> Towards a financially viable transition to sustainable energy

Efficient regulation for tomorrow's energy system

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SUMMARY

The decision to initiate a transition to sustainable energy has brought about a paradigm shift in Germany's energy policy, with the German government targeting a complete overhaul of the energy supply system by 2050. The aim is for the lion's share of future electricity generation to be accounted for by renewables. This will only be possible with significant investment in the expansion of renewable energy generation capacity, backup capacity to guarantee security of supply and grid infrastructure development. This substantial challenge is set to become even greater now that phasing out nuclear power has once again become a priority for Germany.

Successful implementation of the transition to a sustainable energy supply will ultimately be determined by two factors: the development of the right technical solutions and the creation of an appropriate economic framework. This acatech POSITION PAPER stresses the need for a fundamental shift in German energy policy in order to ensure that the transition to sustainable energy is both financially viable and implemented in a manner that is acceptable to all sectors of society. The current regulatory framework, and in particular the Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz – EEG*), which is the main instrument for promoting green electricity technologies in Germany, fail to provide the correct investment and innovation incentives to take adequate account of the energy sector's multiple *systemic* interconnections. Failure to coordinate individual measures is adding unnecessarily to the cost of the transition to sustainable energy and is ultimately threatening the success of the entire undertaking. In order to stimulate the debate, this paper will make a series of concrete recommendations concerning the key features of a coherent, long-term and sustainable regulatory framework.

The scale of the challenge

Based on our current knowledge, we are only able to provide ballpark estimates for the individual cost components involved in the transformation of the energy system. Furthermore, these should be regarded as lower limits for the potential financial outlay. The largest individual cost item is the expansion of renewable energy, and this alone will require a minimum investment of the order of 300 to 500 billion euros between now and 2050.

The ultimate cost of the transition to sustainable energy will only become apparent once all the (investment) decisions of the relevant private and public actors are known, and these decisions will be influenced by the overall framework in which they are taken. Many of the technological, economic and political developments that will have a profound impact on the costs and returns of the transition to sustainable energy are currently nigh on impossible to predict. In addition, the goals of the German government's energy policy do not appear to have been derived from a coherent strategy and there is a lack of clarity concerning the government's political priorities where significant conflicts arise between these goals. This is hardly a sound basis for implementing the transition to a sustainable energy supply.

It is urgently necessary for the transition to sustainable energy to gain widespread acceptance among businesses and the general public. Since the key to achieving this acceptance will be how much the transition costs, policymakers need to attach greater priority than they have done in the past to the cost-effectiveness of energy policy instruments. In other words, there can no longer be any excuse for government failing to pay due attention to the cost issue. Even in the best-case scenario, the transition will require a major commitment which will in turn generate significant costs. Furthermore, since the energy sector is closely tied in with the rest of the economy, if the wrong energy policy decisions are made there will be long-term repercussions for the economy as a whole. If the transition to sustainable energy is not managed cost-effectively, its cost could cross a critical threshold beyond which support for it would evaporate completely, causing the transition to fail.

Realigning regulatory policy for a financially viable transition to sustainable energy

Any realignment of the instruments for promoting renewable energy should use the appropriate investment and innovation incentives to expand renewables as cost-effectively as possible and, above all, to foster their technological and economic *integration* into the energy system as a whole. It is also necessary to establish whether the percentage of renewable electricity should still be increased in the short to medium term, even if this would mean that the cost of meeting the carbon reduction targets would be significantly higher than necessary – as is currently the case under the Renewable Energy Sources Act.

Whilst the deadline for completing the full transition to sustainable energy is 2050, leaving ample room for manoeuvre in terms of the pace of implementation, there is nonetheless already an urgent need for action to overhaul energy policy. The keys to success in this regard are the coordination of national measures at European level and the integration of the transition to sustainable energy into the international climate policy strategy. Ultimately, Germany's transition to a sustainable energy supply will only be able to make an effective contribution to meeting global climate protection goals if an internationally coordinated reduction in greenhouse gas emissions is achieved.

Now is the time to lay the foundations for the efficient energy system of the future

A number of key pillars required for efficient electricity sector regulation can be identified based on the findings of economic and technological analysis. acatech's principal recommendations to policymakers are as follows:

1. The EU Emissions Trading Scheme (EU ETS) should be strengthened as the main system for promoting a lower carbon energy supply in Europe and its scope should be extended beyond the electricity sector.

2. Especially with a view to establishing the timescale for capacity expansion, it is important to clarify whether setting particular quotas for renewable electricity actually constitutes a policy goal in its own right or whether the supply of renewable electricity is purely an instrument for meeting carbon reduction targets.

3. the Renewable Energy Sources Act should be replaced as Germany's national instrument for promoting renewables as soon as possible. Its replacement should take the form of a long-term, market-based promotion mechanism, for example a quota-based support system for renewables using green electricity certificates (quota model) or some alternative market-based approach. This will promote more efficient integration of renewables into the energy system and ensure that investments are made at the right time, in the right technologies and in the right locations.

4. The cooperation mechanisms created by the Renewable Energy Directive should be used at EU level to enable this new market-based promotion mechanism to be progressively implemented and harmonised across a growing number of countries throughout Europe.

5. The existing mechanisms for adjusting power plant output in response to short-term power grid bottlenecks (redispatch) are in urgent need of improvement in order to ensure adequate incentives for the provision of secure power plant capacities at a regional level. This would potentially allow the threat of supply bottlenecks in certain German regions to be averted.

6. Furthermore, over the next two to three years, the pros and cons of introducing a national capacity mechanism should be carefully assessed in terms of its ability to iron out the increasing number of price peaks forecast to occur in the electricity wholesale market, thereby potentially delivering more stable price signals to investors in new power plant capacity.

7. Particular attention should be paid to the rapid expansion of electricity grids. At the same time, the regulatory framework should be reformed in order to create the conditions at the interface between electricity generation and the grid that will enable the emergence of “smart grids”, especially in the realm of distribution grids. This will ensure better integration of the increasingly fluctuating and fragmented supply of renewables.

8. Efforts should be made at European level to promote basic research into energy-efficient technologies and carbon-free energy generation.

9. The national measures implemented by Germany as part of the transition to sustainable energy should be integrated into the German and European negotiating strategy with regard to global climate protection measures. Furthermore, the EU Emissions Trading Scheme should be progressively extended to include other countries across the globe through transfer and side payments to developing and newly industrialised countries under a fund-based model. This will enable sustainable success to be achieved in the global fight to combat climate change.

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1 INTRODUCTION

The challenge of moving to a sustainable energy supply
The energy strategy adopted by the German government in September 2010 sets out its climate policy goals, targets for expanding renewable energy and energy efficiency targets initially until 2020, but also for the much longer term up to 2050. These targets will require a complete transformation of Germany's energy supply system. The strategy states that renewables should be responsible for the lion's share of the electricity generated in Germany by 2050. These targets will require a significant effort on the part of the energy market actors. In addition to the technical challenges, it will be especially important to ensure that the economic issues are also resolved, since the massive investment that will be needed in new plants and energy infrastructure will have to be planned, approved and implemented primarily by private actors.

Furthermore, in June 2011, in the wake of the Fukushima nuclear disaster, the German government took the decision to phase out nuclear power, thereby accelerating the shift towards sustainable energy. Whilst the energy strategy's goals were retained, the government completely scrapped its 2010 plan to extend the lives of Germany's nuclear power stations, thus reinstating the key components of the original nuclear phase-out timetable. However, even though it has accentuated the relevant economic and social challenges and caused them to enter the public consciousness, the decision to phase out nuclear power is still only a part of the overall transition to sustainable energy.

In order to cast a more objective light on what has become a very emotionally charged debate, this acatech POSITION PAPER presents an *ad hoc* opinion that discusses the economic and financial viability of the transition to sustainable energy, based on the findings of technological and economic analysis. It also makes a number of key recommendations.

The absence of a coherent set of targets makes the situation harder to analyse
Recently, there has been much debate about how to finance the transition to sustainable energy and indeed about whether it is even financially viable at all, in view of the huge scale of the challenge and the faltering progress that has been achieved to date. The debate does address the three key aspects of the cost of the transition: (i) the massive expansion of renewable electricity generation capacity, (ii) the extensive development of adequate backup capacity and (iii) the integration of renewables into the energy supply system. Nonetheless, the debate generally fails to take a holistic, systemic view of the situation.

The majority of commentators from the business and academic communities are especially critical of the lack of an overarching project management structure to provide individual actors with guidance on their (investment) decisions. After all, the circumstances under which they are having to take these decisions are characterised by considerable uncertainty regarding future demand and the outlook in terms of technological developments on the supply side of the market. However, as things currently stand, it is fundamentally impossible for this type of overarching project management structure to exist.

This is because the energy strategy's goals involve a mixture of climate policy targets (emissions reduction) and energy policy targets (expansion of renewables, increasing energy efficiency). It is not clear whether these targets were coherently derived from an overarching strategy, nor is it apparent how the individual targets are supposed to relate to each other. If the main aim was to achieve effective climate protection, the energy policy targets would be nothing more than *instruments* and would therefore have a lower political priority – otherwise there would be a danger that stipulating a *concrete* energy mix as a binding condition might hinder the adoption of the most cost-effective solution for meeting the carbon reduction target.

On the other hand, if the expansion of renewable energy were to be a separate and, in principle, equally important goal, this would require policymakers to provide clear guidance on how to prioritise the goals and how to resolve any conflicts that might arise between them. Although it is not possible to discuss this topic exhaustively in this paper, there could, in particular, be climate policy reasons for suggesting that it would make more sense to begin by ramping up other measures geared towards cutting emissions whilst implementing a slower transition to renewable energy than provided for by the energy strategy. Consequently, policymakers urgently need to clarify their energy and climate policy strategies and provide guidance on how to approach the problems associated with balancing the relevant goals. Furthermore, the outcomes of this process should be communicated transparently and opened up to public debate.

This lack of clarity has one very practical consequence as regards the implementation of the transition to sustainable energy and the associated costs: it is not possible to establish a clear road map for meeting the targets and it will furthermore be impossible, from an economic perspective, to put a reliable figure on the ultimate cost of the transition as is common practice among businesses embarking upon complex investment projects. Notwithstanding the above, an overview of current modelling studies indicates that, however great the uncertainties may be, the required investment will certainly be of the order of hundreds of billions of euros. However, given the lack of clarity regarding the goals system, all the forecasts currently at our disposal should be regarded as lower limits for the likely cost of the transition.

In order to achieve the transition to sustainable energy, policy instruments will need to be realigned

Future climate and energy policy decisions and the (investment) decisions of the actors in the different markets cannot afford to wait for a coherent set of goals to be established, even though this is something that does need to be addressed very urgently. Consequently, this position paper will instead take the current mixture of climate and development goals as the hypothetical baseline for calculating the potential cost of the transition to sustainable energy in addition to asking under which conditions the cost of the transition could at least be kept under control.

In view of the increasingly apparent flaws in the existing instruments for implementing its own goals, it is undoubtedly rather alarming that politicians should have failed to ask any critical questions about their fundamental design. Despite the fact that the current set of targets and the decision to phase out nuclear power have accentuated the challenges considerably, there has been no discussion of how the detailed design of the EU Emissions Trading Scheme (EU ETS) could be improved and the government has been unwilling to contemplate anything other than incremental amendments to Germany's Renewable Energy Sources Act (EEG). If the cost of the transition to sustainable energy gets out of hand as a result of the increasingly inappropriate nature of the policy instruments designed to manage it, then widespread public support for the transition can be expected to dwindle.

acatech therefore believes that the key requirement for a successful transition to sustainable energy is an efficient regulatory framework that enables private actors to take rational investment decisions. In view of the extreme complexity of the task at hand and the associated uncertainties, it is crucial to ensure that the systemic level is taken into account at all times. Consequently, policymakers should adopt a holistic perspective to regulation of private enterprise and, when it comes to individual investment decisions, should favour decentralised decisions arrived at through competitive structures over State planning. Competition creates the necessary incentive compatibility and decentralised decision-taking ensures that information which is available locally but which central planners do not have access to can be used to arrive at the most cost-effective solution through a competitive process.

This position paper will initially focus on the situation in Germany. At this level, it will be necessary to bring about a fundamental shift towards a system for promoting renewable energy generation capacity whose costs can be more tightly controlled and that fosters the economic integration of renewables into the energy system. In addition, the provision of conventional backup capacity will need to be secured together with the development of a smart grid that facilitates the integration of increasingly volatile and decentralised generating capacity.

These changes at national level should be urgently integrated into a pan-European approach, particularly through coherent development of the existing EU ETS instrument, whilst new measures to promote renewable generating capacity should be established on a transnational basis. Finally, it is important to recognise that climate change is a global problem and that measures must therefore be taken to promote an effective global climate policy.

Structure and scope of the position paper

Chapter 2 of this position paper will present an overview of current energy scenarios, provide some ideas as to the possible extent of the investment requirements for the transition to sustainable energy and offer a critique of the existing policy instruments for promoting the transition. Chapter 3 will describe the key features of policy instruments that would be more appropriate from a regulatory point of view. These instruments would facilitate a technology-neutral approach, as well as offering the prospect of coordinating promotion mechanisms internationally.

At national level, the focus will be on a more market-based approach to promoting the expansion of renewables which will be illustrated using the example of a quota-based support system for renewables using green electricity certificates, known as a quota model. We will also describe how the EU ETS can be expanded and how market-based promotion of renewables can be coordinated at European level. This chapter will conclude with a look at how, in the future, efforts to achieve the transition to sustainable energy in Germany might be integrated into a global climate policy strategy under a fund-based model. Chapter 4 will present a summary of the paper's specific recommendations.

