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IBS RESEARCH REPORT 05/2018
NOVEMBER 2018

RISKS ASSOCIATED WITH THE DECARBONISATION OF THE POLISH POWER SECTOR

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Cite as:
Witajewski-Baltvilks et al. (2018). Risks associated with the decarbonisation of the Polish power sector. *IBS Research Report 05/2018.*

Substantive editing – Agata Miazga
Proofreading – Matthew Bastock
Interior design RZECZYOBRAZKOWE

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Abstract

The Polish power sector currently stands at a crossroads, facing two alternative pathways. First, the *decarbonisation* pathway with radical CO_2 emissions reduction, which involves a fast phase-down of coal. Second, the *baseline* pathway that abandons emission reduction targets, and involves a slow coal phase-down. Both pathways are associated with risks. The decarbonisation pathway requires large-scale investment in carbon-free technologies in the power sector that may crowd out investment in other sectors of the economy. Other risks associated with this pathway include the destabilisation of the power system, dependency on imported technologies and job losses in mining. The baseline pathway may involve the loss of international reputation, the waste of research and development (R&D) resources on coal technologies, and a growing dependency on imported coal. In this report we define the electricity mix associated with each pathway and compare their financial and macroeconomic costs using simulation models. We also perform a qualitative analysis of the risks that are not captured by the models. We argue that the decarbonisation pathway is unlikely to be significantly more costly than the alternative pathway of no reduction targets. Some socioeconomic risks of decarbonisation such as a potential fall in employment and increased dependency on imported technologies could be mitigated if the government communicates to firms and workers that the scale-down of coal sector is inexorable given the global commitment to combat climate change. However, it will be accompanied by a simultaneous scale-up of the sector related to carbon-free technologies.

Keywords: low-carbon transition, DSGE and bottom-up modelling, stakeholder engagement
JEL codes: Q43, Q52, Q58

• The research leading to these results received funding from the European Union Horizon2020 under Grant Agreement No. 642260. The report extends the findings presented in the research article by Antosiewicz et al. (2018). We would like to thank Jan Rutkowski, Piotr Lewandowski, Robert Jeszke (and his team) and Grzegorz Klima for their valuable comments and suggestions, as well as Agata Miazga for her indispensable editorial support. We would also like to thank all stakeholders participating in the interviews, the survey, and the workshop that led to the results described in this report. The usual disclaimers apply. Any errors contained in this report are our own.

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Overview

Poland cannot significantly reduce its carbon footprint without changing the way it produces electricity. In this report we quantify the economic costs and identify the risks associated with a transition of the electricity-generation sector away from fossil fuels. We develop a baseline pathway, in which Poland continues to rely on coal, and a decarbonisation pathway, whereby the coal sector is more rapidly phased down, and compare them using an array of quantitative and qualitative tools. We show that the decarbonisation pathway is unlikely to be significantly more costly than the baseline pathway. Furthermore, the government could mitigate some of the risks of decarbonisation if it communicates to firms and workers that the scale-down of the coal sector and the scale-up of the sector related to carbon-free technologies are inevitable.

As can be seen in Fig. 0.1, the **decarbonisation pathway will involve higher costs** than the baseline pathway. However, the overall cost for the economy will be small, and furthermore, as shown in Fig. 0.2, in the decarbonisation pathway the electricity sector will emit half the CO_2 than that of the baseline pathway by the middle of the century. The main difference between the pathways is the elimination of coal and lignite power plants under decarbonisation, although coal will continue to be used for combined heat and power plants. Furthermore, investment in costly biogas, biomass, and photovoltaics is significantly higher for the decarbonisation pathway. Both pathways predict a similar, increasing level of investment in onshore wind power and the introduction of nuclear power.

Figure 0.1. Cumulated cost of electricity generation 2015–2050

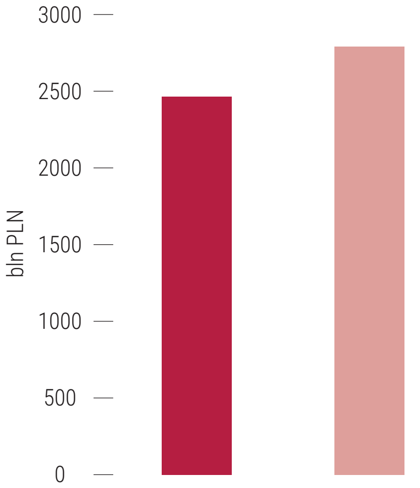
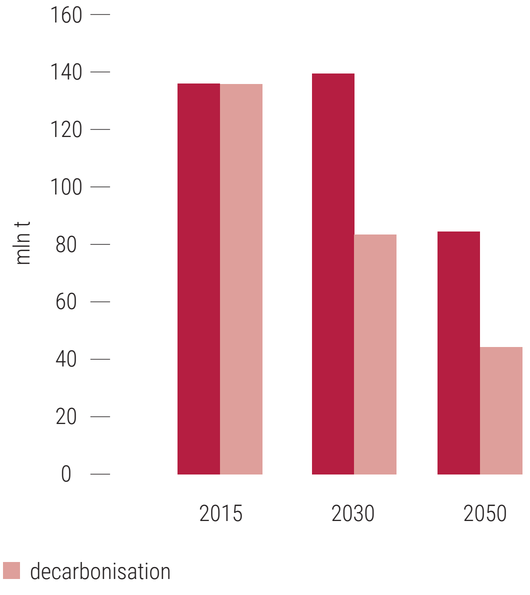


Figure 0.2. CO_2 emissions in the electricity-generation sector



Source: Output of the MOEM model.

Despite the significant investment required to achieve decarbonisation of the electricity sector, **the cost for the entire economy is small**, and, what is more important, transitory. The total capital and operating expenditure is 14% higher for the decarbonisation pathway, but it is important to note that it is spread over a period of 30 years and that this sector accounts for a small part of the economy. The drop in gross domestic product (GDP) reaches a maximum of 0.6% relative to the baseline due to a crowding-out of investment in the remaining sectors. The decline in household consumption follows a similar pattern and reaches a maximum of 1%. Finally, the increase in the unemployment rate would not exceed 0.1 percentage points. The highest deviation of these macroeconomic indicators would take place in the 2040s, and towards the middle of the century we predict that they would return to the baseline value. A macroeconomic analysis is also conducted for differing assumptions regarding future prices of emission permits, technology costs, and other constraints on technological preferences. All results point to a shallow and transitory economic slowdown.

In addition to the general macroeconomic study, we conduct an analysis of other risks and issues that are linked to the baseline and decarbonisation pathways using tailored quantitative and qualitative methods. These risks are the following.

Forgoing decarbonisation may lead to a **loss of international reputation** due to the fact that climate change and decarbonisation are important issues at both the EU and global levels. This can impede Poland's ability to create political alliances and partnerships, primarily within Europe, including in areas that are outside of the climate and energy agenda, such as economic, agricultural, or trade policies.

Continuous reliance on coal might also pose a threat for **energy security** and economic growth in the long run. This is contrary to the popular belief that Poland has rich coal reserves that are economically viable. Poland is facing increasing coal production costs, and attempts to restructure the coal sector have only been partially successful, thus resulting in increased demand for imported coal. A part of the demand for coal will be met by imports from Russia, and since it already supplies Poland with a large quantity of oil and gas, dependence on one country as a supplier of energy might pose a threat to the stability of energy supply. Energy security could be preserved if the costs of coal extraction in Poland go down or if the energy mix becomes more diversified.

Opting for a coal-based energy system will require significant spending on R&D to increase the efficiency of both coal mining and electricity generation. **The benefits from coal-related R&D** will probably be **limited** as the global shift to alternative energy sources becomes more pronounced. The accumulated knowledge and know-how related to the coal-mining and coal power plant sector would only contribute to overall economic growth through spill-over effects if these technologies continue to be utilised long into the future. However, there is a high probability that globally coal will lose the race against other energy sources, therefore investing in other technologies is probably more beneficial for the economy, especially in the long run.

Increasing the share of **intermittent renewable energy sources**, especially from wind turbines, does not pose a threat from the point of view of rising system costs and energy security. Under decarbonisation, coal will be replaced by a mix of wind and gas turbines, which is only slightly more expensive than coal generation. The gas turbines need only be turned on sparingly during peak energy demand or when there is insufficient wind power, so that additional gas use does not exceed 15% of Poland's total use. Faced with the alternative of importing coal and the recent diversification of gas imports, this does not seem to threaten the stability of energy supply. Pushing for a low to medium share of renewable generation results in a levelised cost of electricity increase of up to 8.1%.

It is unlikely that switching to renewable energy sources would result in **technological dependency** on foreign technology and manufacturers. In the case of offshore wind technology, currently the domestic industry can be responsible for 50% of the value chain in wind turbine production, and with a supportive government policy this share could reach 70%. Furthermore, Poland has the potential to develop technological niches which could provide specialised RES components.

Decarbonisation does not necessarily imply a significant **decline in employment** due to laying off a large number of working-age workers in the mining sector. We show that natural attrition resulting from transitions to retirement are roughly consistent with the drop in the demand for coal under the decarbonisation of the economy. Furthermore, coal miners should have ample opportunities to find employment in the construction sector, which requires workers of similar education and experience levels. This is especially true for the Silesia region, where the majority of miners are employed and which currently boasts low unemployment .

When choosing a pathway, policy-makers need to take into consideration **public acceptance** issues, both at the local and national levels. The most contested issues are high-voltage transmission lines; the construction of new coal mines, especially open-pit lignite mines; and renewable energy system installations such as onshore wind turbines.

Political will is also a crucial element for fostering decarbonisation of the energy system. It is closely linked to general public opinion on this issue, but the direction of this effect is not entirely clear due to the possibility of reverse causality. While public opinion influences the political debate, the political debate simultaneously influences public opinion. We argue that political parties tend to promote environmental issues in times of low inequality and when the economy is expanding. Political will can also be influenced by well-organised stakeholders such as coal-mining trade unions.

Introduction

The Polish power sector stands at a crossroads, facing different pathways with contrasting CO_2 emission reduction ambitions: the decarbonisation pathway, which sets ambitious emission reduction targets, and the baseline pathway, which abandons emission reduction targets. The decarbonisation pathway would involve fundamental changes in the structure of production of the power sector compared to the baseline pathway. Such a radical structural change may involve costs for both the economy and society, especially because it entails a phase-down of the coal-mining sector, which employed 94,000 workers in 2015. On the other hand, the baseline pathway would prevent Poland from contributing to global efforts to mitigate climate change. As with other countries (Hess et al., 2018), a heated debate has emerged in Poland between the advocates of each alternative.

The primary purpose of this report is to examine the evolution of the power sector and the economy under the decarbonisation and the baseline pathways and assess the risks associated with each one. We also determine the conditions under which these risks can be amplified or avoided.

We show that the macroeconomic costs associated with the decarbonisation pathway are not significantly higher than the costs associated with the baseline pathway, according to simulation models. Both pathways are associated with risks that cannot be captured by models, such as the loss of international reputation under the baseline pathway or the inability of workers from the mining sector to find employment in other sectors under the decarbonisation pathway. The risks associated with decarbonisation are manageable; however, they urgently require the preparation of a consistent strategy to enact the necessary changes in the power sector and the related sectors.

Our analysis is divided into three parts. In Part 1, we predict the evolution of the electricity mix under each pathway and investigate the macroeconomic costs of these evolutions using simulation models. Specifically, in this step we employ a bottom-up model of the optimal electricity-generation mix and a macroeconomic Dynamic Stochastic General Equilibrium (DSGE) model. The bottom-up model predicts the cost-minimising electricity mix with and without constraints on emissions. It also enables a comparison of the costs of generating electricity under the two pathways. The general equilibrium model examines the relative socioeconomic consequences of adopting the mixes under each pathway, including the effects on GDP, aggregate consumption, unemployment, and wages. We also explore how the results of the standard economic analysis change when we alter the assumptions on some of the parameters, namely technological costs, emission permit prices, and the availability or social acceptance of nuclear power. The two models allow us to define the electricity mix associated with each pathway and estimate their costs. We abstract from the question of which policy tools (e.g. RES auctions or feed-in tariffs) could be used to implement the pathways in the most efficient way.

The results of this part of the analysis suggest that the least-cost pathway under the constraint of the threefold reduction in emissions involves a gradual replacement of coal with a mix of onshore wind, nuclear, natural gas, biogas, and biomass. The baseline pathway is associated with larger aggregate consumption than the decarbonisation pathway, but the difference is modest.

In Part 2, we identify and discuss several risks that are omitted from the analysis in the first step due to the limitations of the models. We investigate three such risks associated with the baseline pathway:
- the loss of international reputation
- the waste of R&D resources on coal technologies
- dependency on imported coal

and three risks associated with the decarbonisation pathway:
- the loss of energy system stability
- dependency on imported technologies
- decline of employment

Each risk is explored using tailored tools such as analytical models, dedicated quantitative models, interviews with relevant stakeholders, and value chain analysis. We also employ the Fuzzy Cognitive Mapping method to illustrate the potential consequences of the two pathways via a graphic showing cause-effect relationships that link policies with economic growth.

The report argues that the risks associated with decarbonisation could be mitigated if the government takes on a co-ordinating role for managing the changes in the power sector and related sectors. In particular, the risks of decline in employment could be mitigated if the government communicates to firms and workers that the scale-down of the coal sector is inexorable given the global commitment to combat climate change. Similarly, the risk of dependency on imported coal could be reduced if the government commits to decarbonisation and communicates to firms that the sectors related to carbon-free technologies will scale up in the near future. Similarly, the stability of the energy system could be preserved by implementing an appropriate electricity mix.

In Part 3, we examine implementation risks, i.e. potential obstacles to the implementation of the decarbonisation pathway. We focus on the lack of support for the pathway by three groups of stakeholders: experts, citizens, and politicians. We explore these risks by conducting a survey of experts, reviewing literature on citizens' support for energy-related investment, and performing econometric regressions that explain when parties talk about climate and environmental issues.

The results suggest that experts seem to understand the need for decarbonisation. However, the lack of strong support among the major political parties for the ambitious emission reduction targets as well as the opposition of citizens towards RES installations in their neighbourhood might pose an important obstacle to the implementation of the decarbonisation pathway.

PART 1

Electricity mixes and their macroeconomic implications – model simulations

MAREK ANTOSIEWICZ AND JAN WITAJEWSKI-BALTVILKS

In this part we define the electricity mix associated with the baseline and decarbonisation pathways and compare their financial and macroeconomic costs using simulation models. To do so, we employ a bottom-up model of the optimal electricity-generation mix and a macroeconomic Dynamic Stochastic General Equilibrium (DSGE) model. We also explore how the results of the analysis change when we alter the assumptions on some of the parameters, namely technological costs, emission permit prices, and the availability or social acceptance of nuclear power.

1. Definitions and methodology

1.1. Defining the key concepts

In this report we will evaluate two distinct pathways for the Polish economy, which we shall name the baseline pathway and the decarbonisation pathway.

We define the **baseline pathway as the path that would be chosen if the objective was to minimise energy system costs** under the given set of economic and technological constraints. We assume that such a choice takes into account the expected evolution of costs of technologies as predicted in Hand et al. (2017), the growth in prices of emission permits under the ETS from €5/tCO_2 in 2017 to €80/tCO_2 in 2050, and the limited availability of resources. Although the emissions tax is taken into account, **no limits on total emissions from the power sector are assumed**.

By **decarbonisation pathway** we mean the path that would be chosen under the same assumptions and with the same objective as those stipulated in the baseline pathway, i.e. the minimisation of energy system costs, but with the additional constraint of a **threefold reduction in emissions from the power sector**: from 137mln t in 2015 to 45mln t in 2050.

