-run adjustments on a time horizon of 2020/2030 without considering expected long-term scarcity and price signals poses problems economically and for climate policy. The interim targets (the Kyoto target and the 2020 target) are attainable at low cost with current technologies given incremental improvements (such as efficient coal-fired power stations and CHP) and a fuel switch from coal to natural gas. Replacing an old lignite or hard coal power station with a new one cuts CO_2 emissions per unit of output by only about 30 to 35 percent. But this kind of replacement would perpetuate an unacceptably high floor for emissions well beyond 2020/2030. Interim targets set only a decade ahead thus give false incentives. A coal-fired power station built today may come within the target corridor for 2020 due to its better efficiency, but would have to be decommissioned before time – before the end of its 40 year rated service life – or upgraded to CCS at very high cost if larger emission cuts are needed after 2030. Reviewing the long-term climate targets only shortly before the year 2025, as foreseen by the EU Emission Trading Directive, would thus lead to unavoidable devaluation of fixed capital. Subsequently modifying reduction targets in line with climate policy necessity would probably therefore spark strong resistance from the parties concerned. Similar problems are to be anticipated concerning infrastructure for the electricity sector. German energy policy must extend its target horizons to at least 2050 if it is to avoid a hard choice between sudden structural upheavals with massive devaluation of fixed capital or climate policy failure.

Proposition 3 Electricity demand can be met in full with renewable energy

By 2050, German – and European – electricity demand can be met in full from renewable energy sources. An electricity supply that is sustainable in the long term, climate-friendly and environmentally compatible is feasible.

100 percent renewable energy is attainable

The share of German electricity generation accounted for by renewable energy has more than trebled in the last ten years from around five percent to over 15 percent. Analyses of the potential show that from a physical and technical point of view, EU primary demand can largely be met out of renewable energy sources. Various studies and scenario analyses have shown it to be technically and economically feasible for electricity supply in particular to be provided almost entirely using renewable energy by 2050.

According to the Lead Study 2008 compiled for the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU), 87 percent of gross electricity demand can be met with renewable energy by 2050 (lead scenario). In an alternative scenario based on even stronger expansion of renewable energy use, the Lead Study puts this figure at 94.4 percent. These conclusions are not based on simple quantity balances: with the aid of appropriate storage technology, any level of electricity demand can be met from renewable energy sources every second of the year.

In Germany, wind energy will play the most significant part in the medium term. The integrated European grid will also become more and more important. Relevant scenarios show Mediterranean solar-thermal power stations in particular becoming a major pillar of European electricity supply. In the long term, electricity from solar-thermal power stations in North Africa can also contribute towards Europe’s electricity supply.

Cost estimates for stepping up the expansion of renewable energy sources entail very large forecasting uncertainties compared with other climate change mitigation options and vary widely as a result. Controversy about estimating the cost of different energy scenarios was one of the reasons why a German Bundestag Commission of Enquiry “On Sustainable Energy Supply under the Conditions of Globalisation and Liberalisation” (2002) failed to reach cross-party consensus. Detailed appraisal of the cost debate is unfortunately beyond the scope of this summary paper. There are indications, however, among other things from the BMU Lead Study 2008, that the long-term system costs of electricity supply based on renewable energy may at least be within economically reasonable bounds and comparable with other alternatives, and in the long run may even result in lower total cost. These indications deserve closer scrutiny.

Efficiency first

An integral feature of all scenarios for renewable energy expansion is continued exploitation of the substantial left-over scope for efficiency improvements. Capping and then cutting electricity consumption can help release cost-effective potential for mitigating climate change, enhance security of supply, and reduce the size of the energy supply needed. Investing in energy efficiency can make better economic sense than investing in generating capacity. It is necessary to boost efficiency at all links in the energy consumption chain. The greater the reduction in energy demand, the easier it will be to achieve an extensive switchover to renewable energy. As electricity generation entails large conversion losses, reducing the consumption of electric power has a disproportionately large impact on primary energy consumption. In its Environment Report 2008, the German Advisory Council on the Environment has proposed a wide range of measures going beyond the policy programmes currently in place.

Renewables-generated electricity requires new infrastructure

Expansion of renewable energy makes it necessary to adapt the electricity supply system to new requirements. Integrating large amounts of renewable energy, with quantitative variation in the case of wind and solar energy, requires flexible deployment of conventional power stations, expansion of electricity storage systems, controllable renewable energy sources and effective demand management. The expansion of renewable energy must go hand in hand with greater use of the technical and economic scope for flexible electricity generation systems and with an expansion of electricity transmission networks.

