Future Perspectives of Electrical Energy Supply

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In order to describe the future perspectives of a renewable-dominated electrical energy supply system that will be stable over the long term, first, goals must be established (see Sect. 2.1). Based on these aims, in Sect. 2.2, indicators which can be applied to evaluate and decide upon technological options are discussed. The theoretical background of the renewable energy aims and indicators is supplemented in Sect. 2.3 by the analysis of the current and potential future aims of energy and environmental politics with respect to the energy system. This section points out some of the political challenges that need to be addressed. Finally, the economics of storage system values is discussed, showing that there is an economic motivation to store electricity (see Sect. 2.4).

2.1 Aims for a Long-Term Viable Development of a Renewable-Based Electricity System

The concurring targets of the energy economy are often shown as a triangle of efficiency, supply security and environmental compatibility. It has become increasingly obvious that the current electricity system is incompatible with environmental protection requirements. When reconstructing the electricity systems, the supply security and environmental compatibility targets of the triangle have to be given adequate consideration as well. Ideas for developing such a system can be taken from economic analyses of overall societal efficiency and sustainability.[1] These are taken here as a basis for the evaluation of the future viability of various technologies for the electricity system as well as of the system itself. The argumentation is based on work done in Droste-Franke et al. (2009) and Droste-Franke (2005). A more detailed discussion of the individual issues can be found there.

[1] Sustainability is used here as specific concepts for maintaining societal assets in the context of ensuring a just intergenerational distribution following de Haan et al. (2008).

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2.1.1 Efficient Allocation and Just Distribution

The fundamental elements of economic action can be reduced to the attribution of existing means to applications (allocation) and to individuals (distribution). In the context of the overall economy, respective economic aims are expressed as efficient allocation and just distribution among current individuals at the present point in time, as well as in the future, between generations living at different time periods. These concepts are known as intra- and intergenerational distributive justice.

From a macro-economic point of view, the efficiency of an economy is linked to optimising the welfare of a society as a whole (cf. Schumann 1992). The optimum is derived as a so-called pareto-optimal state in which nobody's utility can be improved without somebody else's utility being degraded. Assuming the conditions of an ideal market and basic assumptions about the preferences of individuals, it can be theoretically proven that an equilibrium of supply and demand on the markets leads to such a pareto-optimum (see Malinvaud 1972). Therefore, the aim of economists is to achieve market conditions that are close to perfect so that trading on the markets leads to a pareto-optimum. A presupposition for this is that market failure, which can be caused by market power, badly regulated ownership rights or imperfect market structures is avoided. For the equilibrium it is furthermore important that it is stable; otherwise it will not be reached.

In order to achieve intra- and intergenerational distributive justice, the concept of sustainable development has been applied in economic analysis. Quoting the most-cited definition given in the so-called Brundtland report, sustainable development means to implement a "development that meets the need of the present without compromising the ability of future generations to meet their own needs" (WCED 1987, p. 43). As no information about the needs of future generations exists, for the operationalisation of the concept, it is assumed that future generations have the same needs as the current generation. The goal is to install a type of economic development that ensures that the needs of future persons having identical needs to the persons living today can be satisfied continuously. Development will require monitoring and sufficient flexibility to be able to adjust to changing preferences. Furthermore, the definition does imply that it must not be accepted that future generations may not be able to satisfy their needs (that are assumed to be equal to the needs of the contemporary generation). Thus, the implementation of the precautionary principle in order to avoid inacceptable risks is implicit in the Brundtland definition.

The concept of capital[2] and assets are critical to this discussion. Capital must be preserved to such an extent that the needs of future generations can still be met. One sub-target is to sustain the total value of the available capital. An equivalent formulation is that the rents obtained from the usage of natural resources must be

[2] Capital is used here as generic term for objects which can be used for the production of economic income. This includes beside others produced and natural capital.

re-invested into reproducible capital (Nutzinger and Radke 1995, p. 32). This concept is called "Solow-Hartwick" sustainability or "weak" sustainability.

Following the definition of the Brundtland report, for an economic development to be sustainable means that no actions must be taken that could risk the loss of capital and jeopardise the ability of future generations to satisfy their needs. This requires using natural capital in such a way that it will still be available in the future. In order to guarantee this, it is not sufficient to follow the concept of weak sustainability, because some types of natural capital are not substitutable. An often discussed interpretation of the requirements for the adequate protection of natural capital is that its functions have to be preserved. This can be ensured by producing functional-equivalent capital providing the functions to the extent they are on the other side degraded or depleted respectively. Preserving the functions can directly be applied as a principle for the usage of non-renewable resources.

Capital is characterised as essential or "critical natural capital" (see Neumayer 1999, p. 27), if it is not substitutable and its reduction to below a critical level could lead to the loss of fundamental life-support functions or mean irreversible destruction resulting in an unacceptable environmental status. The concept can be operationalised by defining limits that ensure that unacceptable risks are avoided, even in situations of risks with high potential impacts, inadequate evaluation because of uncertainty, and lack of knowledge about impacts. Environmental areas in which a critical burden could occur are: climate change, ozone layer depletion, dispersion of toxic substances, and pollution of ecosystems, among others. Another term for this concept is "critical sustainability".

2.1.2 An Operative Action Rule

The different aims of economic efficiency and distributive justice in its various facets can be combined in the following action rule formulated in the form of four priorities (see Droste-Franke 2005; Droste-Franke et al. 2009):

Priority 1. *Protection from unacceptable damage through compliance with critical limits of load*
Critical stocks of each relevant societal asset component[3] must not be under-run.
Priority 2. *Preservation of the total value of produced and natural capital*
Provided that priority 1 is met, adequately evaluated changes of all relevant societal asset components must add up, at minimum, to zero. In the case that priority 1 can only be reached with a negative balance, this must be minimised.[4]

[3] These include, among other things, natural assets, e.g., ecosystems. The stocks can principally be measured in arbitrary units.

[4] This addition is introduced in order to cover the case in which the efforts for guaranteeing the protection from inacceptable damage are so great that a reduction of total assets is necessary. An equivalent formulation is: In the case that priority 1 cannot be reached without a negative balance, the maximum level of societal assets must be aimed for, so that a balance of zero can be reached.

Priority 3. *Maximising intertemporal welfare*
The present value[5] of the intertemporal benefit must be maximised, thus achieving priorities 1 and 2.
Priority 4. *Just distribution of basics at present*
The basics for meeting needs, resulting after achieving priorities 1–3, must be justly distributed within and between societies and generations according to societally defined rules.

The agreed critical loads for the preservation of critical assets in this context are to be seen as a result of societal processes in which the acceptability of potential impacts from the respective environmental burden is discussed. Discussions for fixing these values build on scientific findings from the corresponding environmental areas. Should new knowledge arise with regard to the values of the critical limits, the costs for achieving the limits, or the impacts occurring if limits are exceeded, then the formerly agreed critical values should be adjusted respectively.

The formulated action rule represents a normative frame, which has to be filled with content. In many areas, critical values are not fixed or are still being discussed. Furthermore, the discussion about what has to be preserved and to what extent enters the models, for example, in the form of different assumptions about rates for discounting future impacts and benefits. In areas for which societal agreements exist about critical limits that have to be met, the presented rule provides a possibility for consideration. This can practically be done through, for example, formulating restrictions for the welfare optimisation process. Restrictions, according to priorities 1 and 2, are particularly important if not all relevant aspects can be evaluated adequately in monetary values or if relevant non-linear effects cannot be sufficiently considered in the optimisation process.

2.2 Indicators for the Evaluation of Balancing Strategies

In order to characterise the purposes relevant for a long-term viable development of the energy system, a classification scheme of Steger et al. (2005, p. 54) which distinguishes between three categories is followed in the analysis:

- protection of the environment,
- availability of resources,
- design of the energy system with respect to society.

While the availability of resources concerns the inputs available for production, the protection of the environment aims at conserving the assimilation capacity and the life-supporting functions of the environment. The way the energy supply system is organised comprises direct influences of the system via its embodiment in society.

[5] By using the present value of the benefit as a uniform value, present prices are used and future benefits are expressed by discounting them to get the present values.

