Time to Adapt – Climate Change and the European Water Dimension
Discussion Paper: Electricity

Introduction

Electricity production in the EU has shown a steady increase since the early days of production, and has become an integral part of daily life in European societies. However, affordability and security of supply are under pressure from increasing demand and rising prices for fossil fuels.

The production of electricity is strongly dependent on water, be it for cooling in power plants, hydropower or the production of biomass. Changes in water resources will have impacts on many types of electricity production, and may become a further threat to the reliability of electricity supply in the future.

Impacts of climate-driven changes in water resources

In some areas, **hydropower** may benefit from increased hydropower potential, while in other countries this potential will decrease due to reduced river runoff. Studies in Switzerland, for instance, have shown that the anticipated increase in evaporation could indeed cause major reductions in river discharge and substantially decrease the contribution of hydropower to meet future energy demands. Countries in Scandinavia and northern Russia could see an increase of 15-30% in hydropower potential, whereas Southern European countries such as Portugal, Spain, Ukraine, and Turkey could see a decrease of 20-50% (Kirkinen et al., 2005). In areas with increased precipitation and runoff, dam safety may become a problem due to more frequent and intensive flooding events.

The generation of electric power in **thermal** (in particular coal-fired and nuclear) **power** stations often relies on large volumes of water for cooling. Few studies have investigated the effect the changing climate will have on electricity from fossil fuels and nuclear power. However, it has become apparent during recent heat waves and drought periods that electricity generation in thermal power plants may be affected by increases in water temperature and water scarcity. The discharge of cooling water may be restricted if limit values for temperature are exceeded, which may force plant operators to work at reduced capacity or even temporarily close plants, with potentially serious consequences for supply. (see Box 1). Furthermore, in regions where water will become increasingly scarce, the use of water for cooling may conflict with other water uses.

Climate-induced changes in water resources may affect **biomass** production in different ways, and different regions of Europe are likely to experience different net effects. On the one hand, increased precipitation, higher temperatures and higher atmospheric CO_2-concentrations might be beneficial for biomass production. On the other hand, similar to other agricultural production, biomass cultivation

Box 1: Climate change and thermal power plants: The French experience 2006

Summer 2006: French electricity producer EDF purchases electricity from the EU wholesale energy market to make up for its lost capacity as a result of increased river temperatures. Nuclear power plants at rivers could not be operated at full capacity, since water law restricted the discharge of cooling water at high temperatures. The move was also aimed at meeting a surge in demand caused by the thirst of air-conditioning units throughout the country, showing the dual impacts of climate changes on demand and supply in the energy sector.

may suffer both from water scarcity and drought or from flood damage to harvests, from more frequent extreme weather conditions or from a higher incidence of pests and fungi.[1]

Intense precipitation events, increased flood risk, and sea level rise may increase the risk of **infrastructure** (generation and supply) damage. In some Member States (e.g. UK and Finland), nuclear power plants, nuclear fuel reprocessing or nuclear waste sites are located near the coast, which could lead to security problems as a consequence of sea level rise. Furthermore, energy supply infrastructure, in particular transmission grids, might be endangered and damaged by flooding events and avalanches. In addition, transmission networks may be affected by climate change impacts that are not related to water resources, such as extreme cold and the melting of permafrost soils. Also, since cable resistance increases with temperature, a warming climate may also lead to power losses in transmission in southern countries (Aguiar et al., 2002).

Changes in temperature will also affect seasonal **electricity demand** patterns. On average, the demand for heating in winter is likely to decrease, while the demand for cooling during the summer months will increase. However, since variability and extremes are also projected to increase, there may be years with drought in summer and cold and dry winters, which would represent a worst-case scenario for regions dependent on hydropower. Generally, it may become more challenging to meet energy demands during peak times due to more frequent heat waves and drought conditions (Rothstein et al., 2006).

Sector overview

The total electricity generating capacity in the **EU 25** amounted to almost 704 GW in 2004. The demand for electricity is forecast to grow by more than 50% until 2030 (European Commission, 2006b). Given the limited potential for higher electricity imports from outside the EU, power generation is expected to grow considerably.