The expansion of transmission networks is needed in order to make use of decentralised generating structures featuring geographical separation of supply and demand and a need to balance generation and demand fluctuations across regions. Looking further ahead, transmission networks must be expanded and linked across national borders. Efficiently transmitting electricity over long distances requires international high-voltage lines with low transmission losses (what is known as a super grid, for example with high-voltage direct current transmission). European-level grid management would also enable regional load peaks to be absorbed and any power station outages to be made good, which would both enhance security of supply and reduce electricity generation costs.

Increasing the renewables share also places more demanding technical requirements on transmission networks, which have to be upgraded towards what is known as a smart grid. A combination of electricity generation management, intelligent routing, integration of decentralised generation capacity and enhanced load management can improve grid load predictability, allow supply to be better matched to demand and hence substantially boost the performance of the electricity transmission network as a whole. This would make the provision of base load capacity using conventional power stations largely obsolete and it would be possible to reduce the need for electricity storage capacity.

The development of an integrated European grid will become urgently necessary. In relevant scenarios, linking Mediterranean solar-thermal power stations, North Sea offshore wind farms and Scandinavian pump storage power plants to centres of consumption is a key element in securing a relatively cost-effective electricity supply from renewable energy. This makes it important to build high-capacity long-distance links as part of a trans-European grid. Only a proper European internal market in electricity with unrestricted transit, safeguarded by effective grid supervision, is capable of ensuring cost-efficient, distributed energy generation from renewables. The EU has the necessary powers in this regard (Article 95 and 156 ff. of the EC Treaty). A problem, however, is that it lacks supporting, comprehensive powers in energy policy. The EU can ensure that there is a free internal market in electricity, but it cannot make stipulations as to energy sources – such as 100 percent renewables – for all member states. The internal market for electricity, reinforced by the expanded transmission network and liberalisation, may thus also have the effect of indirectly benefiting other energy sources.

Implementing a strategy to generate most electricity from renewable energy sources thus poses major challenges for policymakers, especially concerning international cooperation, the creation of transborder incentive systems for market development, rapid infrastructure expansion and adequate public involvement. These challenges can hardly be mastered without clear policy decisions and priorities, including at European level. The necessary decisions can only be taken based on fair comparison of the available system options in the context of a broad-based energy policy debate.

Sustainable renewables-based electricity supply can and must ensure biodiversity conservation

Renewables-based energy supply must take account of biodiversity conservation and environment protection from the outset. Current land use and landscape fragmentation are a major threat to biodiversity in Central Europe. For an energy supply system to be sustainable and climate-friendly, use must be made of landscape and regional planning to prevent electricity generation – including renewables-based electricity generation – from putting biodiversity under further pressure, and harm must be prevented by carrying out comprehensive impact assessments with regard to the environment and specifically biological diversity. Spatial and time-series information is needed at all decision making levels so that potential negative impacts can be estimated and minimised. This need is heightened by the fact that biological impacts on species and populations and physiochemical impacts on water, soil and the atmosphere are scale-dependent. The environmental policy objectives of the Habitats Directive, the Water Framework Directive and related protection programmes (such as Integrated Coastal Zone Management) must be attained.

Similar considerations must be incorporated in particular into decisions concerning the use of overhead or underground transmission lines, which have very different depths of impact on the environment. In biomass cultivation, suitable account must be given to competing agricultural and forestry land uses. Appropriate sites must be selected and cultivated with ecologically suitable biomass crops. When siting wind farms, it is necessary to consider not only the impact on bird fauna, but potential habitat fragmentation and other material ecological aspects. Additional use must only be made of hydropower in places where unaltered, near-natural watercourses are not affected. Accompanying ecological research must continue to be promoted, for example into impacts of underwater noise and vibration on populations of harbour porpoise and other mammals. In this way, the environmental impacts of greater use of renewable energy sources can be minimised.

Proposition 4 Having large amounts of base load generating capacity is incompatible with the expansion of renewable energy

In the view of the German Advisory Council on the Environment, we currently face a fundamental choice between two different development paths for our future electricity supply. The two possibilities are:

– Massive expansion of renewable energy sources, which must be combined with quick-start generating capacity (gas-fired power stations), electricity storage and considerable expansion of the electricity transmission network;

– Expansion of power generation capacity based on base-load power stations (coal with CCS and/or nuclear) while forgoing further substantial expansion of renewable wind and solar energy for power generation as a large percentage of wind and solar power in the energy mix cannot be usefully combined with base load-oriented electricity generation.

The apparently imminent decision in favour of currently discussed plans to build large numbers of new base-load power stations would thus be a decision against the further expansion of renewable energy.