This position paper is only able to look at the key pillars of national and European energy and climate policy. Its scope does not allow it to analyse the details of specific regulations in individual markets or funding projects. Moreover, the paper focuses on trends in the *electricity* market and therefore does not address important areas such as heating and transport that also have an important role to play in the transition to sustainable energy and will undoubtedly have a major say in whether or not it succeeds. Nevertheless, there is little doubt that the electricity sector will be the key to the transformation of the energy system that is needed in order to achieve the sustainable energy transition. This is in no small measure due to the high proportion of total greenhouse gas emissions that is attributable to electricity generation and the central role of electricity in the smooth functioning of virtually every sector of the economy. One important focus of future research into the transition to sustainable energy is likely to be the study of interfaces with other subsystems and the associated interdependencies. However, this development will not alter the core content of the recommendations made in this position paper with regard to the specific area that it addresses.

2 THE TRANSITION TO SUSTAINABLE ENERGY

2.1 POLICY GOALS

Germany's strategy to shift towards a sustainable energy supply establishes politically motivated targets for developing the structure of Germany's energy supply up to 2050. In particular, this includes targets for cutting greenhouse gas emissions and reducing energy consumption. It also stipulates that the structure of the energy mix should be substantially altered. The strategy targets a 40 percent cut in greenhouse gas emissions by 2020 and a 95 percent cut by 2050 (compared to 1990 levels), together with a 20 percent reduction in primary energy consumption by 2020, rising to 50 percent by 2050. The key changes to the energy mix involve reducing nuclear power's share to 0 percent by 2022 and raising renewable energy's share of primary energy consumption to 18 percent by 2020 and 60 percent by 2050.

A number of additional secondary targets were also established for the electricity sector that will be the subject of a more detailed analysis below. In particular, the strategy is aiming for a 10 percent cut in electricity consumption by 2020, rising to 25 percent by 2050 (compared to 2008 levels). At the same time, the goal is for renewables to increase their share of gross electricity consumption to 35 percent by 2020 and 80 percent by 2050. Secondary targets were also set for other sectors of the economy that will play an important role in the transition to sustainable energy but are not considered in detail in this acatech POSITION PAPER, such as transport and logistics, heating and housing. These include, for example, measures relating to the renovation of buildings. However, in view of the especially pressing need for action regarding the electricity system – and the particularly serious nature of the dangers that could arise if expensive mistakes are made and the stability of the system is jeopardised – this position paper will focus on the electricity supply.

In addition to the targets for greenhouse gas emissions, electricity consumption and the make-up of the energy mix, a number of other reasons were given for the decision to move to a sustainable energy supply. These included lessening the impact of any possible future raw material shortages and reducing dependency on fossil fuel imports, the greater security of supply that would be expected to result from these factors in the long term, and the opportunity to create value locally through the expansion of renewable energy and the associated infrastructure. Alongside climate protection and security of supply, particular attention was also paid to the third element of the triad of energy policy targets, i.e. cost-effectiveness.

More specifically, the strategy stated that the cost of promoting renewables as part of the transition to a sustainable energy supply should not exceed the current level of 3.59 euro cents per kilowatt-hour. This restriction is of fundamental importance. It is of course quite right that cost-effectiveness should be viewed as an end in itself, in order to prevent scarce economic resources from being wasted. However, in the context of the transition to sustainable energy, it should also be seen primarily as a means of ensuring that the much-needed support of the public and the business community for this once-in-a-generation project is not lost as a result of an excessive increase in the financial burden on companies and households.

In addition, it is important to remember that the extent of the resources available over the next few decades could be significantly reduced as a result of events that are at least partly beyond the German government's control. The escalation of the banking and financial crisis in the US into a global recession between 2008 and 2010, followed immediately afterwards by the sovereign debt crisis in the Eurozone are currently the two most striking examples of these dangers. The greater the emphasis placed on the cost-effectiveness of the transition to sustainable energy, the likelier it is that the implementation process will be able to withstand similar macroeconomic shocks in the future.

Finally, it should not be forgotten that the ultimate goal of the transition to sustainable energy is not primarily to achieve a specific energy mix or push a particular technology. Rather, it is to demonstrate to the rest of the world that an industrialised nation is capable of accomplishing the decarbonisation – especially in the realm of electricity generation – that is needed to prevent irreversible climate change without prejudice to the perfectly reasonable expectation that both private and business customers should have access to a secure, competitive and affordable energy supply.

2.2 TECHNOLOGICAL CHALLENGES AND POSSIBLE SOLUTIONS

Any analysis of the regulatory instruments needed to secure the transition to sustainable energy must begin with an assessment of the technological challenges. A coherent approach must be adopted to the technological, economic and regulatory elements of the system if technical requirements such as eco-friendliness, system stability and security of supply are to be satisfied in a cost-effective and thus democratically legitimate manner.

In keeping with the traditional technological make-up of the energy system, energy sector regulation is currently largely based on the following assumptions:

- the majority of our electricity comes from a small number of large-scale generating units located close to where the demand is, whilst decentralised electricity producers (wind power, PV, biomass, CHP) remain on the periphery of the electricity supply system rather than at its core,
- smaller customers have little or no involvement in the market,
- electricity reaches consumers in a top-down manner, i.e. passing from the supplier to the transmission grid and then to the distribution grid,
- in view of the fact that they have a natural monopoly, regulation of distribution grid operators should be geared primarily towards keeping costs down. Furthermore, operators have the duty and the freedom to accept whatever type of electricity generation and consumption they like in more or less whatever quantity they wish, and
- the stability of the whole system is always guaranteed.

The transition to sustainable energy is forcing us to ask some serious questions about all five of these central features of the existing system. Despite this, the approach that has hitherto been adopted to delivering the necessary technical, economic and regulatory changes to the system has simply been to bolt a series of individual elements onto the old structures. The result is that these changes have not been properly coordinated. In other words, the combination of accelerated expansion of wind power and PV capacity with a major expansion of the grid does not suffice to create a coherent overall system architecture. The danger of an overly complex system could be the undoing of the transition to sustainable energy.[1]

Consequently, apart from clarifying and prioritising their goals, the other key challenge for policymakers is to understand the overall system so that they are better able to manage implementation of the transition to sustainable energy. If the transformation of the supply system is to succeed, the existing interrelations and interdependencies between the different system components and between current and future actors will need to be adequately recognised and new interactions will have to be taken into account so that the correct regulation or deregulation measures can be implemented.

The highly complex nature of the system, its extreme interconnectedness across the whole of Europe and the paramount requirement to ensure its stability mean that the State cannot fine-tune it. Furthermore, the European

1 See Appelrath et al. 2012.

context must not be neglected, since it is of fundamental importance at both the technical (grid) level and the economic (single market) level.

The biggest change compared to the current system is that, over the course of the transition to sustainable energy, methods of electricity generation that produce a fluctuating supply will go from playing a supplementary role to becoming the largest power source and therefore the one that determines the nature of the entire system. And, of course, this fluctuating supply is governed by the weather, meaning that there may even be times when no electricity is being generated at all. There are various possible approaches to tackling this challenge, but all of them will require major expansion of the distribution and transmission grids. As far as the transmission grids are concerned, work will need to focus on enhancing power lines, whereas in the case of the distribution grids the emphasis will be on upgrading substations. The four main, mutually complementary options are as follows:

(1) Construction of additional storage devices and (backup) power plants;
(2) Instigating greater supply price sensitivity;
(3) Demand side management;
(4) Greater integration of the European market.

(1) The system must be able to keep supplying electricity even when the sun isn't shining and the wind isn't blowing. Consequently, even in future systems that meet the goals of the transition to sustainable energy, the fluctuating capacity supplied by renewables will need to be backed up by thermal capacity, e.g. biomass, coal and gas, and adequate storage capacity. Both now and in the medium-term future, the cheapest means of providing this backup is likely to be through conventional thermal power plants, especially gas-fired power stations. On the other hand, apart from a limited number of applications, it is not yet possible to store electrical energy at all cost-effectively and there is still a substantial need for R&D in this area. Pump-storage power plants are the only exception, however there is only limited potential to expand their use in Germany. Beyond that, the only technologies currently being studied for seasonal electricity storage involve pilot projects investigating the conversion of electricity into hydrogen or methane which can subsequently be converted back into electricity. However, the efficiency losses that occur during this process mean that it is still a long way from being cost-effective.

Whatever form this backup capacity eventually takes, the issue of the market model used to finance it also needs to be addressed. Since the backup power plants and storage devices will only be operational for relatively short periods of time, they will have to cover their fixed costs with comparatively high margins. The harder it is to forecast operating time over the entirety of the investment's payback period, the higher these margins will have to be.

(2) In the ideal scenario, the current market price would be the signal to tell suppliers when it is most profitable to generate electricity and feed it into the grid, thus triggering the appropriate adjustments. However, for technical reasons, this does not happen with solar PV plants and wind farms – the electricity that they supply is price inelastic. Better forecasting of wind and sunshine would certainly help to plan when to start up the backup power plants and might even allow the amount of expensive backup energy used to be partially reduced. However, the incentives needed to make this possible are currently lacking. Consequently, the only way of achieving a more flexible supply of renewable energy in Germany would be to supplement electricity generated by wind power and PV with biomass electricity. Unfortunately, however, biomass offers only limited potential.

In addition to certain technical challenges relating to the plants themselves, there are a number of systemic issues such as the market design that need to be resolved. One particular problem is how to market small quantities of energy. This will only be possible if small electricity generators agree to come together to form larger entities ("virtual power plants") using an information and communication infrastructure-based network (ICT networking).

(3) Industry and other large consumers are constantly engaged in trying to optimise their energy requirements. They are quite prepared to explore efficiency measures and load shifting options as long as the resulting savings outweigh any possible disadvantages arising during production. Indeed, these types of contract are already widespread today. It is likely that further efficiency optimisations will be sought in the future, provided that they can be achieved in a sufficiently cost-effective manner.

By contrast, only a small proportion of domestic customers are currently able to adopt more flexible consumption patterns and this will remain the case for the immediate future. Even in the medium term, the total contribution made by households will remain low. Nevertheless, there is a case for including the larger thermal loads generated e.g. by heat pumps and large refrigeration equipment – and in the future also electric vehicles – in the relevant management systems. Smart meters will play a crucial role in tapping this potential. In order to facilitate the investment required to achieve more flexible demand, it will be paramount to send consumers a stable price signal via the electricity wholesale market.

(4) In the context of the single European market for electricity, it would make little sense for the measures to implement Germany's transition to sustainable energy to be geared towards a future where electricity is primarily generated from renewable sources within Germany, but where at the same time Germany relies on conventional power plants in other countries to cover any supply shortages. However, the construction of additional interconnectors and transport power lines will facilitate closer market integration and this will to some extent also permit fluctuations in the supply of renewable electricity to be evened out over long distances. A decentralised electricity supply based on renewables will thus continue to require the transport of electricity and will certainly not lead to local self-sufficiency.

Which of the four options described above should be implemented – and to what extent – is not a question that can realistically be answered by technical experts or government planners. Ultimately, it is something that market mechanisms will have to determine. As things currently stand, it is therefore necessary to pursue all four options and in particular to push ahead with the relevant research.

2.3 ANALYSIS OF INVESTMENT REQUIREMENTS

The main factors that will determine the ultimate cost of the transition to sustainable energy are as follows: developments in individual technologies and their cost, the extent to which non-economic barriers to power grid expansion and power plant construction are removed, the evolution of electricity demand and, importantly, the shape of the regulatory framework governing the investments involved in the transition. Since these parameters are, by their very nature, subject to considerable uncertainty, particularly in terms of the technological and political risks, it is extremely difficult to make concrete predictions about the costs and investment levels associated with the transition to sustainable energy.

Before moving on to the description of concrete scenarios and the relevant cost estimates and investment requirements for each scenario, it is important to highlight the fact that all of the studies presented below are subject to certain limitations. The studies should all be treated as "blueprints" where technical scenarios are developed in a normative sense to show which investment measures could be deployed in order to deliver the policy goals regarding the structure of the energy supply. However, the robustness of these scenarios has only been tested very selectively, if at all. There is therefore considerable uncertainty as to how sensitive the findings are to variations in the extent to which the key assumptions are met. Moreover, alternative policy instruments are usually ignored.

Although the extent to which it is possible to compare the different studies is limited, from a methodical point of view they are nonetheless based largely on the following four key assumptions:

- *Firstly,* important technical parameters – especially with regard to power grids – are often ignored, albeit to a varying degree. These limitations should be taken into consideration by policymakers when assessing the feasibility of the scenarios and their estimated costs and investment requirements.
- *Secondly*, it is assumed that the grid infrastructure will be significantly expanded in Germany and abroad and that this will not be constrained by non-economic barriers such as a lack of public support.
- *Thirdly,* it is the view of this acatech POSITION PAPER's authors that all the studies are based on fairly optimistic assumptions concerning the future costs of renewable energy. However, these costs will play a key role in determining investment levels. Furthermore, offshore wind power accounts for a large proportion of electricity generation in all of the studies. Given our lack of experience with this type of energy and the current difficulties in bringing down its cost and connecting it to the onshore grid, it is debatable whether the large-scale supply of electricity from offshore wind farms can be achieved, particularly in the short term.
- *Fourthly,* normative studies implicitly assume that central planners are in a position to approve the necessary investments and are freely able to implement and finance them. These studies completely fail to take into account the fact that, in the real world, there are all kinds of obstacles to translating political will into concrete (investment) behaviour on the part of consumers and businesses.

In view of these optimistic assumptions shared by the different studies, and given the well-known "optimistic bias" of normative technology scenarios, all the cost estimates for the transition to sustainable energy presented below should be regarded as best-case scenarios.

