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Effects of Climate Change on the European Nuclear Power Sector[1]

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Abstract

Anthropogenic emissions of greenhouse gases cause climate change and this change in turn induces various direct impacts, e.g., changes in regional weather patterns. The frequency of heat waves and droughts in Europe is likely to rise.

Yet, beyond these immediate effects of climate change, there are more indirect effects: Droughts in Europe will cause water scarcity and a lack in water supply will affect further sectors and critical infrastructures. An arising lack in water supply for cooling purposes will negatively affect the electricity generation in European nuclear power plants and this, in turn, will exert an influence on electricity exchanges between countries. In this study we analyze the influence of climate change on electricity exchanges between European countries.

Keywords: adaptation, climate change, critical infrastructures, electricity trading, energy security, nuclear power plants, vulnerability

JEL classifications: Q54, Q41, H54, Q56

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I. Introduction: Climate Change and Critical Infrastructures

In recent years a major concern in the European Union (EU) was the critical infrastructure protection (CIP) against terrorist attacks and other security related risks. In 2004, the European Commission (EC) adopted a Communication, i.e., a pre-legislative proposal, with the title "Critical Infrastructure Protection in the Fight against Terrorism" (EC 2004) and, thereafter, in 2005, the Commission adopted a Green Paper (EC 2005) on a European Programme for Critical Infrastructure Protection (EPCIP). In the Green Paper, the need to help reducing vulnerabilities concerning critical infrastructures was acknowledged. The threats are seen in terrorism, natural disasters and accidents; the risk of any disruptions or manipulations of critical infrastructures should be minimised. Consequently, while the initial focus of the emerging European CIP policy was on terrorism as a threat for disruptions,[2] the policy evolved into an all-hazards approach. In December 2006, the European Commission adopted a Communication (EC 2006) which describes the overall framework for EU-level CIP activities.

In Council Directive (EC 2008) on the identification and designation of European critical infrastructures (CIs) and the assessment of the need to improve their protection, the European Council identifies energy and transport sectors as European critical infrastructures. Yet, the Directive also states that a step-by-step approach to identify and designate European CIs is pursued and that energy and transport sectors are those chosen in the first step. Other candidate sectors are 1) information, communication technologies, 2) water, 3) food, 4) health, 5) financial, 6) public and legal order and safety, 7) civil administration, 8) chemical and nuclear industry, and 9) space and research (Annex 2 of EC 2005).

The relevant sectors can be split into subsectors and in this paper – concerning energy –the 'electricity subsector which includes infrastructures and facilities for generation and transmission of electricity in respect of supply electricity' (see Annex I of EC 2008) is of main relevance while in the water sector we are mainly interested in water supply issues. More specifically, we are interested in the links between these two subsectors despite the fact that the common EPCIP framework which - according to the Green Paper (EC 2005) - has to define competences and responsibilities of involved agents, envisages to settle CIP principles on a sector-by-sector basis. On the one hand, as Fritzon et al. (2007: 32) stress concerning this sector-by-sector approach: "Such a strategy allows for CIP to be tailored to different CI needs and varying legal competences for CIP across the policy spectrum." Yet, on the other hand, the fragmentation of regulations must not go so far that spillovers and synergies

[2] This threat was in Europe especially strongly perceived after the 9/11 attacks 2001 in New York, the Madrid train bombings in 2004 and the terror attacks hitting London in 2005.

between different sectors become disregarded and will not be exploited. "Assessing the impact of systemic interactions is one of the most important but least understood aspects of modern risk assessment" (IRGC 2009: 25). De Bruijne and van Eeten (2007: 19) stress that CIs "are becoming more dependent on each other's 'always on' availability" and as a consequence these infrastructures have "become increasingly vulnerable to large-scale, cascading disruptions across sectoral boundaries".

The main threat which is regarded in this analysis is climate change causing a rise in the frequency and intensity of heat waves and droughts in Europe. These heat waves and droughts will negatively affect water supply and – indirectly – power generation. It is this connection between water supply and power generation which is the focus of our analysis. More specifically, based on expected changes in climate, we assess the impacts of these changes on the electricity system taking into account country-specific shares of nuclear power in the electricity system and the exchanges of electricity within the countries (see Rübbelke and Vögele (2010) for the details). Using a climate change scenario of the IPCC, we analyze what will happen to electricity production and exchange if air temperature changes as expected in this scenario.