The current debate about the future of electricity supply in Germany is often carried out on the premise that coal-fired power stations are required to provide base load power as a necessary adjunct to renewable energy sources. These coal-fired power stations, it is argued, are needed in particular in light of Germany's statutorily mandated phase-out of nuclear energy. This line of argument restricts the energy policy debate to the question: ***Coal or nuclear power?***

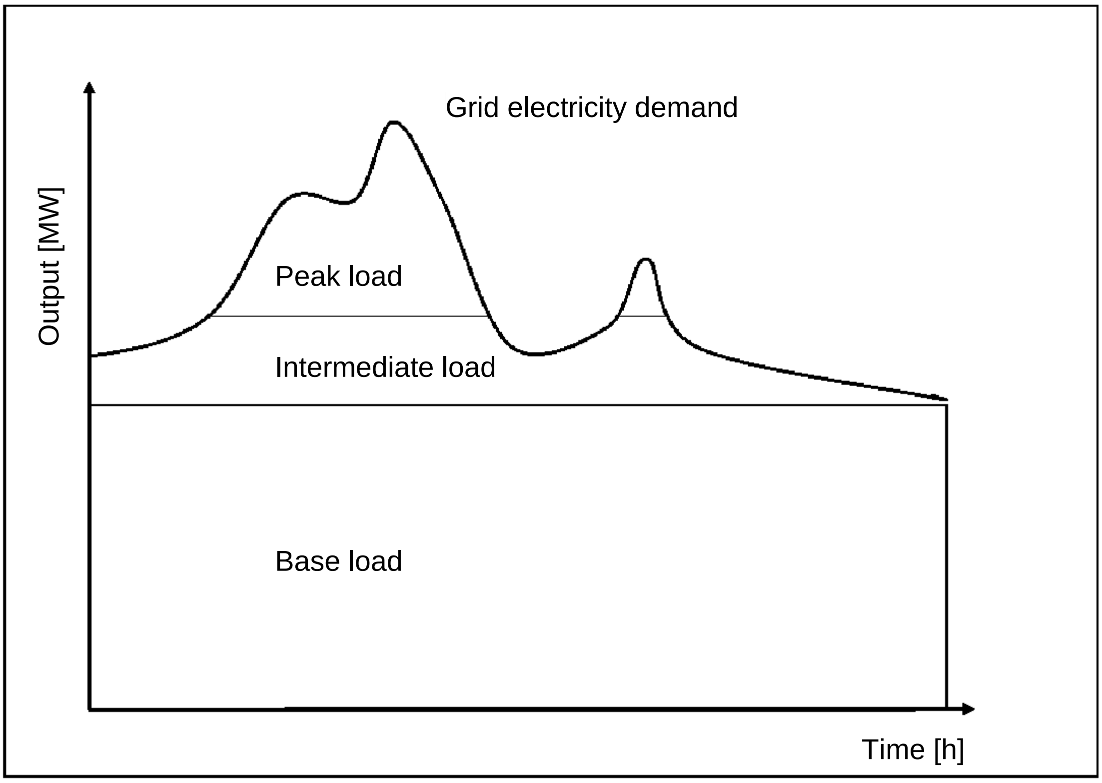
Objective analysis, on the other hand, shows that an electricity supply without coal or nuclear power is possible on the basis of renewable energy sources, and that the expansion of renewable energy that this entails is incompatible with having large numbers of base load power stations. The central question for the future of our electricity supply is thus: ***Electricity generation built around base load power stations (coal and/or nuclear) or built around renewables?***

Systematic analysis of the characteristics of the main renewable energy sources used to generate electricity and of the characteristics of base load power stations (coal or nuclear) shows that wind power in particular, which can be used at comparatively low cost and on a large scale both onshore and offshore, is not compatible with the technical and economic characteristics of base load power stations.

In today's electricity supply system, electricity demand is met over the course of the day and the year by base load, intermediate load and peak load power stations whose output can be varied as needed. Figure 1 shows this based on a stylised daily electricity demand curve. To ensure that electricity demand is met in full at all times, a decision is made at fifteen minute intervals regarding the deployment for the next fifteen minutes of power stations that provide 'firm' power (that is, whose availability can be controlled by the operator). The main determining factor in this *dispatch* decision (see glossary) is the variable cost of the available power stations: Power stations are dispatched in ascending order of variable cost, known as merit order.

