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ScienceDirect

Energy Procedia 63 (2014) 7485 – 7493

Energy Procedia

GHGT-12

Challenges to integrate CCS into low carbon electricity markets

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Abstract

This paper discusses challenges for integration of CCS into competitive electricity markets by using the European electricity supply system as an example. The work is based on techno-economic modelling of the European electricity generation sector up to Year 2050, assuming a tightening cap on CO2 emissions down to almost no emissions by 2050. It is concluded that natural gas fired conventional power plants is likely to be a serious competitor to coal CCS in the short to medium term providing large emission reduction by fuel shifting from existing coal power plants to new high efficiency gas fired plants. This can be a barrier for early deployment of CCS without additional support. It is also concluded that for regions with large amount of intermittent electricity generation, short term balance in generation will impose challenges to handle CCS plants in relation to load following requirements. Yet, there are regions with good availability of coal combined with unfavorable conditions for wind power, for which CCS can operate in typical base load.

Peer-review under responsibility of the Organizing Committee of GHGT-12

Keywords: CCS, flexibility, operation, integration, variable generation

1. Introduction

The long term goal of the EU energy and climate policy is to reduce CO_2 emissions to comply with a 2ºC warming target. In line with this, the European Commission (EC) has presented an "Energy roadmap 2050" [1], which presumably will found the basis for targets and goals for the European energy system to 2050. The scenarios presented in the Energy roadmap communication depicts different ways to fulfil the EU´s decarburization objective, i.e., greenhouse gas emissions from the energy system should be reduced by at least 80% by 2050 relative 1990

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Peer-review under responsibility of the Organizing Committee of GHGT-12
doi:10.1016/j.egypro.2014.11.785

emission levels. Moreover, the roadmap indicate large CO_2 emission cuts within the electricity supply system, i.e., between 93-99% relative to the 1990 emissions, which obviously calls for competitive new power technology with more or less zero CO_2 emissions. In this, CCS technologies will play a significant role but the CCS technologies will then be part of a system with large amounts of intermittent and renewable power generation. This imposes challenges for CCS since load following capabilities will be valued higher and the future role and competitiveness of base load plants is thereby unclear. Thus, a future electricity system with large amounts of intermittent electricity generation will obviously put higher requirements on the thermal plants, including plants with CO_2 capture, with respect to their ability to perform stop and start and part load operation.

CCS plants are typically seen as base load plants and it is not obvious how they can be operated with varying load. Yet, there are a number of studies which have investigated different strategies for and characteristics of part load operation of CCS plants [2-11]. These studies focus on the performance of individual plants [4-9] or a small number of plants [10] with respect to their ability to operate in part load. While [4-10] do not give any information on what will the typical requirements on part load operation within an electricity generation system consisting of a portfolio of technologies, [2], [3] and [11] do evaluate a portfolio of technologies in an energy systems analysis but do not include any aspects on regional variations in the electricity generation mix or limitations in transmission capacity between regions in an integrated electricity market such as Europe. In order to investigate how requirements of part load operation vary across regions, the entire electricity generation system must be analyzed over the region of interest with a sufficiently high time resolution with the modeling incorporating a portfolio of technologies. The aim of the work presented in this paper is to take a first step in this direction, modeling pathways for the transformation of the European electricity system. The region consists of EU27, Norway and Switzerland and we discuss requirement on future CCS operation based on results from scenario analyses for the European electricity supply system with the aid of a modelling package consisting of a techno-economic investment model (ELIN) and a dispatch model (EPOD regional) applied to a particular year.

2. Methodology

The ELIN/EPOD modelling package [12, 13, 15] is applied up to the year 2050 under a typical scenario following the EU energy roadmap. Thus, for such a roadmap, the ELIN modelling will yield a system with large amounts of intermittent electricity generation mixed with thermal plants including CCS plants. The system is then further analysed by the EPOD modelling for the system as it looks for a particular year, with respect to the dispatch characteristics of the different generation technologies. Two scenarios are included; a “Climate Market” scenario and a “Regional Policy” scenario. The Climate Market scenario is inspired by the “Reference High GDP” and the “Diversified Supply Technologies” scenarios from the Energy Roadmap communication by the European Commission (EC) [1]. These scenarios combine relatively high economic growth with a policy almost entirely focusing on carbon markets. The Regional Policy scenario includes several policies and targets as well as a cap on CO_2. The Policy scenario is coarsely based on the “High Energy Efficiency” scenario of the EC Energy Roadmap communication [1]. Yet, we assume an even more aggressive end-use efficiency strategy implying slowly declining overall electricity demand post 2030. In both cases, the ELIN modeling basically simulates the EU-ETS system for which the cap of the emission from the electricity generation system of the entire region (EU27+ Norway + Switzerland) is reduced over the period. In the Climate Market scenario, this is the only policy measure after Year 2020 and the cap is reduced over the period to comply with a 93% reduction in emission in Year 2050 relative to the emissions in Year 1990. In addition to the CO_2 cap, the Regional Policy scenario then includes several policies and targets including specific targets for renewable electricity generation (RES-E), demand side efficiency measures as well as a cap on CO_2. The CO_2 cap in the Regional Policy scenario corresponds to a 99% reduction of CO_2 emissions in Year 2050 relative to Year 1990.

The ELIN model (see [12, 13]) is a long-term dynamic optimization model which describes the present generation system derived from the Chalmers power plant database [14] and an extensive basket of new technologies which are to meet the changes in future demand as existing capacity is phased out. The model includes 16 intra-annual time steps (four seasons, weekday/weekend and day/ night) to reflect variations in load, and thus, the model accounts to some extent for the need of power with different characteristics (peak/base-load). In the modeling, the existing capacity may be used until the end of the assumed life time or be prematurely phased-out due to a CO_2 penalty or the relatively lower efficiency compared to that of new plants. This is to account for the turn-over in capital stock of the existing power plant infrastructure, timing of investments and infrastructural implications