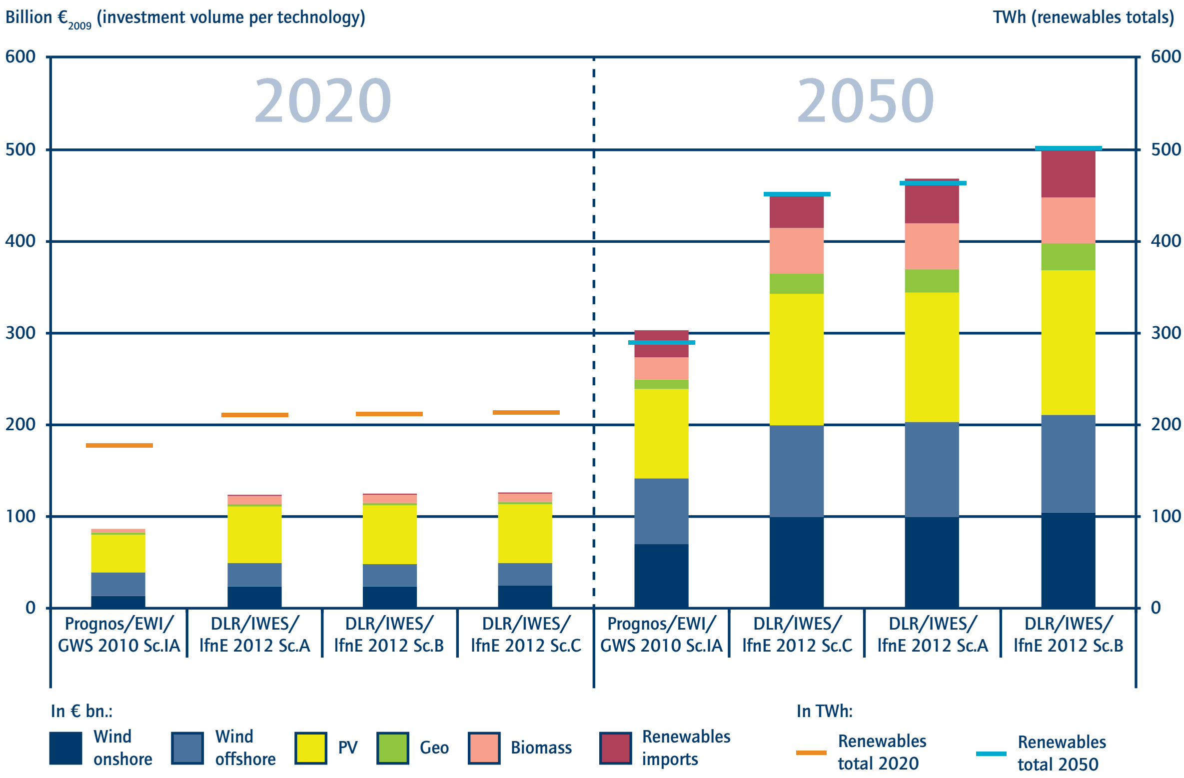
Studies focused specifically on German energy policy

The German government commissioned two main studies in order to analyse the investment requirements for renewables. The **Renewable Energy Long-Term Scenarios 2011** (*EE (Erneuerbare Energien)-Langfristszenarien 2011*)[2] present scenarios where an 85 percent cut in CO_2 emissions is achieved by 2050, together with – at the very least – the renewable energy expansion targets established in the German government's energy strategy. The **Energy scenarios** (*Energieszenarien*)[3] for the energy strategy also analyse how a renewables-based energy supply that is as CO_2-neutral as possible can be delivered by 2050. There is very little difference between the two studies in terms of the estimated investment costs for renewable energy.

Figure 1 summarises the key forecasts. Each column provides a graphic representation of the estimated investment requirements for a specific scenario in one of the two studies. It is immediately apparent that the differences in the projected investment requirements for renewables can largely be put down to differences between the studies regarding how much capacity is forecast to be built.

2 DLR/Fraunhofer IWES/IfnE 2012.
3 Prognos/EWI/GWS 2010.

Figure. 1: Cumulative investment in renewables (excluding hydroelectric) to 2020 and 2050



For the period up to 2020, three out of four scenarios in the two studies come up with similar cumulative figures for investment in renewables of slightly over 100 billion euros. However, there is far less agreement regarding the long-term projections up to 2050. Depending on the projected value for the total amount of electricity generated from renewable sources, the estimated investment volumes in the different scenarios range from just over 300 billion to approximately 500 billion euros. These figures would be roughly equivalent to somewhere between 0.3 and 0.5 percent of GDP over the same period.[4]

Both studies are based on very optimistic assumptions. Firstly, they presume that renewable energy costs will fall

[4] In present value terms, for example, based on a discount rate of 1.4 percent as used in the Stern Report for a similar period of time, and assuming homogenous investment trends over time, the range of investment volumes would be between 230 and 380 billion euros. However, the discount rate selected as the basis for the calculations will in fact undoubtedly have an influence on the result and it is furthermore very hard to predict the exact times when investments will be made when projecting over such a long period of time. Consequently, there is a danger that approximate present value calculations may give a misleading impression of accuracy with regard to the order of magnitude in question. In any case, this does not alter the fact that very substantial levels of investment will be required just to expand the use of renewables, since all the currently available cost projections are still subject to a large degree of uncertainty and should thus tend to be regarded as a lower limit for the necessary financial outlay.

sharply. They estimate that investment costs for onshore wind power will decrease by around 30 percent between 2010 and 2050, with a reduction of over 60 percent for PV and offshore wind power over the same timescale. Secondly, both studies ignore non-economic barriers to additional power plant construction (for both renewable and conventional energy generation) and power grid expansion. Power grid congestion within individual regions is implicitly left out of the equation altogether. Moreover, both studies presuppose a significant expansion of interconnectors between individual regions. Optimistic assumptions regarding grid expansion and future reductions in the cost of renewables also fundamentally underpin those studies that predict that 100 percent of Germany's electricity needs will be met by renewable energy by 2050[5].

A significant expansion of the grid will be required in order to connect and integrate renewables. According to the **grid studies of the German Grid Agency** (*Deutsche Netz-Agentur – dena*)[6], 850 kilometres of new transmission grid lines would be needed by 2015, rising to as much as 3,600 kilometres by 2020, at a cost of just under one billion euros a year. Both studies assume that the grid will be expanded in a manner that enables all the electricity generated by renewable energy plants to be transported onwards. In other words, they fail to take into consideration the possibility of shutdowns for valid economic reasons or the issue of non-economic barriers to grid expansion.

The current draft of the **Grid Development Plan**[7] targets the construction of 1,700 kilometres of new high-voltage lines and the upgrading of 4,000 kilometres of existing power lines by 2022. In addition, the grid operators are planning to deploy 2,100 kilometres of new, efficient, high-voltage DC transmission lines. A total of approximately 30 billion euros would be necessary to expand the grid and connect offshore wind parks to it. And the costs for the distribution grids could well exceed the cost of expanding the transmission grids, as demonstrated in the following studies that concentrate on the European level.

Studies focused on European energy policy

There are several studies of European energy policy that provide a good overview of the investment volumes and structures that would be needed to achieve an extensive shift to renewable electricity generation. The **European Commission's Energy Roadmap 2050 (2011)** explores a variety of avenues for delivering the desired target of a 20 percent reduction in CO_2 emissions by 2020, rising to between 80 and 95 percent by 2050. In addition to “reference” and “current policy initiatives” scenarios, the study envisages five accelerated decarbonisation scenarios that would enable the CO_2 emission reduction targets to be met by 2050.

Based on the assumption electricity demand is set to rise sharply, the “current policy initiatives” scenario calculates that the required investment in the electricity generation sector will come to just under 2 trillion euros over the period up to 2050, whilst the investment required to meet the decarbonisation targets using primarily renewable energy is put at 3.2 trillion euros. As far as investments in the grid are concerned, it is calculated that the lion's share (up to 1.77 trillion euros) will be focused on the distribution grids, whereas up to 420 billion euros will have to be invested in the transmission grids.

In the “high renewable energy sources” scenario, the total investment required to deliver the decarbonisation targets comes to approximately 5.4 trillion euros. The lack of region-specific data means that it is not possible to deduce what the concrete implications of the study are for Germany. However, for purely illustrative purposes, if we assume that the costs would be distributed in accordance with the size

5 DLR 2011; Greenpeace 2010.
6 dena 2005; dena 2010.
7 Netzentwicklungsplan 2012.

of each country's economy (based on GDP), then in very broad terms the investment figure for Germany might be expected to come to around 1.08 trillion euros.

The study **Roadmap 2050 – a closer look**[8] investigates the potential cost implications of inadequate grid expansion for the European electricity sector, based on a renewable energy share of 80 percent and an 80 percent reduction in CO_2 emissions in relation to 1990 values. Compared with a scenario where the grid is expanded in a cost-optimal fashion – where the optimal locations are selected for renewable energy plants and the total investment in renewables and grid expansion comes to 3.369 trillion euros –, the alternative scenario based on only moderate grid expansion projects a figure of 3.426 trillion euros.

In keeping with the European Commission's targets, the **European Climate Foundation's Roadmap 2050 (2010)** also investigates development scenarios based on a CO_2 reduction of 80 percent compared to 1990 values. It also assumes that the electricity sector will have to achieve at least 95 percent decarbonisation. In a decarbonisation scenario where renewables account for 80 percent of production, the total investment costs in the period up to 2050 are calculated at 3.2 trillion euros. This is approximately 120 percent higher than in the baseline scenario (1.45 trillion euros). Depending on the scenario, the investment in the grids required to deliver these ambitious expansion targets ranges from 50 to 200 billion euros over a 40 year period, thus accounting for a relatively small share of the total investment figure.

In contrast to the studies described above, which mostly restrict their analyses to individual case studies or a limited number of scenarios, **Jägemann et al. (2012)** systematically calculate the cost implications of a variety of different economic and policy frameworks up to 2050. According to this study, the minimum total system costs for the European electricity sector to meet a CO_2 reduction target of 90 percent by 2050 come to between 1.387 and 1.588 trillion euros.[9] However, if the National Allocation Plans set additional fixed targets for renewable energy by 2020 and the goal of expanding the share of renewable energy to 80 percent by 2050 is pursued at European level, the total system costs then increase to between 1.596 and 2.004 trillion euros.

Summary: it is not possible to put a reliable figure on the cost of the transition to sustainable energy

In summary, there are at present no studies either for Germany or Europe as a whole that provide a comprehensive estimate of the investment requirements or system costs of different pathways to achieving the transition to an electricity supply based principally on renewable energy whilst also highlighting the areas still characterised by a degree of uncertainty. Furthermore, the existing studies often fail to include the system costs for storage, the transmission grid and in particular the distribution grid. Consequently, we currently lack any robust and comprehensive evaluations of the economic effects of the sustainable energy transition policy either for Germany or for Europe.

The only thing that can be done with any confidence is to suggest rather optimistic ranges for the extra investment volumes required for the transition to sustainable energy. A well-founded, scientific comparison of the relevant scenarios that clearly identifies and evaluates all the assumptions and dangers could go some way towards diminishing the high degree of uncertainty that currently exists. It would be important not just to compare the assumptions that the various studies are based on but also to perform a coordinated comparison of the different models by comparing and evaluating the various scenarios using the same basic assumptions, e.g. with regard to fuel price trends. Moreover, the investment requirements arising from the transition to sustainable energy will ultimately

8 EWI/Energynautics 2011.

9 This assumes that there will be no additional targets for expanding renewables and no restrictions on the use of nuclear power.

need to be compared against the challenges associated with the renovation of existing power plants and grids that will inevitably have to be undertaken over the next few decades. Consequently, the cost risks involved in the reference scenario represented by the conventional technology pathway constitute a further source of uncertainty that must be taken into account.[10]

Of course, a small degree of uncertainty about the precise level and type of investment will always remain. The main requirement to ensure that this risk can still be borne by private investors is a sound policy framework and an energy policy with a regulatory design that allows plenty of scope for economic incentives. This is key to ensuring that the substantial level of investment required can be realised cost-effectively.

2.4 REGULATORY STATUS QUO: THE RENEWABLE ENERGY SOURCES ACT AND THE EU EMISSIONS TRADING SCHEME

There are currently two main regulatory instruments driving the expansion of renewable energy and the reduction of greenhouse gas emissions in Germany: the German Renewable Energy Sources Act (*Erneuerbare-Energien-Gesetz* – *EEG*) which is applicable at national level, and the EU Emissions Trading Scheme (EU ETS) at European level. These two instruments are at the centre of the academic and political debate regarding the most suitable regulatory framework for implementing Germany's transition to sustainable energy and the EU's climate policy goals in the shape of concrete carbon dioxide emission reductions. Before any potential reforms can be discussed, it is necessary to describe the current status of both instruments. This is done in the following two sections, which do not, however, address the challenges arising from the coexistence of the two pieces of regulation.[11]

Renewable Energy Sources Act

Renewable electricity generation has received statutory support in Germany since 1991 and since 2000 this support has been provided through the Renewable Energy Sources Act (*EEG*). The Act requires grid operators to give precedence to the connection of renewable electricity plants, the purchase of the electricity generated by such plants, its transmission and its distribution to electricity customers ("feed-in priority"). Furthermore, the grid operators are required to pay the operators of renewable energy plants a minimum price for their electricity which is guaranteed for a 20-year period (feed-in tariff). In addition to meeting politically determined capacity targets, the Renewable Energy Sources Act is also intended to provide targeted support for the development of green electricity generation technologies. The less cost-effective technologies thus generally benefit from a higher minimum tariff.

In order to provide power plant manufacturers with an incentive to keep costs down, the guaranteed feed-in tariff for newly built plants decreases by a fixed annual percentage (degression). The additional costs arising from the difference between the feed-in tariff paid to renewable energy producers and the market price of the electricity they generate are shared out among all electricity consumers via a standard EEG surcharge administered by the grid operators that is the same throughout Germany. Over the past few years, the EEG surcharge has risen steadily from 0.54 euro cents per kilowatt-hour in 2004 to its current level of 3.592 euro cents per kilowatt-hour in 2012. In 2010 alone, the total sum paid in surcharges came to more than 12 billion euros which is roughly equivalent to the entire annual budget of the Federal Ministry of Education and Research.