Figure 1

Schematic diagram showing the meeting of daily demand under today's electricity supply system

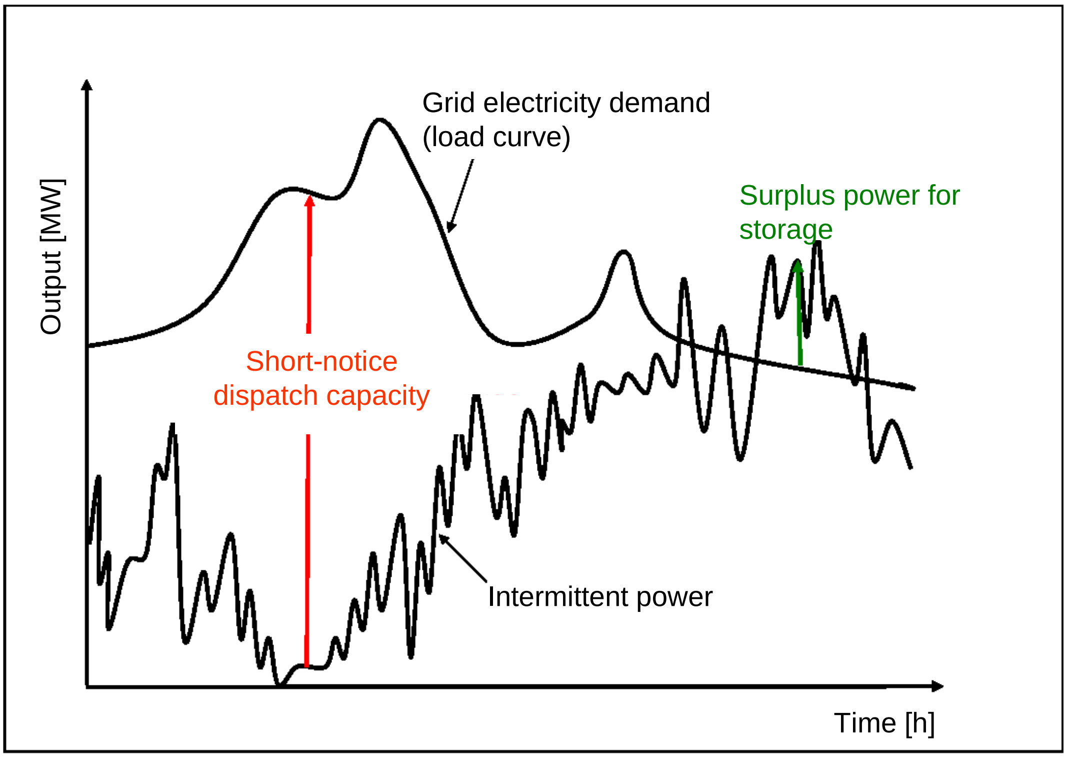


SRU/Propositions on Electricity 2009/Fig. 1

If a large percentage of the electricity supply comes from wind and solar energy – sources of *intermittent power* (see glossary) – then dispatch decisions for power stations that provide firm power change fundamentally, as shown in Figure 2. The aim is no longer to meet current grid demand in its entirety with firm power capacity, but only to make up the shortfall between the strong and potentially rapidly varying contribution from wind energy and demand by deploying power stations that generate firm power.

Figure 2

Schematic diagram showing the meeting of daily demand in an electricity supply system containing a large proportion of wind energy



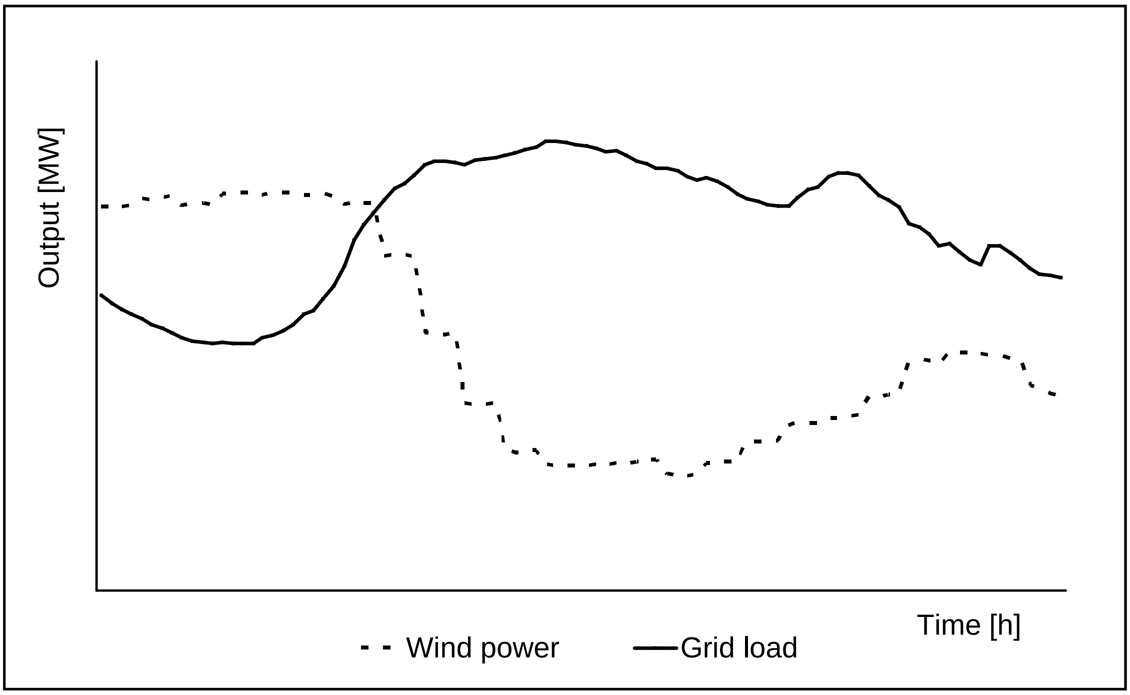
SRU/Propositions on Electricity 2009/Fig. 2

