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The impact of the long-term EU target for renewables on the structure of electricity production in Poland

Lidia Gawlik [a, *], Adam Szurlej [b], Artur Wyrwa [b]

[a] Mineral and Energy Economy Research Institute of the Polish Academy of Sciences, Wybickiego 7, 31-261 Krakow, Poland
[b] AGH University of Science and Technology, Faculty of Energy and Fuels, Mickiewicza 30, 30-059 Krakow, Poland

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ABSTRACT

This paper outlines the results of various scenarios for optimizing Poland's future energy system up to 2050. The objective of the study was to demonstrate through the use of models how the level of binding targets for the share of renewable energy (RES) in final energy consumption would impact the evolution of the Polish energy sector. The differences in the compared scenarios consist of the level of RES (renewable energy sources) targets while assuming the same ETS (emissions trading system) CO_2 reduction pathways. These scenarios of differing RES targets are compared with other ones where the level of RES obligatory for 2020 has not been increased in the 2020–2050 period. The lack of increasing RES targets applies no preference for any particular technology, and the resulting energy mix is cost-optimal.

Potential variations in the energy mix are shown, addressing the fuel and technological structure of electricity production. The analysis presents the costs of electricity generation in the examined scenarios and the level of capital expenditures for the development of new capacities. It examines how RES technologies may develop in Poland with and without the national RES targets after 2020, and the consequences for coal as well as the development of clean coal technologies.

1. Introduction

Significant progress is being made towards meeting the 2020 objectives of the EU political framework guiding the development of the energy sector based on the Climate and Energy Package [1] with its three targets – reduction of GHG (greenhouse gas) emissions, an increase in renewable energy use, and improvement in energy efficiency. In addition, the Energy Roadmap 2050 [2] has set the direction for long-term regulation aimed at developing an environmentally sound energy market. The EU 2050 objective to reduce GHG emissions by 80–95% below 1990 levels implies, among other things, substantial decarbonizing of the electricity supply. The EU Framework for Climate and Energy Policies 2030 [3] continues the multi-target approach. The final agreement sets the combined targets for 2030 related to: (i) GHG emission reduction (i.e. at least 40% compared to 1990), (ii) energy efficiency (i.e. 27% improvement compared to projected energy consumption) and RES (renewable energy sources) (i.e. at least 27% share of renewable energy in overall energy consumption).

Recent findings of the Intergovernmental Panel on Climate Change confirm that climate change is unequivocal [4], so there is no doubt that the European efforts are proceeding in the right direction.

European policy beyond 2020 with its main goal – decarbonizing of the energy supply – is generally not contested, though there are many doubts concerning the level of the targets as well as the methods of achieving them. This is confirmed by Ref. [5], that the structure of energy use inside the EU is much stronger influenced by political targets and positions regarding climate protection, energy security and the use of nuclear energy than by available technologies. The studies on future European decarbonizing pathways revealed, that the same CO_2 emission reduction target can be reached under alternative technological and policy choices. An example of analysis of energy system evolution considering different policy environment can be found in Ref. [6]. The study of [7] shows that 80% GHG reduction target by 2050 can be reached with RES shares in electricity production that differ by almost 15% depending on the model used.

* Corresponding author. Tel.: +48 507 148 120.
E-mail address: lidia.gawlik@min-pan.krakow.pl (L. Gawlik).

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The EU climate policy approach is becoming an increasing challenge for Poland's coal-based power sector. The most important tasks, considered to be effective under Polish conditions include increasing the efficiency of electricity generation from solid primary energy sources, developing carbon sequestration, widening the use of renewable energy sources (particularly wind and solar energy), and pursuing nuclear power [8]. These directions of development will allow for the achievement of the 2020 targets, but may not be effective beyond that point. The main concern is whether it will be possible to use domestic fossil fuels (Polish reserves of hard coal are the biggest in the EU and lignite reserves place the country at the second position). The 3-target system seems to restrict the right to choose the best way of reaching further cuts in GHG emissions under local conditions. Future plans of the European Union to impose targets on the member states will have an impact on the optimal directions of development of the energy sector in Poland and may lead to significant increase of electricity generation costs [9].

The structure of installed capacity in the Polish electricity system in 2013 was such that over 52% of all generating units were power plants based on hard coal, and 24% were lignite-fired power plants, the driving factor for which has been the abundance of domestic resources of those fuels. In recent years there has been an increase (9%) in the share of technologies based on renewable energy resources [10]. A characteristic feature of power generation in Poland is the significant share of very old (over 40 years) facilities, and thus low-efficiency power plants [11]. For this reason, in the years 2010–2020 it will be necessary to replace about 7 GWe of total generating capacity [8].