Across the EU 25, in 2004 thermal power plants accounted for 58% of installed capacity. Nuclear power plants represented 19%, hydroelectric power plants 18%, and wind turbines just under 5% of total capacity.[2] The national mix of energy sources in electricity generation varies within wide ranges. Hydropower plays a large role in the Nordic, Alpine and Iberian Mountains. The structure of power generation is forecast to change significantly in favour of renewables and natural gas, whereas nuclear and solid fuels will lose shares in the expanding electricity market (European Commission 2006b).

One of the biggest drivers for these changes is climate change. The electricity sector receives great attention as one of the largest sources of greenhouse gas emissions; policies and measures mainly focus on the sector's **climate change mitigation** potential. Electric power generation is the key sector in the European Emissions Trading Scheme, and several European and national policies aim to increase electricity production from renewable energy sources.

Long-term planning is a key characteristic of the energy industry. Investments are large and repayment periods long due to the long operating life of plants and infrastructures. **Substantial investment** will be necessary in the future in order to replace decommissioned power stations and to build new capacities to meet increasing demand. In a baseline scenario, the European Commission expects these investments to amount to around € 625 billion. Significant investment in transmission grids of around € 3 to 4 billion annually will furthermore be needed for maintenance and upgrading (European Commission, 2006b).

Options for adaptation

The electricity sector has a range of measures at its disposal to adapt to climate change

1 See discussion paper on agriculture.

2 EU News release 66/2006 from 22 May 2006.

impacts. Given the long lifetime of infrastructures and the magnitude of investments, adaptation has to be included in today's planning and strategies, and adaptation efforts have to be undertaken at different levels of planning and management.

Technical adaptation options for specific energy generation and infrastructure

Climate change impacts, and thus the efforts needed for adaptation, vary between regions, but also between fuel and plant types. Differences also exist with regard to adaptive capacity. Also, the relative weight of the different types within the overall mix of energy sources (see sector overview) should be taken into account.

- **Hydropower:** Adaptation measures have to be tailored to the specific circumstances hydropower might face. In countries where precipitation and runoff will increase, adaptation measures may focus on ensuring dam safety. The energy industry is already taking action in this respect, changing risk levels for flood protection, improving discharge facilities, or using water storage facilities to harness water and to avoid flood damage. Generally, information tools such as flood mapping will become more important in such regions. In areas where water flow will decrease due to drought, using turbines that use lower nominal power could be a way to adapt to lower water flow.
- **Thermal power plants**: The most obvious way to make thermal power plants less susceptible to climate-induced changes in water temperature and availability would be to reduce their water demand, by increasing the efficiency of cooling systems or the overall efficiency of plant operation. In cases of increased flooding frequency and higher flood levels, flood defence measures may have to be upgraded or newly established, in particular to protect nuclear power plants. Dikes should be designed so that, even in the case of a dike breach, the remaining barrier is of sufficient height to prevent the flooding of nuclear power plants (Mai et al., 2002).
- **Biomass:** Agricultural practices and crop choice might be modified in order to adapt to the impacts (see above). Drought-prone regions could switch to crops that can withstand water scarcity better than current types. Adaptation measures might furthermore include improvements to production and harvesting technology. For example, improving integrated pest management could help biomass crops adapt to increases in pest insects.[3]

Diversification

As shown above, types of power plants differ greatly in their adaptive capacity and efforts needed for adaptation. Furthermore, limits to adaptation exist for each individual type of energy production. For example, even if a thermal plant uses a water-saving cooling system, it cannot reduce its water demand to zero, and will thus still be affected by falling water flow levels.

Through the **diversification** of electricity production this vulnerability can be reduced. Broadening the range of power plant types and fuels in the generation mix (e.g. wind, hydropower, solar) and using a mix of centralised and decentralised supply patterns will help to increase the flexibility of the system and its resilience to more variable climatic conditions (Rothstein et al., 2006).