In contrast to almost all power stations producing firm power, wind farms and solar installations need no fuel and therefore have practically no variable generating cost. For reasons of economy, their electricity is therefore always used first to meet demand before drawing on firm power capacity to make up the difference.

Figure 3 shows how the relationship between renewables-generated power and demand might look, using the example of possible future wind power output based on extrapolated (onshore and offshore) wind power figures for the transmission network operated by E.ON Netz AG and a typical daily electricity demand curve.

Figure 3

Possible onshore and offshore wind power output (extrapolated) and typical grid load curve in the state of Schleswig-Holstein



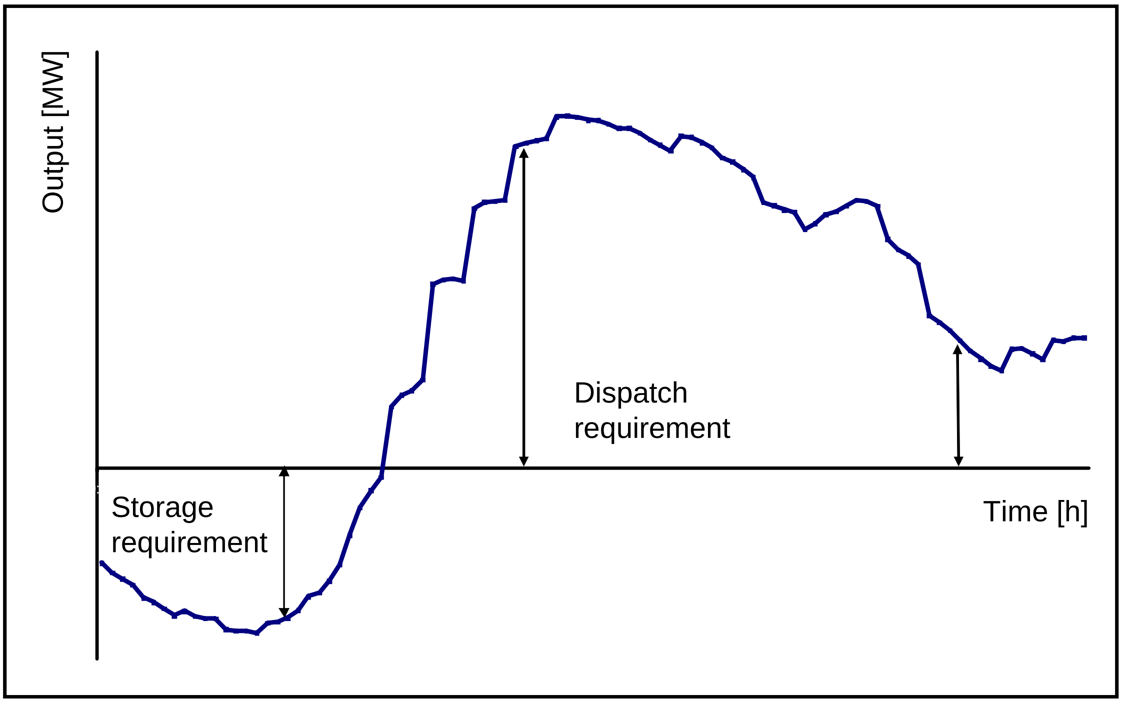
The depicted wind power curve is based on current data from E.ON Netz AG extrapolated on the basis of a major expansion of onshore and offshore wind energy.