In order to ensure that the surcharge does not jeopardise the competitiveness of energy-intensive businesses, extensive exemptions apply to companies in the manufacturing industry. Moreover, the number of businesses benefiting

10 See Matthes 2012, p. 52.
11 This issue is addressed in section 3.1.1.

from these exemptions has increased steadily over the past few years. This has, of course, led to a substantial increase in the burden on other industries and on private consumers. According to the EEG Progress Report[12], in 2011 around 16 percent of all electricity consumption and more than 36 percent of the electricity consumed by the manufacturing industry benefited from the exemptions.

The high costs of the EEG can largely be attributed to the rise in the percentage of renewable electricity generated using solar PV technology. In 2010, just under 39 percent of the EEG surcharge was spent on promoting PV electricity generation, despite the fact that solar PV technology accounted for barely 15 percent of all the electricity covered by the Renewable Energy Sources Act in that particular year. The costs of the new capacity that has been built during the past few years will continue to represent a significant financial burden for consumers over the course of the next two decades. The future costs arising solely from the solar PV power plants built in Germany between 2000 and the end of 2011 have a current value of just under 100 billion euros at 2011 prices.[13]

The literature forecasts a sharp increase in electricity prices over the next few years based on projected rises in the EEG surcharge and grid charges. Assuming that the Renewable Energy Sources Act remains in force, McKinsey estimates that by 2020 the inflation-adjusted total for EEG subsidies (differential cost) will be 17 billion euros and additional grid charges will add a further 4.5 billion euros to this figure. The resulting real increases in the price per kilowatt-hour of electricity would come to 0.7 euro cents for electricity-intensive industries (assuming that they remain exempt from the EEG surcharge), 4.9 euro cents for other industrial sectors, 5.1 euro cents for the business, trade and services sectors and 6.3 euro cents (incl. V.A.T.) for domestic consumers.[14]

Erdmann (2011) arrives at a similar conclusion, calculating that the EEG surcharge will reach 6 euro cents per kilowatt-hour by 2025. Adjusting for inflation, this would mean that electricity prices for domestic consumers would rise from their current level of 25.5 to 28.5 euro cents per kilowatt-hour which is equivalent to an increase of just under 12 percent in real terms. Erdmann quite rightly makes the following observation about this finding: "The target established during parliamentary consultations on the transition to sustainable energy of not allowing the EEG surcharge to exceed 3.5 [euro cents per kilowatt-hour] has, for the time being, not been supported with credible policy measures."

EU ETS

Since 2005, the EU ETS has regulated the volume of emission permits within the European Union, setting a cap on the greenhouse gas emissions of energy suppliers and energy-intensive industries. It thus regulates approximately half of all greenhouse gas emissions in the EU. Power plant operators are allowed to trade emission permits on emission trading markets or directly with each other, resulting in a single market price. In the EU ETS, we already have a harmonised regulatory instrument for the whole of Europe that provides incentives to use existing low-emission electricity generation technologies as well as stimulating investment in R&D focused on even lower-emission technologies than those that are currently available.

However, in contrast to the Renewable Energy Sources Act, under the EU ETS private actors are free to decide which technology they use and where they wish to deploy it, as well as which aspect of the technological and economic discovery process to invest in. Nevertheless, the current implementation of the EU ETS still suffers from a number of failings that severely constrain its effectiveness. These include the fact that it is primarily confined to the large-scale

12 BMU 2011.
13 See Frondel et al. 2011. (The calculation was updated using the capacity expansion figures for 2011.)
14 See McKinsey 2012, p. 7.

firing plant sector, the lack of continuity beyond 2020 and in particular the rather generous initial endowment with emission certificates when economic performance is taken into account, especially bearing in mind the slump in economic activity in 2009 and 2010 owing to the economic and financial crisis.[15] As a result, the price signal sent out by the emissions trading scheme has hitherto been too small and unstable to have any credible long-term effect on the investment decisions of the relevant actors.

Following Europe's lead, Australia, South Korea, some US federal states[16], the Canadian province of Quebec and some of the larger provinces in China have begun to introduce emissions trading systems, thereby putting a price on CO_2 emissions. In January 2013, California is set to launch a mechanism that will include the transport and buildings sectors as well as the electricity and industrial sectors. Talks are already underway concerning how to link these emerging emissions trading systems with each other and with the EU scheme.

15 See SRU 2011, p. 249 ff. and Tindale 2012.

16 See Schmalensee 2012.

3 REGULATORY INSTRUMENTS – AT NATIONAL, EUROPEAN AND INTERNATIONAL LEVEL

In order to deliver the targets of the transition to sustainable energy in the electricity sector, major investments and behavioural changes will be required on behalf of all the relevant market players. The State, in its capacity as a consumer or investor, will only be affected to a relatively limited degree, since – according to Germany's current constitutional order – it will be private entities[17] that assume the lion's share of the investments and behavioural changes. The main task for policymakers and government will be to develop a coherent regulatory framework and ensure that it is implemented by the relevant administrations. This will go a long way to determining the extent to which the investments and behavioural changes needed to deliver the policy goals and associated requirements of a stable system and a cost-effective electricity supply actually occur (effectiveness) and whether they are achieved without wasting economic resources (efficiency).

It is important to ensure coherence of the targets and regulatory frameworks not just at national level but also between national policy and European climate and energy policy, as well as between central government policy and regional and local government policy within Germany. Failure to do so would result in partial conflicts as far as the targets are concerned and contradictory policy instruments that would undermine investor confidence and thus make it more expensive to obtain the much-needed capital. In order to win the support of private and business customers for the transition to sustainable energy, and to prevent decisions taken at one level in the political system from being blocked by another level, it will also be important to consider the redistributive effects associated with the regulatory instruments that are introduced.

Taking these requirements as their starting point, the following sections will analyse and make concrete recommendations regarding the regulatory issues that are particularly important for a transition to sustainable energy in Germany and at European and international level which is both financially viable in the context of a market economy and capable of meeting the targets that have been set.

3.1 ELEMENTS OF A GERMAN SUSTAINABLE ENERGY TRANSITION POLICY

Implementing the transition to sustainable energy will require massive investment in grids, energy storage facilities and energy-saving technologies, renewable electricity generation capacity and conventional backup capacity, as well as extensive R&D initiatives. However, these initiatives do not need to be undertaken all at once – they should be implemented in the appropriate sequence over a period of approximately 40 years. The energy sector is unlike almost any other industry reliant on a stable framework to enable investments to be planned and implemented efficiently. In addition to their sheer scale, this is due to the long-term nature of investments in power plants and grids as well as other types of energy infrastructure such as storage facilities. Furthermore, these investments are generally tied to a particular location, making it almost impossible to transfer the investment to a different location if the investor believes that the conditions are becoming less favourable.

As a result, the grid-based energy sector is more dependent on government than other industries.[18] In view of the fundamental transformation of the system that will occur during the transition to sustainable energy, it is therefore urgently necessary to ensure that a clear understanding exists of the factors that will have a key influence on future investment decisions. It will also be important to establish the legal situation with regard to planning and planning approval processes. The following two key issues are currently at the top of the agenda:

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17 Or public enterprises that are generally structured like private businesses, for example municipal services.
18 See Monopolkommission 2009; Bankenverband 2011.

1. *Realigning the way that renewables are promoted*
   How can the framework for promoting renewable energy best be converted from the Renewable Energy Sources Act into a market-based system? One of the keys to success will be ensuring that future investors in the relevant power plants have to take into account the same price signals as all the other investors in the system.

2. *Securing backup capacity*
   Will the electricity wholesale market at the level of the single German price zone send out adequate price signals that are acceptable to society and thus stimulate the necessary new investment in conventional power plants even if the fluctuating supply from renewable energy plants substantially increases its share as planned? Even if the answer to this question is yes, adequate capacity distribution among the regions would still not be guaranteed, at least while transport bottlenecks exist within Germany.

3.1.1 A NEW APPROACH TO PROMOTING RENEWABLE ENERGY

The EU ETS constitutes an attempt to internalise the externalities of CO_2 emissions in order to tackle climate change, by incorporating them into the calculus of the originators. The mechanism promises to deliver any carbon reduction target at the lowest possible cost to the economy. If it were able to keep this promise, there would be no reason to use any other instruments or indeed to promote particular technologies. Conversely, promoting specific technologies would only be justified if it could be demonstrated that

1. emissions trading is not promoting cost-efficiency and

2. at least in the long term, the additional support would help to achieve lower costs than on an unregulated emissions trading market.

If the situation were to remain static and there were no changes to the technological status quo, it should indeed be possible to use emissions trading to deliver the emissions targets cost-effectively, as long as a market power could be prevented from emerging on the emission permits market. However, it is empirically relatively difficult to predict events when the context is more dynamic. In a dynamic setting, where one of the main objectives is to promote technological progress so that the cost of cutting CO_2 emissions can be continually driven down, it is at least in principle possible for the market to fail. In this scenario, it would be possible to justify additional State support over and above the emissions trading scheme.

This is because the R&D decisions of decentralised actors are sometimes not enough on their own to guarantee the development of the optimal technologies. There are three main reasons for this phenomenon:[19]

1. R&D might generate spillover effects (positive externalities) whereby the innovators are unable to keep all the returns from their innovations for themselves.

2. Innovations always involve a learning curve that often results in substantial economies of scale, generally in relation to the production and application of the new technology in question. However, the production and application of a new technology can also be prevented from coming about through lock-in of established technologies.

3. Innovation inevitably involves substantial risks. Depending on how risk-averse the innovators are, this can mean that even very promising innovation projects fail to get off the ground.

In addition to market failure, there has been some discussion in academic circles of the possibility that policymakers might fail to lower the CO_2 emissions caps sufficiently. This

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[19] See e.g. SRU 2011, p. 239 ff; Weber/Hey 2012, pp. 44 – 45; IPCC 2012, p. 147 and pp. 871 – 872.

could also have a negative impact on emissions trading and is another possible justification for providing additional support for renewables.

However, the same basic argument also applies to this additional support. Policy failures generally occur when State interventions result in the accrual of unearned income. Whilst this is true of emissions trading, it applies equally to the promotion of renewable energy through the Renewable Energy Sources Act. The actual effectiveness of an instrument thus comes down to how well it has been implemented in practice. The promotion of PV technology is a classic example of a policy failure, since the reduction of feed-in tariffs has now turned into a purely political debate that is certainly no longer governed by technology policy considerations.

The prospects of correcting policy failures in the field of emissions trading are relatively good. For one thing, the policy failings are exclusively on the distribution side and do not affect efficiency of allocation. Moreover, the distribution problem could be solved relatively easily by creating a largely independent institution along the lines of the European Central Bank (ECB) that would assume responsibility for supervising emissions trading in the future.

If sufficiently good grounds exist to justify additional support over and above the EU ETS – either because of the market or policy failures described above or because it is felt that there is a case for establishing stand-alone targets for renewables expansion – then it is of course necessary to consider exactly what shape this support should take. There is considerable debate about the relative merits of price-based systems (e.g. the Renewable Energy Sources Act) and quantity-based systems (e.g. quota systems, auctions, portfolio standards) for promoting renewable energy. How these instruments rate is very dependent on the details of their design, including a) the intended duration of the instrument, b) whether it is technology-specific or technology-neutral, c) whether its fundamental design enables market-based price formation, d) whether it places the risk on private or public actors and e) the regulatory parameters (e.g. feed-in priority or differentiation between different locations) that it establishes.[20]

In any fundamental reform of the instruments for promoting renewable energy, it would in principle be desirable for policymakers to target the specific causes of the market and policy failings that need addressing. In contrast to the approach that has generally been adopted in the past, this would in particular involve not only explicitly stating which supposed failing was meant to be addressed by a specific measure, but also undertaking ongoing empirical reviews to establish whether the failing in question actually (still) exists. On this basis, the evaluation of instruments for promoting renewables, whatever their type, would not only have to include an assessment of their static and dynamic efficiency, their redistributive effects and their political feasibility, but would also have to establish whether the instrument could be replicated throughout Europe and how great the inefficiencies resulting from its coexistence with the EU ETS would be. Finally, any instrument that was deployed would have to be subject to continuous and independent review.

From an academic perspective, the debate surrounding which support models are best suited to overcoming different types of market failure has yet to be fully resolved in the present context. Price-based systems tend to have the upper hand if the goal is also to stimulate an expansion of capacity in as many different renewable energy technologies as possible. Quota-based systems, on the other hand, are best suited to achieving an optimally cost-effective overall supply of a set amount of green electricity without stipulating which technology should be used to generate it. Consequently, where the yardstick for success is primarily the effective promotion of a broad portfolio of technologies deployed in parallel in each individual country, it is hardly surprising that evaluation studies and model-based

20 See IPCC 2012, p. 150 ff. and p. 855 ff.

simulations of the efficiency and effectiveness of feed-in tariff systems and quota models should come out in favour of feed-in systems.[21]

However, in the context of Germany's transition to sustainable energy – which is what interests us here –, the promotion of a broad spectrum of different technologies can no longer be a priority. A variety of different types of renewable energy have already undergone an extremely significant expansion on the German market compared to other countries around the world. Furthermore, Germany has set itself even more ambitious targets for the expansion of renewable electricity production in the future. If these targets are to be met in a relatively efficient manner, it will be necessary to give consideration to the fact that feed-in tariff systems suffer from three key structural drawbacks: (i) the lack of competition between renewable energy plant operators, (ii) the failure to take into account the requirements of the market and (iii) the serious problems encountered by the State in terms of obtaining the data it needs to ensure rapid and appropriate adjustment of the relevant tariffs to reflect cost reductions in individual green electricity technologies achieved e.g. through economies of scale and learning curve effects.[22]

Against this backdrop, it would seem to be clear that simply making incremental adjustments to the existing instrument (the Renewable Energy Sources Act) cannot be the correct way to address the challenges posed by the transition to sustainable energy. Furthermore, the reality of politics is that policymakers are not going to wait for a definitive scientific answer to the question of whether and to what extent additional support for renewables actually makes sense. Rather, we can be sure that, come what may, they will press ahead with additional measures to promote renewable energy over and above the emissions trading system. As a result, this position paper recommends switching to a market-based support scheme in order to tackle the Renewable Energy Sources Act's most serious flaws in the short to medium term. This could, for example, take the shape of a quota model with green electricity certificates.