Management of demand

Climate change will change the electricity demand patterns across Europe, together with a multitude of other factors, which makes the exact direction and magnitude of changes hard to predict. Nevertheless there are several approaches that may increase the system's resilience to climate change impacts. **Increasing energy efficiency** will be a very effective adaptation and mitigation measure for European societies, and should be further promoted by policy-makers at national and EU level. **Load management** is used by energy companies as a response to changes in supply and demand patterns. It is mainly based on voluntary demand-response programs with customers and reduces customer peak electric loads at times of supply constraints. Such approaches require load forecasting models in combination with seasonal climate condition models (Rothstein et al. 2006).

Decreasing overall electricity demand, in particular during peak times, may require additional action by other sectors. For instance, an appropriate design of buildings may reduce the demand for cooling power.

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[3] See also discussion paper on agriculture.

European policy framework for adaptation

The EU is taking steps to address its own greenhouse gas emissions in the energy sector. In the context of Europe's climate policy, adaptation of the electricity sector to climate change is currently lower on the political agenda compared to mitigation. Nevertheless there are several elements in the current policy framework that can be used for the development of adaptation strategies.

EU Energy policy

With the launch of the "Strategy for a Sustainable, Competitive and Secure Energy" in March 2006 (Green Paper, European Commission, 2006a), the European Commission set out the EU's approach to a future comprehensive energy policy. The document focuses on the aim to satisfy growing energy demand and safeguard supply. It proposes measures in six key areas: 1) competitiveness and the internal market; 2) diversification of the energy mix; 3) security of supply and solidarity between Member States in the case of supply crises; 4) sustainable development; 5) innovation and technology; and 6) external policy. While the Green Paper does not specifically address the issue of adaptation to changing climatic conditions, some of the measures may provide a basis for the development of adaptive action.

- **Strategic approach to future energy mix and technology development.** Under the second priority area, a **Strategic EU Energy Review** is proposed which should analyse the advantages and drawbacks of different energy sources, and which would offer a clear European framework for national decisions on the energy mix. It is furthermore suggested to agree on an overall strategic objective, based on thorough impact assessment, that would balance the goals of sustainable energy use, competitiveness and security of supply. As part of the fifth key area the need for a **strategic energy technology plan** is pointed out. The aim of the EU's strategic approach to energy research and development is to deliver security of supply, sustainability and industrial competitiveness.

  When developed and implemented, these strategic approaches might take account of the impacts of climate change on energy production, and use adaptive capacity and flexibility as a criterion for assessing different energy sources. For the long-term sustainability of Europe's energy system, its resilience to future climatic change plays a key role.

- **Security of supply and solidarity between Member States**. This priority area includes the protection of the physical security of Europe´s energy infrastructure against risk from natural catastrophes. The development of smart electricity networks, demand management and distributed energy generation are mentioned as possible measures. Furthermore, the strategy proposes to establish a European Energy Supply Observatory, to improve network security through increased collaboration and exchange of information between system operators, and to improve the physical security of infrastructure. These measures might also help to increase the adaptive capacity of energy supply systems, and should be implemented with a view to climate change impacts.

- **Coherent external energy policy**. The EU's external policy should also consider global effects of climate change and their implications for a secure energy supply. Climate change impacts on international supply grids may have to be considered.

Other EU legislation and policy documents in the field of energy, for instance on the construction of grids/interconnectors, renewable energies and other energy sources, energy efficiency, and electricity, may be applied or reviewed in the light of climate change impacts and adaptation.

IPPC Directive

The adaptation of thermal power plants might be supported through recommendations on Best Available Techniques under the EU Directive on Integrated Pollution Prevention and Control (IPPC Directive).[4] This Directive establishes common rules for permitting and controlling industrial installations. Permit conditions must be based on Best Available Techniques (BAT), which are defined through an exchange of information between experts from the EU Member States, industry and environmental organisations, and published in BAT Reference Documents (BREFs).

[4] Council Directive 96/61/EC of 24 September 1996 concerning integrated pollution prevention and control.