SRU/Propositions on Electricity 2009/Fig. 3

Taking the difference between the two curves in Figure 3 produces the demand for firm power and power storage on a 15-minute interval basis shown in Figure 4.

Figure 4

Resulting daily storage and dispatch demand curve



SRU/Propositions on Electricity 2009/Fig. 4

It is clear from Figure 4 that in this scenario, there is no longer a constant base level of demand for firm power capacity throughout the day. This means that there is likewise no longer any demand for base load power stations. Instead, economic and technical considerations dictate that the remaining demand should be met using power stations in the intermediate or peak power range.

If the expansion of wind energy continues in accordance with German government plans and with the dictates of an electricity supply that is cost-effective and sustainable in the long term, the portion of grid load to be met by conventional base load power stations will shrink to a fraction of today's installed base of generating capacity. This conclusion is shared by the BMU Lead Study 2008: “When renewable shares are very high […], conventional baseload electricity generation largely disappears. The remaining fossil-fired condensing power plants are then exclusively deployed as a source of capacity to ensure the security of electricity supply.”

This problem is also brought up by energy utilities. E.ON and Électricité de France recently made clear in a position statement to the UK government that they consider a large renewables share to be incompatible with building new capital-intensive base load power stations. They put the acceptable limit at 25 to 33 percent.

In an energy system with a large proportion of intermittent power from renewable energy sources, base load power stations therefore not only become less important:

Their technical characteristics (very slow start-up over a period of several hours) mean that they are no longer capable of usefully and cost-effectively providing firm power capacity in the new system. Instead, quick-start power stations and power stations with good response characteristics are needed. In consequence, the investment decisions to be made in the near future should not be to build coal-fired or nuclear power stations, but should give preference to units with a low initial outlay and possibly higher fuel costs, such as gas-fired power stations.

Proposition 5 The system choice should go in favour of renewables

Fossil fuels and nuclear energy today account for some 80 percent of German electricity supply. The current infrastructure is geared towards the established dominant fuels, and transforming the system poses a major challenge (see Proposition 3). Despite this, the system choice should go in favour of renewable energy, as coal and nuclear energy are unable to secure a sustainable electricity supply for the future. Due to the limited storage capacity for carbon dioxide and limited deposits of uranium, coal and nuclear energy are at best capable of postponing the transition to renewable energy sources by a few decades.

Coal with CCS: Limited storage capacity for CO2, uncertainties and risks

Due to the large greenhouse gas emissions involved, continuing to generate electricity from hard coal and lignite would only be made compatible with climate policy goals if carbon capture and storage (CCS) were to be implemented on a large scale. A national legal framework for the use of CCS is currently being developed with great urgency. The German Advisory Council on the Environment has recently subjected this to critical appraisal in a statement. So far, however, it is not yet clear how far the use of CCS would make sense and be efficient as a climate policy measure in the context of electricity generation from coal. The first critical factor is the available capacity for underground carbon storage in Germany and elsewhere around the world. Reliable figures on this are not yet available; the only certainty is that such capacity is limited. On current estimates, the storage capacity in Germany has a static range of about 30 to 60 years. However, direct competition may arise for the use of the subterranean structures involved, for example with the utilisation of geothermal energy or for storing pressurised air or heat, thus potentially compounding the system conflict with renewables.

Another competing use is foreseeable in the long term: The IPCC concludes that global negative emissions may be necessary by combining energy from biomass with CCS if the climate policy targets are not to be missed. If this option is to be kept open, subterranean cavities ought not be filled with CO_2 from coal burning today.

The limited storage capacity alone means that CCS cannot be a long-term solution for the climate problem. Using CCS would only put off the transition to renewable energy by about the length of one power plant generation. To this is added a range of open questions regarding CCS technology. The ecological risks of storing CO_2 underground have not been sufficiently investigated. CCS technology itself is at an early stage of development and is not yet available on an industrial scale. The cost of avoiding carbon emissions is particularly high when it comes to retrofitting existing power stations in view of the expected substantial losses in efficiency and corresponding increase in fuel costs. Industry calls for state aid suggest that even under a strict emission trading regime, CCS does not represent a worthwhile CO_2 avoidance strategy from a private sector standpoint.

In light of the uncertainties regarding storage capacity, cost trends and environmental impacts, the German Advisory Council on the Environment considers it indefensible for the impending path choice to be made in favour of continued use of coal with CCS.