By **risk**, we mean the possibility that a phenomenon, action, or policy, whose outcome is uncertain, may result in bringing adverse consequences for economic, social, or cultural assets. Although in this study we **focus on economic risks**, we also aim to identify and discuss the most important risks that are not directly connected to the economy, such as the loss of international reputation.

1.2. The toolbox

1.2.1. MODEL OF OPTIMAL ENERGY MIX (MOEM)

VERSION OF THE MODEL

The structure and the original calibration of this model was developed by the Department of Strategic Analysis within the Chancellery of the Prime Minister (Klima et al. 2015). The model's code, the original data files used for calibration, the user interface, examples of basic simulations, and a detailed description of how it works is available online.[1]

For the purpose of this study, we used the original structure of the model; however, we recalibrated it somewhat. Specifically, we:

- updated the current level and expected evolution of costs of onshore wind, offshore wind, and solar photovoltaic (PV) technologies using the 2017 Annual Technology Baseline prepared by the National Renewable Energy Laboratory (Hand et al., 2017);
- assumed that the level of domestic gas resources available for use in the power sector is limited to 10 bln m^3 (see the Appendix for a detailed explanation of this value);
- assumed that the cap on imports of gas for use in the power sector is limited to 7 bln m^3 per year (see the Appendix for a detailed explanation of this value);
- assumed that emissions from biofuels do not count towards the overall emission limit – for instance, emissions from biomass are offset by the future negative emissions from land use; and
- changed the emission reduction targets in order to explore more ambitious targets (see Section 1.1).

1 www.premier.gov.pl/wydarzenia/aktualnosci/model-optymalnego-miksu-energetycznego-dla-polski-do-roku-2060-0.html

The remaining parameters are the same as in the analysis by Klima et al. (2015). In particular, we assume the same cost parameters for coal-based electricity, biomass, biogas, and nuclear. Following Klima et al. (2015), we assume that imports enable an increase in power available to the system. However this power cannot be larger than 1.8GW.

Due to the changes in the calibration, the output of the model differs from that obtained by the team at the Department of Strategic Analysis.

THE PURPOSE AND SCOPE OF THE MODEL

The MOEM solves the optimisation problem for a planner aiming to minimise total energy system costs, including both capital expenditures (CAPEX) and operating expenses (OPEX), under a set of physical, economic, and technological constraints. The output of the model represents the evolution of the electricity mix, the power mix, use of resources, and emissions from 2015 until 2050.

The model takes into account several factors, including:
- the evolution of costs for key electricity-generating technologies
- the availability (with the annual resolution) of domestic resources and caps on imports
- the possibility to construct new coal mines, including lignite mines
- the time required for the construction of mines and power plants
- growth in annual demand for electricity
- changes in demand for electricity across hours and days over a year
- the demand for heat in the heating network connected to CHP plants
- the evolution of EU emission allowances (EUA) prices.

MODEL LIMITATIONS

The model has three main limitations:
- It does not explicitly take into account the intermittency of renewable energy sources, but rather addresses this factor through a simplified distribution. We discuss this issue in detail in Section 5.1.
- It assumes that the evolution of costs of technologies is exogenous.
- It assumes that the demand for electricity is exogenous.

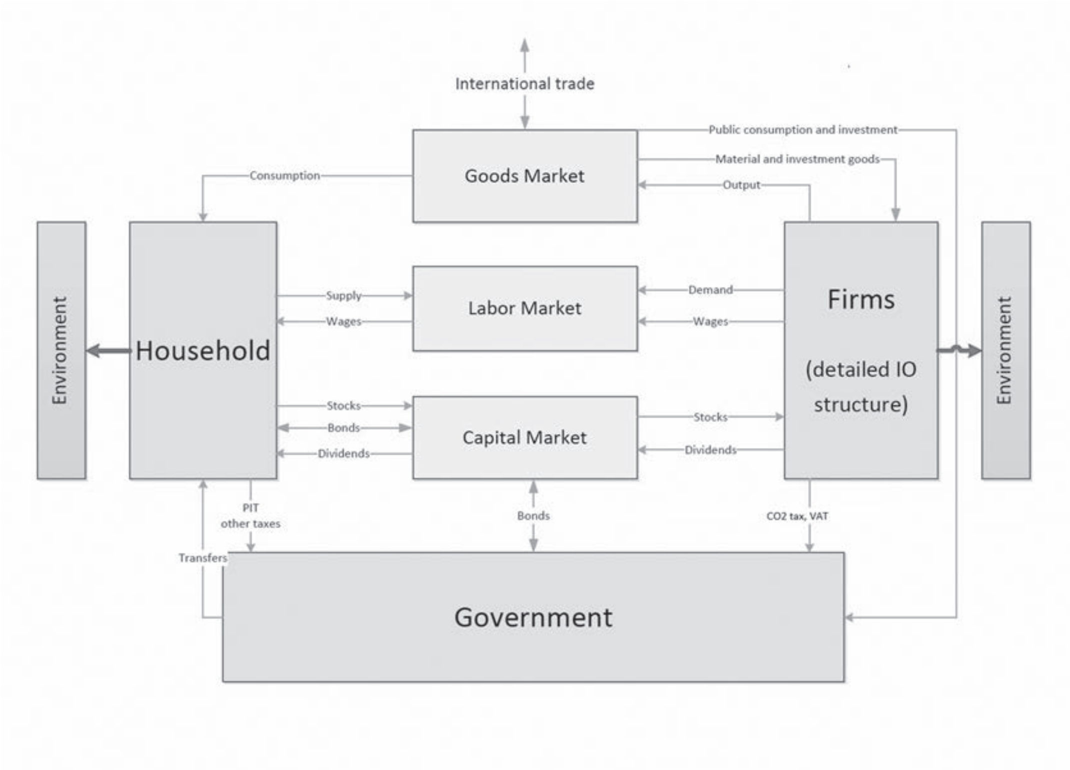
1.2.2. MACROECONOMIC MITIGATION OPTIONS MODEL

PURPOSE AND SCOPE OF THE MODEL

The MacroEconomic Mitigation Options (MEMO) model is a multi-sector DSGE model that simulates the dynamics of an economy, in this case the Polish economy. It assumes that a representative firm in each sector produces its output using four inputs: capital, labour, energy, and materials, with the possibility of substituting one input with another. For instance, after an increase in the price of energy, firms may choose to switch to a more capital-intensive and energy-saving form of production.

The output of each firm can (i) be used as material by a firm in another sector, (ii) constitute a component of an investment project undertaken by another firm, (iii) be purchased by households for consumption, (iv) be purchased by the government, or (v) be exported (Figure 1.1.). For instance, the output (goods and services) delivered by the construction sector will primarily be utilised as a component of investment projects undertaken in other sectors, while the output of the education sector will be a component of public and private consumption.

Figure 1.1. Interactions between economic agents in the MEMO model



Source: IBS.

The choices of firms are determined by a desire for intertemporal profit maximisation, which implies that firms take into account not only the current state of the economy but also expectations about the future. This is particularly important when firms make decisions about investment and hiring – if a firm expects high demand in the future, it is more willing to undertake investments and hire workers than a firm expecting an economic slowdown.

When firms choose their inputs and outputs, they take all prices (including the price of their own outputs) and wages as given. This means that the economy can be described as sets of choices of inputs (demand) and choices of outputs (supply) as a function of prices. For instance, an increase in the price of construction will involve a drop in demand for construction by other sectors and an increase in supply by construction firms. We assume that, at each point, the economy is in a state of equilibrium: prices are such that supply and demand are balanced and market clearing occurs.

The state of equilibrium has important consequences for the dynamics of the economy. For instance, a large-scale investment project in the energy sector that raises the demand for construction will lead to an increase in the price of construction goods to ensure that demand is met by supply. However, an increase in the price of construction goods may lower the profitability of investment projects in other sectors, and this may in turn slow down the accumulation of capital and lead to lower output from these sectors in the future.

An important component of the MEMO model is the labour market module. This module is built on the framework of search and matching, which is frequently used in modern macroeconomic models to study the dynamics of unemployment. The framework assumes that, in every period, an unemployed worker faces some probability of being employed in the following period. This probability is a function of the number of vacancies and the number of job seekers. An increase in demand for workers (e.g. due to additional demand generated by a large-scale investment project) will increase both the number of vacancies and the probability of finding a job, and will thus reduce unemployment.

BOX: THE MEMO TOOLBOX – WEB APPLICATION

The MEMO model is available for anyone to use via the MEMO Toolbox web application. Lay users can assess the macroeconomic consequences of implementing climate-change mitigation policies in three countries: Chile, Greece, and Poland. Through a user-friendly interface, users can easily conduct simulations by providing input data (e.g. changes in taxes, investment plans) and analyse the results (e.g. on GDP, consumption, investment, taxes, export/import, employment) through built-in visualisation tools or export them to a spreadsheet. The application can address several questions, such as:

- What effect would a carbon tax have on unemployment and wages in different sectors?
- How would a reduction in the PV installation costs affect energy prices, energy demand, and GDP?
- What effect would feed-in tariffs for PV have on industrial output (when combined with a bottom-up analysis)?

The models contained within the toolbox have been used in the past to assess the socioeconomic cost of decarbonising the Polish electricity-generation sector and to help assess the consequences of carbon taxation in Chile on energy poverty. The MEMO models were developed at the Institute for Structural Research (IBS) by Marek Antosiewicz and Jan Witajewski-Baltvilks as part of the TRANSrisk project.

More materials:

- MEMO Toolbox application and manual -> www.transrisk.ibs.org.pl
- Examples of use -> www.ibs.org.pl/research/transrisk/

Source: IBS and www.transrisk-project.eu/.

MODEL LIMITATIONS

The model does not take into account the rigidity of wages at the sectoral level: wages are free to adjust to any change in demand. For instance, according to the model, a drop in demand for miners will cause a large decrease in miners' wages. This has important consequences for the dynamics of unemployment. Downward adjustment of wages implies that the drop in the number of vacancies is smaller than would be the case if such adjustments were impossible. This, in turn, translates into a smaller increase in unemployment. In other words, if our assumption does not hold and sectoral wages cannot freely adjust, then the MEMO model will underestimate the increase in unemployment due to a reduction in demand in the mining sector. We discuss this issue in more detail in Section 5.3.

The model, in addition, does not take into account the potential barriers of entry to the RES technology market for domestic firms. In the current set-up, we assume that RES installation requires the same participation of domestic firms as an average investment project in the Polish economy. If this assumption fails, e.g. because almost all components of RES installations are produced abroad and Polish firms do not have any chance to compete in this market, the decarbonisation scenario will have a larger impact on imports. We discuss this risk Section 5.2.

Another important limitation of the model is that it does not account for the effect of structural change on the direction of R&D efforts and their effect on the growth of the economy. Despite some attempts to endogenise technological change in the literature (Acemoglu, 2012), this problem cannot be fully solved in economic models due to the absence of equilibrium under perfect competition (see Acemoglu, 2007 for a more detailed discussion). We discuss this issue further in Section 4.3.

1.2.3. INTEGRATION OF THE TWO MODELS

There are three outputs of the MOEM model that are used as inputs in the MEMO model:

- Changes in the use of fossil fuels: gas and coal (oil is not used in the Polish power sector).
- Energy system costs, calculated as the sum of capital expenditure and operational expenditure divided by the amount of electricity produced.
- Capital expenditure.

In general equilibrium simulations, the demand for electricity predicted by the MEMO model may be different to the demand for electricity assumed in the MOEM model because the MOEM model does not take into account that an increase in electricity prices will cause a reduction in the demand for electricity. To address this problem, we have scaled the changes in the use of fossil fuels and changes in capital expenditure within the MEMO model by the resulting ratio of the simulated demand for electricity and the steady-state demand for electricity.[2] For instance, if the MEMO model predicts that an increase in electricity prices in the decarbonisation pathway will lead to a drop in electricity demand by 10%, capital expenditure and changes in resource use predicted by the MOEM model will be scaled by a factor of 0.9 in the MEMO model.

2. Core electricity mixes

In this section we analyse the economic costs of the transition of the electricity-generation sector in two alternative pathways. We develop a decarbonisation pathway, which assumes a 70% reduction of CO_2 emissions in the power sector, and a baseline pathway, which abandons emission reduction targets. We compare them using a standard economic toolbox: a bottom-up, optimal electricity mix model (the MOEM model) and a general equilibrium model of macroeconomic dynamics (the MEMO model). In Section 2.1 we employ the MOEM model to predict the evolution of an electricity mix that minimises the costs of electricity generation in each pathway by 2050. We also compare the investment and operational costs of the two pathways. In Section 2.2 we analyse the economic consequences of following the decarbonisation pathway instead of remaining on the baseline pathway. We conclude this section by highlighting the strengths and limitations of the models used in our analysis.

2.1. Optimal electricity mixes

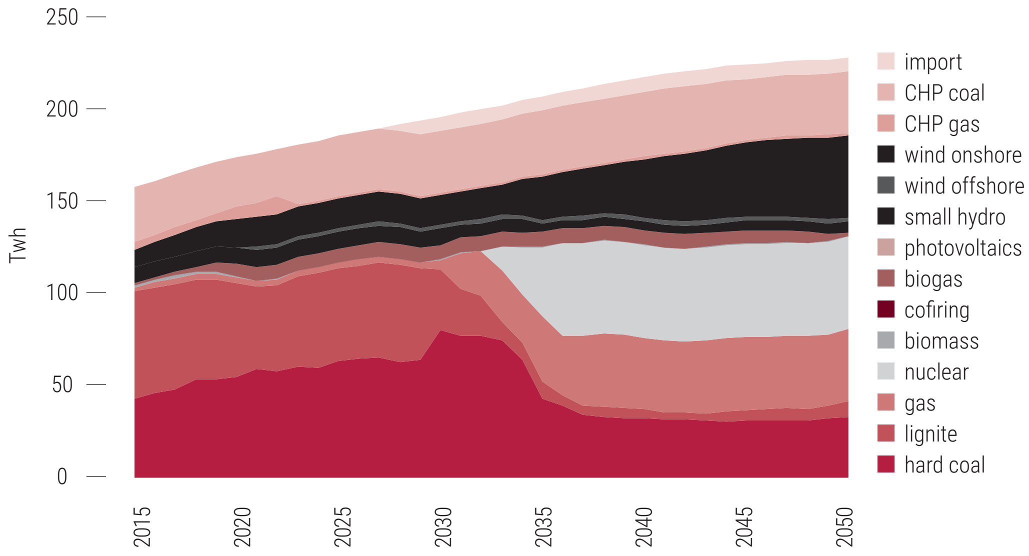
2.1.1. THE BASELINE PATHWAY

In the first part of this section, we present the simulations of the baseline pathway. This pathway minimises energy system costs under the assumption of a growth in EUA prices. No other constraints regarding allowed emissions are imposed. The pathway incorporating these criteria according to the MOEM model (see Section 2.2.1 for a breakdown of the assumptions used in the model) is shown in Figure 2.1.

In the baseline pathway the share of coal in the electricity mix would decrease, but only after 2030. It will decline to 33% in 2050 (from 83% in 2015).

2 More precise estimates would be obtained if we used the new electricity demand estimated by the MEMO model in the second round of the MOEM simulations and then reiterate the simulations. We could not apply this procedure in this study, however, owing to the significant time requirement for each computation of the optimal pathway by the MOEM model.

Figure 2.1. Optimal electricity mix in the baseline scenario



Source: Output of the MOEM model.

Until 2030, there is very little change in the electricity mix. There is a relatively small decrease in the share of coal and a moderate increase in onshore wind. The simulation also suggests that biogas, which is absent at the beginning of the analysed period, achieves a noticeable share by 2030. The contribution of other sources does not change significantly.