2.2.1 Indicators for Environmental Effects

In evaluating the environmental effects of energy systems, emissions of chemical substances are relevant. Direct emissions of noise and radiation are of less importance, but are also considered if relevant.

For the categorisation of relevant substances, characteristics regarding the environmental dispersion, the chemical transformation and the relevant environmental impacts are consulted. The first category resulting from these perspectives is represented by chemical pollutants that directly affect organisms and materials via chemical reactions and mechanical impacts. Amongst other impacts, these lead to harmful effects on ecosystems, crops, materials and human health. Pollutants for which harmful impacts are observed even at very low concentration levels are called toxic substances. Particularly important in this context are substances with long lifetimes, which may accumulate in the environment. Major representatives are heavy metals, persistent organic pollutants and radio-nuclides. Furthermore, optical influences of the atmosphere, such as opacity, can be observed, particularly due to the emission of fine particles and their precursors. Another relevant effect that is currently dominating the discussion of environmental impacts is the emission of gases, which increase the so-called greenhouse effect of the atmosphere. They have an influence on the radiation budget of the Earth by absorbing radiation from the ground in the infrared frequencies and re-emitting partly to the Earth. This effect results in a long-wave counter radiation, causing a higher temperature at ground level than would be observed without these gases. Increasing the natural concentration of the greenhouse gases as well as emitting further gases showing a similar effect on the radiation balance, lead to higher average temperatures and climate change effects. Important are particularly gases absorbing at so far vacant frequencies in the infrared area. The complete effect of the gases typically unfolds only after some years. Not of central importance to this study, but also of relevance, are gases that contribute to the stratospheric depletion of the ozone layer.

As already mentioned in the section dealing with the design of the energy system, by following the four priorities in the action rule, two types of risks have to be distinguished: first, risks with limited potential for damage in the areas of human health and produced or natural capital and second, risks that result in large unacceptable damages.

In the case of marginal or small damages to the environment, the evaluation is ideally carried out by quantifying the utility losses caused by environmental and human health impacts. For the evaluation of utility losses and external costs from energy systems, the impact pathway analysis has been established within the ExternE project series, which began in the early nineties (European Commission 1995, 1999, 2005a). Starting from the emission of substances, the physical impacts on the environment and human health are estimated by modelling the dispersion and chemical transformation. Based on these estimates, the related utility losses are quantified in monetary terms as far as possible. The uncertainties in the estimates increase with each further step in the impact pathway. If high uncertainties exist in parts of the pathway, intermediate indicators like for example, the amount of emissions, concentration increase or additional physical impacts can be consulted additionally or alternatively to the monetised costs for the evaluation of risks arising from energy systems. The impacts that will be analysed from this area are:

– impacts on human health, material damage, crop loss and biodiversity loss caused by environmental pollution,
– various relevant marginal impacts from climate change.

In the area of risks with potentially inacceptable impacts, agreed critical limits should be met. This aspect has already been discussed in the evaluation of the energy system design. Critical limits are defined for many indicators from the respective impact pathway. These can be the amount of emissions, concentration levels or environmental flows, such as the deposition rate of substances. In the case of greenhouse gases, for instance, targets agreed upon for emission reductions in order to avoid potential unacceptable damage, e.g., those required for meeting the two-degree aim, can be interpreted as critical limits. For the aggregation of effects from different emissions, substances with the same impact can be normalised by estimating the relative share of the individual contribution to the respective total impact. In the case of greenhouse gases, for instance, CO_2 is taken as a reference and emissions of all gases are usually expressed in CO_2 equivalents. In the case of acidification and eutrophication problems, first, concentration levels and deposition values have been taken as a basis for politically fixed limits to the environmental burden. These have then been translated into amounts of emission reduction, which form the foundation for international agreements, e.g., the Gothenburg protocol and related declarations. Impacts considered with respect to critical limits are:

– eutrophication and acidification due to environmental pollution,
– land use,
– depletion of the stratospheric ozone layer,
– greenhouse effect.

Some of the environmental aspects are mentioned for both areas, small and large potential damages. However, the subjects of analysis differ between the two types of risks.

2.2.2 Indicators for Resource Availability

For the evaluation of resource use, it is necessary to know whether resources are depleted by usage or whether they recover to a sufficient extent during usage. Important to resource availability is the competition among different utilisations. This means that situations are possible in which the same resource can be applied only by one party and is blocked for employment by others.

Relevant resources that are not depleted by utilisation, but are characterised by competing applications, are available surface area and space. Using an area for building up a new power plant, for example, fixes the respective land use for the lifetime of the plant. Another example is energy crops competing with the cultivation of food. Indeed, the quality of land could change due to specific usage. In that case, re-establishment to the previous state is in the first instance a question of costs and the loss of values, and not of critical loads. To a large extent, only the change of land use will have a strong influence on the environment, particularly on the entire ecosystem, so that this kind of usage can be interpreted as being critical. An evaluation of land use change should be carried out, as far as possible in comparison to the previous land use. In addition to recovery costs, losses of utility, as well as other (non-use) values (e.g., option value, loss of originality), are particularly important for the evaluation of land use changes if the previous state cannot be recovered.

A special case is resources for which the recovery rate is larger than the depletion rate, such as regenerative cultivated biomass, and resources not being depleted by usage over time in any way, such as the continuous flow of sunlight and wind velocities. As long as the ability of regeneration is guaranteed, there are no temporal resource problems from using a resource.

Further relevant resources in the area of energy systems are materials obtained from the ground. These are on the one hand energetic resources such as gas, oil and coal and on the other hand minerals that are required for the production of energy technologies. These materials are also called non-renewable resources, because their regeneration rate is much lower than the depletion rate. Non-renewable usage of land also has to be mentioned in this context. For these kinds of resources, critical situations may occur that are characterised by increasing shortage and, thus, increasing prices and supply costs. In this way, the amount of known resources being economically exploitable, also called "reserves", may decrease over time. An important indicator for the resource availability is the ratio of the reserves to the current production (reserves-to-production ratio). This indicates how long the reserves would last if the current production rate was kept constant. Steger et al. (2005, p. 54) also call this indicator the "period of secure practice". Following Steger et al. (2005), for a sustainable management of non-renewable resources, the "period of secure practice" should not decrease over time and not become less than 60 years. This is the time period estimated to be necessary for restructuring the energy system. Claiming that the reserves-to-production ratio should not decrease does not mean that the respective non-renewable resource must not be used, but that a decrease in the stock of economically exploitable resources must be balanced by reducing the production, e.g., by using alternatives. Scarcity of non-renewable resources can additionally be forced by the monopolistic structure of the supply side, which results from the naturally determined hotspots of resource availability in only a few countries and the large infrastructure required to deliver some of the resources to the demand side, such as pipelines and refineries. Therefore, observable concentration in reserves and delivery and supply chain in nations or companies are further interesting indicators.

2.2.3 Indicators for the Design of the Energy Supply System

Following Steger et al. (2002, 2005), three relevant aspects can be distinguished concerning the design of an energy system: supply reliability, risk avoidance and openness of options. Furthermore, the invested and variable economic costs of the options and, thus, the amount of fixed monetary capital, are important. Numerous indicators have been discussed in this area. These indicators aim mostly at the evaluation of complete energy systems (see, for example, Kopfmüller et al. 2000; IAEA 2005; IEA 2007; RNE 2007). However, in this study the subject of investigation is only a part of the energy system. Thus, only some of the discussed indicators are applicable to this analysis.

Concerning supply reliability, it is important that the quality of electricity supply with a high share of renewable energy sources, such as solar radiation and wind, can be ensured sufficiently through balancing electric power and energy. Strategies and technologies applicable for this purpose are at the focus of this study. A sufficient quality of supply would of course be reached if the quality provided were the same as that of the current energy system. Additionally, it has to be discussed in how far flexibilities on the demand side should be considered in the system in order also to use demand-side management and to outbid the allowed ranges in which no increase of damages to devices and to people is anticipated. A further aspect that is relevant for supply reliability is the extent to which dependencies on third parties exist with regard to purchased resources. This issue has also been discussed in the previous section.