The investment decisions connected with the needed replacements as well as with new plants that would cover increases in demand for electricity will have to take into account many aspects of energy sustainability [12], including mutually-exclusive elements associated with the operation of the energy supply, such as energy security, social equity, and environmentally sound development (i.e. environmental impact mitigation). As concerns the changes in the energy mix in Poland, the decisions are not easy; while the country possesses large domestic reserves of hard coal and lignite, other energy sources are limited. Gas might become an option in the case of the development of shale gas reserves currently undergoing exploration. Outside of this scenario, expensive imports would serve to limit the expansion of gas power plants. The deployment of nuclear power has been delayed due to various obstacles. The recent study [13] shows that building new nuclear power plants is not a cost effective option before 2040, as it has higher CO_2 abatement costs than coal with CCS, wind and hydro. Development of renewables, in particular solar and wind, also encounters greater difficulties in Poland than in the leading European countries, as the potential for exploiting such resources is lower due to less favorable climatic and geographical conditions. These conditions are promising for biomass, which can play an important role in reaching the decarbonizing targets. However, as argued by Ref. [14] the reduction in CO_2 emissions is most effective when existing biomass potential is used locally for heating purposes, thus avoiding emissions embedded in its transportation and processing.

The objective of this paper is to outline how the level of binding targets for the share of renewable energy in final energy consumption would impact the evolution of the Polish energy sector.

2. Research methodology

To understand the possible directions of future energy sector development, a mathematical modeling approach was employed. The TIMES-PL model was applied built with the use of TIMES generator [15]. TIMES-PL is a bottom-up model dedicated to the analysis of the Polish fuel and energy system evolution, which includes all existing power plants and combined heat and power plants [16]. It has been used recently to study the perspectives of coal supply for Polish power sector up to 2050 [17]. Each thermal power plant is reflected in the model separately. Also, each gas fired combined heat and power plant is represented individually. Other existing power plants and CHPs are aggregated into main types according to the fuel used and eventually the type of turbine installed (condensing or back pressure). Additionally, 25 main types of new power plants are presented. The model minimizes an objective function representing the total discounted system costs over the time horizon from 2011 to 2050 taking into account selected constraints. Each year is split into 224 time slices in the model in order to improve the temporal characteristics of both demand and supply sides (in the latter case this is particularly related to the increasing share of intermittent renewable technologies) [18]. The main equations include: energy and other commodity balances, capacity-activity constraints, reserve margins, etc. The main decision variables include: activity variables (e.g. production of electricity, fuel consumption, etc.), new capacity additions, energy flows, storage capacities, etc. All energy technologies in the models are characterized by a number of technical and economic parameters and the perfect competition between them is assumed.

TIMES-PL was chosen for this research as its methodology is comparable to the PRIMES model developed by the National Technical University of Athens [19] which was used in the EU for analyses of the consequences connected with implementation of the directives within the Climate and Energy package. The models developed with TIMES generator have been widely applied to estimate the impacts of different policies related to renewables [20], energy efficiency and climate [21]. A comparison of modeling results of the PRIMES and TIMES-PL models for baseline energy scenarios for Poland up to 2050 can be found in Ref. [22]. There are some other modeling efforts related to the short- and mid-run projections of Polish power generation system considering the market power [23] and liberalization of the electricity market [24].

TIMES-PL was used for scenario analyzes to assess the demand for coal up to 2050 in the study of [17]. The studies presented here are inspired by the results obtained there and largely adopt the same assumptions, especially when it comes to the level of future demand for electricity in the country, possible supply capacities of fuels for energy sector and their prices. This approach allows for the analysis of a larger number of scenarios in which the future is currently unknown, with particular attention paid to the possible consequences of the long-term EU climate policy and its final shape on Polish energy sector and its structure.

2.1. General assumptions

The purpose of the model was to optimize the production structure in the energy sector while ensuring that demand for electricity will be met, a factor which has been determined through forecasting (Table 1).

This forecast is based on the assumption that the energy intensity of the Polish economy (measured by the ratio of final energy

Table 1
The demand for electricity by 2050, TWh.

Year	2011	2015	2020	2025	2030	2035	2040	2045	2050
Demand	122	127	140	150	162	174	186	197	204

Source: [17].