The 2030s start with a rapid drop in lignite due to the depletion of currently used mines; a similar drop is predicted in all scenarios considered. Lignite is initially replaced by hard coal (usage of which increases from 39mln t in 2020 to 52mln t in 2030) and later by gas (usage increases from 1.3bln m^3 in 2030 to 7.2bln m^3 in 2040).

Between 2032 and 2035, the completion of a nuclear power plant construction leads to a tectonic drop in the share of hard coal, from 51mln t to 36mln t. The reason why coal cannot compete with nuclear energy is the high price of EUA after 2030. Since coal power plants need to purchase permits to continue production, their operational costs are relatively high.

The last period of the analysis, between 2035 and 2050, features an increase in the share of RES, in particular onshore wind. This can be explained by the decline in RES costs (Hand et al., 2017).

There are several general observations to make regarding the baseline pathway. First, the optimal solution under the assumption of growing EUA prices predicts a significant fall in the share of coal. Second, despite the large drop in installation prices of onshore wind predicted in Hand et al. (2017), this source does not play a major role until the late 2030s. Third, under the assumption of nuclear costs at the level of 25.8mln PLN (6mln EUR) per MW, nuclear electricity enters the mix in the baseline pathway. However, it is not available before 2035, due to the long construction time needed. Fourth, some sources (solar, offshore) never enter the mix, even though we assume a sharp decline in associated costs following the reference scenarios projected by Hand et al. (2017).

2.1.2. THE DECARBONISATION PATHWAY

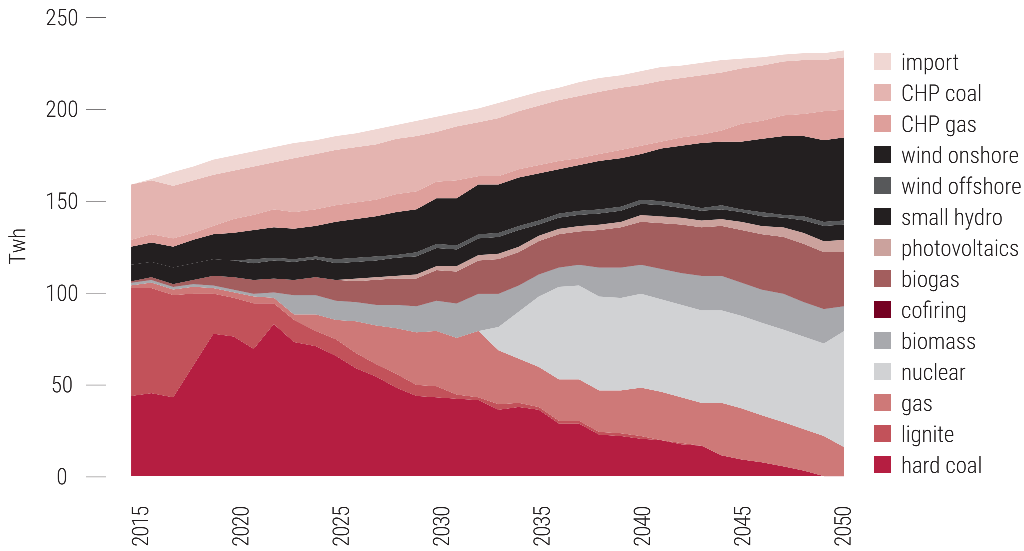
In this section we present the simulations of the decarbonisation pathway, i.e. the pathway that would be chosen by a benevolent planner with exactly the same objective as in the baseline (the minimisation of energy system costs) and under the same assumptions as in the baseline, but with the additional constraint that the planner commits to a threefold reduction in emissions from the power sector.

The decarbonisation pathway obtained from the simulations (Figure 2.2) can be divided into several phases.

In the decarbonisation pathway the share of coal in the electricity mix would start to decrease in 2020. It will decline to 12% in 2050 (from 83% in 2015).

The first phase (until 2022) features a moderate decline in the share of coal. The use of electricity originating from coal combustion decreases from 98TWh in 2020 to 94TWh in 2025, and coal is replaced by onshore wind and biogas. Another noticeable element of this phase is the temporary replacement of coal with gas in cogeneration of electricity and heat (CHP). The simulation also predicts a large-scale replacement of electricity from lignite with electricity from hard coal, although this prediction needs to be treated with caution. Government plans for lignite assume a continuation of production without significant changes until 2030. These plans could be revised in the medium term, although immediate adjustment is unlikely. Furthermore, although doubling the consumption of hard coal could theoretically be achieved by an increase in imports, such a scenario is not likely to be accepted by policy-makers due to concerns about the potential loss of energy security.

Figure 2.2. Optimal electricity mix in the decarbonisation scenario



Source: Output of the MOEM model.

The second phase, between 2022 and 2032, features a more rapid drop in the consumption of coal. This drop is enabled by an increase in generation of electricity from onshore wind, biofuels, and natural gas. As later discussed, the increase in biomass and natural gas is temporary.

Between 2032 and 2040, the completion of a nuclear power plant causes a further reduction in demand for coal. Nuclear power also enables a reduction in the use of natural gas and biomass. The construction of new onshore wind plants is restrained. In fact, the production of electricity from onshore wind declines due to the depreciation of older wind turbines.

In the last phase, we can witness fast growth of onshore wind and solar photovoltaics (PV). In 2050, onshore wind becomes the second biggest source of electricity, after nuclear, and its share reaches 20%.

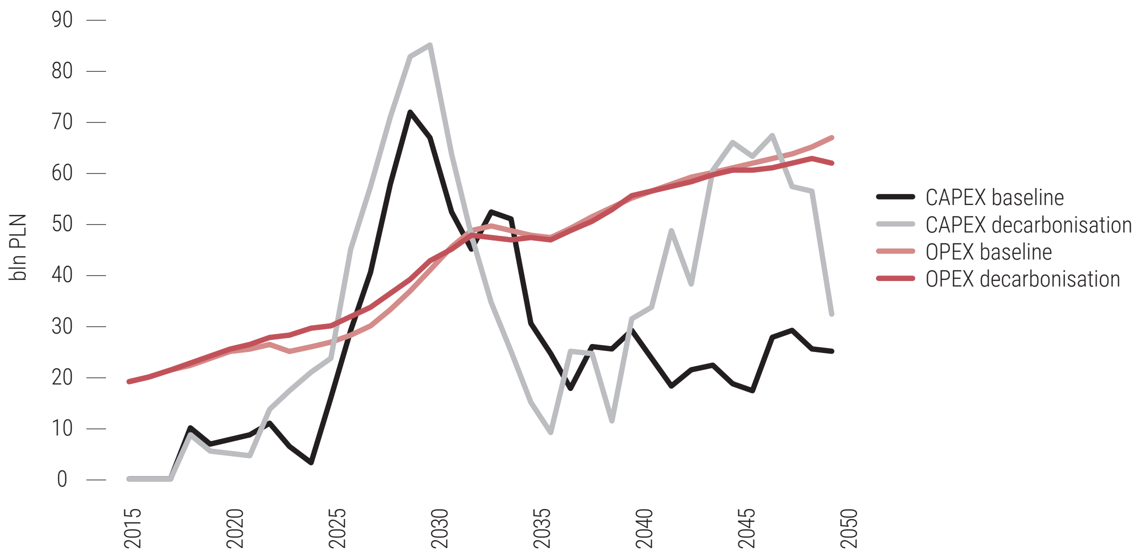
Again, we can make some general observations about the evolution of the mix in the decarbonisation pathway. First, the decline in the use of coal is significantly stronger in the decarbonisation scenario. At the end of the analysed period, coal is used only in CHP plants generating electricity together with steam, which is used later in the heating networks. Second, the decline is more gradual compared to the baseline scenario, which implies that the transition of factors of production, notably labour, from the mining sector to other sectors may be less abrupt than in the baseline scenario. We discuss this in more detail in Section 5.3. Third, natural gas and biomass could be used as a transition fuel, thus enabling a reduction in emissions until the nuclear plant is completed. Finally, PV, biogas and biomass have a significant share in the electricity mix at the end of the analysed period, in contrast to their negligible share in the baseline pathway. Consequently, the mix in the decarbonisation scenario is more diversified.

2.1.3. COMPARISON OF ENERGY SYSTEM COSTS AND CO2 EMISSIONS UNDER THE TWO PATHWAYS

The capital (CAPEX) and operational (OPEX) expenditures required by the energy system under the two pathways are presented in Figure 2.3. Both pathways involve a peak in capital expenditure between 2025 and 2035, which is necessitated by the construction of a nuclear power plant. In the 2020s, CAPEX in the decarbonisation scenario is larger due to the construction of RES installations and gas power plants. The difference in CAPEX between the two pathways in the 2030s and 2040s stems from the timing of the construction of onshore wind capacity: the fast growth of that capacity in the baseline scenario starts in the mid-2030s, while in the decarbonisation pathway it is delayed until the early 2040s. Since the growth of onshore wind capacity in the decarbonisation scenario is much faster, the CAPEX eventually becomes much larger than in the baseline scenario.

The decarbonisation pathway will involve higher costs than the baseline pathway, but decarbonisation would result in the electricity sector emitting half the quantity of CO_2 than that of the baseline pathway by 2050.

Figure 2.3. CAPEX and OPEX required by the energy system in the two pathways



Source: Output of the MOEM model.

The OPEX projected in Figure 2.3. includes fuel, operation, and maintenance costs for all plants, as well as the total costs of EUA. Initially the OPEX costs of the two pathways do not diverge. While the baseline pathway involves a larger use of coal and larger purchases of the EUA, the decarbonisation pathway requires a significant use of biomass, biogas, and natural gas. The difference between the two pathways becomes clear only in the 2030s, when EUA prices are very high.

Figure 2.4. Cumulated cost of electricity generation 2015–2050

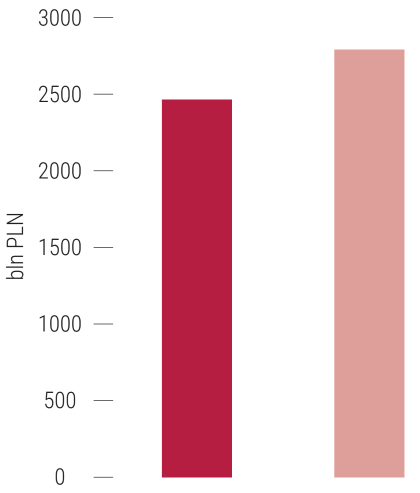
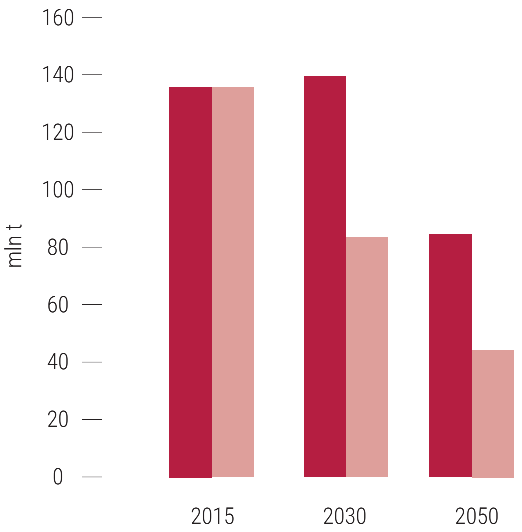


Figure 2.5. CO_2 emissions in the electricity-generation sector



baseline decarbonisation

Source: Output of the MOEM model.

Figure 2.4 represents the cumulated cost of generating electricity under the two pathways in the period 2015–2050. The cost was obtained by computing the total cost of the system (summing CAPEX and OPEX) in each year and summing for the period 2015–2050. Electricity under the decarbonisation pathway would be 13.6% more costly than under the baseline pathway. In the next subsection we demonstrate that this difference would not have any major consequences for the economy.

The level of annual emissions under the two pathways is presented in Figure 2.5. The evolution of emissions under the decarbonisation scenario was imposed by an exogenous assumption that defines the decarbonisation pathway (see Section 1.1). The evolution of emissions under the baseline pathway is an output of the model.

The reduction in emissions in the baseline pathway is small and delayed compared to the decarbonisation pathway. Until 2030, emissions stay at a roughly constant level. After 2030 they decrease significantly only due to increasing EUA prices and falling RES prices. In 2050 the level of emissions is at approximately the same level as the level of emissions in the decarbonisation pathway in 2030.

2.2. Macroeconomic implications

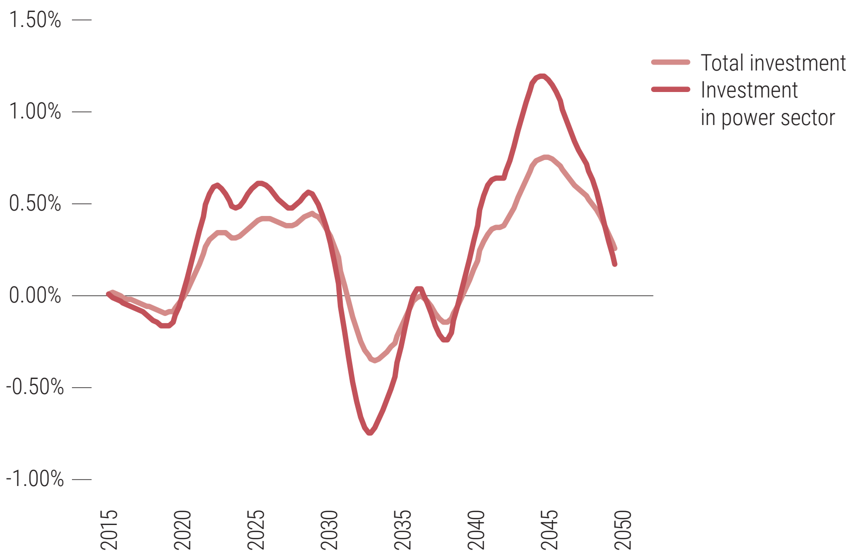
The cost of decarbonisation of the electricity sector for the entire economy is small and transitory (despite the significant investment required).

In this section, we present the macroeconomic consequences of the switch from the coal-dependent baseline to a decarbonisation pathway predicted by the MEMO model. Figures 2.6–2.9 show the evolution of key macroeconomic indicators in the decarbonisation pathway relative to the baseline. The results show a deviation from the baseline growth path: the points above zero on the y-axis imply that the variable takes a larger value in the decarbonisation pathway than in the baseline pathway, while the points below zero imply the opposite.

One direct consequence of the switch to the decarbonisation pathway is an increase in investment in the energy sector (Figure 2.6). This variable reflects the difference in CAPEX between the two pathways scaled by GDP. On average, the investment required in the decarbonisation scenario is larger by 0.5% of the baseline GDP, although the difference clearly fluctuates over time.

Investment in the energy sector crowds out investment in other sectors of the economy. This effect is illustrated in Figure 2.6. While an increase in investment in the energy sector leads to an increase in total investment levels, the latter increase is smaller and delayed. The difference between energy-sector investment and total investment must be compensated for by a drop in investment in other sectors of the economy. The reason behind this crowding-out is an increase in the price of goods necessary for investment. Decarbonisation-related investments increase the demand for construction and the output of the industrial sectors. The price of those goods increases and, consequently, investments in other economic sectors become more costly. This implies that fewer investment projects are undertaken in other economic sectors.