In economic terms, even the quota model would not constitute the ideal final solution. For the stipulation of a quota for renewable electricity would mean that it would not be possible to take advantage of differences in the marginal costs for cutting CO_2 emissions both inside and outside the green electricity sector, as would be possible if the support for renewable energy sources was limited to an emissions trading system encompassing all sectors of the economy.[23] A quota model with green electricity certificates should therefore be regarded as a pragmatic interim step to enable a transition from the Renewable Energy Sources Act to a more efficient scheme for promoting renewables. In addition, it would allow any learning curve effects to be internalised, thus achieving dynamic efficiency, and could also be designed in a way that was compatible with the EU ETS.

A market-based approach to promoting and expanding renewable energy

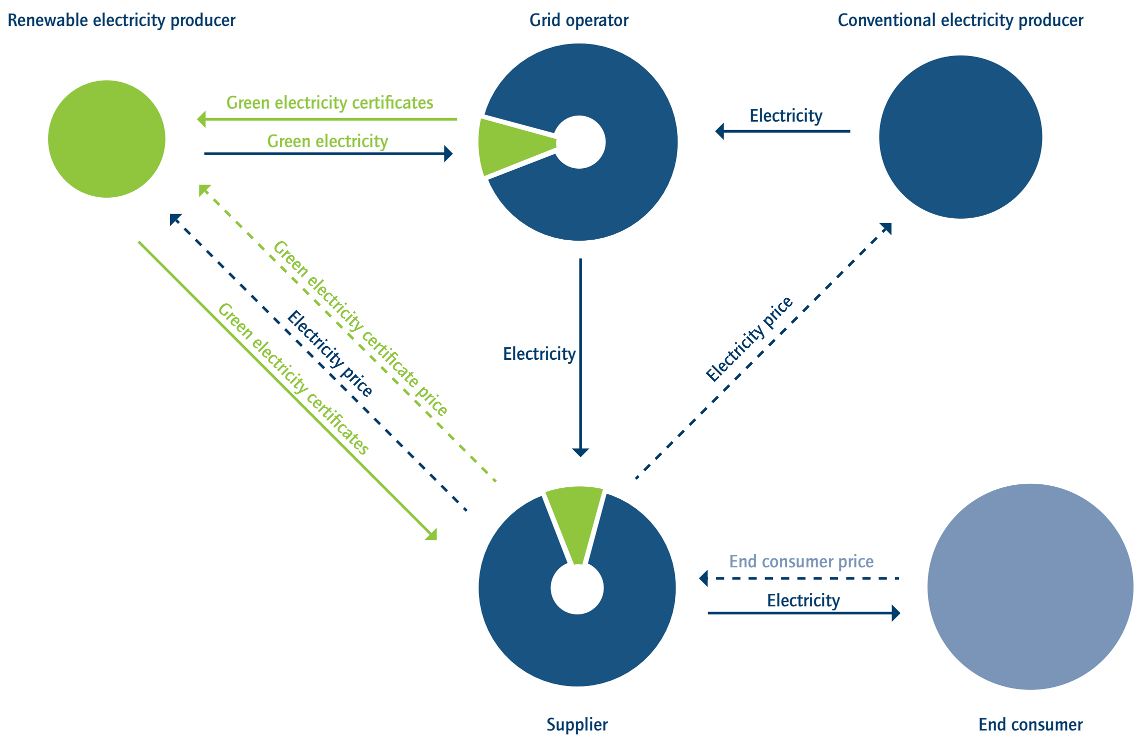
The current scheme for promoting the expansion of renewables in Germany contains significant untapped efficiency potential, since the Renewable Energy Sources

21 See Butler/Neuhoff 2008; Haas et al. 2011; Ragwitz et al. 2012.
22 See Häder 2005, p. 615.
23 See IPCC 2012, pp. 916 – 917 for a concise discussion of the interactions between emissions trading and supplementary policies geared towards promoting renewable energy. In Germany's case, the problem in the past has been that the measures to support renewable electricity production that have been implemented on top of the emissions trading scheme have resulted in lower emissions in the German electricity sector, causing certificate prices to be lower than they would be in the absence of the Renewable Energy Sources Act. The upshot of this is that carbon reduction measures are not taken in other sectors that participate in the emissions trading scheme, since it is cheaper for them just to buy certificates. As a result, electricity generation sectors elsewhere in the EU and the industrial sectors that participate in the emissions trading scheme end up having higher emission levels which completely negate the emission reductions achieved by the German electricity generation sector through the Renewable Energy Sources Act. All that is ultimately occurring is that the emissions are being displaced – the net reduction in CO_2 emissions brought about through the Renewable Energy Sources Act at EU level is zero (see BMWA 2004, p. 8; Morthorst 2003.)

Act promotes the large-scale expansion of currently very expensive generating technologies, even though there are far more efficient ways of fostering their development. The Renewable Energy Sources Act's exclusive focus on promoting the trialling of niche technologies for the expansion of renewables should be abandoned as soon as possible in favour of a market-based promotion system that is compatible with the pan-European and technology-neutral underlying principles of the EU ETS. To this end, the Monopolies Commission and the German Council of Economic Experts have proposed a quota-based support system for renewables involving a quota model with green electricity certificates.[24] Assuming that the principle of supplementary support is already a fait accompli, this acatech POSITION PAPER also recommends that it should at least be implemented through a market-based instrument such as the quota model.

Figure 2 is a simplified flow chart representing the green electricity market under the quota model. In this model, energy suppliers are legally required to ensure that a given percentage of the electricity that they supply to the end consumer comes from renewable sources. They are obliged to hold the relevant number of green electricity certificates each year to prove that they have met this minimum quota. Failure to do so results in them having to pay fines far in excess of the cost of the missing certificates. Renewable electricity producers receive green electricity certificates

Figure 2: Simplified flow chart representing the green electricity market[25]



24 See Monopolkommission 2011; Sachverständigenrat 2011.
25 Sachverständigenrat 2011, p. 257.

for every unit that is fed into the grid. The certificates are issued by the grid operators, who are the only people in a position to say which technology was used to generate the electricity fed into the grid. The green electricity certificates can then be banked and traded on certificate markets, even beyond a single compliance period. This prevents extreme price volatility and guarantees a single market price at any given time.

Under this model, renewable electricity producers would receive payment for the electricity they supply from two different sources: firstly from the sale of the electricity they feed into the grid at the current market price and secondly through disposal of the green electricity certificates issued to them. The price of the certificates would serve to guarantee technology-neutral promotion of renewables. The supply of green electricity certificates would correspond to the output of the producers generating renewable electricity and feeding it into the grid, whilst the minimum statutory quota would create a minimum demand for green electricity certificates.

However, energy suppliers would in principle be free to meet a higher quota than the statutory minimum. In other words, demand for green electricity certificates would not be capped by the quota. Since investor confidence in the long-term continuation of the promotion system would be a key requirement for successful expansion of renewables, investors would receive a guarantee (along the lines of the Renewable Energy Sources Act regulations) that they would be issued with certificates for the electricity from newly built plants for a 20-year period. Furthermore, the tradability of these green electricity certificates would also be guaranteed for the same period.

This system would offer a number of advantages over the Renewable Energy Sources Act. Firstly, the quota-based development of renewables would be easier to manage than with the Renewable Energy Sources Act's price controls. Secondly, the technology- and location-neutral promotion scheme would ensure that future expansion of renewables occurred in a cost-effective manner, reducing the burden of the transition to sustainable energy for both industry and consumers. The single tariff for renewable energy would mean that the most appropriate technologies would be deployed in the most suitable locations. Thirdly, renewable electricity producers would, in future, have a strong incentive to charge the current market price for the electricity they fed into the grid and even to invest in the storage technologies needed to integrate renewables into the system. This would allow them to choose the most profitable moment to feed their electricity into the grid without being tied to doing so at the time when the electricity was actually produced.

The principal advantage of the quota model and other market-based promotion schemes (such as a bonus model offering a technology-neutral bonus for green electricity) is that they have a system-based feedback effect on the profitability of potential additional renewable energy plants. For example, the price for electricity generated using solar PV would be low during hours of bright sunshine if there was already a lot of PV capacity on the market. Consequently, PV would be less profitable compared to other methods of electricity generation, and indeed compared to other types of renewable energy, and less additional capacity would automatically be built as a result. The electricity price-based competition between technologies and locations would therefore inevitably address the key system requirements that are urgently necessary in order to integrate renewables into the overall energy system.

Importantly, this system would offer the prospect of gradual harmonisation with similar promotion schemes in other EU member states and transnational expansion of the certificate trading system. This would allow the efficiency reserves that currently exist on the European electricity market to be unlocked.

It should be remembered, however, that any new instrument for promoting renewables, including quota models, will in practice only be as successful as the details of its design allow it to be.[26] The design of the new promotion scheme should therefore take into account any unintended incentive effects that it might bring about. Furthermore, it should from the very beginning be subject to academic evaluation by independent third parties as is already the norm in other policy areas, e.g. the introduction of labour market policy measures.

In order to ensure that the new instrument is designed with due care, it will be especially important to take on board the learnings from previous quota-based support initiatives to expand capacity using quota models. These did not initially meet with unqualified success,[27] however subsequent modifications enabled them to be significantly improved in terms of both their effectiveness and efficiency.[28] The principal keys to the success of quota systems[29] established by various empirical analyses have already been taken into account in the model presented above.[30]

A safe pathway from the Renewable Energy Sources Act to the quota model

Any market-based promotion model would need to establish a roadmap for the transition from the current Renewable Energy Sources Act. The transition to the quota model could be implemented in two phases.[31] The first step towards cost-effective delivery of the expansion targets would involve a short transition period of no more than one year during which the subsidies for all new plants established under the Renewable Energy Sources Act would be harmonised through the introduction of a single rate with immediate effect. This would at least ensure that the construction of additional renewable energy capacity would be guided by the respective cost of producing the electricity, even if the incentive for demand-led supply would remain low. In any case, there would now be a strong incentive to make targeted use of the advantages of particular regional locations in terms of average wind strength and hours of sunshine when building new plants during the transition period, since there would no longer be any supplementary subsidies to compensate for the disadvantages of a given location.

The second step would then involve the changeover to a market-led, quota-based support system for renewables. Newly built plants would from now on be covered by a green electricity certificate trading system. The existing rights of plants built under the Renewable Energy Sources Act would be protected.[32] Priority connection by the grid operators and feed-in priority for renewable electricity would be retained in future expansions under the quota model. The concrete figures for the annual minimum quotas would be derived from the

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26 See IPCC 2012, pp. 52 – 153 and p. 855 ff.

27 See Butler/Neuhoff 2008; Haas et al. 2011; Klessmann et al. 2011.

28 See Ragwitz et al. 2012, pp. 15 – 16; IPCC 2012, pp. 895 – 907.

29 See Haas et al. 2011, p. 2192.

30 Offshore wind power plays an important role in electricity production in all the key scenarios for expanding renewables that run up to 2050 (see Section 2.3). In a single quota model, however, this technology, which is still extremely high-risk and costly, would be unlikely to get a look-in, at least for the time being. Assuming that policymakers nevertheless wish to ensure that offshore wind power continues to be promoted in Germany even in the immediate future – and they would need to provide specific reasons for why this should be the case –, then they would have to undertake a critical assessment of whether it would make sense to provide targeted support over and above the quota model for this method of electricity generation by promoting a competitive tender process for the relevant capacity (see SRU 2011, pp. 267 – 273).

31 See Sachverständigenrat 2011.

32 In this respect, the quota model would not undermine investors' expectations – quite the opposite, in fact. The need to find an alternative to the Renewable Energy Sources Act for promoting the transition to sustainable energy was already anticipated, for example, by the Association of German Banks (*Bankenverband*) as long ago as October 2011: "From a regulatory point of view, it will be necessary to reduce and finally completely discontinue feed-in tariffs in the medium to long term. However, any such changes should not be applied retrospectively." The need to provide the stable framework required to ensure investor confidence would be met through the quota model design described above in conjunction with the roadmap outlined in this paper for migrating from the Renewable Energy Sources Act to the quota model.

capacity targets for renewables expansion that have already been set by policymakers. The basis for these calculations would be the installed capacity at the time of the changeover from the Renewable Energy Sources Act to the quota model.

It is perfectly possible that the rate at which renewables are expanded could falter as investors learn to make the necessary adjustments. However, in view of the spectacular growth in renewable energy capacity over the past few years and the fact that grid expansion has failed to keep pace with this growth, this would be something that would be very much acceptable, not to say desirable. In the medium to long term, the quota model actually offers policymakers and potential new investors an even more stable framework than the Renewable Energy Sources Act.[33] The necessary adjustments to the tariffs under the old system resulted in repeated "closing-down sales", which in turn created a high degree of uncertainty about how much new capacity would be built.[34] The quota model, on the other hand, would allow the capacity expansion targets set by policymakers to be implemented in a very long-term and predictable manner. All the market participants would know right from the start what the minimum quotas would be and when they would come into force. In order to meet investors' key need to have a sound basis for their planning, the precise details of how the model would operate would need to be finalised in good time and communicated in a transparent manner.

3.1.2 SECURING REGIONAL BACKUP CAPACITY

There is currently much discussion regarding the need to support the provision of guaranteed power plant capacity through an additional incentive mechanism known as a capacity mechanism. Politicians often claim that there is a case for capacity mechanisms on the grounds that the existing price signals are not currently enough to justify the investment in new facilities that is urgently needed in order to guarantee security of supply.