With respect to the aim of risk avoidance, risks that are not acceptable to society should be obviated and high risks should be minimised as far as possible. Beyond technical risks, risks related to environmental burdens are considered here. This includes risks with a large number of small potential individual impacts, including on human health, for which impacts should be minimised. In addition, large-scale risks are also relevant; these are, for example, major environmental damages. Avoiding such risks requires the establishment of critical limits as defined by society.

Maintaining an openness of options for new discoveries stemming from research and development is important for realising an optimal energy system. Different energy technologies show various levels of potential promise in this regard. Interesting characteristics of the technologies are the applicability of alternative fuels, their lifetime and the long-term nature of required investments.

Investment costs and variable costs of the different technological options are major variables to take into consideration in the design of a future energy system. Once a decision is made for a specific option, costs occur, binding up capital that could otherwise be invested in alternative societal aims. Thus, it is important to look closely at costs. However, to get the whole picture, socio-economic costs have to be taken into account, additional to microeconomic components. Furthermore, long time periods have to be taken into account, because low costs at present may implicate high costs in the future. In the approach followed for this study, energy system set-ups will be optimised for certain points in time, while the framework conditions and political decisions influencing the implementation of strategies will be considered. The starting points for the projection of framework conditions are future scenarios derived within other studies (see Sect. 3.1). Additional to already existing studies, this study will analyse strategies for balancing power and energy for electricity supply in greater detail than has been done previously and will likewise also consider economic, political and legal aspects.

2.3 Political Governance Towards a Renewable Energy Electricity System in Europe

The theoretical discussion above relating to the aims and goals for a viable, low-carbon future energy supply is important as background information. It is society, however, that must decide on the necessity of investing in and developing a new energy system (or in this case, electricity system), the direction of that system, and the extent of measures to be taken to spur on the transition. To get a picture of actual developments with respect to the establishment of a new electricity system, a detailed analysis of current and planned political governance processes and policies is indispensible.

The analysis starts with a description of the system and the current trends reflecting the impacts of already initiated policies. This is followed by a discussion of specific policy activities that are aimed at restructuring the electricity system. Finally, important challenges for energy policy are discussed.

2.3.1 Historical Background, Current Status and Development of Europe's Energy System

A variety of factors are driving a slow transition of European approaches to energy in general, and electricity in particular, including concerns about Europe's heavy dependence on energy imports from abroad, rising fossil fuel energy prices, and ecological constraints. These concerns were summed up in a January 2007 European Commission Communication on EU energy policy: "[T]he days of cheap energy for Europe seem to be over. The challenges of climate change, increasing import dependence and higher energy prices are faced by all EU members" (European Commission 2007a). The challenge for Europe is providing the right incentives and structures to make an energy transition towards greater renewable energies, especially in the electricity sector, possible. The transformation will require not only technological innovations and engineering solutions, but also an appropriate policy framework and public understanding and acceptance.

2.3.1.1 Europe's Growing Energy Dependence

In 2009, close to two-thirds of the total energy consumption mix in Europe was based on fossil fuels (36.6% oil, 15.7% coal, and 24.5% natural gas). Nuclear held a 13.6% share and renewable energies combined an 8.9% share (Eurostat 2011d).

However, European supplies of fossil fuels are constrained. The European Union is a net energy importer. Its dependency on energy imports has increased from 45% in 1997 to 53.8% in 2008. EU energy dependency is particularly high in the cases of oil (83.5% in 2009), coal (62.2%) and natural gas (64.2%) (Eurostat 2011d). With growing demand for energy resources and minerals coming from emerging economies (e.g., China, India, South Africa, Brazil), expectations are that energy prices will rise, hurting European economies.

2.3.1.2 Climate Change Constraints

Even more pressing than these resource constraints are the environmental constraints tied to the heavily fossil-fuel based economies of Europe and other regions of the globe. The Intergovernmental Panel on Climate Change (IPCC) and many other bodies warn that the emissions from fossil fuel burning are contributing to a warming of global average temperatures and putting the planet at risk of severe weather extremes. The warming of the planet will affect seasonal temperatures and rainfall patterns, turning some parts of the planet into desert-like regions and others into flood areas. The melting of polar ice and glaciers could contribute to sea level rise, impacting coastlines and low-lying states. More severe storms and hurricanes and periods of excessive heat and drought are also predicted. The survival of planet and animal species could also be put at risk (IPCC 2007).

2.3.1.3 Climate Change as a Driving Force Behind the Search for a Low-Carbon Electricity System

Climate change policies have been critical to recent changes in European energy policies. Reducing greenhouse gas emissions will require Europe to shift away from its still heavy dependence on fossil energies. Climate change prerogatives, defined to protect from unacceptable climate change effects, have been a driving factor in the promotion of greater energy efficiency, greenhouse gas emission reductions and renewable energy.

2.3.1.4 Growing Diversification of the Energy Supply

The incentive to diversify energy supplies and increase domestic production sources is becoming increasingly strong. EU domestic energy production in 2009 stood at 28.4% nuclear, 20.4% coal, 18.8% natural gas, 12.8% crude oil, and 18.3% renewable energy. It is striking that by far the fastest growing energy sector is renewables, which accounted for only 9.7% of domestic energy production in 1999, but, as noted above, twice that amount a decade later. Based on Eurostat data, it is possible to calculate that during the same time frame production of other energy sources fell: crude oil (−33%), natural gas (−14.5%), and solid fuels (−14%) (Eurostat 2011d). Thus, the incentive to diversify energy supplies and increase domestic production, especially of renewable energy, is becoming stronger. Renewable energy power capacity is expanding.

The EU has begun to think more strategically about how it can shift from its still heavily fossil-fuel based energy structure toward a more low-carbon energy supply. While Europe remains heavily dependent upon fossil fuels, a clear shift in the energy mix over time is becoming visible. In the electricity sector, renewables accounted for 11.9% of EU-27 gross electricity consumption in 1990, 13.8% in 2000, and 16.7% in 2008 (ibid.). As renewable energies are relatively non-controversial, can be domestically developed, and are also climate-friendly, there has been a big push in this direction in recent years. The challenge for the coming decades will be to create an infrastructure, including electricity grid structures and storage systems, that will make possible the further rapid expansion of renewable energy.

2.3.1.5 Trends in Renewable Energy Production in Europe

There was a 38.4% increase in renewable energy production capacity between 2002 and 2007 within the EU. During the same time frame, domestic production of other energy sources dropped off: 28.7% in the case of crude oil, 18.1% in the case of natural gas, and 11.1% in the case of solid fuels. Renewable energy growth in electricity generation has been particularly strong in relation to photovoltaics and wind (see Fig. 2.1).

2.3.2 Political Governance Activities for Organising the Future Energy System

2.3.2.1 Regional Cooperation in Developing Renewables

There are several ambitious regional renewable energy policies that are forming. One is in the North Sea region, where Norway, Sweden, Germany, France, the Netherlands, Denmark and the United Kingdom are cooperating in the development of a regional grid structure and offshore wind parks. For northern Europe, offshore wind could provide large shares of electricity in the future years, although this will require the development of a grid structure to transport the wind from offshore wind

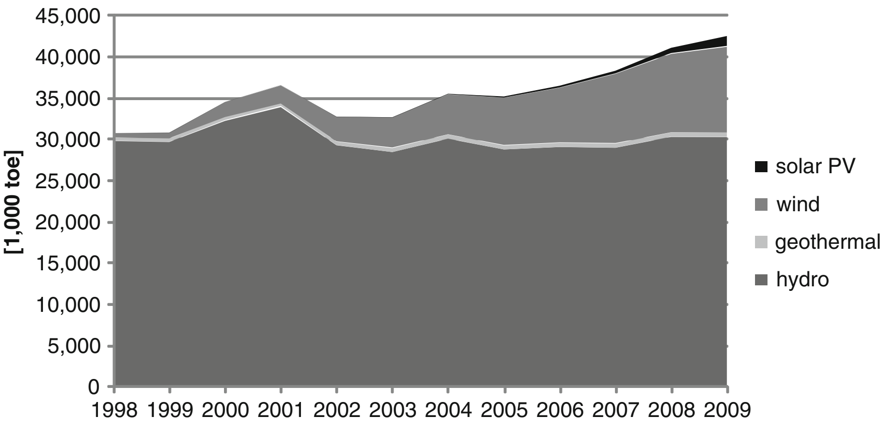

Fig. 2.1 Electricity generation from renewable sources (Data source: Eurostat 2011g)

park locations to demand centres. The German Environment Advisory Council (SRU) has focused attention on the important potential of offshore wind in the North Sea and pump storage capacity in Scandinavia for contributing to meeting ambitious renewable energy goals (SRU 2011).