Figure 2.6. The difference between the decarbonisation and baseline pathways in terms of total investment and investment required in the power sector

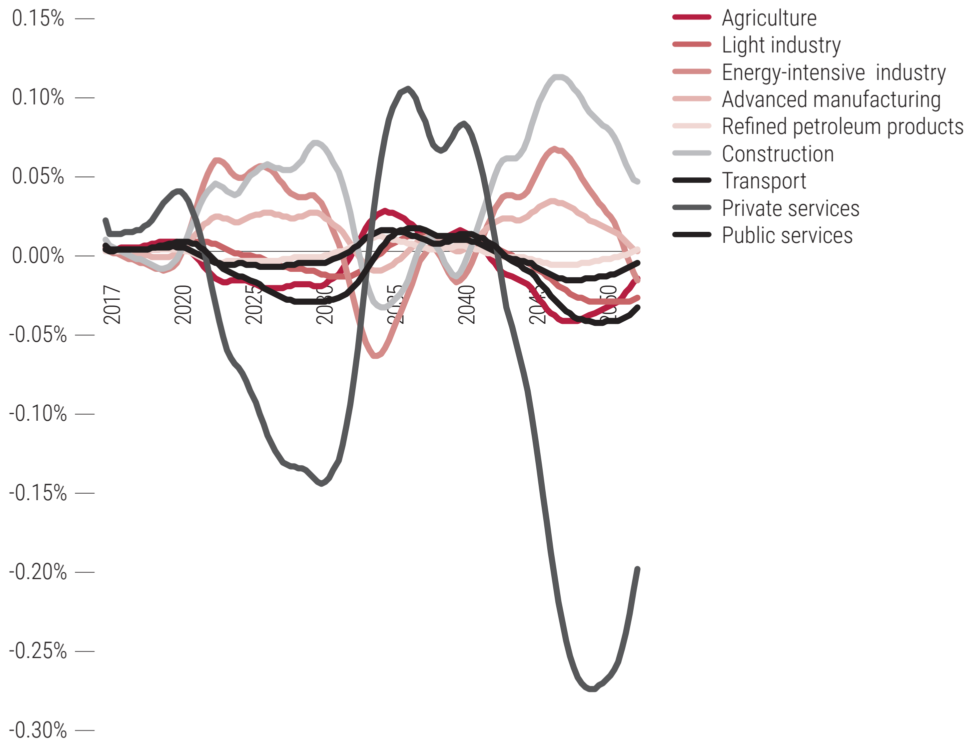


Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

A drop in investment leads to a drop in output in most sectors in the medium term (Figure 2.7). The largest decline takes place in services (a drop by 0.3% of the baseline GDP). A similar pattern, although with smaller amplitude, can be observed for almost all other sectors, though industry and construction are exceptions. The output of these two sectors must increase in order to meet the demand of an increase in total investment.

Figure 2.7. The difference between the decarbonisation and baseline pathways in terms of value added in the main sectors of the economy



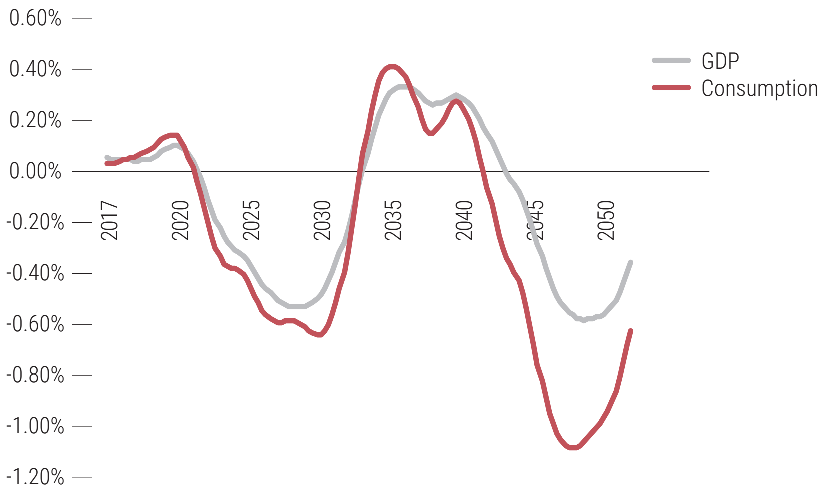
Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

The total effect of decarbonisation on GDP decrease and unemployment increase is negligible.

The total effect of a switch to the decarbonisation pathway is a modest drop in output and consumption per capita (Figure 2.8). The difference between the two scenarios is greatest in the late 2020s and late 2040s, i.e. the periods when investment requirements in the decarbonisation scenarios are highest. In these periods we can also observe that the drop in consumption is deeper than the drop in GDP, as larger investments in this period imply that a smaller share of GDP can be devoted to consumption. However, the scale of the drop in consumption appears to be insignificant. In the late 2040s, consumption is 1% lower than in the baseline. For instance, if we assume growth in consumption in the baseline scenario will be at an annual rate of 3%, then the average annual growth rate in the decarbonisation scenario would be 2.97%.

Figure 2.8. The difference between the decarbonisation pathway and baseline pathways in terms of GDP and consumption

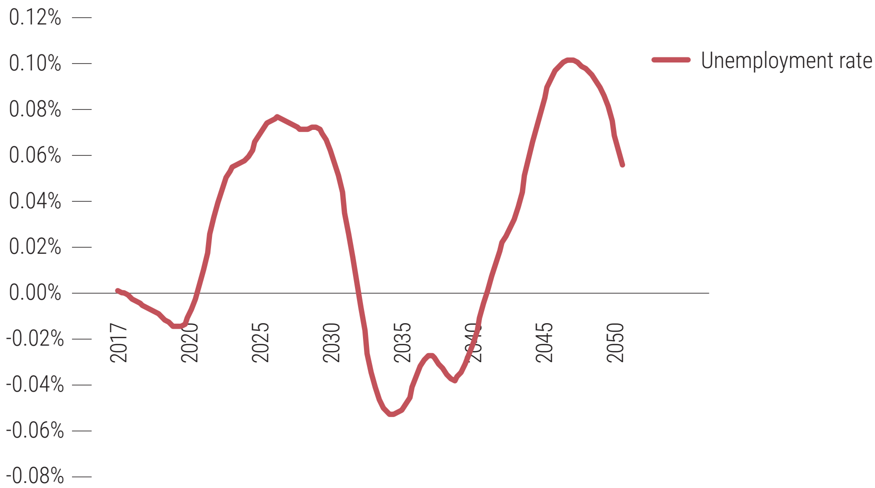


Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

Slower GDP growth translates into lower demand for labour and increased unemployment. However, the effect may be considered small: the peak unemployment would appear in the late 2040s and the effect would be less than 0.1% point above the baseline (see Figure 2.9).

Figure 2.9. The difference between the decarbonisation and baseline pathways in terms of unemployment rate



Source: Output of the MEMO model.

2.3. Strengths and limitations of the methodology

The simulations presented in Section 2.2 have a dual purpose. First, they expose the causal mechanism linking the adoption of a decarbonisation strategy and the reductions in GDP and consumption. Second, they generate an estimate of the expected economic loss associated with the decarbonisation pathway.

The result of the positive cost of decarbonisation was obtained by the construction of our research design: we defined our baseline as the pathway that minimises electricity system costs, and thus any additional constraint on the system (including emission reductions) that alters the mix in this pathway must result in higher electricity costs. From a macroeconomic perspective, higher power-generation costs imply that more resources must be used in the electricity sector, resulting in less resources being available to other sectors. This loss of efficiency in use of resources must inevitably lead to a drop in consumption. This result is independent of the model structure or any calibration of the parameters. In fact, the economic loss from imposing an environmental constraint will be predicted by any neoclassical or equilibrium model that assumes optimisation of agents and complete market clearance (Nikas et al., 2018a).

The conclusion that imposing environmental constraints causes economic loss relies on the assumption that there are no externalities from the behaviour of firms, that markets are perfectly competitive, and that consumers and firms are rational. The externalities arise when firms do not consider all of the social costs and benefits of their decisions. For instance, if emissions by an energy company result in a loss of international reputation and this is not taken into account in decision making, the firm generates an externality. If large externalities arise in the real world, the optimal pathway indicated by standard economic models that ignore externalities will be different from the truly optimal pathway from a social point of view. Similarly, if markets are not competitive (e.g. wages cannot freely adjust) or if agents are not assumed to display optimisation behaviour, standard economic models can give wrong predictions. We investigate some of these issues further in Part 2.

In addition, the results rely on the assumption that the parameter values assumed in the models are correct. For instance, if coal-fuelled electricity costs are miscalculated, the least-cost pathway may not feature a moderate decline in coal consumption. Similarly, the difference in costs of the two pathways can be biased if the model wrongly estimates the costs associated with the least-cost pathway under the environmental constraints. In the following section we perform various simulations based on alternative assumptions on the key parameters.

3. Alternative electricity mixes

In this section we show what the outcomes of the analysis of the baseline and decarbonisation pathway are under alternative scenarios for the evolution of EUA prices, intermittent renewable energy costs, and the availability of nuclear technology. This exercise is motivated by the following considerations. First, it enables us to construct a narrative on how the different pathways may evolve under various circumstances. Second, the range of results demonstrates the level of uncertainty that is associated with model outcomes and should be considered in decision making. Third, the additional results inform decision making about the level of sensitivity of the modelling results presented in Section 2 towards changes to specific parameters.

3.1. Low EUA prices

In this section we examine the outcomes of the MOEM and MEMO models under the assumption that EUA prices will stay at a very low level. Following the assumption in the baseline simulations prepared in Klima et al. (2015), we assume that the permit price for 1t of CO_2 will be €7 in 2030 and will grow to the level of €10 in 2050 (compared to the assumptions of €30 and €80 respectively, as discussed in Section 2).

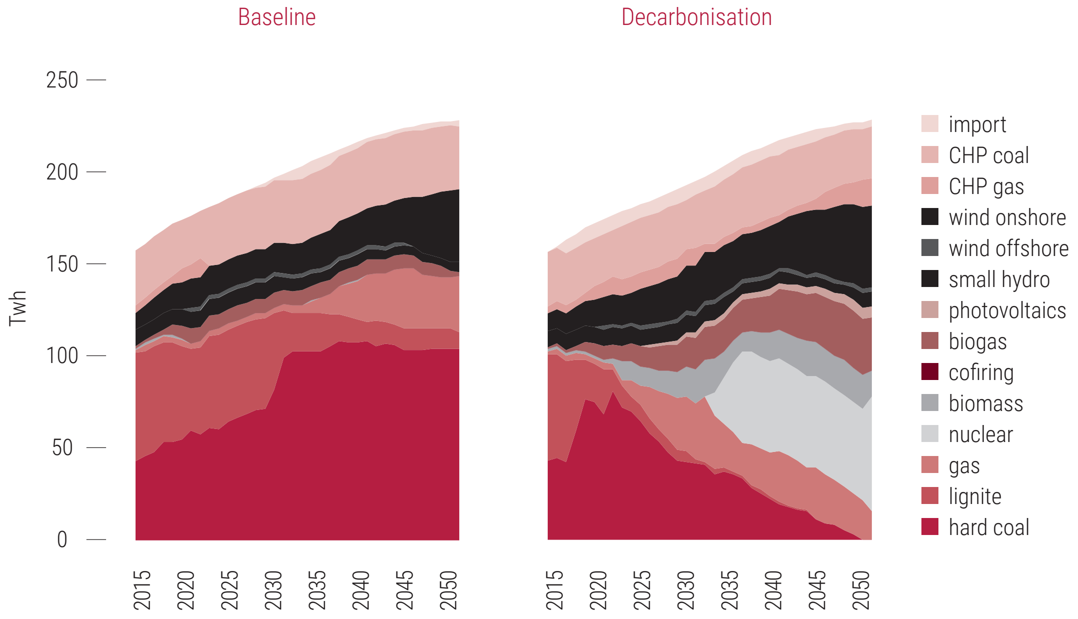
The prices of emission permits will significantly influence the optimal electricity mix only in the baseline scenario.

Interestingly, the MOEM model simulations suggest that, despite the low ETS prices, the share of wind in the baseline energy mix (without emissions constraints) is very close to that in the decarbonisation scenario. This finding implies that onshore wind technology will become competitive even when ETS prices are low. However, fast diffusion of this technology in the baseline pathway will not start before the 2040s. Onshore wind is the only renewable with a significant share in 2050.

A noticeable feature of the baseline pathway under low EUA prices is the substantial growth in coal use. This increase is associated with the total absence of nuclear energy, which entered the energy mix in 2030s in the high-price scenario.

As expected, the decarbonisation pathway appears to be similar under the two ETS price level scenarios, the replacement of emission-intensive fuels is necessitated by the emission constraints, and emission prices have only a very small impact on the optimal solution.

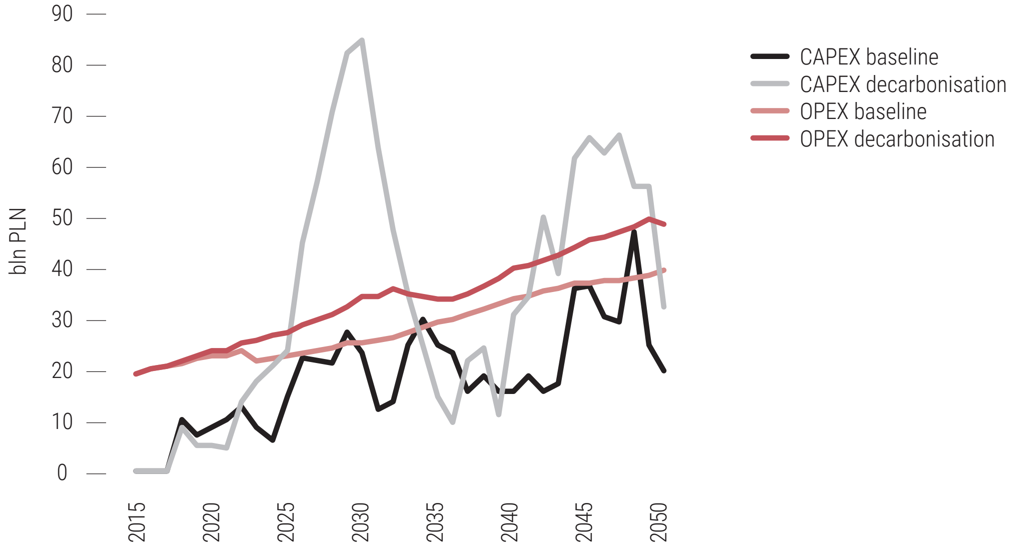
Figure 3.1. The optimal electricity mix under the baseline (left) and decarbonisation (right) pathways, assuming low EUA prices



Source: Output of the MOEM model.

The simulations that assume low ETS prices predict a large difference in the CAPEX required in the two pathways, which is mainly driven by the creation of nuclear power capacity and larger-scale deployment of RES in the decarbonisation pathway.

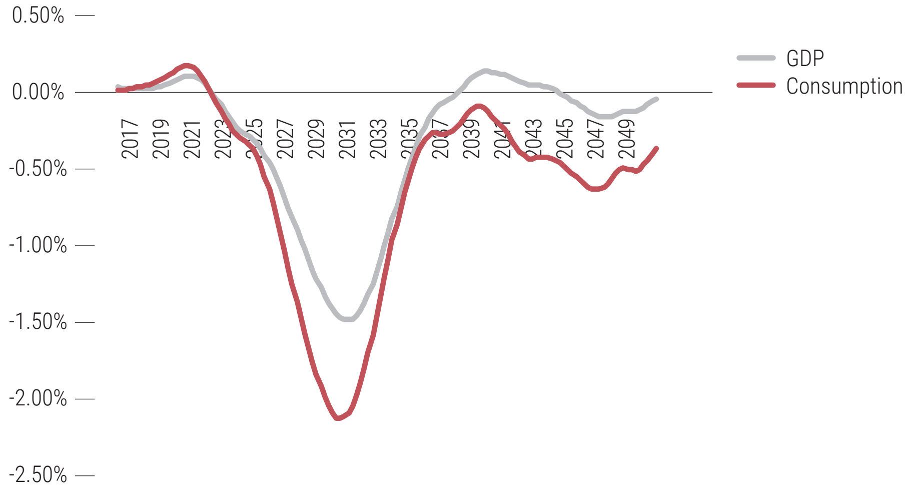
Figure 3.2. CAPEX and OPEX under the decarbonisation and baseline pathways, assuming low EUA prices



Source: Output of the MOEM model.

