Energy 126 (2017) 285–305

Contents lists available at ScienceDirect

Energy

journal homepage: www.elsevier.com/locate/energy

Integrated assessment of a phase-out of coal-fired power plants in Germany

Heidi Ursula Heinrichs*, Diana Schumann, Stefan Vögele, Klaus Hendrik Biß, Hawal Shamon, Peter Markewitz, Johannes Többen, Bastian Gillessen, Fabian Gotzens, Anna Ernst

Institute of Energy and Climate Research (IEK), Systems Analysis and Technology Evaluation (IEK-STE), Forschungszentrum Jülich, Wilhelm-Johnen-Straße, 52425 Jülich, Germany

ARTICLE INFO

Article history:
Received 24 August 2016
Received in revised form
2 March 2017
Accepted 4 March 2017

Keywords:
Energy system model
Input-output analysis
Representative survey
Public perception
Integrated assessment
Coal phase-out

ABSTRACT

Germany is liable to miss its greenhouse gas reduction target for 2020. Nonetheless, additional political measures such as an early phase-out of coal-fired power plants might make it possible to reach this target. However, this generates several (conflicting) challenges, which arise from the technical, environmental, economic, and social implications.

An integrated assessment of phasing out coal-fired power plants was therefore performed by investigating impacts on the German energy system, the economy, and public perception. The latter is explored by analyzing representative data from our latest annual survey of the German public. Economic impacts on the sectoral level are illustrated by an input-output analysis. Furthermore, an energy systems model examines the long-term technical consequences.

Our scenario-based analysis shows that phasing out coal in the German electricity sector is not sufficient to fully meet German emission reduction targets. Additionally, the input-output analysis indicates strong sensitivity with the CO_2 certificate price, only resulting in an overall economic benefit in the case of a high certificate price. The survey shows that public acceptance of coal for electricity generation is low and decreasing. By combining all the results, a more detailed analysis was performed of the consequences of an early phase-out of coal-fired power plants.

1. Introduction

1.1. Motivation and background

Germany is liable to miss its greenhouse gas reduction target for 2020. Nonetheless, additional political measures such as an early phase-out of coal-fired power plants might make it possible to reach this target. However, this generates several (conflicting) challenges, which arise from the technical, environmental, economic, and social implications.

Despite their high CO_2 emission rate, coal-fired power plants provided over 41% of the electricity generated worldwide in 2013 [1]. In Europe, coal continues to play an important part in the electric supply generating 26% of total electricity in 2013. Germany also relies heavily on coal for generating 45% of the electricity supply and is thus above the world average. As a result 34% of the energy-related carbon dioxide emitted in Germany stems from the use of coal-fired power plants [2]. In order to reach the German climate mitigation targets especially coal-based energy is a matter of concern and, thus, recent debates in Germany question the time schedule of decommissioning coal-fired power plants. Some political parties [3] and NGOs [4] propose an early phase-out, leading to stepwise decommissioning of lignite-fired power plants with a total capacity of 2.7 GW (cf. [5–7]).

Similarly to the political goals in Germany, on 8 June 2015 the British daily newspaper the Guardian ran an article entitled “G7 leaders agree to phase-out fossil fuel use by end of this century” [8]. In the case of coal, national policies seem to pursue this target. The U.S clean power plan is one example announced by President Obama and the United States Environmental Protection Agency (EPA) on 3 August 2015. The United States Energy Information Administration (EIA) used a pre-version of this policy in calculating

* Corresponding author.
E-mail address: h.heinrichs@fz-juelich.de (H.U. Heinrichs).

http://dx.doi.org/10.1016/j.energy.2017.03.017
0360-5442/

Abbreviations

CATI	Computer-assisted telephone interview
BAU	Business as usual scenario
BMWi	German Federal Ministry for Economic Affairs and Energy
EIA	United States Energy Information Administration
EPA	United States Environmental Protection Agency
EPO	Early phase-out scenario
FPO	Fast phase-out scenario
O&M	Operation and maintenance
PV	Photovoltaics
UBA	German Federal Environment Agency

the impact on coal-fired power plants in the United States. The findings indicated a doubling in the phasing out of coal-fired power plant capacity until 2040 in comparison to the reference scenario [9]. The United Kingdom is closer to achieving a complete phase-out of coal, where the process started in the mid-1980s. The amount of electricity in the UK provided by coal-fired power plants decreased from the 1990 level from over two thirds to under 30% in 2014 [10,11]. Most remaining power plants, except one, were built before 1975 [10] and are due to be decommissioned by 2025 according to an average lifetime of 50 years. Recent commentaries emphasis that the phase-out has almost been completed (cf. [12,13]). However, smaller countries also plan to phase-out coal-fired power plants. Denmark, for instance, aims to phase out the use of coal for electricity generation by 2035 [14]. This underlines the prominence of coal phase-out strategies not only for the German case but worldwide to achieve greenhouse gas mitigation targets.