Interest in the large-scale solar energy potential of the Mediterranean and northern African regions are also rapidly building in Europe. The German Aerospace Center (*Deutsches Zentrum für Luft- und Raumfahrt* – DLR) has conducted satellite-based studies that suggest as little as 0.3% of the desert areas of the Mediterranean and northern Africa would be necessary to produce enough electricity and desalinated seawater to meet the expanding needs for energy and water in Africa and Europe.

Before solar energy could be delivered to Europe from the region, grid interconnectivity will have to be achieved. Efforts to integrate energy markets in general are still at a nascent stage, but movements are rapid. At the bilateral level, Joint Declarations on Energy Cooperation have been signed between the European Commission and Morocco (July 2007) and Jordan (October 2007) and an EU-Egypt Memorandum of Understanding on Energy was reached in December 2008 (European Commission 2008a).

At the multilateral level, plans are forming for a Mediterranean Ring under the European-Mediterranean Partnership (the Barcelona Process). The idea is to provide electric power transmission grid interconnectivity among the littoral states of the Mediterranean Sea. The concept envisions linking electric power grids from Spain to Morocco, on to the Magreb (north Africa and western Arab) countries, through Egypt and the Mashreq (eastern Arab) countries, and on to Turkey and then Greece. The electric grid could potentially link into the European grid through Greece. Currently, the integration of electricity markets is still limited. The European Commission is helping to fund related projects, such as the Maghreb Electricity Sub-Regional Project, which aims to create an electricity market among Morocco, Tunisia and Algeria. Morocco and Algeria are co-operating in a joint venture to connect the Algerian power grid to the European Union through Morocco.

The initial objective of the Mediterranean Solar Plan is for 20 GW of added renewable energy capacities by 2020 for the region. It is expected that 3–4 GW of this will come from photovoltaics, 5–6 GW from wind and 10–12 GW by concentrating solar power (CSP). CSP uses mirrors that reflect and concentrate sunlight on a central column filled with water, in turn turning the water into steam that can be used to drive turbines. For this plan to function, the physical interconnection of Tunisia and Italy and Turkey and Greece is considered necessary (EPIA 2008).

The TREC international network of scientists and engineers (now known as the DESERTEC Foundation) together with the Club of Rome have presented an idea for solar energy development in the deserts of northern Africa: DESERTEC, Clean Power for Europe. DESERTEC envisions a future where mass-scale production of concentrating solar power (CSP) in the deserts of northern Africa will supplement European renewable energy sources and help Europe to reduce its carbon dioxide emissions and meet its electricity needs.

A group of 20 German firms, including Siemens, Deutsche Bank, RWE and E.on plan to form a consortium to invest in the order of 400 billion € into the development of CSP in northern Africa. The goal will be to achieve 15% of European electricity needs within a decade (Connolly 2009).

2.3.2.2 National Actions Within the EU on Climate Change and Renewable Energy

There is considerable diversity in both renewable energy supply and renewable energy policy among the member states of the EU. Iceland and Norway have already achieved 100% renewable energy for their electricity consumption. (Norway at times even produces more renewables than it can consume.) Due to the early introduction of a favourable feed-in tariff, Denmark expanded the share of renewable energy in its gross electricity consumption from 2.6% in 1990 to 28.7% in 2008. In the same time period, Germany, which also introduced a feed-in tariff, expanded the share of renewable energies from 3.8% to 15.4%, Ireland basically more than doubled its share from 4.8% to 11.7%, the Netherlands increased from 1.4% to 8.9% and Spain saw a growth from 17.2% to 20.6% share.

Some countries, however, saw little change in the share of their renewables in their gross electricity consumption (e.g., Italy) or even experienced a decline. In Austria, there was a drop from 65.4% to 62% and France from 14.8% to 14.4% (Table 2.1).

Efforts to develop a EU renewable energy-based electricity structure will be heavily influenced by the block's three largest economies: Germany, the United Kingdom and France. All three have in recent years shown signs of more strongly embracing renewable energy, although big differences remain among them, particularly in their positions on nuclear energy.

France is a relatively small emitter of greenhouse gases, largely due to its heavy dependence on nuclear energy (78% of electricity) and hydroelectric plants (12%). In 2007, the French government launched the *Grenelle de l'Environnement*, under which it plans to invest in fourth generation nuclear power plants, develop renewable energies, and promote public transportation and green buildings.

The *United Kingdom* is the EU's largest producer of oil and natural gas. North Sea oil and gas production peaked in 2000, however, and since then the United Kingdom has become a net importer, although its import dependency (21.6% in 2006) is relatively low compared with, for example, Germany (62%) or the EU average (54%). The United Kingdom could also be strongly impacted by climatic changes should sea levels rise or the Gulf Stream shift course. The British parliament became the first in the world to set a long-term, legally binding framework to address climate change when it passed the Climate Change Act in 2008. The Act mandates a cut in greenhouse gas emissions by 80% by 2050. The law requires that the UK's carbon account be 80% below 1990 levels by 2050; moreover, it requires a reduction of at least 26% by 2020 (compared with 1990) and periodic carbon budget reviews (Turner 2008). The British strategy for meeting this goal includes plans for renewables, energy efficiency improvements, carbon capture and storage (CCS) and new nuclear power plants (Committee on Climate Change 2009).

Table 2.1 Share of renewable electricity in gross electricity consumption (in percent) 1990–2008 (Source: Eurostat 2011b)

	1990	1995	2000	2005	2008
EU27	11.9	13	13.8	14	16.7
Belgium	1.1	1.2	1.5	2.8	5.3
Bulgaria	4.1	4.2	7.4	11.8	7.4
Czech Republic	1.9	3.9	3.6	4.5	5.2
Denmark	2.6	5.9	16.7	28.3	28.7
Germany	3.8	5.0	6.5	10.5	15.4
Estonia	0	0.1	0.3	1.1	2.0
Ireland	4.8	4.1	4.9	6.7	11.7
Greece	5.0	8.4	7.7	10.0	8.3
Spain	17.2	14.3	15.7	15.0	20.6
France	14.8	17.8	15.1	11.3	14.4
Italy	13.9	14.9	16.0	14.1	16.6
Cyprus	0	0	0	0	0.3
Latvia	43.9	47.1	47.7	48.4	41.2
Lithuania	2.5	3.3	3.4	3.9	4.6
Luxembourg	2.0	2.3	2.9	3.3	4.1
Hungary	0.5	0.7	0.7	4.6	5.6
Malta	0	0	0	0	0
Netherlands	1.4	2.1	3.9	7.5	8.9
Austria	65.4	70.6	72.4	58.4	62.0
Poland	1.4	1.6	1.7	2.9	4.2
Portugal	34.5	27.5	29.4	16.0	26.9
Romania	23.0	28	28.8	35.8	28.4
Slovenia	25.8	29.5	31.7	24.2	29.1
Slovakia	6.4	17.9	16.9	16.7	15.5
Finland	24.4	27	28.5	26.9	31.0
Sweden	51.4	48.2	55.4	54.3	55.5
United Kingdom	1.7	2.0	2.7	4.3	5.6
Iceland	99.9	99.8	99.9	99.9	–
Norway	114.6	104.6	112.2	108.4	109.4

Germany has particularly ambitious climate and renewable energy goals and legislation. The German government has actively promoted renewable energy, beginning with the 1990 Electricity Feed-in Law and the Renewable Energy Law of 2000 (with a target for doubling the share of renewable energy in the electricity market from 5% to 10% by 2010).