The large difference in the required investment between the baseline and the decarbonisation scenarios in the late 2020s translates into relatively large differences in terms of GDP and consumption between the two pathways. In 2030, GDP in the decarbonisation scenario is 1.5% lower than in the baseline scenario. The difference in consumption is even sharper: in 2030, consumption is 2% lower than in the baseline scenario. The simulation also suggests this drop is temporary and there is no significant difference between the two scenarios in the 2040s and 2050s.

Figure 3.3. The difference in GDP and consumption between the decarbonisation and baseline pathways, assuming low EUA prices



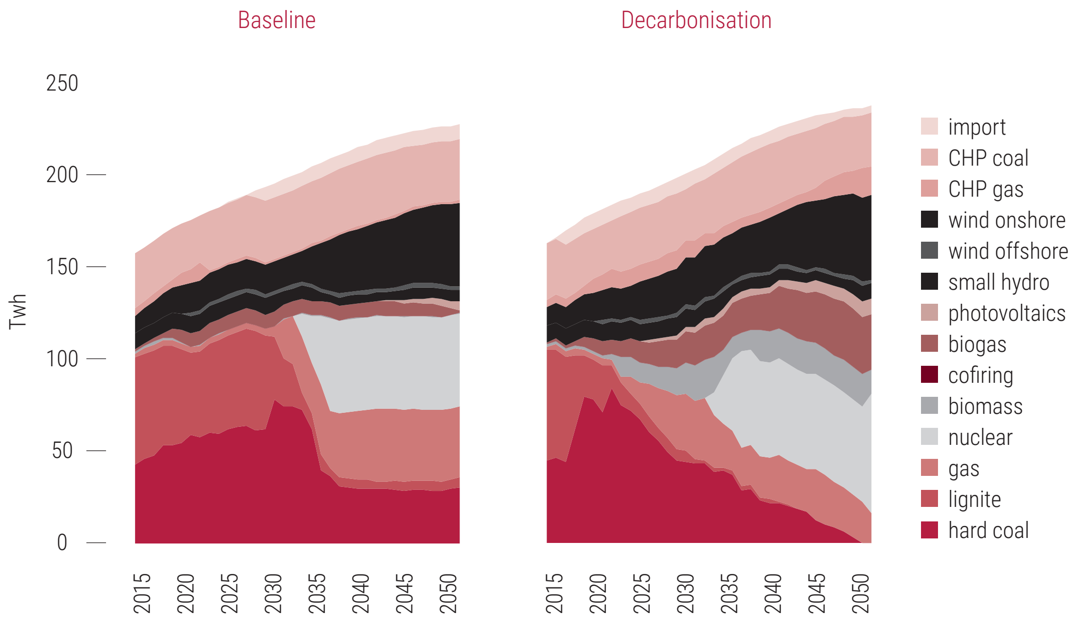
Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

3.2. Low costs of intermittent RES

To examine the case of a fast decline in installation costs of major intermittent RES (solar PV, onshore wind, and offshore wind), we use the 'low' cost trajectory projections in Hand et al. (2017), which assume that, between 2017 and 2030, PV, onshore wind and offshore wind costs will fall by 43%, 21%, and 40%, respectively, compared to the fall by 24%, 7%, and 31% in the trajectories used in Section 2. Surprisingly, a large reduction in RES installation costs does not significantly change the optimal mix under the baseline pathway. PV energy is introduced into the mix in the late 2040s; its share in 2050, however, is negligible. Similarly, traces of offshore wind can be observed, but clearly this technology does not play a significant role in this scenario.

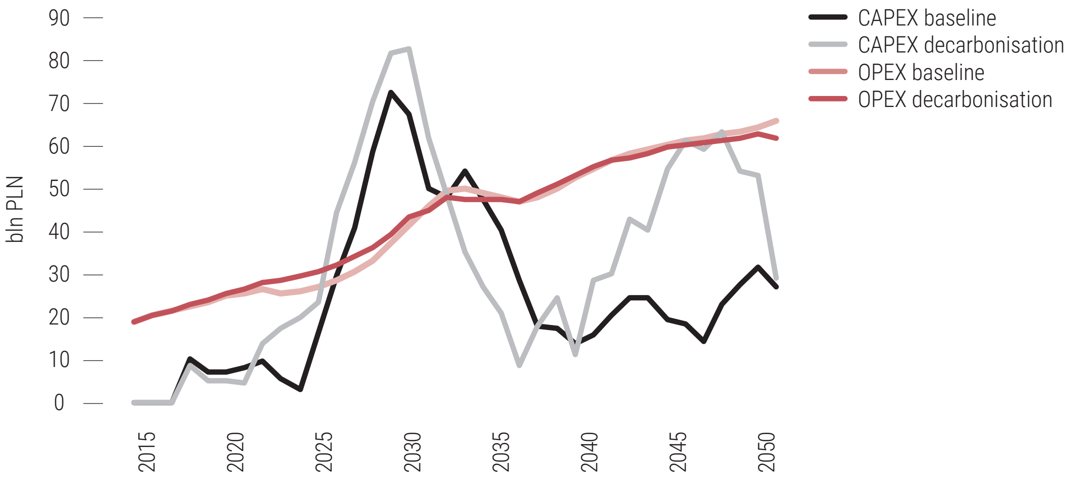
Figure 3.4. The optimal electricity mix under the baseline (left) and decarbonisation (right) pathways, assuming low costs of intermittent RES



Source: Output of the MOEM model.

Lower costs of installation decreases CAPEX in both pathways. As expected, this effect is stronger in the decarbonisation pathway due to the larger deployment of RES. As a result, the difference between CAPEX in the two pathways decreases: the cumulative CAPEX between 2017 and 2050 in the decarbonisation pathway is 300bln PLN larger than that of the baseline pathway under the assumption of low RES installation costs, and 330bln PLN larger under the assumptions used in Section 2.

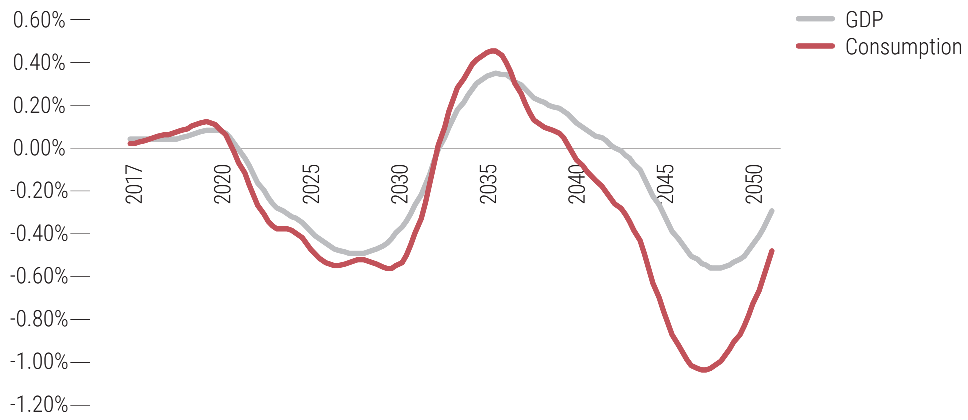
Figure 3.5. CAPEX and OPEX under the decarbonisation and baseline pathways, assuming low costs of intermittent RES



Source: Output of the MOEM model.

The GDP and consumption pattern resembles the pattern observed under the scenario used in Section 2: except for the 2030s, the decarbonisation pathway involves a loss, albeit an insignificant one in terms of its size. The largest loss in terms of GDP and consumption takes place in the late 2040s. In 2047, consumption under the decarbonisation pathway is 1% lower than under the baseline pathway.

Figure 3.6. The difference in GDP and consumption between the decarbonisation and baseline pathways, assuming low costs of intermittent RES



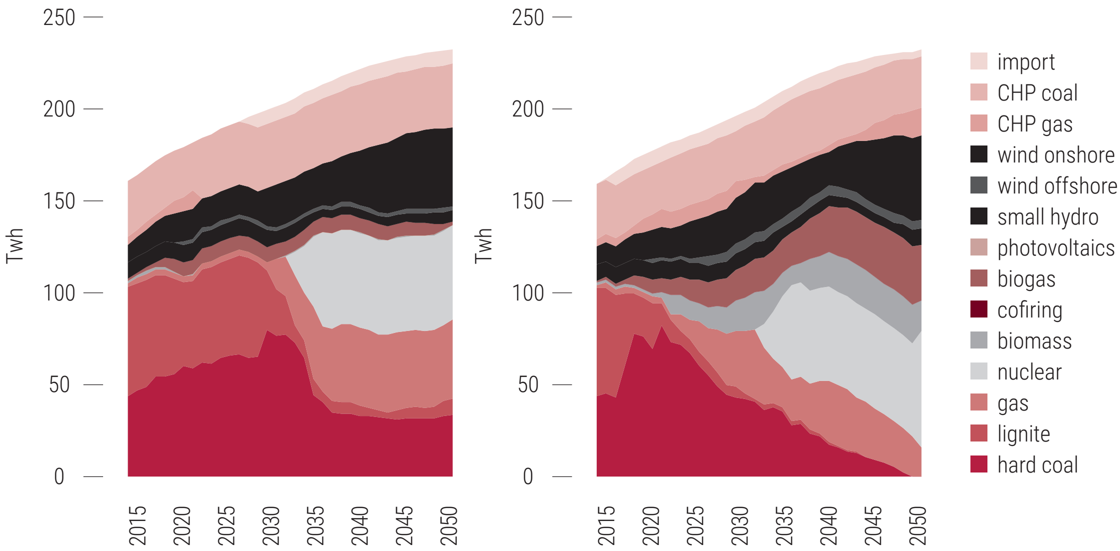
Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

3.3. High costs of intermittent RES

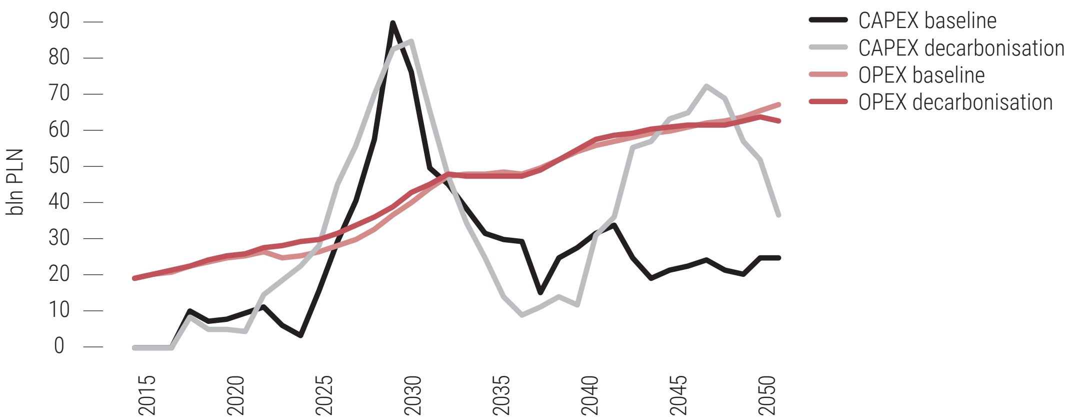
For completeness, we also report the outcomes of the analysis under the assumption that the RES installation costs follow the 'high' trajectory given in Hand et al. (2017).

Figure 3.7. The optimal electricity mix under the baseline (left) and decarbonisation (right) pathways, assuming high costs of intermittent RES



Source: Output of the MOEM model.

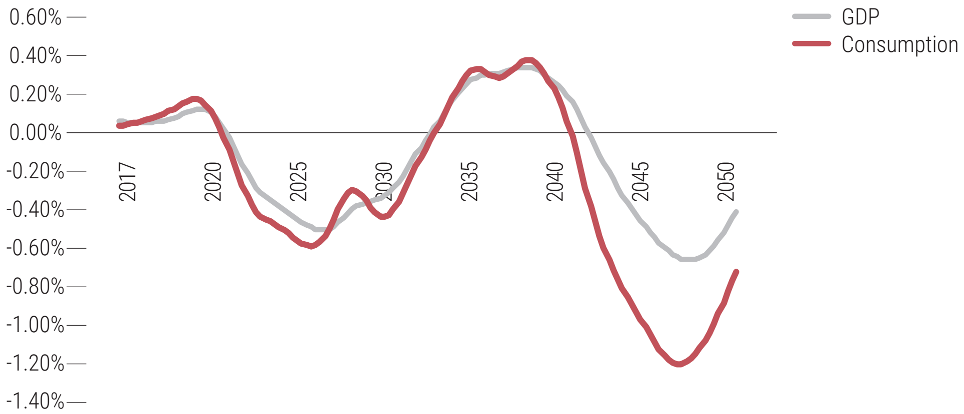
Figure 3.8. CAPEX and OPEX under the decarbonisation and baseline pathways, assuming high costs of intermittent RES



Source: Output of the MOEM model.

The results for GDP and consumption in the high-cost RES scenario do not differ significantly from those obtained in Section 2. The loss in consumption is slightly larger (1.2% in 2047), because now the large adoption of renewables is more expensive. However, the size of the loss remains rather small from a macroeconomic point of view.

Figure 3.9. The difference in GDP and consumption between the decarbonisation and baseline pathways, assuming high costs of intermittent RES



Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

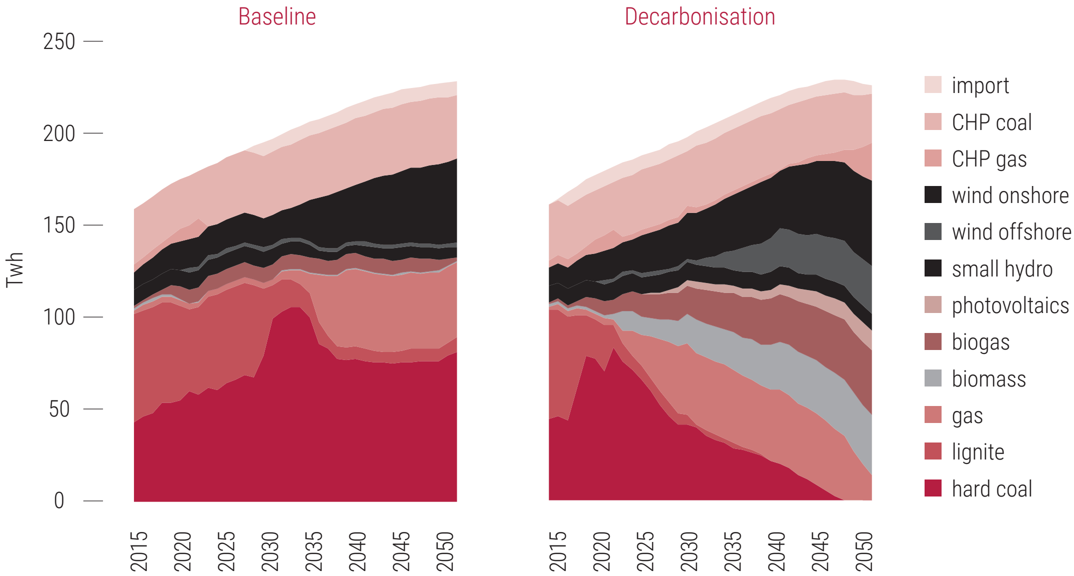
3.4. No nuclear technology

If there is no support for nuclear technology, it could be substituted with the deployment of offshore wind.

