Energy for Sustainable Development 28 (2015) 10–20

Contents lists available at ScienceDirect

Energy for Sustainable Development

Investment needs for climate change adaptation measures of electricity power plants in the EU☆

Wietze Lise [a,b,d,*], Jeroen van der Laan [c,d]

[a] AF-Mercados EMI, Ankara, Turkey
[b] ECORYS Research and Consulting, Ankara, Turkey
[c] Trinomics, Rotterdam, the Netherlands
[d] Energy & Environment unit, ECORYS, Rotterdam, the Netherlands

ARTICLE INFO

Article history:
Received 26 July 2013
Revised 22 May 2015
Accepted 11 June 2015
Available online xxxx

JEL Classification:
Q4
Q54
G32

Keywords:
Power plants
Climate change adaptation
Risk assessment model

ABSTRACT

Climate change is expected to have impacts on the power sector, leading to, among others, a need for adaptation measures in the sector in the near future. This paper analyses the need to adapt to climate change impacts for power generation technologies in Europe until 2100. Europe is broadly divided into four geographic climate zones, for which regional climate change impacts are quantified with the help of the ENSEMBLES RT2b data. The European future technology mix is based on two Eurelectric energy scenarios: 'Baseline 2009' and 'Power Choices'. A Risk Assessment Model is formulated which assesses the cost to power plants for adapting to climate change. The analysis shows that thermal generation units most urgently need adaptation measures against floods, whereas off-shore wind power plants would need to take adaptation investments against sea level rise. Furthermore, electricity grids need to adapt to the increased incidence of storms. Finally, hydro generation in the Mediterranean regions needs to adapt to lower levels of precipitation.

Introduction

Climate change, as indicated in the IPCC's Fifth Assessment Report, is expected to heavily impact on today's society, including the power sector (IPCC, 2014). Effects of climate change include an increase in the frequency of extreme weather conditions, an increase in mean temperature and modification of the regional water and wind cycles. These climate change indicators are expected to have an impact on the power sector such as causing supplementary infrastructural needs or not allowing machinery operations at 100% due to the impacts of climate change. For these reasons, it is foreseen that there will be a need to invest in climate change adaptation measures for electricity generating facilities in the near future and the quantification of these investments is one of the purposes of this paper, as well as estimating the costs for lost generation due to climate change.

The European Strategy on adaptation to climate change, adopted in June 2013, established climate change adaptation as a core feature of the EU's climate change policy (EC, 2009a, 2009b; European Council, 2013). Climate change mitigation aims at reducing possible future impacts by dealing with the drivers of climate change (e.g. reducing greenhouse gas emissions), while climate change adaptation aims at minimising the impacts and negative consequences of climate change by building resilience into sensitive systems or by exploiting potential benefits. Clearly mitigation is not coming about quickly enough, due to the stalled conference of parties (COP) negotiations and as a result adaptation measures need to be considered urgently to prepare for the impact of climate change.

The power sector is particularly sensitive to climate change, as its successful operation depends on a number of climate-related conditions. Changes to these conditions could strongly impact the entire value chain of the power sector, affecting electricity generation and infrastructure, as well as electricity consumption patterns.

The European Strategy on adaptation to climate change proposes a framework, following the published Commission's Impact Assessment of April 2014, for EU-wide policy action strategy at EU, Member State and local levels (EC, 2007, 2013). It enlists the possible climate change impacts on the power sector, particularly through its link to water supply, rising sea levels and coastal area management. The Impact Assessment suggests that existing legislation should be integrated, e.g.

☆ We thank the European Commission (DG Energy) for funding this project under contract number TREN/09/NUCL/SI2.547222, EUR 24769. We are grateful for the Journal's editor for providing detailed comments and referee's comments, which helped improve the paper's exposition considerably. However, opinions and conclusions expressed are solely the author's.

* Corresponding author at: ODTU Teknokent, Met Alanı, Mustafa Kemal Mahallesi, Dumlupınar Bul. No:208, D Blok No:3 Çankaya-ANKARA/TURKEY. Tel. +90 312 385 9354; fax: +90 312 354 6927.
E-mail address: wietze.lise@afconsult.com (W. Lise).

http://dx.doi.org/10.1016/j.esd.2015.06.003
0973-0826/

European Water Framework Directive, European Floods Directive, and the European Marine Strategy Framework Directive. It also sheds some light on future policy developments. Change in water supply, increased incidence of floods and sea level rise can be considered a major threat for operating power plants.

IPCC Working Group 1 (Solomon et al., 2007) expects the global average temperature to increase by about 0.2 °C per decade for the next two decades. Moreover, the impacts of climate change vary regionally; Northern Europe is expected to experience increased annual precipitation and higher winter temperatures, while Mediterranean Europe is expected to experience decreased precipitation and will be most vulnerable to increased summer temperatures and droughts. The average wind speed is likely to increase, leading to an increase of extreme weather events and a higher output of wind generation. In Central-Eastern Europe, precipitation is likely to decrease in summer, with more frequent droughts, and increase in winter. The snow season is very likely to become shorter and snow depth across most of Europe is projected to decrease. The increased occurrence of heat waves, for instance, is likely to affect the cooling of nuclear and gas-fired power plants, but could also lead to increased demand from peak plants (gas turbines and pumping stations). Droughts would reduce the output from hydro power plants, due to lower levels of water inflows into the hydro reservoirs. Electricity networks may be overloaded because of sudden increases in the power demand for cooling, which increases also the chances of contingencies due to extraordinary hot weather events.