As an early coal phase-out may cause not only positive ecological impacts but may also lead to economic and social changes. We used an integrated approach in order to analyze these possible impacts and interdependencies resulting from an early phase-out in Germany. Our approach combined methods from economics, engineering, and social science to produce findings that provide a more robust assessment of future energy systems.

However, the consequences of an early coal phase-out are manifold and thus also negative consequences are feared. For instance, the employment rate could be negatively impacted by closing down coal-fired power plants (see e.g. Ref. [15]). In Germany, currently more than 30 000 people are employed in the coal mining industry and in coal-fired power plants. Most of these jobs are thus endangered. However, coal-fired power plants have to be replaced eventually. The construction of power plants with renewable energy sources and a more extensive use of such sources (as well as of gas-fired plants) may create new jobs.

1.2. Literature overview

Energy demand and energy supply do not exclusively depend on technical factors. For instance, changes in energy systems could affect the overall economy (see e.g. Ref. [16]). That is why traditional energy systems models need to be extended by linking them with other models or by integrating features such as public perceptions and behavior as constraints. Frequently, input-output models are used to assess the impact of changes in energy systems on the economic development of individual sectors as well as on the overall economy (see e.g. Refs. [17–20]). Usually, the models are linked by using a soft-link approach allowing models to be applied independently. In contrast, a hard-link approach analyzes simultaneously the changes of technical and economic structures (see e.g. Refs. [21,22]). However, the models cannot be used separately and model adjustments are more difficult to implement.

Social aspects have been considered in a few studies on energy systems (see e. g. Refs. [23,24]. But up to now, social sciences disciplines, methods, concepts, and topics have rather been underutilized in energy research (see e.g. Refs. [25,26]). A quantitative content analysis of 4444 research articles published in the journals ‘The Energy Journal’, ‘Energy Policy’, and ‘Electricity Journal’ from 1999 to 2013 revealed that only 19.6% of the authors reported training in any social science discipline [25]. Less than 0.3% of authors reported disciplinary affiliations in areas such as history, psychology, anthropology, and communication studies. Of the 4444 articles, only 12.6% applied qualitative methods and less than 5% of citations were from social sciences and humanities journals [25]. Furthermore [27], have shown that societal limitations, such as social acceptance and political feasibility, are only sporadically considered in energy scenarios published by German public actors (e.g. by the Federal Ministry for Economic Affairs and Energy (BMWi) or the Federal Environment Agency (UBA). Therefore, this study addresses current weaknesses in energy research by demonstrating how the integration of quantitative empirical social research, macro-economic input-output analysis, and technical energy system models can improve energy systems assessment.

1.3. Contribution of the study

There are several important areas in which this study makes an original contribution to energy research. Firstly, the paper illustrates a new integrated approach to addressing the technical, economic, and social dimensions predominantly influencing the transformation of energy systems. Furthermore, by applying our approach to the case of the German coal phase-out, we derive findings that provide more robust information for the current debate on the German national greenhouse gas reduction strategy.

In this manner, we can show that our integrated approach results in different future energy systems compared to stand-alone approaches. These differences can reveal possible conflicts or inconsistencies in previous transformation pathways for energy systems and might enable decision makers to avoid them. In this way, our approach can provide a multifaceted and, thus, a more robust basis for public policy research.

To explain our approach and its application to the German coal phase-out, we organize our paper as follows. First, we describe the three methodological parts of our assessment approach and how we combine them (cf. Section 2). This also includes our chosen scenario framework. We then present our results (Section 3) and discuss their implications.

2. The applied integrated assessment approach

We developed an integrated approach in order to investigate the impacts of a coal phase-out in Germany on the technical energy system, the economy, and public perception. This approach combines a survey on public perceptions, a macroeconomic input-output model, and an energy system model. The following sections will explain each methodological step in more detail.

2.1. Representative survey on the public perception of a coal phase-out in Germany

In order to assess the public perception of a coal phase-out in