One final iteration of the analysis is carried out under a scenario where nuclear technology is not available. The adoption of this technology remains uncertain for two reasons: first, it may be blocked by groups of ecologists and policy-makers concerned about associated safety issues; second, it requires large-scale mobilisation of capital in a relatively short period of time, which may be infeasible.

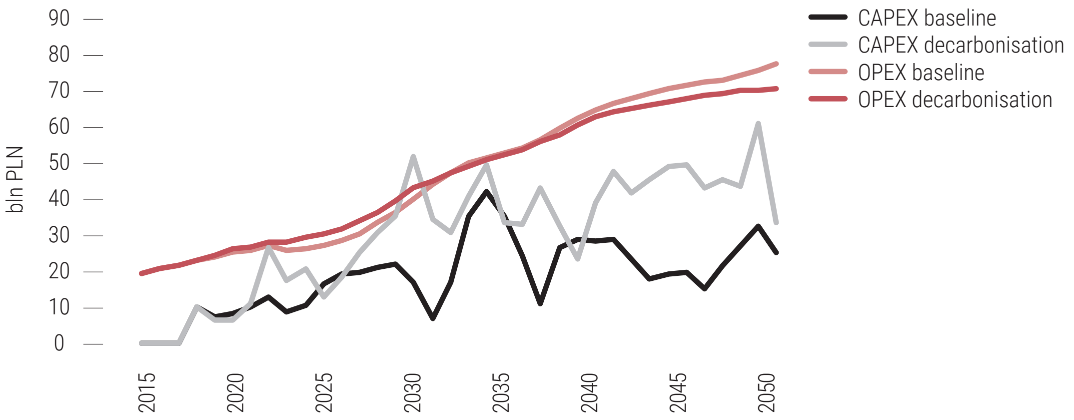
The first important observation from this exercise is that nuclear power can, to a large extent, be replaced by offshore wind (11% in 2050, which is larger than solar PV) in the decarbonisation pathway. The second observation is that the absence of nuclear power in the decarbonisation pathway may lead to power shortages. The simulation indicates a small shortage of 3% appearing in the second half of 2040s. To avoid this, a drop in demand would be required.

Figure 3.10. The optimal electricity mix under the baseline (left) and decarbonisation (right) pathways, assuming that nuclear technology is not available



Source: Output of the MOEM model.

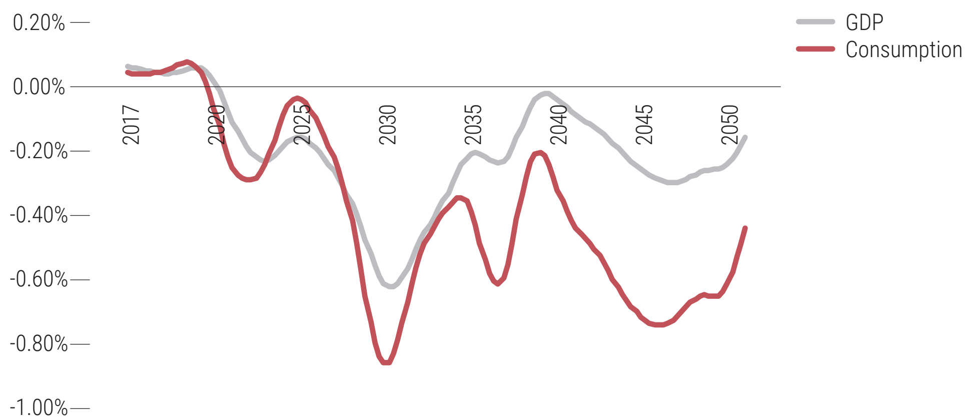
Figure 3.11. CAPEX and OPEX under the decarbonisation and baseline pathways, assuming that nuclear technology is not available



Source: Output of the MOEM model.

An increase in the construction of gas plants and renewables in the decarbonisation pathway now results in high demand for investments, starting in the late 2020s and lasting until the end of the analysed period (see Figure 3.11). This investment requirement translates into GDP and consumption losses. However, as in the case for the other scenarios, this loss is not significant.

Figure 3.12. The difference in GDP and consumption between the decarbonisation and baseline pathways, assuming that nuclear technology is not available



Note: The unit on the vertical axis is the level of GDP in the baseline scenario.

Source: Output of the MEMO model.

PART 2

Consequential risks beyond models' simulations

Due to the models' limitations, the simulations cannot account for all potential consequences of changes in the electricity mix. In this part we discuss the risks that are not captured in the simulations in Part 1. We discuss three risks associated with the baseline pathway and three associated with the decarbonisation pathway. Each risk is explored using tailored quantitative and qualitative methods. Furthermore, we attempt to quantify the importance of these risks using the Fuzzy Cognitive Mapping method.

4. Risks associated with the baseline pathway

In this section we highlight three risks associated with the implementation of the baseline pathway: 1) loss of international reputation, 2) dependence on imported coal, and 3) wasted investments into coal-related R&D. The description of the risks are based on the scientific literature, public debate, and interviews with relevant stakeholders.

4.1. International Reputation[3]

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Loss of international reputation due to continued consumption of coal could have negative consequences in other policy areas (e.g. agriculture, trade, or innovation).

The first of the investigated risks is the potential loss of Poland's international reputation as a result of implementing the baseline (i.e. coal-dependent) scenario. Since Poland is an active player in international relations at various levels, and given that climate change and energy transition are crucial topics discussed in international circles, this risk has been identified as a relevant and realistic development. Yet measuring the risk in objective terms is challenging; it can therefore only be interpreted in a relative way.

According to Cook (2016), reputation is important on the international stage because it facilitates cooperation among multiple actors and provides ex ante insight into the feasibility of a given form of cooperation. While 'reputation' itself is a multidimensional concept (Pineiro-Chousa et al., 2017), it can be defined as a relationship between at least two actors (a reputation holder and a reputation observer) that is based on the latter's expectations, beliefs, and attitudes towards the former's behaviour (Cook, 2016; Downs and Jones, 2002; Gray and Hicks, 2014). Such an understanding implies a few challenges that should be addressed. First, the process of creating a reputation does not take place in a vacuum – it is interpretative and context-dependent and, in international relations, it hardly ever 'starts from scratch' because it is influenced by the history of past experiences between actors (Cook, 2016). Second, a reputation is formed in the eyes of the individuals that constitute the audience for reputation-forming actions, and not states per se (Gray and Hicks, 2014). This is especially important, since it is not the broad public that is being present in the international environment, but national politicians, international bureaucrats, and selected interest groups (cf. Dreher and Lang, 2016). Third, an actor can be characterised by having many different reputations, therefore a reputation formed on the basis of a chosen action or policy (in this case the energy policy) does not exist in isolation from other actions and policies (Downs and Jones, 2002; Gray and Hicks, 2014).

In this respect, Poland suffering from a loss in international reputation (or, in other words, gaining a negative reputation from the international environment) could materialise if the Polish government chose to follow the pathway involving the high use of coal. It should be noted that the possibility of this risk occurring is already high: some years ago Poland gained something of a reputation as being an opponent of the EU's ambitious climate and energy policies (Ancygier, 2013; Gradziuk, 2014), meaning that expectations of an improvement in this area are not high (Wyciszkiewicz, 2014). Similarly, based on stakeholder interviews, in a global context the representatives of the Polish government are also perceived as not fully considering the significance of climate change, its complexity, or the need to undertake mitigation measures. For example, on the United Nations Security Council, on which Poland currently holds a non-permanent seat, the Polish representatives are perceived to not show enough interest in linking security issues with climate change, despite this issue having been recognised as an important security issue (e.g. in the context of Small Island Developing States, as well as the way climate change impacts on both migration and conflict vulnerability), even though it is believed that a change of stance could contribute to strengthening Poland's diplomatic position as an actor willing to take a lead (cf. Dröge, 2018).

[3] The results of this section are based on a literature review and interviews with four stakeholders from the government, political advisory, and industry sectors. The authors would like to express their gratitude to the stakeholders for their time and for providing important inputs that greatly contributed to this section.

A loss of international reputation can have several negative consequences. First, having a reputation that exerts low expectations from the very beginning of decision-making processes could lead to Poland being excluded from certain political alliances, coalitions, or partnerships that are created, or from efforts to establish ambitious decarbonisation plans and programmes in other policy areas outside energy, because it may be perceived as more of an obstacle to negotiations rather than a constructive collaborator. This is especially true since international and EU legislation concerning climate and energy policies represents an interdependent system related to agricultural, innovation, research, and trade policies. Second, the already established direction of such international and EU agreements (e.g. the Paris Agreement or the 2030 Energy and Climate Framework) aims at incremental and constant decarbonisation, so the Polish government will need to implement adequate regulations anyway. Finally, the system of financial incentives and subsidies provided by the EU in the form of its cohesion policy will continue to promote investments in low-carbon measures, which might bring obstructions during the negotiations of the EU's Multiannual Financial Framework. Additionally, since most of these funds will be directed to be spent at the local level, it will only strengthen the preference of citizens and local authorities to invest in renewables over other energy sources (Ancygier and Szulecki, 2014; Gwiazda and Ruszkowski, 2016), which will be reinforced by their health concerns related to air pollution and smog.

To create a positive image when it comes to climate change and energy transition issues, the Polish government has undertaken various steps addressed to both the public at large as well as international actors. The most important among them are: (i) hosting the United Nations Climate Change Conferences (COPs), which have already been organised in Poland three times (COP14 in Poznań in 2008, COP19 in Warsaw in 2013, and COP24 in Katowice in 2018); (ii) stimulating growth and development in the field of electromobility; (iii) advocating the idea of climate neutrality based on forestation (cf. Szulecka, 2016); and (iv) international research endeavours aimed at the development of clean-coal technologies. Additionally, the Polish government has (v) constructed a narrative based on the greenhouse gases (GHG) reduction targets stipulated in the Kyoto Protocol, which were obtained with considerable surplus and coupled with constant economic growth (cf. Skłodowska, 2018); (vi) called for a more just and fair reworking of the numbers related to GHG emissions and reductions in relation to other countries and their economies, and (vi) cited the US withdrawal from the Paris Agreement in June 2017 as a justification of its public support of coal (cf. Popkiewicz, 2017).

Nevertheless, although Poland is a member of various international forums dealing with climate-change mitigation measures, the European Union is the most important stage for Polish policy-makers. It is here where key negotiations take place, binding decisions are made, and where a state's reputation is formed. In the European setting the general position of the Polish government regarding its inclination to preserve the coal-based energy sector is clear, therefore there are no excessive expectations or attempts from other EU actors to change it. Polish representatives place great emphasis on the negotiations on the detailed provisions of the regulations in the EU's policy-making process since such negotiations serve not to help create a positive reputation for Poland, but, more importantly, are the basis upon which specific solutions are determined, which afterwards will need to be transposed and implemented into the Polish legal system. Additionally, the high level of technical and legal specificity related to these processes does not make it an attractive topic to be communicated to the broader public and therefore contributes little to a country's reputation outside of policy-making circles.

The risk of Poland gaining a negative international reputation by implementing the coal scenario is a realistic one. If it happens, its effects will be more observable at the European level than at the global one. In the global context, the implementation of a coal scenario may be equated with an unambitious climate policy, which may be interpreted as self-oriented behaviour that does not take any shared responsibility for the plight of those members of the international community that are more vulnerable to climate-change effects or for future generations. In the European context, despite the complexity of 'reputation' as a notion and the different potential interpretations that may spring from it, the most serious consequences of that risk may occur in regard to Poland's economic policy and its various interrelated branches. Thus, Poland's international reputation can also be understood as a function of its economic policy and, when combined with the EU's normative climate and energy policies, such a loss in reputation should not be overlooked by the Polish authorities.

4.2. Dependence on imported coal

ALEKSANDER SZPOR

For many decades, Poland's rich coal resources helped meet the country's energy demands and therefore constituted an important part of the Polish economy (Szpor and Ziółkowska, 2018). However, if some of the recent trends in the sector persist, its coal-based energy system may become more of a hindrance than a solution for energy independence and economic growth.

Continuing reliance on coal might pose a threat for energy security and economic growth in the long run. This risk could be mitigated if the costs of coal extraction in Poland goes down or if the energy mix becomes more diversified.

To take a negative scenario, despite further state support of the coal sector, restoration of the sector's long-term economic viability is unlikely. Even if productivity within the sector improves, it will most likely be achieved by a further reduction in domestic coal production. In this case, importing coal would only strengthen the position of Poland as a net coal importer. The possibility of increasing coal imports to Poland is reinforced by the fact that the current methodology of estimating coal resources does not take fully into account the economics of coal exploration.

The realisation of this scenario would have two major consequences. First, an increased share of Russian coal in domestic consumption would increase Poland's exposure to pressure from this country. The significance of this is compounded by the fact that Russia is already the main exporter of oil and gas to Poland. Secondly, it would undermine the recent and planned investments in coal-based energy infrastructure (power plants and grids). The dominance of coal is often defended by the argument that the fuel is produced by the domestic economy. If domestically produced coal is replaced by imported coal, this argument will no longer be valid.

4.2.1. THE PUBLIC DEBATE

Higher imports of coal to Poland is related to several internal and external factors. Internally, the situation of the coal sector is bound by limited production capacity. It is being presented by the current Minister of Energy as a result of the previous government's negligence over its failure to mobilise domestic capital (Wawrzyszuk, 2017) or even as part of the policy of that government to intentionally destroy the sector (Radiomaryja.pl, 2017).

Among less prominent participants of the public debate, there is a widespread opinion that the weak competitiveness of the Polish coal-mining sector is strongly related to wage pressures exercised by coal-mining trade unions. This is especially the case in the largest coal-mining company in Poland, where around half of the fixed costs relate to personnel costs (Dudała, 2018). A number of other problems, such as complex remuneration schemes or inefficient organisation of work, also reduce the flexibility of major coal companies and their ability to compete on the market in terms of production capacity (Oksińska, 2018).

Another important part of the discussion on internal factors are the geological and economic aspects of Polish coal reserves. Representatives of the coal sector and many politicians claim that the combination of rich coal resources and domestic business in Poland form a comparative advantage that Poland should explore (Kn/PAP, 2017).

Other views expressed in the public debate include the belief that rich coal reserves are a myth, as the economic reserves (in contrast to resources) are scarce. This is reflected in the constantly increasing depths of mines and lengths of galleries, which have two major negative effects on productivity. First, this factor prolongs the time needed to transport miners to longwalls and effectively reduces the time spent on actual mining. Second, it increases the risk of catastrophes occurring (e.g. methane explosions) and thus requires more investment in security measures (CIRE.PL). Another important geological constraint is limited domestic resources of coal with a low share of sulphur (which is especially required in heat production).

Imports of coal are also facilitated by other external factors like the good quality of Russian coal, despite an established political narrative whereby it has been labelled 'worthless Russian coal' (Fakt.pl 2014). The competitiveness of

Russian coal is also supported by the investments made in transport infrastructure in Russia and Belarus, as well as the fact that the transport of coal in Russia enjoys state subsidies.