A number of other fundamental arguments have been put forward as to why the wholesale markets – known as "energy-only markets"[35] – may not be enough on their own to guarantee security of supply in the forthcoming market phase during which new facilities are expected to be built at a high rate.[36] These include insufficient price elasticity of demand, the fact that consumers will not be prepared to accept price peaks and potential market power problems if shortages arise. Subsidising and prioritising the construction of additional plants supplying fluctuating amounts of renewable energy with very low marginal costs – in particular PV and wind power – will only serve to accentuate the challenges facing the energy-only market that have been identified in the literature.

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33 Feed-in tariffs such as those provided for by the Renewable Energy Sources Act protect investors against most of the risk categories that are relevant to the renewable energy sector (see the overview in Ragwitz et al. 2012, p. 45). They are therefore often wrongly considered to minimise the overall risks. In actual fact, rather than simply disappearing, the relevant risks end up having to be borne by other actors. Theoretical modelling studies indicate that, in the long term, the sum of risks borne by society as a whole is, if anything, likely to be lower under a quota model than under a feed-in tariff system (see Schmalensee 2012, p. 62).

34 This problem will only be accentuated by the compromise on future initiatives to promote solar PV reached in the German parliamentary committee that mediates in disputes between the lower and upper houses shortly before this acatech POSITION PAPER was finalised. In addition to a further reduction in the tariffs, it was agreed that PV will only continue to receive support under the Renewable Energy Sources Act until a total capacity of 52 gigawatts is achieved. Starting from the existing installed capacity of around 28 gigawatts, if we assume that capacity continues to expand at a rate of about 7 gigawatts a year, the subsidies for new plants could end as early as 2016. The combination of a cap on the maximum capacity accompanied by falling subsidy levels could stoke competition to build new plants over the next few years, resulting in higher costs (see Mihm 2012).

35 An electricity market is known as an "energy-only market" if, as has hitherto been the case in Germany, no separate payments are made for providing generating capacity, meaning that in principle it is only electricity wholesale prices that can provide the necessary incentives for investment in generating capacity (see Böckers et al. 2012, p. 6).

36 See EWI 2012, p. 7 ff.; Böckers et al. 2012, p. 4 ff.

Capacity mechanisms at national level

A variety of recent studies have addressed the possible introduction of these mechanisms, the latest of which was commissioned by the Federal Ministry of Economics and Technology (*BMWi*) and is entitled "Investigation of a Future Electricity Market Design"[37]. The studies demonstrate that, despite the partial shutdown of nuclear power plants in March 2011, Germany's single price area currently still provides enough power plant capacity to cover peak load periods. It thus appears that the introduction of capacity mechanisms in order to guarantee profitable investments in power plants within the single price area is not necessary in the short term.

Nevertheless, these studies also show that, from around 2020, the requirements for new backup capacity construction will reach a point that, for a variety of reasons, could pose serious challenges for the existing energy-only market. However, although the introduction of capacity mechanisms could guarantee some measure of security of supply, it would be accompanied by other effects, such as higher transaction costs, the danger of ad-hoc political interventions and the distortion of the market. The available studies indicate that it will be necessary to carry out careful assessments before introducing capacity mechanisms at national level, although there is still plenty of time for this to be done.

In principle, policymakers face the same challenges in this context as they do with regard to the promotion of renewable energy (chapter 3.1.1). State intervention cannot be convincingly justified simply on the grounds that a supposed problem (be it capacity bottlenecks or market failure) has been identified in very broad terms. Instead, concrete reasons for the intervention should be established and their validity should be tested empirically on an ongoing basis. Based on these criteria, an effort should then be made to evaluate the success of the State intervention in terms of its effectiveness and efficiency in delivering the relevant goals.

Regional capacity bottlenecks

Even if Germany as a whole still has enough generating capacity, capacity shortfalls can still occur in individual regions. Regional grid bottlenecks can sometimes prevent the available capacity (on one side of the bottleneck) from being used to meet the demand (on the other side). If several different price areas existed in Germany, these shortfalls would translate into corresponding price differences, thus sending out different investment signals for different locations. However, German legislation still requires a single price area to be maintained, meaning that these signals are not being sent. Traditionally, grid bottlenecks have been managed using what is known as redispatch management[38]. However, only the approximate value of the variable costs is reimbursed to the power plants used to effect the redispatch and consequently no additional incentive to invest is created.

Nüssler (2012) shows that if power plants in the south of Germany continue to be shut down whilst new conventional capacity continues to be built, particularly in the west and north of the country, a capacity shortfall could occur in the south in the foreseeable future. The likelihood of this happening will be even greater if the delays that have plagued the expansion of the German grid in the past continue. However, capacity mechanisms without a regional component would not help to address this challenge, since the decision on where to locate power plants would continue to be taken on the basis of the prevailing myth of an entirely congestion-free grid throughout the single price area, thus

37 EWI 2012.

38 When bottlenecks occur, redispatch management relieves certain lines in the grid by shifting the electricity fed in by power plants to different locations. The grid operator intervenes in power plant deployment by instructing individual generating units to increase or decrease production. Redispatch management is not a market-based process, since it does not convey the price signals generated by the bottleneck to the responsible market players. Whilst it can provide a temporary fix, it is no substitute for the grid expansion required to achieve a permanent solution to long-term bottlenecks. (Sources: www.amprion.net/glossar; www.swissgrid.ch/swissgrid/de/home/experts/ppo/redispatch_measures.html).

completely failing to take the real situation of the grid in different locations into account.

Possible approaches as to how the geographical dimension could be better taken into account include creating different price areas or, if the single price area is maintained, modifying the redispatch mechanism so that it provides proper incentives or introducing a geographical generation component for grid connection. There is a major need for further research in this area. In view of the expected capacity and power grid expansion, this research would seem to be far more urgent than continuing to trial the introduction of national capacity mechanisms.

3.1.3 ENABLING SMART GRIDS IN THE DISTRIBUTION GRIDS

Two major changes will come about as a result of the increasing role of electricity generated by wind power and solar PV in the future energy system. These are the production of electricity in the distribution grid and the associated load flow reversal on the one hand, and fluctuations in electricity generation on the other. Chapter 2.2 has already discussed potential technical solutions to the problem of fluctuating supply, concluding that it is currently advisable to pursue all the available options. However, in order to tackle the issue of a more decentralised supply, it is necessary to switch our focus to the distribution grids. It is here that the changes in consumption patterns and business models and processes will be most evident.

A decentralised supply requires expansion and technical modification of the distribution grids. Depending on the extent to which wind power and PV are expanded, the distribution grid will need several hundred thousand kilometres of new power lines, compared with "only" a few thousand kilometres for the transmission grid. Until now, investments of this nature were always underpinned by the principle of being able to guarantee the feed-in of virtually all decentralised production at any given time. In the future, however, the requirement to absorb every single peak in production into the grid would result in a completely excessive expansion of the grid. This is because new grid facilities would be lying unused at times when solar or wind power was not being supplied owing to adverse weather conditions. This points to a fundamental problem in terms of striking a balance between potentially switching off generating facilities – i.e. managing them – and expanding the grid.

The development of smart grids in the distribution grids is necessary, in order to enable generating facilities to react flexibly to grid problems in the event of surpluses of several hours' duration in the distribution grid that cannot be relieved by the transmission grid, or to afford grid operators flexible control over these facilities. This would involve establishing ICT links between generating facilities and introducing comprehensive monitoring at the level of individual distribution grids so that extremely high security of supply standards could continue to be met at an acceptable cost.

An initial concrete requirement for the development of smart grids is a standards-based "energy information network". This could largely use existing ICT infrastructure. Metering devices fitted with small on-board computers and a secure communication link would then need to be provided in the distribution grid to producers and consumers. Under this system, the distribution grid operators will be active enablers for future energy markets as well as ensuring local system stability and providing transmission grid operators with crucial support when it comes to securing the stability of the European electricity system.

A number of possible concrete measures to enable the transition to smart grids were developed and presented in detail in the acatech STUDY "Future Energy Grid"[39]. The key recommendations are as follows:

[39] Appelrath et al. 2012.

- Distribution grid operators must be put in a position where they can maintain grid stability even when high quantities of renewable energy are being fed into the grid. If possible, this should be done without market interventions or emergency shutdowns. In order to achieve this, “regional marketplaces” should be established where the grid operators can buy system services for their grids from the relevant balancing group managers (without discrimination). This could be done in a manner not dissimilar to the transmission grid operators' balancing power market.
- It is necessary to regulate when investments must be made in new operating equipment (power lines and transformers) or when to allow room for intelligent management on behalf of the distribution grid operators, in order to secure system stability whilst at the same time reducing the costs associated with the necessary expansion of the grid. Grid fees based on the “polluter pays” principle should also be introduced by law at the distribution grid level. In particular, the institutional framework should in future enable a balance to be found between accelerated grid expansion and market-led shutdowns of renewable energy plants with a view to prioritising cost-effectiveness. Ultimately, there is no need for every single spike in electricity production to be passed on to the higher levels of the grid.
- One prerequisite is that grid operators must have incentives to invest in the relevant smart infrastructure. Since not all of the 800 grid operators currently active in Germany will be able to plan and implement the new brand of grid management, a solution needs to be found. Proposals made by the Federal Network Agency (*Bundesnetzagentur – BNetzA*) include merging grids and third-party management.
- There is scope to achieve greater integration of consumers into the market. The first step would be to enable suppliers to estimate their domestic customers' electricity consumption independently and allow them to buy it in and pay for it on the market. This would make the installation of smart meters and the introduction of variable tariffs attractive, at least to some customers. A different business model would come about if variable tariffs were used to contribute to system services or to help even out fluctuations in electricity generation. Consequently, smart grids and the market integration of renewable energy production are a key *requirement* for the introduction of smart meters in Germany.
- The new electricity supply structures that are emerging are reminiscent of the Internet, and it has not taken long for people to start talking of an “Internet of Energy”. A parallel can be drawn in terms of people's willingness to invest. All the successful Internet business models are based on the existence of an infrastructure that is available to all the participants and is underpinned by widely accessible standards. Major innovations thus benefit from low entry barriers and a large market. Furthermore, low transaction costs mean that they are able to generate huge sales figures from a large number of small transactions. In order to develop smart grids, an energy information network modelled on the Internet should therefore be established as a market enabler. This would have to reflect international standards as far as possible, in particular to ensure that international markets could be tapped into. Much work still needs to be done with regard to the regulation of the electronic meters, market communication and operator model.

3.1.4 ENABLING INVESTORS TO BUY INTO THE TRANSITION TO SUSTAINABLE ENERGY

Anyone wishing to make an investment needs to have enough equity at their disposal. In many cases, grid operators and suppliers will have insufficient capital reserves to cover the level of investment that is going to be required over the next few years. It will therefore be crucial to attract institutional or financial investors to help finance these initiatives. There are two key considerations that apply to all equity investors but in particular to those people investing in the industry for the first time: 1. the risk-return ratio and 2. the degree of confidence with which this ratio can be calculated. The latter is especially dependent on the predictability and reliability of the regulatory framework. Especially in the case of first-time institutional investors in the industry (insurance companies, pension funds, etc.) it would appear that the second factor is currently by far the more important of the two.

Any modification of the framework will thus initially cause the financing institutions to adopt a cautious attitude towards investment while they learn how to calculate the impact of the new framework on the risk-return ratio of the different projects. Any changes to the framework should therefore be made as gradually as possible. Should this not be possible, as is the case with the Renewable Energy Sources Act (see above), any fundamentally new mechanisms should – both in terms of when they are introduced and how they are designed – place particular emphasis on ensuring that market players are rapidly able to understand how they work.

The deprivatisation and return of many distribution grids to local authority control is a worrying trend, especially in view of the need for investment in both transmission and distribution grids. There is a danger that this will lead to at least partial fragmentation of the grids, with a subsequent loss of economies of scale, making investments in upgrading the grids more expensive. If deprivatisation continues, there is also a danger that investments in grid infrastructure would be primarily governed by local authority budget considerations and would focus far less on the requirements of the other energy industry players such as producers, transmission grid operators and consumers.

Finally, smaller operators are unlikely to be able to cope with the increasingly complex ICT-based management of smart grids. Moreover, it is not clear how local authorities are going to find the capital needed to finance the necessary investment in the grid from within their often rather overstretched budgets. As such, deprivatisation would in any case need to be accompanied by innovative financing partnerships with first-time investors in the industry.

It should be possible to draw on a wide palette of innovative financing instruments, including long-term loans, but also e.g. public participation models, fund models, securitisation and project bonds. The relevant legal and regulatory frameworks should be adapted in order to allow institutional investors but also the widest possible range of other investors to buy into the transition to sustainable energy.[40] This could help to broaden the base of support for the transition whilst also reducing reliance on individual investors or classes of investors. Nonetheless, it remains likely that larger investors and institutional investors will play a more important role in financing capacity expansion in the future than they have done up until now.

The Renewable Energy Sources Act is designed to ensure that investors can be very confident in the returns they can expect from investing in individual plants. The same would not be true of the quota model presented by this acatech POSITION PAPER as an example of a market-based management approach geared towards integrating renewables into the market. Nevertheless, investor confidence in the likely returns could be increased by offering investment portfolios that spread the risk across a variety of renewable energy plants using different technologies and in different locations. It is true that the guarantee of minimum returns through such a risk diversification strategy would not be directly available to smaller investors, or at least not to the same extent. However, fund and participation models would still allow smaller investors to participate and would also enable diversification-based risk structuring.

40 See Bankenverband 2011; GDV 2012.

3.1.5 TOWARDS AN OPEN-MINDED INNOVATION AND TECHNOLOGY POLICY

The ideal innovation and technology policy would establish a reliable price path for greenhouse gas emissions, expand the infrastructure for innovations and ensure unrestricted competition to innovate among private actors. In the context of the transition to sustainable energy, these are the three key requirements for technological progress. If necessary, the quest for innovative solutions to radically transform the energy supply system could be supported by targeted innovation policy interventions. However, these interventions would have to be understood to be part of the innovation process and not simply the realisation of one planner's ideas about what the future will hold.[41] Instead of pursuing a policy focused on individual technologies which sails close to the wind in terms of interfering with competition and the market, the State should focus on promoting basic research. In the context of the transition to sustainable energy, this would involve a particular emphasis on materials research.