The growth of renewables is also linked to decisions to phase out nuclear energy in Germany. In 2000, the German government passed a nuclear phase-out law (a ban on new plants and a phased shutdown of existing reactors) that targeted a phase out by around 2021. In December 2007, the government introduced an Integrated Energy and Climate Package setting a target of reducing greenhouse gas emissions by around 40% of 1990 levels by 2020. The package included 14 pieces of legislation that promote energy efficiency and renewable energies in the electricity and heat sectors, among other areas (BMU 2007). Then, in October 2010, the German parliament passed a new Energy Concept for the Future (BMU 2010). The plan reaffirmed an earlier goal of reducing greenhouse gas emissions by 40% by 2020 and also included a series of targets for the coming decades: 55% reduction by 2030, 70% by 2040, and 80–95% by 2050. Renewable energy is to account for 80% of electricity by 2050 (with interim goals of 35% by 2020, 50% by 2030, and 65% by 2040). The share of renewable energies in gross final consumption is also to increase to 18% by 2020, 30% by 2030, 45% by 2040, and 60% by 2050. Energy efficiency is also to be pushed forward, by cutting primary energy use by 50% by 2050 relative to 2008 levels. More controversially, the concept prolonged the shutdown dates of the country's nuclear power plants by an average of 12 years (Bundesregierung 2010). After the Fukushima nuclear reactor disasters, this decision was again changed. The seven oldest nuclear power plants were taken off line immediately after the Fukushima nuclear catastrophe. They are to remain off line. Another plant that was already off line for technical repairs is to remain off line. This shutdown reduces German nuclear capacity by about 40%. Of the remaining nine plants, six are to be phased out by 2021 at the latest. For the three youngest plants, a 2022 shutdown date is possible. These policy decisions have major implications for energy and electricity policy in the years to come. To meet both its climate change goal and the replacement of nuclear generation capacity, Germany plans to invest strongly in renewable energy development. This means there will need to be rapid development in centralised offshore and onshore wind, decentralised solar photovoltaics, solar thermal, concentrated solar thermal (in southern Germany, but also possibly in southern Europe and northern Africa), geothermal and biomass. It will also be necessary to develop electricity storage capacity and build a high-voltage grid structure.

As can be seen, the three largest economies of the European Union have very different energy mixes. This complicates efforts to establish common goals on electricity generation across Europe. Nevertheless, the EU has managed to win consensus on promoting the growth of renewable electricity.

Due to geographic as well as political and economic factors, the extent and distribution of renewables in the final total energy mix of member states varies substantially. Countries where there is large hydro potential – Norway, Sweden, Finland, Austria and Switzerland – can meet large shares of domestic demand from hydro. They may also in the future be able to provide hydro-pump storage capacity. Denmark, Germany and Spain have done comparatively well in building non-hydro renewable energies (wind and, in the case of Germany and Spain, also substantial amounts of solar). Denmark obtains approximately one-quarter of its electricity from wind. Germany has experienced a strong growth in renewables in the past years, so that between 2005 and 2010, the share of renewables grew more than 10% to approximately 17% of the total final electricity consumption.

Along with further expansion of renewable energy at the national level, for Europe to achieve a greater share of its electricity from renewables in the future will require far greater cooperation among member states, better interconnectivity, and the development of high-voltage electric grids and electricity storage infrastructure.

2.3.2.3 European Policies for a Low-Carbon Energy Market

In comparison with the level of policy harmonisation that has been achieved in the environmental area, integration of European energy markets and harmonisation of European energy policy has been relatively limited. Integration and policy harmonisation have been stymied by the different energy mixes of member states and strong concerns about national energy sovereignty. Yet, pressures to change this and to develop a more coordinated and low-carbon energy mix are growing.

Despite the strong role of national governments in energy policy matters, considerable progress has been achieved in developing EU targets in areas where energy policy is closely tied to climate considerations. EU climate policy is seen as a way of moving member economies towards greater energy autonomy, resource efficiency and technological progress.

Early steps were taken to promote an energy transition in the 1990s when several individual European countries established voluntary greenhouse gas emission reduction targets. Negotiations leading to the formation of the Kyoto Protocol in 1997 further helped to raise European public awareness of climate change. The Kyoto Protocol entered into force in 2005. Under the Kyoto Protocol, the EU-15 committed itself to an 8% cut in their greenhouse gases relative to 1990 levels.

Under an internal burden-sharing arrangement, different national targets were formulated for the different member states. The national targets were based on a mix of factors that included national capabilities, the existing energy mix, and per capita economic wealth. Some countries took on very large reduction targets relative to their 1990 emissions levels (Austria −13%, Belgium −7.5%, Denmark −21%, Germany −21%, Italy −6.5%, Luxembourg −28%, Netherlands −6%, United Kingdom −12.5%), others agreed to stabilise their emissions (France and Finland 0%), while other poorer member states were permitted to increase their emissions (Greece +25%, Ireland +13%, Portugal +27%, Spain +15%), but at rates lower than what a business-as-usual trajectory would have predicted. Sweden adopted a +4% target but later adopted national legislation that imposed a −4% target by 2010.

Trends to develop renewables in Europe began to take on a supranational flavour in the late 1990s in parallel to these climate policy goals. In 1997, the European Community prepared the “Energy for the Future: Renewable Sources of Energy”, White Paper for a Community Strategy and Action Plan (European Commission 1997). This was the first time that the European Community set a renewable energy goal. The goal established then has yet to be achieved: 12% of total energy consumption from renewables by 2010. (As of 2007, the European Union was meeting 6.7% of its total energy needs from renewables.)

In 2001, as the European Community began to gear up for ratification of the Kyoto Protocol and, following the implementation of renewable energy legislation in Germany, Spain and Denmark, more serious attention began to be turned to the potential to develop renewables within the electricity sector in Europe. Directive 2001/77/EC formulated a goal to achieve 21% of the EU’s electricity from renewable energy sources by 2010. Indicative targets were established for each EU member state. As of 2008, 16.7% of the European Union’s final electricity consumption was from renewable sources, still short of the 21% target. As of 2007, Denmark, Germany and Hungary were the only countries that had met their specific targets already (European Commission 2009c).

In March 2007, the EU Council set a series of new climate and energy goals and targets that were later embodied in EU Decision No 406/2009/EC (European Commission 2009a). The EU recognised the importance of preventing a rise in global average temperatures of more than 2ºC above pre-industrial levels, the level beyond which the IPCC warns that the consequences of climate change could become particularly severe and possibly irreversible. For developed countries, this meant achieving a reduction of 60–80% of greenhouse gas emissions compared to 1990 levels.

To begin the process of meeting this challenge, the EU committed to reducing the EU-27's greenhouse gas emissions by 20% of 1990 levels by 2020 or 30% if other major emitting countries commit to comparable action, expanding the share of renewable energy in the EU's primary energy mix to 20% by 2020 and enhancing energy efficiency by 20% compared to 2005 levels by 2020.

These goals are to be reached with the assistance of various policies and programs. One is a revision of the EU carbon Emissions Trading Scheme (ETS) that was established by Directive 2003/87/EC. The EU ETS covers over 12,000 major emissions sources (e.g., utilities, manufacturing industries, cement industry, pulp, paper) and covers approximately 40% of all EU carbon dioxide emissions. As a result of the Linking Directive (Directive 2004/101/EC), emission reduction credits obtained through the clean development mechanism and joint implementation, including in renewable energies, can be used in the ETS (European Commission 2004). The first phase of the emissions trading scheme, which ran from 2005 to 2007, encountered some serious problems due to an over-allocation of permits by individual member states to their industries. As a result of stronger control and intervention by the European Commission, national governments issued fewer permits for the second phase, which runs from 2008 until 2012. The third phase, which begins in 2013, will gradually phase out the free allocation of emission allowances and replace it with auctioning. To meet the 2020 goals, the emission allowances available to industries will be reduced by 21% of 2005 levels by 2020 (European Commission 2010b).