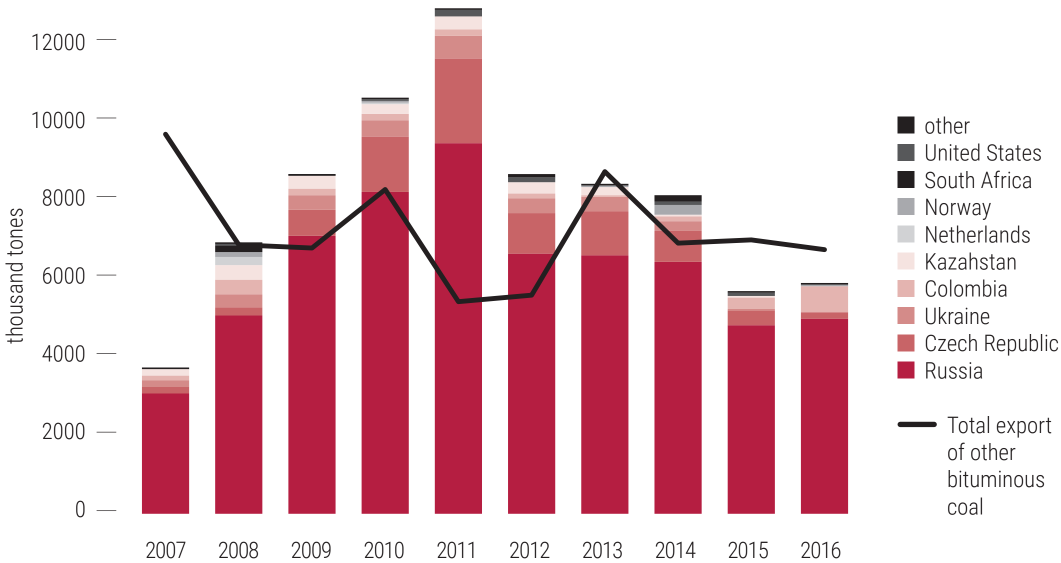
4.2.2. THE MAIN TRENDS AND PROSPECTS

Of the three main types of coal produced and consumed in Poland, only lignite coal cannot be transported over long distances. Therefore, it is hardly exportable or importable. Considering also that the power plants fired by lignite cannot use any other type of coal, we shall not include that factor in the main analysis of this risk.[4]

The two other types of coal – thermal and coking – are produced in, imported to, and exported from Poland. The production and consumption of coking coal are significantly lower than that of thermal coal. However, as the price of coking coal is substantially higher, it remains more attractive than thermal coal. In terms of import partners, coking coal is more balanced, and Russia plays a minor role in it. Russia's dominance in terms of imports is clear in thermal coal, and hence our main analysis focuses on this type of coal.

Between 2007 and 2016, Poland was mostly a net importer of thermal coal and Russia was Poland's main supplier (Figure 4.1).[5] In this period, domestic thermal coal production fell from 73.8 to 59.2 Mt, that is by around 20%. In the same period, the level of thermal coal imports increased (from 3.7 to 5.8 Mt) and the level of exports fell (from 9.5 to 6.6 Mt). Production and balance of trade data from the last decade does not manifest very clear trends, and therefore no definite conclusions for the future can be drawn. However, a comparison of the data from the initial and final years of this period indicates that the Polish coal sector is covering a diminishing share of domestic thermal coal demand. Up until now this process appears to have been very slow and it seems the dominant position of domestic coal will not disappear in the near future. However, the role of imported coal can become significant in the long run if the relative competitiveness of Polish mines continues to decline.

Figure 4.1. Polish imports by country partner and total exports of other bituminous coal (2007–2016)



Source: Eurostat.

[4] In this context the role of lignite is important only as in the context of it being one of the fuels balancing the exposure of risk related to the importation of fuels.

[5] The main types of coal produced and consumed in Poland are thermal coal (classified as 'other bituminous coal') and coking coal. Coking coal in the given period (2007–2016) was imported mainly from Czechia (35%), the United States (32%), and Australia (26%), and only 2.7% of the total was imported from Russia.

The competitiveness of the main coal companies did not improve visibly in this period despite the restructuring programmes undertaken by the previous and current governments. A study by Dubiński and Turek (2017) showed that the restructuring process over the last 25 years did not solve the problem of its inefficiency related to, among other factors, support for permanently unprofitable mines. An analysis of the key indicators in the same period of time by Korski, Tobór-Osadnik, and Wyganowska (2016) pointed to the decreasing quantity of good quality coal leading to the disappearance of location rent within the Polish coal-mining sector. Based on their analysis, the authors expect further reductions in coal consumption in Poland in the future.

More in-depth research into selected coal mines carried out by Jonek-Kowalska and Turek (2016) confirmed the negative impact of natural risks and inflexible remuneration schemes on the performance of coal mining. The latter factor has proved particularly costly during the period of downturn in the sector. Moreover, a study by Jonek-Kowalska (2017) showed that plans for installing new technologies are unlikely to be implemented in the short or medium term due to financial constraints.

4.2.3. CONCLUDING REMARKS

The increasing dependence of Poland on imports of coal, especially from Russia, is a scenario that is likely to occur; however, the scale and pace of this process would only pose a substantial risk if several trends were to coincide.

First, it would require that none of the major policies to diversify energy sources supplies were realised, namely the electrification of transport (aimed at reducing the dependence on oil supplies coming almost entirely from Russia) and the new gas pipeline (the 'Baltic Pipe') from Norway (to reduce dependence on gas imports from Russia).

Second, it would require that the internal transformation of coal did not achieve at least a major part of its strategic goals, namely improvements in the flexibility of wages in coal-mining companies, the closure of permanently unprofitable mines, and investments in R&D.

As for the pace of increasing imports of coal, although new investments in coal mines are rather unlikely within this timeframe, at least part of the existing mines will continue to produce coal for political, technological, and economic reasons. Also, the import capacity of Poland and export capacity of Russia cannot be substantially increased overnight.

Considering the above, the risk of increasing imports from Russia is high, yet the pace and limits of this process can be controlled to a certain degree through investments both in the coal sector and in alternative energy technologies independent from supplies from Russia, such as RES (including biomass) and gas (should the Baltic Pipe be realised before 2022).

4.3. Waste of R&D resources

JAN WITAJEWSKI-BALTVILKS

In the baseline scenario, the benefits from coal-related R&D (required to increase the efficiency of both coal mining and electricity generation) will be limited as the global shift to alternative energy sources becomes more pronounced.

Remaining on the baseline pathway involves the continuation of large-scale investments in coal-related industries including the mining sector, manufacturers of specialist machinery and furnaces, and specialist coal plant construction companies. Part of this investment will be devoted to research on how to improve existing technologies as well as how to adapt technologies developed elsewhere to Polish conditions. Similarly, the continuation of production in coal-related industries will allow the new generation of engineers, designers, and constructors to gain or expand their experience in handling coal-related technologies. Research and experience reinforce one another and together form a tacit knowledge at the sectoral level, which we could label as coal-related know-how.

Normally, this know-how would be of high value because it (i) increases the efficiency of production in the future and (ii) allows for further improvements in technology (see the discussion of the spill-over effects in the managerial and growth literature). The longer those technologies will be utilised in the future, the larger the return on this investment will be.

On the other hand, the effort of gaining know-how will bring only a small return if coal-related technologies lose the race with alternative energy technologies. The global technological frontier of renewable energy sources will most likely continue to move forward very fast. The moment that these technologies become much cheaper than the coal technologies, the global demand for coal and the output of coal-related industries will start shrinking rapidly. Unavoidably, the Polish energy sector will have to follow this trend and the domestic demand will shrink too. Should this happen the knowledge and experience gained today will be of no use in the future.

At the same time, the effort put into acquiring know-how in coal technologies has opportunity costs. If today, instead of investing in coal, Poland invested in RES, the R&D sector will have an incentive to follow the same switch. High domestic demand for RES will incentivise companies, including manufacturers, developers, and constructors, to invest in R&D into RES technologies. In addition, the investment will spark the learning-by-doing process that allows firms and, most importantly, involved individuals, to gain valuable experience. The RES-related know-how acquired from domestic research and experience will be valuable because it will help to absorb the fast technological progress of RES at the global technological frontier (Goulder and Schneider 1999). In the absence of such know-how, the costs of RES installations will likely be higher than in other countries.

Whether or not RES technologies win the race with coal technologies depends heavily on the choices of other countries. If large global regions, such as the EU or China, signal their commitment to invest in clean-energy technologies (such as RES), then inventors and R&D companies across the world will have a clear incentive to continue the development of these technologies. In fact, these technologies are today developed not only in Europe but also in China and the US. Should this trend continue, RES technologies will inevitably win the race with the traditional energy technologies (such as coal-extraction technologies) in the long run. This argument is formally discussed in Witajewski and Fischer (2018).

The work by Witajewski and Fischer (2018) predicts that the switch of Polish companies from gaining coal-related know-how to gaining RES-related know-how will take place without government intervention when RES technologies start winning the race. Nevertheless, the intervention can be desired for two reasons. First, promoting investment in coal will delay the switch. Society would gain more if companies started gaining RES-related know-how as soon as possible. Second, investment in coal may the send the wrong signal to firms that the demand for coal-related is guaranteed in the future.

5. Risks associated with decarbonisation pathway

In this section we present three risks related to the implementation of decarbonisation pathway. Our analysis derives from the public debate in which widely discussed risks are a) intermittency of RES, b) dependency on imported technologies and c) inability of workers from the mining sector to find employment in other sectors .

5.1. Intermittency of RES

MAREK ANTOSIEWICZ

The Model for the Optimal Energy Mix in Poland discussed in the first part of the report does not take into account several factors that are crucial when conducting an analysis of the transformation to an electricity-generation system based on RES. Since it is a long-term horizon planning model in which the time period is a year, it does not incorporate crucial details of the functioning of the energy system that appear when the system is modelled using a finer temporal resolution. Because of this, it is important to supplement the analysis with additional research that takes such elements into account.

Increasing RES output will result in only a small cost increase, and will carry no other significant risks. Currently the cheapest RES option for Poland is onshore wind power, which should be supported by significant gas power reserves.

One such factor are costs linked to the intermittency of renewable electricity sources – primarily wind and solar. Relying on these power sources requires back-up power generation for periods of time when electricity from these sources is not available, and therefore results in additional costs. Furthermore, the MOEM takes into account the hourly, daily, weekly, and seasonal variations in energy demand in only a simplified way, and it is possible that not taking them into account underestimates the costs of integrating renewable energy sources. Another group of costs are linked to the necessity to strengthen the energy grid and make it more flexible in order to accommodate fluctuations in electricity production. Finally, the integration of RES may reduce the efficiency of conventional power plants due to the fact that at times of low demand and high RES production they might need to be turned off.

In order to assess the aforementioned issues, we use a bottom-up energy system of the Polish electricity-generation system called Calliope (see Pfenninger, 2017). Due to the high temporal resolution of the model (the time period of the model is one hour), the model is particularly well suited to analyse the problems of wind and solar intermittency. The model defines available electricity-generation technologies along with their costs (which are divided into several categories: the capital cost of installation, the lifespan of plants, fixed and variable maintenance costs, the cost of fuel) and constraints (such as minimum or maximum installed capacity, hourly flexibility of output, available resource for wind and solar), as well as time series data for electricity demand. A single simulation consists of running the model for an entire year (e.g. 8.760 hourly time periods for the year 2015) and results in an optimal energy mix consisting of installed capacity and electricity generation by plant type. For electricity demand we use data for the year 2015 from the Polish National Grid Operator (www.pse.pl), whereas cost parameters are taken from Klima et al. (2015), EIA (2013), DECC (2014), and PB (2013).

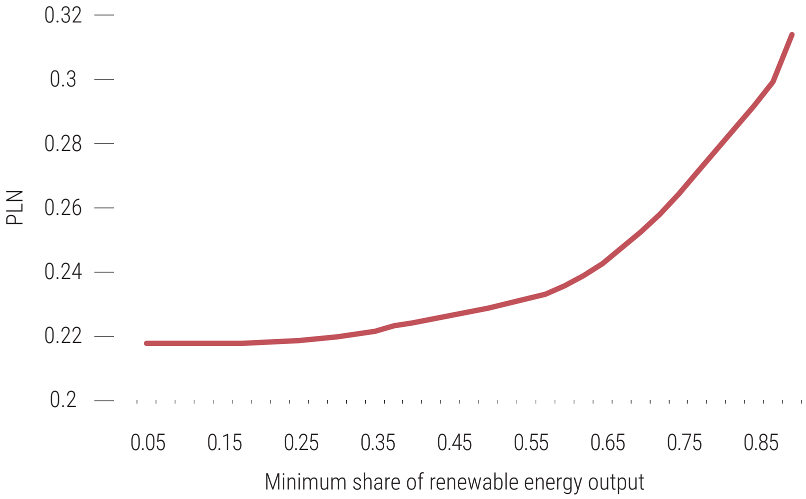
In order to assess the potential cost increase associated with pushing for a higher share of renewables, we run a simulation sweep in which we impose an additional constraint that the share of electricity generated from RES must exceed a given threshold from 5% to 95%, and analyse how the resulting energy mix changes while we increase this share.

The resulting levelised cost of producing electricity is shown in Figure 5.1. Increasing the required share of renewable electricity production results in an increase in the cost, as well as the rate at which the cost increases. The initial increase in the cost is relatively small. For a low (up to 30%) and mid (up to 60%) share of renewables, the cost goes up by only 0.9% and 8.1%, respectively. After crossing the 60% barrier of RES in the mix, costs go up significantly. At current prices, a mix consisting of 90% of RES would cost 44.2% more.

Figure 5.2 shows the details of the resulting energy mix, both in terms of energy generation and the installed capacity structure. As we increase the required share of renewable energy in the system, we see that coal is slowly being replaced with wind power. However, a significant back-up of flexible gas power is needed in order to generate power during periods of peak demand and insufficient wind production. While gas turbines are relatively expensive to operate, they only need to be used sparingly and therefore the overall increase in the cost of producing electricity is not large for medium shares of renewables in the mix. The slightly higher rate in price increase in the 30–60% range is due to the fact that at this stage wind power is starting to push out lignite from the mix, which is cheaper than hard coal.

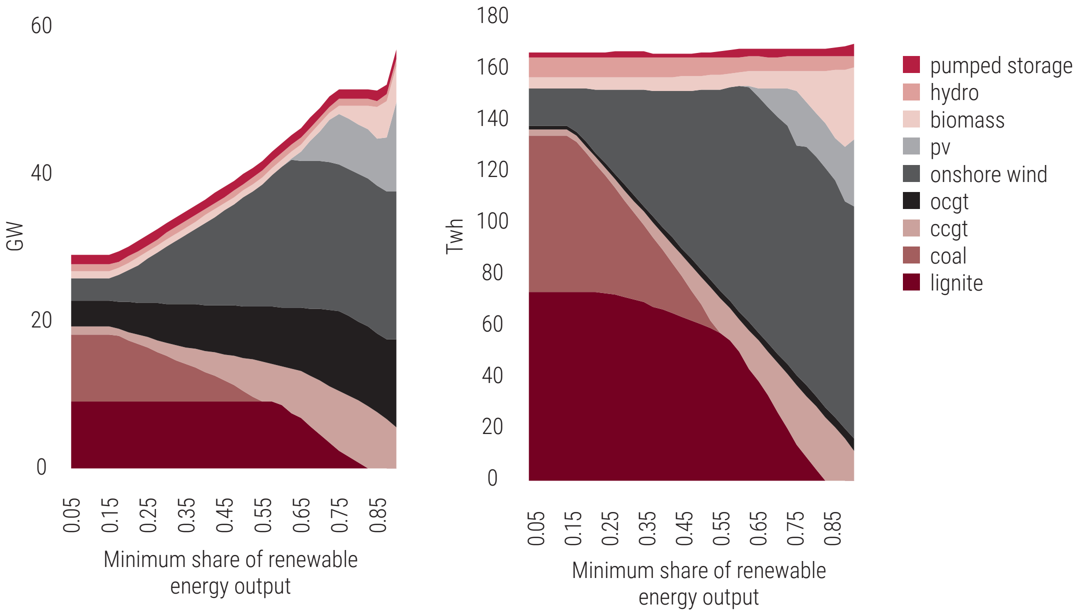
To conclude, the analysis carried out using the Calliope model does not show significant risks associated with the intermittency of energy sources when pushing for renewable energy in the range of up to 50%. Since Poland is struggling to achieve a 15% share of renewable energy in its mix, in the foreseeable future we see no techno-economic barriers for opting for such a change. The amount of gas that will need to be used for backing up wind-power generation is 1.09 to 2.59 bln m^3 for a share of renewables, equal to 30% and 60%, respectively. This is no more than 15% of Poland's yearly gas consumption, and following the opening of the LNG terminal Świnoujście, we see no threat in terms of energy security.