The design of the Renewable Energy Sources Act fails to meet the above requirements. The artificial creation of a sufficiently large market was intended to ensure the establishment of the supposed technologies of the future in Germany, enabling the companies benefiting from this support to win a lasting share of the global market. The widespread promotion of different generating technologies does in principle make it possible for solutions that are initially less cost-effective to eventually establish themselves on the market. However, there does not appear to be any time limit on how long this instrument for promoting renewables will remain in force, nor does it offer any means of effectively putting a stop to instances of mismanagement as in the case of PV technology.[42]

The market-based management approach recommended by this acatech POSITION PAPER and the quota model used to exemplify how it could be implemented establish a clear distinction between delivery of the expansion targets and any technology policy goals. The economic policy strategy for the transition to sustainable energy should therefore be supported by a complementary innovation and technology policy. This policy should be open-minded in terms of its results and be prepared to encounter setbacks and to write off some of the resources that have been invested. However, any technology policy interventions and demonstration projects designed to complement the quota model should have a clearly defined timeframe in terms of the duration of their funding and their results should also be subject to critical evaluation.[43]

3.2 INTEGRATING THE TRANSITION TO SUSTAINABLE ENERGY INTO EU ENERGY POLICY

There is currently a lack of coherence between the regulatory frameworks for the electricity sector at EU level and the national and regional levels in Germany. Consequently, it is not possible to guarantee that the explicit targets and implicit secondary conditions will definitely be met. Furthermore, the regulatory framework is very economically inefficient, with major redistributive effects that are increasingly likely to result in political conflicts. In addition, there are a number of significant interactions with neighbouring European countries, both with regard to electricity generation and trading as a result of the single common price and with regard to the grids, for example in terms of electricity transit.

It would therefore appear to be urgently necessary to bring the goals of Germany's transition to sustainable energy into line with EU energy policy and the rules of the single

41 See Sachverständigenrat 2009.
42 See Sachverständigenrat 2009; BMWA 2004.
43 See Sachverständigenrat 2009.

market. In view of the interactions described above, it will also be important to ascertain which of the (national) goals are binding and definitely have to be implemented and which goals are intended to act merely as guidelines at national level. There are three areas that should be focused on at European policy level: the strengthening and long-term expansion of the EU ETS, the progressive introduction and transnational coordination of market-based instruments for promoting renewables in the EU, such as quota models, and the harmonisation of frameworks and secondary conditions accompanied by a conscious effort to discontinue any redundant and consequently inefficient instruments.

3.2.1 STRENGTHENING AND EXPANDING EMISSIONS TRADING

The main regulatory policy priority at European level should be to strengthen the EU ETS as the chief, cost-effective energy and climate policy instrument and to promote its long-term expansion. Within the EU, the focus should be on coherently expanding the system to include other sectors and on optimising the trading system. In order to achieve the latter, it will be especially important to establish binding long-term carbon reduction targets at European level that extend beyond 2020 and are consistent with climate policy targets. The emissions trading system should be primarily responsible for delivering these targets. Certificate banking beyond a single compliance period should also be allowed, in order to promote more stable price formation.[44] In order to strengthen the emissions trading scheme institutionally and ensure that it is not influenced by member states' industrial and redistributive policy goals, its supervision should potentially be entrusted to a predominantly independent institution along the lines of the European Central Bank (ECB).

Any national or European level support measures and regulations to complement the emissions trading scheme should not create the expectation among the European CO_2 market actors that a significant proportion of the CO_2 reductions stipulated by the cap can be achieved through extra taxes on CO_2 emissions, compulsory surcharges on electricity prices or similar non-competitive financing models, thus making it possible to get round or significantly relax the budget restrictions that are effectively imposed by the emissions trading scheme. In the medium term, once the EU ETS has been strengthened as described above, it should eventually be opened up to selected non-European countries so that it can achieve the desired degree of effectiveness in the context of global climate policy.

3.2.2 IMPLEMENTING MARKET-BASED PROMOTION OF RENEWABLES TRANSNATIONALLY ACROSS THE EU

Assuming that the EU ETS is strengthened in its capacity as the lead instrument, as described above, existing renewables promotion models in individual EU member states that are based on technology-specific feed-in tariffs along the lines of Germany's Renewable Energy Sources Act should be progressively transformed into technology-neutral models that comply with EU single market rules, insofar as the respective member states still see a need for additional support for carbon reduction technologies over and above the incentives already provided by the emissions trading scheme. In this context, it would be especially beneficial to progressively introduce a standardised, pan-European, market-based system such as a quota model.

Cross-border trading of green electricity certificates under an internationally harmonised quota model could help to further

44 The literature discusses a variety of additional measures to prevent the short-term collapse of the emissions trading system. In addition to various proposals geared towards reducing the over-endowment of certificates, these also include the establishment of minimum incentives by introducing a minimum price for certificates, the introduction of a price cap for certificates in order to limit any possible pressures and border tax adjustments in order to prevent displacement of emissions to countries outside the EU ETS (see SRU 2011, pp. 249–256; Tindale 2012).

reduce costs, since each country will tend to have specific preferences as to which different generating technologies it uses. Moreover, an international quota model would enable fluctuations in the supply of e.g. wind power to be minimised more effectively at European level than would be possible nationally. Since only a few European countries (the UK, Sweden, Poland, Belgium, Italy and from 2015 also the Netherlands) currently have quota-based systems,[45] the first step following any change to the German system would be at least to create a common certificate market with these countries.[46]

This harmonised European model could then be progressively expanded to include any other countries that switched to a quota-based approach in the future. The harmonisation of European support mechanisms that would be achieved by so doing would also create a more stable investment environment, meaning that the returns sought by investors would be expected to fall[47].

3.2.3 IMPROVING AND HARMONISING FRAMEWORKS AND SECONDARY CONDITIONS

The energy policy framework and secondary conditions at EU level should be harmonised as far as possible. This harmonisation can and should consciously seek to discontinue any instruments that are superfluous to the EU ETS (and its possible expansion through e.g. an international quota model) and which are therefore inefficient. In this regard, a particularly close look needs to be taken at the EU Energy Efficiency Directive. In view of the current emissions trading scheme, the Directive is now redundant in terms of delivering climate policy goals, however it continues to cost the economy a substantial amount of money.

In addition, the energy mix policy for electricity in Europe should be harmonised, at least for predominantly congestion-free interconnected regions where it is not possible to implement a national energy mix. In Germany's case, the relevant region would at least include France, the Benelux countries, western Denmark, Poland, the Czech Republic, Austria and Switzerland. Moreover, a common understanding of security of supply would have to be developed within this region and would then need to be guaranteed through the appropriate transnational mechanisms and investments. In order to consolidate the transition to sustainable energy at European level, it would also be necessary to establish a common target for the maximum acceptable additional financial burden for electricity consumers. Furthermore, cross-border cooperation between transmission grid operators would need to be enhanced and they would have to be provided with improved access to information on electricity flows within the common European grid.

The final aspect in terms of the harmonisation of the framework and secondary conditions is that Europe's climate and energy policies will need to be more closely coordinated with an appropriately designed research policy. Any climate policy that is to be successful in the long term will require significant technological advances. However, in many areas the basic principles have yet to be developed, for example with regard to energy storage, alternative energy production, carbon capture and storage (CCS) and carbon capture and use (CCU). The extent to which the market can deliver solutions to satisfy the framework conditions of the transition to sustainable energy will be largely determined by the advances made in basic and applied research.[48]

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45 See Ragwitz et al. 2012, pp. 11 – 12.

46 The three international cooperation instruments established by the Renewable Energy Directive to help countries meet the binding national renewables expansion targets (statistical transfer, joint projects and joint support schemes) mean that the key legal and institutional requirements are already in place (see Ragwitz et al. 2012, pp. 46 – 61).

47 See GDV 2012, p. 7.

48 The energy research strategy developed by the German academies of science (Leopoldina/acatech/BBAW 2009) proposes a number of research priorities relevant to our future energy supply and places particular emphasis on the need to adopt a systemic and international approach to energy research.

3.3 OPENING UP THE EU ETS INTERNATIONALLY USING A FUND-BASED MODEL

By switching from the Renewable Energy Sources Act to a market-based support scheme along the lines of a quota model, Germany's massive expansion of solar PV capacity would be halted. As a result, Germany would no longer be financing a huge part of the learning curve for the rest of the world in a specific technology that can undoubtedly make a major contribution to cutting emissions, albeit in other countries where solar radiation levels are higher. In the future, it would therefore seem appropriate for this support, that has hitherto largely been provided through Germany's Renewable Energy Sources Act, to be delivered through an international fund system such as the Green Climate Fund. This would ensure that the costs for promoting the expansion of renewables in developing countries could be shared internationally. It would also lead to greater transparency, since this type of technological, climate-related development aid would now be clearly recognisable as such to the public in the donor countries. It would thus no longer come across as a non-transparent side-effect – unpublicised by policymakers – of a promotion model that was ostensibly designed to achieve very different goals.

The interaction between energy and climate policy

In Germany, the transition to sustainable energy is currently mistakenly regarded as a purely national endeavour. In actual fact, however, its ultimate success will depend on whether it can make a significant contribution to reaching an international climate agreement or to the emergence of an international coalition incorporating major newly-industrialised countries and developing nations big enough to achieve a reduction in CO_2 emissions that actually makes a difference on a global scale. Germany is quite clearly never going to solve the problem of climate change by going it alone. Indeed, even if Germany were able to achieve zero greenhouse gas emissions, there would be no measurable or observable impact on the climate. Even Europe will be unable to halt global climate change on its own.[49]

Ultimately, the huge amount of money invested in transforming Germany's energy system into an electricity supply model based almost entirely on renewable energy can only be justified if everything possible is also done to deliver the goal of cutting emissions not just in Germany but on a global scale. It is therefore urgently necessary to adopt a global perspective to Germany's transition to sustainable energy and ensure that it is integrated into global climate policy. The final section of this acatech POSITION PAPER will therefore present the two most important recommendations that it has made up to this point through the prism of the interdependence between energy and climate policy. This will allow one further key recommendation to be identified.

The key challenges for climate policy

There are two fundamental policy issues that need to be addressed in order to solve the problem of climate change. The first is the need to reach agreement on a global carbon budget that defines the remaining capacity of the atmosphere to absorb greenhouse gases. This task can already be said to have been accomplished, insofar as the international community's 2°C target implicitly also establishes a greenhouse gas emissions budget, i.e. the volume of greenhouse gases that humanity can still expect the atmosphere to absorb.

The second is the need to determine the regional distribution of the rights to utilise the atmosphere's absorption capacity. The Copenhagen negotiations failed dismally in this regard. The fundamental reason for the conflict regarding distribution is that although limiting the use of the atmosphere to absorb carbon would create a valuable resource in the shape of emission allowance allocations, it would also lead to the destruction of another, formerly valuable resource, since it would now no longer be possible to extract

49 See Edenhofer et al. 2011; Weimann 2012.

and burn a large proportion of the carbon stored in the earth. This would result in major redistribution effects that would affect different countries in different ways.

These distribution issues and conflicts of interests will need to be resolved if an effective climate agreement is to be achieved. The willingness of countries to commit to ambitious climate policy goals will depend on how favourable the specific cost-benefit ratio is and how quickly the costs and benefits accrue and become tangible for governments and voters alike. Consequently, the following three main approaches should be considered[50]: firstly reducing the cost of climate protection through a more efficient carbon reduction policy, secondly linking climate protection agreements with other treaties (issue linkage) and with sanctions (especially trade restrictions) and thirdly linking climate protection agreements with transfer payments (side payments).

First of all, as already argued above, this acatech POSITION PAPER strongly recommends implementation of the first option, e.g. through the introduction of a single quota model throughout Europe. A switch from the Renewable Energy Sources Act to a quota model would allow Germany to reduce the inefficiency of its current renewable energy promotion initiatives whilst at the same time revitalising the EU ETS as the main system for reducing emissions at European level. If successful, the combination of these two factors could constitute a best practice model for reducing the cost of climate protection both in Europe and in other countries and regions throughout the world.

The second measure has already been used, albeit with varying degrees of success, on several occasions in the past – for example Russia's ratification of the Kyoto Protocol in exchange for the EU's undertaking to support its membership of the WTO. Although imposing trade restrictions on countries that refuse to commit to combating climate change may well increase the chances of them cooperating, there is very little that can actually be done in this regard, since any sanctions could be viewed as protectionist measures that would rapidly enter into conflict with WTO rules.

Against this backdrop, the most promising strategy would appear to be to complement the reduction in the cost of climate protection by using transfer or side payments to work towards a climate protection agreement encompassing as many countries as possible. The cornerstone for this approach was already laid in Copenhagen, when the industrialised nations promised the developing nations financial transfers to the tune of 30 billion US dollars between 2010 and 2012 as well as an annual total of 100 billion US dollars from 2020 onwards, although this last figure is also supposed to include private investments. The Green Climate Fund (GCF) was subsequently established in Cancún with a view to coordinating the promised financial support. The Fund should become operational some time next year and will provide developing countries with support to reduce emissions and adjust to the consequences of climate change.

A bottom-up process to globalise the EU ETS

This initiative will only succeed if the industrialised nations do actually deliver the level of financial resources that they promised in Copenhagen (if not more). When one considers the amount of money already spent on Germany's transition to sustainable energy and Europe's climate policy, not to mention the resources that are scheduled to be spent in the future, then Europe has no excuse for failing to meet its commitments. However, the contributions to the GCF suffer from the same overall coordination problem as global climate policy as a whole, in the sense that those countries that fail to meet their individual financial commitments are still likely to benefit from the positive effects of the initiative. There is therefore a significant danger for the nations that do contribute to the Fund that their generosity will be exploited by freeloaders, thus ruining any chance of accomplishing the intended effect.

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50 See Edenhofer et al. 2011.