Nuclear energy: Risks, finite resources and lack of final disposal sites

Generating electricity from nuclear energy is less harmful to the global climate than coal-fired power generation. Nuclear power is nonetheless unsustainable due to the risks in operation and transportation and in particular due to the problems of waste disposal. A majority of Germans are still in favour of their country's commitment to phasing out nuclear energy. A national climate strategy based on massive expansion of nuclear energy would face considerable public acceptance problems. Expansion plans in earlier decades failed among other things owing to vehement protests from civil society. An expansion of nuclear energy on climate policy grounds would likewise be neither sustainable nor politically viable in Germany.

Finite resources alone disqualify nuclear power as a long-term solution for the climate problem. Today, nuclear power meets only about six percent of global primary energy use. At constant consumption, the proven global uranium reserves would last for 40 to 63 years, depending on the proportion of demand met from other sources (inventories, depleted weapons-grade uranium and uranium from reprocessed fuel rods). Using nuclear power to achieve significant cuts in global greenhouse gas emissions from power generation would require large numbers of new nuclear power stations and would exhaust uranium deposits significantly sooner. Greater reliance on reprocessing, on the other hand, would substantially heighten the risk of proliferation and the misuse of nuclear material for military or terrorist ends.

The German Advisory Council on the Environment considers further use of nuclear power to be indefensible due to the unresolved waste disposal problems and the danger of misuse by terrorists. Also, considering the limited reserves of uranium, it is not compatible with long-term strategic planning for a sustainable electricity supply.

Conclusions

Like most other industrialised countries, Germany could feasibly have an electricity supply based on renewable energy sources by 2050. Under certain conditions, it is even possible that a renewables-based electricity supply could cost less than an electricity supply based on fossil fuels. All building and replacement of generating capacity must be directed towards the goal of an electricity supply that is sustainable and climate-friendly in the long term, with a time horizon of up to at least 2050.

In light of the climate policy goals, the only two serious options for the period to 2050 are coal with CSS and renewable energy. Significant expansion of nuclear power appears politically unrealistic and poses unacceptable risks. The coal with CCS option is currently subject to major uncertainties regarding available storage capacity for captured carbon dioxide, potential competition with other needs, environmental risks, technical feasibility and cost trends. No policy decision should be made in favour of CCS before these issues are resolved.

Going over to a wholly renewables-based electricity supply places the emphasis on quick-start power stations with good response characteristics, enhancement of electricity storage capacity and technologies, and expansion of electricity transmission networks. Coal-fired and nuclear power stations being taken out of service in the next few years need to be replaced with a mix of renewable energy sources (primarily wind power) and gas-fired power stations. Even at comparatively high gas prices, a strategy of this kind is more cost effective than building more base load power stations. The main challenge for renewables expansion is that of mobilising political support at national and European level for a restructuring of the energy supply, energy infrastructure and the accompanying regulatory framework.

Due to the system conflict between power stations that are geared technically and economically to base load use and strongly fluctuating renewable energy sources, the planned construction of considerable amounts of new coal-fired generating capacity is incompatible with a strategy of transition to an entirely renewables-based energy supply.

Current plans to build new coal-fired power stations therefore stand in stark contrast to the necessary evolution of the German electricity system towards an energy supply system that is sustainable and climate-friendly in the long term.

The current debate about a ‘choice’ between coal and nuclear power is misleading, as both options lead to a base load-oriented electricity supply system. Except for a small residual level of base load capacity, it no longer makes sense and in the medium term is no longer economic to build new base load power stations while utilising the available capacity for renewable energy. In a supply strategy based on coal-fired power stations (with or without CCS) and nuclear power, the proportion of supply accounted for by renewables would have to be sharply limited if the base load power stations are to be operated economically.

The German Advisory Council on the Environment considers that an electricity supply based entirely on renewable energy is feasible, is technically and economically viable, and has marked advantages over other conceivable development paths. The policy framework for the imminent investment decisions should therefore place this option at the centre of focus.

Glossary

Balancing power

Balancing power is used in the electricity supply system to make up for unforeseen variations in electricity demand and supply (e.g. power station outages) over periods of up to one hour. When needed, balancing energy must be available in less than a minute. The power needed is therefore obtained by quickly decreasing or increasing the output of power stations that are already in operation. In a subsequent stage, use is made of power stations with good response characteristics (peak load power stations) and comparatively high generating costs (e.g. pumped storage hydropower and gas turbine power plants).

The very short-term variations arising in the use of wind power can be balanced out in regional distribution networks or are absorbed directly by modern variable-speed wind turbines and so do not create any need for *balancing power*. *Balancing power* does have to be provided for variations in wind strength over the space of a few minutes (up to a quarter of an hour, sometimes referred to as the 'minutes' reserve). The more accurate the forecasting systems for wind power, the better cost-effective generating capacity can be brought on line in time following the 15-minute *dispatch* decisions.