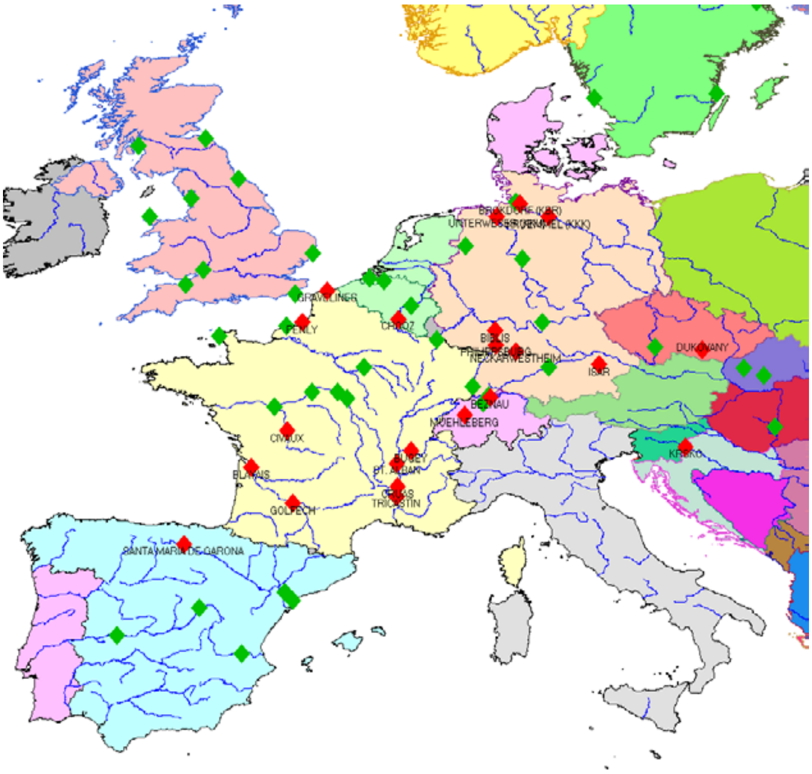
II. Supply Disruptions in the European Nuclear Energy Sector

During the heat wave in Europe in the summer of 2003, more than 30 nuclear power plant units had to reduce their production because of limitations in the possibilities to discharge cooling water (IAEA 2004). Some nuclear power plants got exemptions from legal requirements to be able to continue their operating activities. Currently, nuclear power has a share of 28% in the electricity supply of the EU (Eurostat 2010). So disruptions in the use of the nuclear power plants may have significant impacts on the electricity supply system. In our analysis we will focus on this important subsector of energy generation.

Fig. 1 gives an overview of the distribution of nuclear power plants in Europe. Nuclear power plants which had cooling problems in the past are highlighted. Most of the nuclear power plants in Europe are located in France. However, Germany, Great Britain and Spain also have a large number of nuclear power plants. The nuclear power plants with cooling problems in summer are mainly located in the south of Europe and onshore near big rivers.

Despite legal exemptions for some nuclear power plants, the whole electricity exchange system was affected by the limitations in the production possibilities. As a result of the cooling problems of the nuclear power plants in 2003, France as the biggest electricity exporter had to import electricity from Great Britain to be able to supply enough electricity to Italy and other countries (UCTE 2004).

Fig. 1: Nuclear power plants in Europe



Remarks: Red: Nuclear power plants with cooling problems in recent years

The climate change scenario we consider corresponds to a projection of the Canadian Centre for Climate Modelling and Analysis for the “A1” emission storyline of the IPCC. In this storyline a rapid economic development with strong attitudes to market-based solution is assumed. As one result of the increase in CO_2 emissions, the air temperature in Europe in the summer will rise by 3°C on average (see Govindasamy, Duffy and Coquard 2003; WORLDCLIM 2010). Especially in the south of Europe, air and therefore also water temperatures tend to increase significantly.

The analysis is based on three different scenarios: 1) A situation like the one in August 2007, 2) An increase in air and water temperatures with no extension of the water intake (scenario “climate change + slight water scarcity”), 3) 10% less water than in the second scenario will be available (scenario “climate change + more serious water scarcity”).

III. Results

The reference situation reflects the exchanges of power plant capacities in Europe on August 15th 2007 at 11.00 a.m. according to data published by UCTE (2008). Assuming an increase in air temperatures, less power plant capacity will be available in France due to cooling problems. Although the vulnerability to climate change can be reduced by changing the inspection and maintenance periods of critical power plants to summer time France will have to reduce its exports of electricity. In our calculation nuclear power plants in Germany and Switzerland will also face cooling problems. In contrast to France and Spain, these countries are able to postpone the inspection and maintenance periods of all critical power plants to August. So the changes in air and water temperatures will have no direct impacts on electricity exports of these countries.

Taking into account that Switzerland as well as Germany and other countries depend more or less on electricity imports from France, these countries will also have to reduce their electricity exports due to the reduction in the imports from France. Thus, in the 2nd scenario, the changes in the electricity exchange system mainly result from constraints of the power plants´ output in France and Spain.

The 3rd scenario shows the situation where additional water shortages are taken into account. Besides France and Spain also Switzerland will have to limit nuclear production. All in all, electricity exports will decrease significantly. As the example of the Netherlands shows, not only the direct neighbors of France will have to look for ways to reduce the supply gap but also countries which depend indirectly on electricity from France. Taking electricity import dependency shares into account, especially Italy will have problems meeting the demand for electricity if no direct or indirect measures are taken. Other countries will have fewer problems because of their low electricity import share.

IV. Conclusions

Climate change does not only threaten CIs, like the energy sector, directly, but there may also be follow-up effects negatively affecting downstream infrastructures. In our analysis we regarded the follow-up consequences of climate-change induced shortages of water supply for cooling purposes in nuclear power plants. In the future, the threat of water shortages affecting the cooling processes of power plants will become a very important issue. Apart from countries with a high nuclear power production share, countries which depend on electricity imports like the Netherlands will also be affected by climate change.