As a pragmatic way of complementing this centralised top-down approach geared towards achieving a global climate agreement through transfer and side payments, Europe could provide additional proof that it is serious about leading the way on climate policy by simultaneously adopting a decentralised bottom-up approach.[51] This would involve the EU making targeted payments only to those countries prepared to join the EU ETS in exchange. The EU would also commit to using the efficiency gains resulting from the expansion of the emissions trading scheme to make substantial transfer payments to new members from newly industrialised countries and developing nations.[52] This bottom-up approach currently seems to offer the best chance of creating an international coalition of nations that is sufficiently large to achieve effective climate protection.

It is important to ensure that the transition to sustainable energy is not confined to shifting the balance of Germany's national energy mix towards renewable electricity. This interim target is in fact no more than a step on the way towards the ultimate goal of preventing the dramatic consequences of irreversible climate change. Consequently, Germany should work at European level to promote the combination of a transfer system and emissions trading scheme as described above. In the final analysis, if it were to prove impossible to forge a major international coalition for effective climate protection in the near future, then even if Germany achieved its own transition to sustainable energy and successfully overcame all the technical, financial and political obstacles outlined in this acatech POSITION PAPER, it would ultimately still have failed in its goal and the billions of euros invested would have been wasted. Consequently, the national transition to sustainable energy will not be enough on its own if Germany genuinely wishes to lead the way in this area.

51 See Weimann 2012.

52 Weimann (2012) outlines a possible concrete design for a mechanism that would achieve the necessary redistribution whilst also protecting the nations prepared to make transfer payments against exploitation and ensuring that they would receive an environmental dividend in the long term.

4 SUMMARY AND KEY RECOMMENDATIONS

This acatech POSITION PAPER discusses the key aspects of how the transition to sustainable energy can be accomplished in a financially viable manner. The decision to focus on regulatory instruments designed to achieve greater cost-effectiveness vis-à-vis the existing energy and climate policy management model is based on the conviction that it will only be possible to deliver the ambitious political and social goals of the transition to sustainable energy by retaining the support of the public and the business community. Policymakers already recognised the importance of this aspect during the parliamentary consultations on the transition and promised that the financial burden arising in particular from the planned expansion of renewables will not exceed the 2011 figure. This position paper makes a number of concrete recommendations designed to establish a credible basis for this commitment.

In a nutshell, the paper urges a fundamental overhaul of the energy sector's regulatory framework based on a coherent and consistent overall design. Instead of continuing to implement new, uncoordinated individual measures, German energy policy in the immediate future should pay special attention to addressing this design issue. The conflicts between goals that will inevitably arise during the course of this process should be resolved decisively rather than being put off until some time in the future.

This acatech POSITION PAPER's three key recommendations are as follows:

1. to coherently strengthen the EU ETS as the chief system for promoting a low-carbon energy supply in Europe and to expand it beyond the electricity sector

2. the Renewable Energy Sources Act should be replaced as soon as possible by a long-term, market-based promotion mechanism such as a quota-based support system for renewables using green electricity certificates (quota model) in order to promote more efficient integration of renewables into the energy system and to ensure more cost-effective capacity expansion. This promotion mechanism should then gradually be extended to the rest of Europe in a harmonised manner, and

3. the national measures implemented by Germany as part of its transition to sustainable energy should be integrated into the German and European negotiating strategy with regard to global climate protection initiatives. Furthermore, the EU Emissions Trading Scheme should be progressively extended to include other countries across the globe through transfer and side payments to developing and newly industrialised countries under a fund-based model. This will enable sustainable success to be achieved in the global fight to combat climate change.

In order to guarantee security of supply in Germany as cost-effectively as possible, it is also recommended that the existing mechanisms for adjusting power plant output in response to short-term power grid bottlenecks (redispatch) should be improved as a matter of urgency. The reason for so doing would be to ensure adequate incentives for the provision of secure power plant capacities at a *regional* level. This would potentially allow the threat of supply bottlenecks in certain German regions to be averted. Furthermore, over the next two to three years, the pros and cons of introducing a national capacity mechanism should be carefully assessed in terms of its ability to iron out the increasing number of price peaks forecast to occur in the electricity wholesale market, thereby potentially delivering more stable price signals to investors in new power plant capacity.

LITERATURE

Appelrath et al. 2012
Appelrath, H. J./Kagermann, H./Mayer, C.: *Future Energy Grid. Migrationspfade ins Internet der Energie* (acatech STUDIE), Heidelberg u.a.: Springer Verlag 2012.

Bankenverband 2011
Bankenverband: *Finanzierung der Energiewende: Investitionssicherheit und innovative Lösungen* (Position paper of the Association of German Banks regarding the transition to sustainable energy), 2011.

BMWA 2004
Bundesministerium für Wirtschaft und Arbeit (BMWA): *Zur Förderung erneuerbarer Energien, Gutachten des Wissenschaftlichen Beirats beim Bundesministerium für Wirtschaft und Arbeit* (Document No. 534), Berlin 2004.

Böckers et al. 2012
Böckers, V./Giessing, L./Haucap, J./Heimeshoff, U./Rösch, J.: *Braucht Deutschland einen Kapazitätsmarkt für Kraftwerke? Eine Analyse des deutschen Marktes für Stromerzeugung* (DICE Ordnungspolitische Positionen No. 24), Düsseldorf 2012.

BMU 2011
Bundesministerium für Umwelt, Naturschutz und Reaktorsicherheit (BMU): *Erfahrungsbericht 2011 zum Erneuerbare-Energien-Gesetz (EEG-Erfahrungsbericht)*, 2011.

Butler/Neuhoff 2008
Butler, L./Neuhoff, K.: "Comparison of feed-in tariff, quota and auction mechanisms to support wind power deployment". In: *Renewable Energy* 33, 2008, pp. 1854 – 1867.

dena 2005
Deutsche Energieagentur (dena): *Dena-Netzstudie I: Energiewirtschaftliche Planung für die Netzintegration von Windenergie in Deutschland an Land und Offshore bis zum Jahr 2020*, 2005.

dena 2010
Deutsche Energieagentur (dena): *Dena-Netzstudie II: Integration erneuerbarer Energien in die deutsche Stromversorgung im Zeitraum 2015 – 2020 mit Ausblick auf 2025*, 2010.

DLR 2011
DLR: *Wege zur 100 % erneuerbaren Stromversorgung. Studie im Auftrag des Sachverständigenrates für Umweltfragen*, 2011.

DLR/Fraunhofer IWES/IfnE 2012
DLR/Fraunhofer IWES/IfnE: *Langfristszenarien und Strategien für den Ausbau der erneuerbaren Energien in Deutschland bei Berücksichtigung der Entwicklung in Europa und global. EE-Langfristszenarien 2011*, 2012.

Edenhofer et al. 2011
Edenhofer, O./Flachsland, C./Brunner, S.: „Wer besitzt die Atmosphäre? Zur politischen Ökonomie des Klimawandels". In: *Leviathan* 39 (2), 2011, pp. 201 – 221.

Erdmann 2011
Erdmann, G.: *Kosten des Ausbaus der erneuerbaren Energien. Eine Studie der Technischen Universität Berlin im Auftrag von vbw – Vereinigung der Bayerischen Wirtschaft, Bayerische Chemieverbände, Verband Bayerischer Papierfabriken, Verband der Bayerischen Energie- und Wasserwirtschaft*, 2011.

European Commission 2011
European Commission: *Energy Roadmap 2050* (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions), 2011.

European Climate Foundation 2010
European Climate Foundation: *Roadmap 2050 – practical guide to prosperous, low carbon Europe*, 2010.

EWI 2012
Energiewirtschaftliches Institut an der Universität zu Köln (EWI): *Untersuchungen zu einem zukunftsfähigen Strommarktdesign. Endbericht zum Gutachten im Auftrag des Bundesministeriums für Wirtschaft und Technologie (BMWi)*, 2012.

EWI/Energynautics 2011
EWI/Energynautics: *Roadmap 2050 – a closer look, Cost-efficient RES-E penetration and the role of grid extensions*, 2011.

Frondel et al. 2011
Frondel, M./Ritter, N./aus dem Moore, N./Schmidt, C.: „Die Kosten des Klimaschutzes am Beispiel der Strompreise für private Haushalte". In: *Zeitschrift für Energiewirtschaft* 35, 2011, pp. 195 – 207.

GDV 2012
Gesamtverband der Deutschen Versicherungswirtschaft (GDV): *Positionspapier des Gesamtverbands der Deutschen Versicherungswirtschaft: Zur Verbesserung der Bedingungen für Investitionen in Erneuerbare Energien und Infrastruktur*, Berlin 23.03.2012.

Greenpeace 2010
Greenpeace: *Klimaschutz: Plan B 2050 Energiekonzept für Deutschland*, 2010.

Haas et al. 2011
Haas, R./Resch, G./Panzer, C./Busch, S./Ragwitz, M./Held, A.: "Efficiency and effectiveness of promotion systems for electricity generation from renewable energy sources – Lessons from EU countries". In: *Energy* 36 (4), 2011, pp. 2186 – 2193.

Häder 2005
Häder, M.: „Einspeisevergütungs- und Quotenmodelle zur Förderung der regenerativen Stromerzeugung". In: *Energiewirtschaftliche Tagesfragen* 55, 2005, pp. 610 – 615.

IPCC 2012
IPCC: *Special Report "Renewable Energy Sources and Climate Change Mitigation" of the Intergovernmental Panel on Climate Change*, 2012.

Jägemann et al. 2012
Jägemann et al: *Decarbonizing Europe's Power Sector until 2050 – analyzing the implications of alternative decarbonisation pathways* (EWI Working Paper), 2012.

Klessmann et al. 2011
Klessmann, C./Held, A./Rathmann, M./Ragwitz, M.: "Status and perspectives of renewable energy policy and deployment in the European Union – What is needed to reach the 2020 targets?". In: *Energy Policy* 39, 2011, pp. 7637 – 7657.

Leopoldina/acatech/BBAW 2009
Deutsche Akademie der Naturforscher Leopoldina/acatech – Deutsche Akademie der Technikwissenschaften/Berlin-Brandenburgische Akademie der Wissenschaften (BBAW): *Konzept für ein integriertes Energieforschungsprogramm für Deutschland,* June 2009.

McKinsey 2012
McKinsey: *Die Energiewende in Deutschland – Anspruch, Wirklichkeit und Perspektiven,* May 2012.

Matthes 2012
Matthes, F. C.: „Langfristperspektiven der europäischen Energiepolitik – Die Energy Roadmap 2050 der Europäischen Union". In: *Energiewirtschaftliche Tagesfragen* 62, 2012, pp. 50 – 53.

Mihm 2012
Mihm, A.: „Einigung im Streit um Solarstrom-Kürzung". In: *FAZ* (*Frankfurter Allgemeine Zeitung*), 27.06.2012, p. 9.

Monopolkommission 2009
Monopolkommission: *Sondergutachten 54, Strom und Gas 2009: Energiemärkte im Spannungsfeld von Politik und Wettbewerb*, 2009.

Monopolkommission 2011
Monopolkommission: *Sondergutachten 59, Energie 2011: Wettbewerbsentwicklung mit Licht und Schatten*, 2011.

Morthorst 2003
Morthorst, P.: "National environmental targets and international emission reduction instruments". In: *Energy Policy* 31 (1), 2003, pp. 73 – 83.

Netzentwicklungsplan 2012
50Hertz Transmission/Amprion/TenneT TSO/Transnet BW: *NETZENTWICKLUNGSPLAN STROM 2012 ENTWURF DER ÜBERTRAGUNGSNETZBETREIBER*, URL: http://www.netzentwicklungsplan.de [Version dated: 05.07.2012].

Nüssler 2012
Nüssler, A.: *Congestion and Redispatch in Germany. A model-based analysis of the development of redispatch* (Dissertation), Cologne University 2012.

Prognos/EWI/GWS 2010
Prognos/EWI/GWS: *Energieszenarien für ein Energiekonzept der Bundesregierung*, 2010.

Ragwitz et al. 2012
Ragwitz, M./Steinhilber, S./Breitschopf, B./Resch, G./Panzer, C./Ortner, A./Busch, S./Rathmann, M./Klessmann, C./Nabe, C./de Lovinfosse, I./Neuhoff, K./Boyd, R./Junginger, M./Hoefnagels, R./Cusumano, N./Lorenzoni, A./Burgers, J./Boots, M./Konstantinaviciute, I./Weöres, B.: *RE-Shaping: Shaping an effective and efficient European renewable energy market. Final report,* 2012.

Sachverständigenrat 2009
Sachverständigenrat: *Jahresgutachten 2009/2010 des Sachverständigenrats zur Begutachtung der gesamtwirtschaftlichen Entwicklun*g, 2009.

Sachverständigenrat 2011
Sachverständigenrat: *Jahresgutachten 2011/2012 des Sachverständigenrats zur Begutachtung der gesamtwirtschaftlichen Entwicklung*, 2011.

Schmalensee 2012
Schmalensee, R: "Evaluating policies to increase electricity generation from renewable energy". In: *Review of Environmental Economics and Policy* 6, 2012, pp. 45 – 64.

SRU 2011
Sachverständigenrat für Umweltfragen (SRU): *Sondergutachten „Wege zu 100 % erneuerbarer Stromversorgung" des Sachverständigenrats für Umweltfragen*, 2011.

Tindale 2012
Tindale, S.: *Saving emissions trading from irrelevance* (CER policy brief), London, June 2012.

Weber/Hey 2012
Weber, M./Hey, C.: „Effektive und effiziente Klimapolitik: Instrumentenmix, EEG und Subsidiarität". In: *Wirtschaftsdienst* 92 (Sonderheft), 2012, pp. 43 – 51.

Weimann 2012
Weimann, J.: *Institutionen für die Beherrschung globaler Commons und global öffentlicher Güter. Kurzexpertise für die Enquete-Kommission „Wachstum, Wohlstand, Lebensqualität" des Deutschen Bundestages*, 2012.

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