Parry et al. (2007) provides a detailed overview of possible effects on the power sector in the 21th century and regional variations of the impacts. This is important as the regions have different electricity generation mixes, available resources and climate- or electricity-related policies and agreements. Climate change impacts will vary depending on the electricity generation technology concerned (i.e. fossil fuels, renewable energy sources (RES) and nuclear). Following Parry et al. (2007), one of the purposes of this paper is to categorise and assess the impact of the different climate change effects per electricity generation technology.

This paper is original in its focus on adaptation measures to climate change throughout the power sector value chain. Seljom et al. (2011) identify the effects of climate change to the power system in Norway and shows, among others, that the reduction in cooling demand far outweighs the increase in heating demand. Dowling (2013) takes this one step further by identifying the impacts of climate change on the EU energy system and concludes, for instance, that the impacts will be larger in Southern Europe than in Northern Europe. Taseska et al. (2012) studies the climate change impacts on energy demand in Macedonia and looks especially at the costs of no action and benefits of adaptation. Chu and Majumdar (2012) discuss the challenges for reaching a sustainable energy future and focus on climate change mitigation. Mideksa and Kallbekken (2010) make a review of the impact of climate change on the electricity market, while Tung et al. (2013) apply this to the Taiwanese power market. Hence, climate change impact adaptation in the power sector is not well-covered in the literature.

The main research questions of this paper are: Which climate change impacts are relevant for electricity generation technologies? What will be the severity of these impacts? To address these research questions, this paper details the possible impacts of climate change effects for each electricity generation technology. From a policy perspective, this paper aims at detailing preventive investments and operational changes that can be taken by power plant operators in the EU to reduce possible climate change impacts in the power sector. This is done by pointing out the differences in climate change impacts per technology and climate zone, since the technology mix and the local conditions differ between climate zones. The main objectives of this paper are, first, to quantify the costs due to lost generation by power generation units by adapting to climate change impacts and, second, to identify investment needs to make power units more resilient against climate change impacts.

The outline of the paper is as follows. The next Section presents the underlying energy scenarios from which the future technology mix can be derived, whereas the third Section presents the climate change scenarios used, which aims at sketching a possible future with substantial mitigation effort (Power Choices, over 90% greenhouse gas reduction by 2050 in the power sector) or no substantial mitigation effort (Baseline 2009). The method for risk assessment for climate change adaptation by power plants is presented in the fourth Section, whereas the fifth Section motivates the quantification of costs needed for climate change adaptation by power plants. The results are presented and discussed in the sixth Section. The final section concludes and provides recommendations.

Energy scenarios

In order to estimate the size of the EU power sector, the level of generation in 2050 by various technologies in the "Baseline 2009" and the "Power Choices" scenarios of Eurelectric (2010) are used. The main reason for working with these scenarios is that they have a relatively long time horizon, namely until 2050, and it includes all existing climate and energy policies implemented or planned to be installed by 2020, and these are also being used for EU policy making. The Baseline 2009 is in line with the IPCC A1B climate change scenario, whereas the Power Choices scenario is a situation with more ambitious and successfully implemented mitigation measures. In the latter scenario the climate change impact is lower, namely a global average temperature increase of 2 °C as compared to an increase of 3.4 °C in the Baseline 2009. Therefore, the climate change impacts under Power Choices are 41% (1–2/3.4) lower than in the Baseline 2009.[1]

Hence, two energy scenarios of Eurelectric (2010) are followed:

Baseline 2009: A baseline scenario, where today's trends are extrapolated until 2050.

Power Choices: A mitigation scenario, where a 75% greenhouse gas reduction target will be achieved overall by 2050 (over 90% in the power sector).

Table 1 shows the development in terms of the share in main technologies in 2010 and 2050 and the changes in demand which drive the two Eurelectric (2010) scenarios.[2]

Thermal power plants, including biomass combustion, can be considered jointly together in the sense that all would not respond well to floods and that they have a need for cooling. They differ when the demand for water is concerned (Macknick et al., 2012), where stand-alone gas turbines need negligible water, if any. Hydro will be particularly sensitive to the water cycle, which is also sensitive to climate change. Finally, mostly intermittent, renewable technologies are relatively new and largely insensitive to climate change impacts. The transmission and distribution grid, however, even today, is already quite susceptible to weather conditions (Mei et al., 2011) and will be in need of precautionary measures to adapt to climate change.

[1] Alternatively other scenarios could also have been followed. However, these two scenarios were among the first to have a time horizon until 2050 at the time when our research was undertaken. Such other scenarios are not evaluated in our paper. Such scenarios could also include additional small-scale distributed solar PV and importation of concentrated solar-generated power from North Africa, among others.

[2] The two energy scenarios used in this study also have demand projections. We would like to stress that these scenarios also show two paths of demand development. The electricity demand in the baseline 2009 scenario is expected to grow slower than in the Power Choices scenario. This reflects opportunities to replace electricity generation with low carbon renewable technologies in achieving a 75% reduction in greenhouse gas emissions. Hence, demand could vary and are dependent, in part, on changes in climate. This is especially true for year to year changes in periods of excessive heat (expected to increase with climate change) and periods of excessive cold (expected to decrease with climate change). The paper points out the adaptation costs for power plants under these extreme events.