Second, much as is the case under the Kyoto agreement, national effort sharing arrangements were introduced to cover emissions from sectors not covered by the ETS: housing, transportation, agriculture and waste. Decision number 406/2009/EC of the European Parliament and of the Commission distributed greenhouse gas emission reduction targets among member states. The reduction targets are relative to 2005 emission levels. Emission reduction targets were influenced by member states' economic wealth (GDP/capita). Richer states agreed to higher reduction targets. Thus, Luxembourg, Denmark and Ireland must reduce their emissions by 20%; Spain by 17%; Austria, Belgium, Finland, the Netherlands and the United Kingdom by 16%; Germany and France by 14%; Italy by 13%, Spain by 10%, Cyprus by 5%, and Greece by 4%. Other states will be allowed to increase their emissions, but at a rate below business-as-usual estimates. Thus, Romania and

Bulgaria, for example, are allowed to increase their emissions, respectively by 19% and 20%. Poland is permitted a 14% increase and Hungary a 10% increase. The combined impact of these targets is expected to reduce EU emissions in sectors not covered by the ETS by 10% of 2005 levels by 2020. States will be permitted to use the Kyoto flexibility mechanisms to meet some of their reduction targets. The combined emission reduction cuts through the ETS and non-ETS sectors are expected to result in total reductions in greenhouse gas emissions by 20% of 1990 levels by 2020 (European Commission 2009a).

Third, in January 2008, the European Commission issued a draft directive that called for an increase in the share of renewables in final energy consumption from the 8.5% level achieved as of 2005 to 20% by 2020. The European Parliament approved Directive 2009/28/EC (the Renewable Energy Directive) in December 2008. All member states are obliged to expand their share of renewables by a minimum of 5% from their 2005 levels. In addition, depending on a country's per capita GDP and renewable energy conditions, additional amounts were taken on by some countries. To apply pressure on member states to fulfil their goals, interim targets were set up as well. States are expected on average to have met 25% of their goal between 2011 and 2012; 35% between 2013 and 2014, 45% between 2015 and 2016, and 65% between 2017 and 2018. A similar kind of burden-sharing agreement to that used with the Kyoto Protocol was established to meet the EU's 20% renewable energy target. Member states' targets were determined on the basis of a formula that included a flat rate increase in renewables of 5.5% above their 2005 levels and an additional increase based on per capita gross domestic product (European Commission 2009b). Ten states have renewable energy targets ranging from 10% to 15%, eleven states targets from 16% to 25%, and six states targets of 30–49% (ibid.:46) (Table 2.2).

Within the different member states of the EU, there is a wide variety of different support schemes in operation, including feed-in tariffs, premium systems, green certificates, tax exemptions, requirements for fuel suppliers, public procurement expectations, and research and development programs. Largely due to sovereignty concerns, the Commission has concluded that while harmonisation of support schemes may be desirable in the long run, at the present time, cooperation between countries and optimisation of existing support schemes must be pursued (European Commission 2005b, 2008c). The Commission has also called for pursuing means to promote long-term stability for investors.

Importantly, there is a link between the Renewable Energy Directive and market trading. Under the directive, member states can link their national support schemes to those of other EU member states. In addition, the directive allows for the import of "physical" renewable energy from third-country sources (making it possible, for example, to import renewables from North Africa). Open trading in renewables is restricted to trades of excess renewables credits (in the form of "statistical transfers") among member states that have met their interim targets (EurActiv 2011a).

A fourth element is a directive addressing the legal framework for carbon capture and storage, a technology that is still in the early stages of development.

Table 2.2 Burden sharing: national renewable energy targets for 2020 (flat rate increase in renewables of 5.5% above existing levels & additional increase based on per capita GDP)

Member state	Share of renewables 2005 (%)	Share required by 2020 (%)
Austria	23.3	34
Belgium	2.2	13
Bulgaria	9.4	16
Cyprus	2.9	13
Czech Republic	6.1	13
Denmark	17.0	30
Estonia	18.0	25
Finland	28.5	38
France	10.3	23
Germany	5.8	18
Greece	6.9	18
Hungary	4.3	13
Ireland	3.1	16
Italy	5.2	17
Latvia	32.6	40
Lithuania	15.0	23
Luxembourg	0.9	11
Malta	0.0	10
The Netherlands	2.4	14
Poland	7.2	15
Portugal	20.5	31
Romania	17.8	24
Slovak Republic	6.7	14
Slovenia	16.0	25
Spain	8.7	20
Sweden	39.8	49
United Kingdom	1.3	15

Many other related directives exist as well. Examples include Directive 2006/32/EC on energy end-use efficiency and energy services, passed in April 2006. This directive establishes a target of a 9% cut in energy use over business-as-usual trends between 2008 and 2017 and requires a rolling series of energy efficiency action plans (2007, 2011, 2014) (European Commission 2006, p.73). Directive 2010/31/EU, passed in May 2010, on the energy performance of buildings complements Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products and Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standard product information of the consumption of energy and other resources by energy-related products.

2.3.2.4 The European Energy Council of 2011

The 2011 European Council (4 February 2011) meeting focused special attention on the importance of securing for Europe "[s]afe, secure, sustainable and affordable energy contributing to European competitiveness" and called for "a fully functioning, interconnected and integrated internal energy market" by 2014. The goal is to allow gas and electricity to move freely across the EU. The Council called upon ACER national regulators and transmission systems operators to move forward on market coupling and guidelines as well as on network codes applicable across European networks. The Council also concluded the importance of adopting technical standards for electric vehicle charging systems by mid-2011 and for smart grids and meters by late 2012.

The Council decision also focused attention on the need to interconnect networks across borders in order to "ensure that solidarity between member states will become operational, that alternative supply/transit routes and sources of energy will materialise and that renewables will develop and compete with traditional sources." The Council suggested that this requires streamlining and improving authorisation procedures for the building of new infrastructure.

The Council further called for greater investments in energy efficiency to enhance competitiveness and strengthen security of supply and to put the 20% energy efficiency target for 2020 on track (European Council 2011).

2.3.2.5 Moving Towards Higher Emission Reduction Targets

There are growing discussions as to whether the EU should move beyond its 20% target for 2020. In 2010, the Commission released a Communiqué discussing the steps that would be necessary for the EU if it were to determine to pursue a 30% emission reduction by 2020 relative to 1990 levels. This has yet, however, to win EU-wide endorsement. Long-term goals are solidifying around a low-carbon energy future for Europe. In October 2009, and again in February 2011 at the EU Energy Summit, European leaders announced a commitment to an 80–95% emission reduction target for 2050 relative to 1990 emission levels.

2.3.2.6 Roadmap for a Low-Carbon Economy in 2050

Success in further expanding the share of renewables in the electricity sector will be dependent upon technological advancements and market signals, political guidance and intervention, and public support.

The European Commission has prepared a roadmap for how a low-carbon economy could be achieved by 2050. It should be noted that this is not a legally binding document. The roadmap includes a target of achieving 93–99% CO_2 reduction in the electricity sector by 2050 in order to make it possible to achieve 80–95% CO_2 reduction in the overall primary energy balance. Mid-term targets for reductions of CO_2 in the primary energy mix are 25% reduction by 2020, 40% by 2030, 60% by 2040, and 80–95% by 2050. Pressures are building for Europe to go beyond the 20% greenhouse gas emission reduction target that was established for 2020, although resistance to stronger targets also remains strong. The 25% target appears to be a compromise between the existing 20% reduction target and the proposed 30% reduction target.

The roadmap calls for major and sustained investment in renewable energy and smart grids along with carbon capture and storage. It also envisions an electrification of the transport sector. Interestingly, the roadmap, which has been prepared by the Director General for Climate Change, predicts that the transition will require an addition 270 billion € (or 1.5% of EU GDP per annum) on top of the existing 19% of GDP currently spent, but that over a 40-year time frame, energy savings and renewable energies could result in sharp reductions in EU average fuel costs, leading to savings that could amount to between 175 and 320 billion € per year (EurActiv 2011b).

With the release of the roadmap, the EU will need to give more attention to the appropriate policy measures and instruments to make the development of a single European electricity market possible. This will require the formulation of national support systems that are flanked by strong EU targets and measures.