Base load

Electricity demand is subject to peaks and troughs. Peak demand levels are mostly reached mornings, midday and evenings, whereas night-time consumption is low. The *base load* – the level of electricity demand that is present throughout the day – is determined by the night-time consumption level (for example due to industrial facilities, street lighting, household and business appliances that are always on, filling of pump-storage power plants and night storage heaters). Variations in electricity consumption are met using different types of power station. *Base load* demand is met by *base load* power stations where the variable costs of generating electricity are as low as possible but which are slow to respond and difficult to vary in output level (nuclear, lignite and run-of-river hydropower plants). If *base load* demand falls short of the forecast level, additional consumers are switched on (such as pump storage capacity and night storage heaters) or electricity is fed to other networks. If the *base load* demand level is exceeded, intermediate and peak load power stations have to be deployed.

Dispatch

The *dispatching* of power stations is the decision made every 15 minutes by a *transmission network* operator (such as E.ON Netz in Germany) to determine which power stations are used to meet demand for the next quarter hour. Decisions on the operation of power stations are primarily made according to merit order, i.e. according to the variable costs of each power station in the fleet. The lower a power station's variable costs, the more likely it is to be selected in the dispatch decision for each 15 minute period.

Intermittent power

The supply of solar and wind power is subject to short and long-term variability due to weather and the seasons. Without energy storage technology and highly responsive, quick-start power stations, it is not possible to meet a large proportion of electricity supply needs with solar and wind energy. To meet electricity demand in full at all times while using large quantities of solar and wind power, it is necessary to combine these energy sources with rapid-response power station and storage capacity in order to make up the entire amount of the shortfall between renewables-based electricity supply and electricity demand.

Transmission network

If energy is generated in one place and needed in another, it has to be transmitted from the one to the other. Electrical energy is transmitted across transmission networks or the 'grid' through which consumers are supplied. Electricity transmission networks are operated at different, set voltages and in the case of alternating current at set frequencies. Electricity is transmitted and distributed as three-phase current. The voltage is modified according to the need. High-power distribution and long-distance transmission take place at high voltages, resulting in lower transmission losses.

The high-voltage network is used for regional distribution of electrical energy. The medium-voltage network distributes electricity to low-voltage network transformer stations and to large consumers. Most municipal utilities feed their electricity into the medium-voltage network. Low-voltage networks are used for local distribution, serving households, business and the public sector. At extra-high voltage level, the *transmission networks* of individual network operators are connected by long-distance lines to the national grid. Transmission network operators are members of the Union for the Coordination of the Transmission of Electricity (UCTE) and also form part of the European grid.

Direct current is not suited to energy distribution, even across relatively large distribution zones in today's alternating current network; for extreme distances, however, new possibilities are opened up by high-voltage direct current (HVDC) transmission with its significantly lower transmission losses.

Mitglieder

Sachverständigenrat für Umweltfragen
Stand: 2009

Prof. Dr. Martin Faulstich
(Vorsitzender)
Professor für Rohstoff- und Energietechnologie
an der Technischen Universität München und
Direktor des Wissenschaftszentrums Straubing

Prof. Dr. Heidi Foth
(stellvertretende Vorsitzende)
Professorin für Umwelttoxikologie und
Direktorin des Instituts für Umwelttoxikologie
der Martin-Luther-Universität Halle-Wittenberg

Prof. Dr. Christian Calliess
Professor für öffentliches Recht und Europarecht
am Fachbereich Rechtswissenschaft
der Freien Universität Berlin

Prof. Dr. Olav Hohmeyer
Professor für Energie- und Ressourcenwirtschaft
an der Universität Flensburg

Prof. Dr. Karin Holm-Müller
Professorin für Ressourcen- und Umweltökonomik
an der landwirtschaftlichen Fakultät
der Rheinischen Friedrich-Wilhelms-Universität Bonn

Prof. Dr. Manfred Niekisch
Professor für Internationalen Naturschutz
an der Universität Greifswald und
Direktor des Frankfurter Zoos

Prof. Dr. Miranda Schreurs
Professorin für Vergleichende Politikwissenschaft und
Leiterin der Forschungsstelle für Umweltpolitik
an der Freien Universität Berlin

Sachverständigenrat für Umweltfragen

Geschäftsstelle
Reichpietschufer 60, 7. OG.
10785 Berlin

Telefon: (030) 26 36 96-0
Fax: (030) 26 36 96-109
E-Mail: sru-info@uba.de
Internet: www.umweltrat.de