For cooling systems of thermal power plants, the state of the art is described in the BAT Document "Cooling Systems" (European Commission, 2001). The document focuses on increasing the overall energy efficiency and reducing emissions into the aquatic environment and to the air. However, since the environmental aspects of cooling systems vary with the cooling configuration applied, the BAT document might be reviewed to set standards for cooling systems that make them more resilient to increasing temperatures and water shortages.

Water Framework Directive

Adaptation efforts by the energy industry related to water resources should be co-ordinated with other water uses under the integrated management approach of the **Water Framework Directive (WFD)**[5]. In some cases, efforts by the industry to implement technical adaptation measures may have to be reconciled with WFD objectives. The expected increase in hydropower potential in some European regions might make further exploitation of hydropower an attractive option. New developments in sensitive areas might conflict with the aim of the WFD to achieve a good water status. The Strategic Steering Group "Water Framework Directive and Hydromorphology" under the Common Implementation Strategy states that the potentially negative impacts of hydropower development on water bodies should be avoided (CIS-WFD 2006), and suggests that in order to minimise the need for new sites, the development of hydropower capacities could be supported by modernisation and upgrading of existing infrastructures.

Furthermore, new standards for water established under the WFD might also limit the abstraction and discharge of cooling water and the production of biomass (degradation of water quality due to fertiliser use), which may set constraints to adaptation efforts by the electricity sector.

Conclusions and key issues

Mitigation, which to date has been the focus of EU climate policy, will not be able to prevent all climate change impacts in the short, medium and longer term. The electricity sector, being itself one of the biggest drivers of climate change, is also vulnerable to climate change impacts.

In particular, challenges may arise from the fact that times of peak energy demand (e.g. for cooling energy in summer) may more often coincide with periods during which electricity production is constrained (e.g. shortage of water for cooling in power plants). Shifts in load and demand peaks may also result from changes in renewable energy production.

Adaptation options are available both for the supply and demand side. Given the long lifetime of infrastructures and the magnitude of investments, adaptation has to be included in today's planning and strategies.

Adaptation in the electricity sector might benefit considerably from an improvement of climate change scenarios, in particular at the regional level, of tools to deal with uncertainties, and of models forecasting future energy demand. Adjustments or improvements to the management of distribution networks at the European level may become necessary.

Energy policy at EU and national level should attempt to combine mitigation and adaptation efforts and make use of synergies and win-win solutions. The adaptive capacity should be used as one criterion to assess the further development of the electricity sector. Decentralised approaches and a diverse energy mix are likely to be beneficial in terms of adaptation. The increase of energy efficiency and future demand patterns should play a key role in national or European adaptation policy.

Currently Europe has started a broad discussion on the future of its energy sector. Several studies in the governmental and private sector on future developments are being carried out. This offers a unique opportunity to better incorporate adaptation to climate change into policy and business approaches.

Key questions

1. **Impacts and vulnerability**: What are the most relevant impacts of climate-change driven changes in water resources on the electricity sector? How vulnerable are different parts of the electricity-supply and transmission systems to climate change impacts?
2. **Adaptation options**: Which adaptation options are available for the electricity sector? Which of them are most effective and cost-efficient?
3. **Policy action**: What could be gained from co-ordinating and implementing adaptation

[5] See discussion paper on water management.

at EU level? How could EU policies support adaptation in the electricity sector? How can mid- and long-term changes be integrated in planning processes? How can combined mitigation-adaptation approaches be encouraged?

4. **Security**: Will existing flood protection for power plants and infrastructure be sufficient under a changing climate?

5. **Integrated approach**: What role should the electricity sector play in an integrated adaptation effort at river basin level? How can possible conflicts between the electricity sector and other water users be resolved? How can water use (e.g. hydropower, biomass production, cooling) for electricity production be integrated with ecological objectives set in the WFD?

6. **Research needs**: Which knowledge gaps exist with regard to impacts, vulnerability and adaptation options? Would the establishment of a database on best practice examples be useful?

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