2.3.2.7 Supporting Infrastructure Development for Renewable Energy

Continued growth in renewable energy capacity will require the development of new electricity grids that are capable of transmitting fluctuating supplies across long distances. Currently, the EU lacks the interconnectors that would make it possible to move electricity across the continent. In November 2010, the European Commission released "Infrastructure priorities for 2020 and beyond – a blueprint for an integrated European energy network" (European Commission 2010a). As the blueprint notes, already the lack of adequate interconnectivity and storage capacity has prevented the EU from being able to respond to energy shortages in some member states or to efficiently make use of existing capacity. Building the necessary infrastructure will require huge investments. The blueprint estimates that around one trillion € will need to be invested through 2020 to meet Europe's energy system needs. About half of this will be necessary for networks for electricity and gas distribution, transmission, storage and smart grids (ibid.).

2.3.2.8 Public Acceptance

An energy transformation could bring many benefits for Europe in terms of reduced health costs and environmental damage as well as in terms of creating new markets and jobs. The renewable energy sector is becoming a major employer in Europe. Europe has become a global leader in renewable energy technologies. It holds about 60% of the world market share in wind energy technologies (European Commission 2007a).

Nonetheless, there will be many public acceptance questions associated with the large-scale expansion of renewables. There will inevitably be problems related to land and accession rights needed for the building of renewable energy facilities as well as supporting infrastructure, including grid structures, interconnectors and storage capacity.

As has been seen at various times throughout Europe, movements opposing wind parks, solar farms or geothermal facilities have successfully blocked the development of some renewable electricity projects and infrastructure. In the future, public acceptance will have to be won if a major redesign of the electricity structure is to be achieved. Participatory decision-making processes must be central to any movements towards wider expansion of renewables. The Ethics Commission for a Safe Energy Supply recommended that the German government establish a Forum for an Energy Dialogue with citizens to involve them in all phases of the planning and decision-making process (Ethik-Kommission 2011). This kind of forum is a matter that should be considered at an early stage of the strengthening of both German and EU renewable energy programs. There are many issues where the public can and should have influence. One area is in relation to the extent to which an approach that is based on larger, more centralised renewable energy facilities and large-scale storage systems or more decentralised structure and storage capacity systems should be followed (e.g., storage systems (batteries) at the household level). Another is in relation to whether grid lines are kept above ground, which is cheaper, or buried, which is more expensive but aesthetically less disruptive. The development of a new electricity structure that incorporates a high percentage of renewable electricity is influenced/affected not only by technological and economic questions but also by societal values and preferences.

2.3.3 Challenges Ahead

Clearly, many challenges remain for a large-scale transformation to a renewable electricity system in Europe. Prior to the Treaty of Lisbon, the European Community had no explicit competence in the energy field. The necessary legal basis for Community action on energy issues stemmed primarily from other policy areas. EU policy on electricity and gas markets was premised on the Community's competence for forming a common market. Its competence relating to renewable energy was tied to articles on the environment.

Changes under the Lisbon Treaty, which came into force on December 1, 2009 and reforms EU institutions and rules, have expanded the rule of the EU in energy policy matters. The treaty has made energy an area of joint competency between the EU and member states. Under the Lisbon Treaty, efforts to further harmonise renewable energy strategies, improve the electricity grid and related storage capacity, promote energy efficiency and enhance energy security should become somewhat easier, although large differences remain in the energy policies, concerns and trajectories of different member states.

2.4 Economics of Storing Values

2.4.1 Energy Economic Background

Thinking about the energy sector usually concentrates on three objectives (Mulder and Willems 2009): (1) security of energy supply, (2) affordability and (3) environmental friendliness. Changes to these objectives or in the potential for their realisation can lead to changes in the energy sector. Although the goal of environmental sustainability played only a small role in energy policy decisions in the past, there has been an increase in the public's consciousness of environmental costs of the existing energy structure. A growing understanding of the link between the burning of fossil fuels and the greenhouse effect has most probably caused this. There is increasingly strong political pressure for the realisation of environmentally sound economic policy. One step in this direction is the European Union's emission trading system (EU ETS). Another is the CO_2 tax introduced in Switzerland and Norway. Clearly, though, not all regions of the world have experienced the same level of concern about climate change. Measures such as those being introduced in Europe are not yet spread widely across the globe.

The greenhouse effect is a global environmental problem; this makes it important to consider some basic information about global CO_2 emissions. Global greenhouse gas emissions (see Fig. 2.2) have remained stable on a per capita basis for the world population. With growth rates at 2.1% in 1971 and 1.2% in 2002–2008 the growth rate of the world population and of emissions have both fallen continuously. In the OECD countries the population grows only at a rate of 0.6%, but the CO_2 emissions per head of the population have had a positive growth rate; growth in emissions falls only during economic crises. In Germany, eastern and western parts together, CO_2 emissions have fallen since 1979, not only when measured in per capita terms but also in absolute terms.[6]

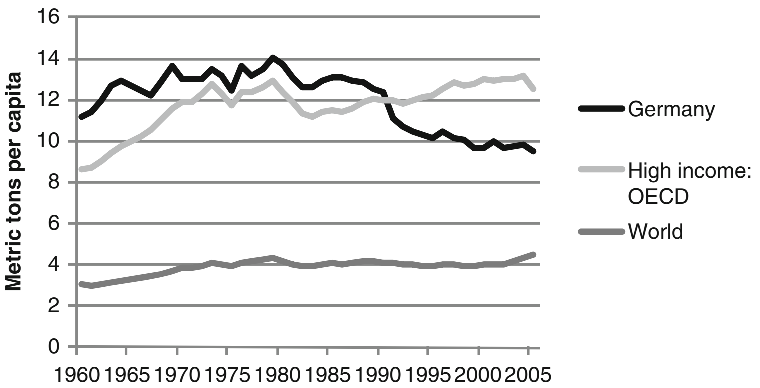

Fig. 2.2 CO_2 emissions (metric tons per capita) from 1960 to 2005 (Source: World Bank 2009)

[6] The reasons for such development are normally discussed in literature addressing the environmental Kuznets curve. This is either panel data analysis or theoretical work. Both approaches are unable to distinguish the difference between Germany and other countries. The major preliminary suspect in regard to Germany is the fall of manufacturing as a share of GDP in the period 1991–1996. The successive numbers are 27.5, 25.9, 23.6, 23.1, 22.6, 22.2. Source: Carbon Dioxide Information Analysis Center, Environmental Sciences Division, Oak Ridge National Laboratory, Tennessee, United States (World Bank 2009). Such a sectoral shift cannot be found in any comparable country.

In addition to energy saving, an increase in energy production from wind and photovoltaic (besides solar thermal, water power, biomass and perhaps[7] CCS coal) is necessary. This will increase fluctuations of energy supply, as wind and sun have a huge variability in the electricity amounts they contribute, depending on weather conditions. The larger the regions under consideration and the better the international electricity network, the smaller are the problems associated with fluctuations, as there is a potential to balance different inputs. However, fluctuations never vanish completely. Therefore, it is critical to examine to what extent storage technologies can achieve an intertemporal shift and how large the necessary excess capacity of other technologies such as gas is to overcome temporary shortages. This implies that storage of value enters the area of electricity provision. So far, there has been relatively little storage capacity available. Pumped storage and batteries have been used to a small extent – see the example of Berlin in Sauer (2009) and Chap. 5 of this book – and hydrogen, which can be produced from the use of excess supplies of wind energy and stored in caverns, is still at an early phase of development (Anderson and Leach 2004).

2.4.2 Theory of Storing Values

2.4.2.1 Storing Values Without Technologies

Money and Credit

If no technology as a store of value were available, value could be transferred into the future by giving something to somebody else against the promise of giving something else back in return later. This would be a non-monetary or real credit. A special form of such a promise is money in the sense of coins and paper (Samuelson 1958). If money is generally accepted and institutionalised, a credit can be turned into goods not only by getting them from the debtor but rather by getting them from any other person. This way, the creditor is not dependent anymore on the promise of a person to deliver goods later against getting other goods now. An example may help to understand the role of money. Without it, the baker could get a pair of shoes from the shoemaker only against the promise of payment through the delivery of a certain amount of bread on each of the following days until a certain point in time. Or vice versa, the shoemaker could get bread for some time against a promise to deliver a pair of shoes later. If, instead, they

[7] The literature is very skeptic in regard to the cost effectiveness of CCS. An exception is Golombek et al. (2009) who estimate that CCS will be competitive at a price of \$30/tCO_2 when integrated but not in its retrofitting versions. At \$90/tCO_2, coal without CCS would vanish completely according to their calculations. Praetorius and Schumacher (2009) summarise the literature as giving a range of 30–50 €/tCO_2 for making CCS (with IGCC) economically viable. The range for capture is 7.6–68.1 €/tCO_2, for transport 6–40 € depending on the distance and for storage 1–6 € depending on the type of place. Alphen et al. (2009) however point out that the Norwegian CO_2 tax has gone up 40 €/tCO_2 without making CCS competitive so far; it is currently announced to be in place in 2015.

have money in coins or notes, they can pay each other exactly what they owe and the one receiving the money, say the shoemaker, can buy something else from somebody else with the baker's money, rather than only getting bread from the baker who buys the shoes. In brief, barter trade and promises are replaced by a form of monetary credit that is accepted by everyone and, in this way, serves as a store of value.