In order to address the threat of a climate-change induced shortage of electricity supply, the European nuclear power sector necessitates adaptation strategies. These adaptations have either to be placed in the sector itself or in the upstream water supply sector.

Put differently, we may especially distinguish between the following two adaptation categories: 1) improving the management of the upstream critical infrastructure in the shape of water supply (many European river basins are transnational and therefore an international coordination is required in many cases), and 2) improving the management of the downstream critical infrastructure in the shape of electricity generation in power plants. Our analysis focused, in turn, mainly on the second category of adaptation options in order to prevent follow-up effects of deteriorations in water supply.

On the one hand, increases in power plant efficiencies as well as replacement of power plants with power plants which do not need a cooling system (e.g., photovoltaic installations) can contribute to reduce the effects of climate change on the electricity supply system. On the other hand, simultaneous changes in the demand for electricity, e.g., due to an increase in the use of air-conditioning, and the concurrent construction of wind-power plants on sites with poor wind conditions in summer will even worsen the situation. Yet, all in all, with coordinated measures of the partners of the European electricity supply system the effects of climate change on the electricity system could be limited. These coordinated measures involve aspects of electricity supply as well as demand and water management to reduce man-made water shortages and the heating up of rivers.

It has also to be taken into account that the considered climate-change induced problems involve international dimensions. A large share of European rivers, and hence water supply from these rivers, are transnational. Thus, improvements of the management of water resources necessitate to a large extent a European coordination in order to be effective. Furthermore, due to the European trade of electricity, deteriorations in the production of electricity will affect a wide range of European countries. Both considered critical infrastructures, water supply and electricity production, therefore, exhibit properties of European critical infrastructures and the European Programme for Critical Infrastructure Protection may provide some assistance to protect them. Yet, overlaps of this programme with other European regulations, e.g., with the EU Water Framework Directive (WFD), should be taken into account and synergies should be exploited. One of the WFD´s objectives is to contribute to mitigating the effects of floods and droughts (EC 2000) and consequently the WFD pursues also the protection of critical infrastructures.

Finally, it has to be highlighted that our calculations are based on the assumptions of unchanged load and unchanged use of other power plants. In the past, the plant operators were able to manage disruptions of electricity supply by importing electricity from other countries or using reserve capacities. But even the association of transmission system operators for electricity, Entso-E, finds it hard to provide exact figures for each country on spare capacities (UCTE, Etso, Nordel, ATSOI, BALSTO and UKTSO 2007).

References

De Bruijne, M. and van Eeten, M. (2007): Systems that Should Have Failed: Critical Infrastructure Protection in an Institutionally Fragmented Environment, *Journal of Contingencies and Crisis Management*, Vol. 15, 18-29.

EC (2000): *Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 Establishing a Framework for Community Action in the Field of Water Policy,* Official Journal L 327 , 22/12/2000 P. 0001 – 0073.

EC (2004): *Critical Infrastructure Protection in the Fight against Terrorism*, Communication from the Commission to the Council and the European Parliament, COM(2004) 702 final, Brussels.

EC (2005): *Green Paper on a European Programme for Critical Infrastructure Protection*, COM(2005) 576 final, Brussels.

EC (2006): *Communication from the Commission on a European Programme for Critical Infrastructure Protection*, COM(2006) 786 final, Brussels.

EC (2008): *Council Directive 2008/114/EC of 8 December 2008 on the Identification and Designation of European Critical Infrastructures and the Assessment of the Need to Improve their Protection*, Brussels.

EUROSTAT (2010): Electricity Statistics – Provisional Data for 2009.

Fritzon, Å.; Ljungkvist, K.; Boin, A. and Rhinard, M. (2007): Protecting Europe's Critical Infrastructures: Problems and Prospects, *Journal of Contingencies and Crisis Management*, Vol. 15, 30-41.

Govindasamy, B.; Duffy, P.B. and Coquard, J. (2003): High-resolution Simulations of Global Climate, Part 2: Effects of Increased Greenhouse Cases. *Climate Dynamics,* 21**,** 391-404.

IAEA (2004): *Operating Experience with Nuclear Power Stations in Member States in 2003,* Vienna.

IRGC (2009): *Risk Governance Deficits: An Analysis and Illustration of the Most Common Deficits in Risk Governance*, Report, Geneva.

Rübbelke, D. and Vögele, S. (2010): *Impacts of Climate Change on European Critical Infrastructures: The Case of the Power Sector*, BC3 Working Paper Series 2010-08, Basque Centre for Climate Change (BC3), Bilbao, Spain.

UCTE (2004): *August 2003 - Monthly Provisional Values,* Brussels.

UCTE (2008): *August 2007 - Monthly Provisional Values,* Brussels.

UCTE, Etso, Nordel, ATSOI, BALSTO and UKTSO (2007): *Winter Outlook Report 2007-2008*. http://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/Winter_Outlook_Report_2007-2008.pdf, June 2010.

WORLDCLIM (2010): *Global Climate Data*. http://www.worldclim.org, June 2010.

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