Land and Heritage

Another way of transferring value into the future is through buying things such as land. Land is tied to nature, which can be preserved in its quality and can be transferred into the future by way of a handover to the next generation.

Time for Education

Still another possibility of transferring value into the future is through investing time into education and using the acquired skills in later periods. Knowledge can be transferred to later generations even without using technologies such as printing books, or having schools. The advantage of institutionalised schools in transferring knowledge is that the recipient gets not only the knowledge but also a certificate testifying that he has acquired the knowledge.

Acquiring land, money and education are ways, therefore, of transferring value into the future without necessarily relying on technologies.

2.4.2.2 Storing Values Using Technologies

Buildings and Machine Capital

Closely related to land are buildings. Buildings are not only useful because we can live in them now, but they will always be needed in the future and, therefore, are a valuable store of value, which is appreciated particularly in inflationary times. Similarly, buying machines allows production for a long time. Capital in the form of buildings and machines is a common way to store value.

Printing and Patents

Whereas education is partly a personal and informal transfer of knowledge, the technology of printing can help easing the storage of its value and make it independent of persons whose ability to transfer it may lead to mistakes, gaps and forgetting. Printing makes documentation possible and allows for the written form of patents. Therefore, technological descriptions are made and published. By way of printing, they are dissolved from personal knowledge and can be transferred without change into the future, which will determine their valuation in line with the expected use of the patent.

Storing Value Through Transport Technologies: Cement, Electricity

A special case of technologies that function as a store of value are those where the production, transport and storing of value take place simultaneously. A case in point is cement production during the truck transport. Electricity sometimes is said to not be storable (Brennan 2009). However, this is wrong in the sense that batteries can be loaded (see Anderson and Leach 2004 and Sauer 2009). With current costs, revenues and technical limitations, electricity is not storable in large amounts.

Store of Value for Electricity

Indirect forms of storing electricity include the production of hydrogen and pump storage, which is the act of pumping water and storing it in dams at higher levels for use in the form of hydropower at times when electricity production from wind or sun is scarce. It is one of the questions regarding future developments in the electricity sector, whether the costs and revenues will be changed through low spot prices for electricity at times of strong wind and high prices at times of weak wind and sun activity. Salgi et al. (2008, p. 100) state that "... electricity prices are highly unlikely to fluctuate enough to allow for the utilisation of the produced hydrogen in stationary applications" and recommend use in the transportation sector. However, their investigation covers only a 2-day demand capacity; our perspective is one of a 12 (between 10 and 20) day capacity requirement at maximum. Moreover, the more critical aspect may be that hydrogen production is perhaps not yet profitable, even if electricity is available at zero cost, because other costs may also be high. However, once gas has to pay for high CO_2 emissions, other flexible supplies of electricity, such as compressed air, hydrogen and electricity made from it, may become more competitive and add to pumped storage capacity. This will be especially true when pumped storage capacity is confronted by a lack of sufficient adequate locations.

If energy from wind and photovoltaics get a high market share, the supply of electricity can be ensured cheaply without nuclear energy and CCS coal as long as there is sufficient stored electricity to cover periods of low renewable electricity supply[8] (Heal 2009a, b). The problem of fluctuations and total inactivity in wind and photovoltaics will differ by region.

For the USA, Heal (2009a, b) indicates that when wind is the source of electricity, four times as much capacity is required relative to what is consumed (i.e., for every one unit of wattage consumed four units of capacity are required) because of the fluctuations of the wind. This ratio is quite realistic for Germany as well. For Germany (see Sauer 2009) wind and photovoltaic may produce a supply of zero for about 12 days (in the range of 10–20).[9] For Europe, the average value for wind energy fluctuates much less than in Germany. Therefore, we are in need of either:

[8] This does not take into account the costs for nuclear risks and problems with CCS. If it is possible for renewables to be more competitive than CCS coal and nuclear energy, these do need not to be taken into account. In less favourable situations though, every aspect and cent may be important. Heal (2009a, b) assumes that gas cannot be used in the base load, although the UK uses 54% of gas, which cannot all be in the demand following load.

[9] The other extreme situation is that of shutting down wind energy if the wind blows too strongly. Also, in these situations other sources are required (Sauer 2009).

A. Investment in transborder transmission, for example, the Super Grid, at the European level to achieve spatial smoothing, which is in accordance with the general idea of integrating regions more strongly, or
B. Overcapacity of other generators, such as gas-fired power stations, in order to compensate for lack of supply as currently occurs during situations of peak load demand,[10] or
C. Storage facilities at the national level (intertemporal smoothing through storage during high electricity production and use during low production periods). For national storage, currently pumped storage and hydrogen inventories are interesting for low-cost smoothing of 12-days supply gaps (see the chapters on these and related technologies). Here a dual use for stabilisation and other purposes should be aimed at in order to make low prices possible. If international networks are improved, as suggested in point A, then storage facilities can also be located abroad.

2.5 Summary and Conclusions

Starting from the basic aims of economic activity of efficient allocation and just distribution, an action rule has been outlined that gives a normative basis for dealing with constraints of and effects on the environment. It is formulated in priorities. The first is to protect the environment from unacceptable damages. The second is to preserve the total value of produced and natural capital. With these restrictions, as a third priority, intertemporal welfare should be maximised. The fourth priority is that just distribution of basics at present should be realised. This fundament is used to characterise indicators that can be applied for the evaluation of strategies for balancing electricity supply and demand with high penetration of fluctuating renewables in the system. Three categories are distinguished for the indicators: protection of the environment, availability of resources, and design of the energy system with respect to society.

As noted above, in addition to theoretical considerations, societal norms and priorities must be appreciated. Society must express which damages it considers unacceptable and how far activities should be raised to combat critical effects that may occur due to environmental change caused by human activities. Looking at energy and environmental policies, it is clear that the most prominent example, which is currently seen as most relevant in the area of energy questions, is the anthropogenic influence on climate. From the review carried out above of current developments relating to the German and European electricity and broader energy systems, including present and planned policies and programs, it is clear that the energy system is already changing. A major driving force is the desire to avoid unacceptable states of the environment in the future that could be caused by

[10] Gas-fired power stations can also be employed to satisfy base load demand. For example, in the UK gas currently delivers 54% of electricity supply.

anthropogenic-induced climate change. There are several key challenges ahead. One is the importance of encouraging the international energy market by strengthening the technical infrastructure, particularly of grids but also storage capacities, for renewable electricity. Second, the competence of Europe in energy questions is rising, but there is still much that needs to be done to strengthen European competencies with regard to a common electricity market. In the absence of a strengthened European voice, it will be necessary to consider what other ways can be pursued to promote a European-wide restructuring of the electricity system. Third, experience with large-scale energy projects, such as wind farms, show that public acceptance, particularly at the local level, has to be won to realise necessary investments into infrastructure. Participatory decision-making processes are thus central to a wider expansion of renewable energy use.

The analysis of the economics of storing values reveals three options for storing electricity values. These need to be analysed in cases where the demand and supply in the energy system have to be levelled out. This is likely to occur when there is a high share of electricity produced from wind and solar radiation. The first option is to expand international grid connections, particularly for transborder transmissions. The second is the over-installation of conventional power plants, e.g., natural gas-fired plants, to compensate for lack of supply. The third is to build up energy storage capacities, primarily of electrical energy. Of course, a mixed strategy is also possible.

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