Figure 5.1. Levelised cost of electricity in PLN per kWh for different levels of minimum required share of renewable energy output



Source: IBS own calculations for Poland using the Calliope model.

Figure 5.2. Electricity production (left panel) and installed capacity (right panel) structures for different levels of minimum required share of renewable energy output



Source: IBS own calculations for Poland using the Calliope model.

5.2. Dependency on imported technologies[6]

ANDRZEJ CEGLARZ

Switching to renewable energy sources is unlikely to result in the technological dependency on foreign technology and manufacturers, according to stakeholders representing the RES industry.

While there are sufficient prospects for the development of renewable energy sources in the Polish power sector, according to some stakeholders (Forum Energii, 2017; Paska and Surma, 2014), Poland will probably not meet the overall 15% RES target in its gross final consumption of energy by 2020 that it committed to as part of the EU's Renewable Energy Directive (2009/28/EC) (Janeiro and Resch, 2017). The potential for the use of RES in 2050 is promising (see Section 3); however, this development is subject to navigating another risk, namely technological dependency. Since from a global perspective the most dominant RES technologies are wind and solar, some stakeholders argue that opting for these technologies in Poland would serve to augment the economic dominance and political power of actors specialising in their production, development, and promotion, such as Germany (Jakóbik, 2018; Ruszel, 2017). Thus, the broad implementation of these technologies in Poland would lead to technological dependency on foreign producers and manufacturers. This, in turn, would result in increasing import costs, a lack of job creation, and the rise of an unprofitable segment that does not contribute to GDP.

According to stakeholders representing the industry, the likelihood of this pessimistic scenario occurring is low because Poland, generally, has enough domestic capacity to avoid technological dependency and to develop technological niches, which would provide highly specialised RES components, solutions, and services. Stakeholders point out that such development is already taking place in relation to photovoltaics (cf. IEO, 2017), electromobility batteries, and biomass. In addition, offshore wind carries great potential to involve Polish capital, firms, and suppliers. According to Sawulski (2017), up to 70% of offshore wind farm investment costs can be covered by the Polish value chain, if it develops in parallel with the technology deployment in Poland (see the detailed description of the offshore market below). Regarding the photovoltaics market, although the installed solar capacity in the system is marginal, 60% of all photovoltaic modules sold in Poland in 2016 were produced domestically (IEO, 2017) and there is the potential to further develop and introduce innovations in this sector.

What is more, some stakeholders argue that incentivising the deployment of RES might bring benefits that go beyond profits for private firms. Choosing a path leading to the development of specific technological innovations or services would contribute to intensifying international cooperation in the energy field (cf. Gawlikowska-Fyk et al., 2017).

It should be also noted that, if technological dependency was to occur, different types of RES could be affected differently. For example, technological dependency would occur not only in relation to a type of technology per se, but possibly also to the availability of specific resources. This is especially relevant to rare-earth elements needed for the production of RES components like in solar panels and, possibly, permanent magnet generators in wind turbines, which could increase their efficiency and reduce their overall costs (Smith Stegen, 2015).

To conclude, the implementation of an RES scenario could bring with it the risk of technological dependency, but this will likely not materialise. It would be only possible if there were negligence in investing in domestic resources and if the domestic industry did not direct any resources into R&D in the RES sector.

6 The results of this section are based on a literature review and interviews with four stakeholders from the government, political advisory, and industry sectors. The authors would like to express their gratitude to the stakeholders for their time and for providing important inputs that greatly contributed to this section.

BOX: EXAMPLE: TECHNOLOGICAL READINESS OF POLISH FIRMS FOR THE DEPLOYMENT OF OFFSHORE WIND

JAKUB SAWULSKI

In recent years offshore wind has become one of the fastest-growing renewable energy technologies in the world. This is the case also in Europe, where the technology is gaining momentum, especially in countries with access to the North Sea. The Baltic Sea is also being explored, mainly by Denmark and Germany, but its potential is still largely unused. Poland – with its favourable geographical position (featuring a long coastal line and good wind and soil conditions) as well as a significant need to establish new energy sources emerging from the gradual decarbonisation of the economy – is expected to play a pivotal role in kick-starting the offshore market on the Baltic Sea.

Currently, at least 50% of the offshore wind farm investment costs can be covered by the Polish value chain.This share can rise to up to 70%, assuming the value chain develops in parallel with technology deployment in Poland.

Sawulski et al. (2018) evaluated the offshore wind innovation system in Poland, addressing the issues related to the development, diffusion, and possible use of offshore wind technology. They used the Technology Innovation System approach based on the methodology developed by Bergek et al. (2008), Hekkert et al. (2011), Luo et al. (2012), and Wieczorek et al. (2012). This procedure consists of both structural analysis, i.e. mapping the main components of the innovation system, and functional analysis, which involves evaluating how the innovation system is behaving in terms of key processes. Following these steps, innovation system failures are identified and policy implications formulated. The study was based on 11 in-depth interviews with stakeholders representing public administration, universities, non-governmental organisations, and industrial actors, as well as on other available sources: scientific and industrial literature, scientific publication databases, patent databases, and governmental data. In this section we summarise their findings.

The authors show that although there are no offshore wind farms in Poland, Polish industry can cover a large part of the offshore wind farm investment. There are close to 70 business entities that are directly active in this sector or ready to be involved in this business on a local and global scale. So far, activity in this area shows that large state-owned companies – PKN Orlen and PGE EO, as well as the privately owned Polenergia – will probably be the most important investors and project developers. There are also at least a few significant players on the global offshore wind market with their businesses located in Poland, i.e.: GSG Towers, Energomontaż-Północ Gdynia, ST3 Offshore, GS Seacon, Aarsleff, and Spomasz Żary. These companies mainly specialise in the supply of foundations, towers, and substations. Their portfolio includes many realised projects, in particular for offshore wind farms located on the Baltic and North Seas. Moreover, Tele-Fonika Kable is one of Europe's largest cable producers, whose cables have been largely used in offshore wind investments worldwide.

The strength of the Polish offshore wind value chain is its well-developed ship-building industry. The offshore wind sector requires specialised vessels for environmental and geological research, transport, and installation of wind farm components, as well as servicing wind farms. The industry covering the construction and repair of ships and boats in Poland includes over 5,000 enterprises (of which about 80 employ more than 50 workers), and employs almost 30,000 workers (2015 data) (Statistics Poland 2016). Polish ship-building companies offer a few models of vessels dedicated for offshore wind farms investments, which have already been used in offshore wind projects worldwide.

In this context, the possible development of the offshore wind technology in Poland may be a new stimulus for the development of the northern part of Poland. During Communism, it was economically one of the most important Polish regions, with the ship-building industry a key specialism. At the same time, this region has been strongly affected by economic transformation, and today the unemployment rate in the West Pomeranian voivodship (one of two provinces in the north of Poland) is significantly higher than in the rest of Poland.

The analysis by Sawulski et al. (2018) shows that, currently, at least 50% of the offshore wind farm investment costs can be covered by the Polish value chain. This share can rise to up to 70%, assuming the value chain develops in parallel with technology deployment in Poland. However, there are still some important gaps in the presence of relevant industrial actors for offshore wind deployment in Poland. This is especially the case when it comes to nacelle and rotor production. These two elements, together with blade supply, account for about one-third of offshore wind farm investment costs.

According to the results of the study, the innovation system is hindered mostly by policy-makers' unclear attitude to offshore wind technology deployment in Poland. This results in, among other things, a lack of national policy objective, unknown future market size, and uncertainty about support policy. The authors identify the political decision to introduce offshore wind to the Polish energy strategy as a precondition for the development of the technology in Poland. However, this is insufficient. The authors identify the lack of turbine suppliers in the Polish value chain as one of the most important blocking mechanisms to ensure greater participation of the Polish industry in future offshore wind projects. In the short term, however, the probability of having a new Polish market player in that area is rather low. Public policy should concentrate on using the available instruments to encourage foreign companies, especially nacelle and rotor producers, to locate their subsidiaries in Poland. This policy could include tax incentives, investment credits, infrastructural subsidies, and the sharing of investment areas (especially in the northern part of Poland), as well as other forms of non-financial support. The aim of attracting foreign investors in that area is to stimulate the technology-absorption process (e.g. by establishing joint ventures), strengthen the national value chain, and in the long-term to transform Polish offshore wind business from the role of sub-supplier to the position of general contractor.

Other policy implications concern improvements in knowledge and energy infrastructure. The problem with the insufficient contribution of knowledge to the innovation system emerges from both the inadequate number of knowledge actors as well as the rather poor quality of research. This stems from inappropriate incentives created by science policies. Scientists do not generally respond to the needs of the private sector, as they are rewarded mainly for theoretical scientific papers and have no inclination to search for inspiration in business and provide commercially applicable knowledge. The incentives for international cooperation, which may help in transferring the knowledge from more experienced countries, are also weak. Regarding infrastructural issues, adapting seaports and building new as well as improving existing grid infrastructure are the two main challenges. For the latter, the concept of international marine networks in the Baltic Sea are highly promising, as they can significantly reduce the costs of connection to the grid (which in Poland incurred by investors). These ideas require support and engagement from policy-makers, especially regarding international cooperation between countries potentially interested in such projects.

5.3. Decline in employment

JAN WITAJEWSKI-BALTVILKS

The large-scale deployment of renewable energy sources implies a significant reduction in the demand for coal and labour in the mining sector. If this drop in demand is associated with job losses for workers, those workers will need to find employment in other sectors. However, if the skills of those workers do not match the requirements of jobs in other sectors, their productivity will be low and some of them will leave the labour market. From a macroeconomic perspective a reduction in the labour force will result in a fall in GDP. From a social perspective, the loss of status, reduction in wages, and large-scale lay-offs in the mining regions will result in social unrest.

The findings from the literature

This mechanism is partly taken into account in the MEMO model and other general equilibrium models. These models usually predict a negative effect of climate policies on labour, though for carbon tax policies there is the possibility of a double dividend through productive spending of tax revenues. Indeed, the prediction discussed in Section 2 of this report confirms the results of other studies. For instance, the ENV-linkage model by the OECD (2018) predicts that an ambitious climate policy will have a negative effect (carbon tax above USD40/tCO2) on the wages of blue-collar workers in OECD countries. It also predicts a small negative effect on total employment if the revenue from the tax is recycled through a lump-sum transfer to workers.

Opposition towards labour restructuring in Poland can be strengthened by the experience of the past transition, which was not fully successful – a large proportion of miners left the labour force altogether instead of finding new employment.

Several other studies have analysed the impact of climate policy on the labour market, usually with the use of computable general equilibrium models. For instance, Boeters and van Leeuwen (2010) used the WorldScan impact assessment model to examine the effect of emission reductions in several European countries. Montgomery (2009) studied the consequences of the American Clean Energy and Security Act of 2009 for the labour market in US. Their model takes into account that wages cannot fully adjust to changes in demand. As a result, the policy leads to a crowding-out effect that results in a growth of unemployment.

However, the traditional economic models likely underestimate the effects of decarbonisation on the decline of employment. Standard economic models, including the MEMO model used in Part 2 of this report, assume a smooth flow of labour between sectors. In contrast, recent empirical evidence suggests that the flow of workers between sectors after major structural changes is slow (Autor et al., 2016; and Tyrowicz and van der Velde, 2014). If workers leaving that sector cannot easily adapt to the requirements of other sectors, then they will leave the labour market altogether and become inactive.

The determinants of employment decline

The scale of the decline in employment following decarbonisation depends on:

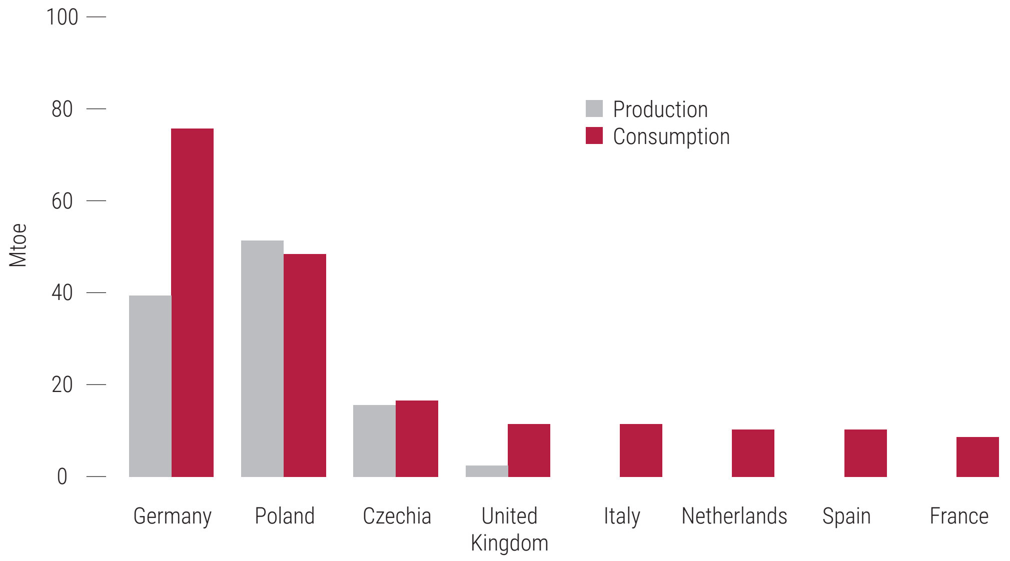
- the change in demand for coal after the deployment of RES technologies
- the change in demand for labour after the drop in demand for coal
- how fast the drop in demand will be and whether the drop in the number of workers could be achieved by natural attrition or whether it must involve lay-offs
- the opportunity of workers to find jobs in other sectors
- whether or not the revenue from the carbon tax is devoted to lower income tax.

Below, we discuss each element of this chain in turn.

The extent of the crowding-out of coal by other energy technologies depends on whether the deployment of renewables is accompanied by policies promoting the electrification of heating and transport. If it is, then additional power from renewables will be utilised to cover the additional demand generated by the electrification and it will not generate pressure to decrease the consumption of coal. However, the scope of the offsetting effect of electrification of transport and heating is limited. For instance, according to the projection made in Barton et al. (2013), in 2050 a fleet of 24.7mln electric vehicles would require 37TWh, which is only 16% of the total electricity produced in Poland in 2050 (see the projections for the MOEM model). If the production of electricity from RES grows faster than the growth of additional demand from the electrification of heating and transport, the crowding-out of coal electricity is unavoidable.

As shown in Figure 5.3, contrary to other major coal-consuming European economies, almost all coal consumed in Poland is produced domestically. In addition, the possibilities of exporting coal from Poland are limited due to its high extraction cost, low quality, and large competition from Ukraine and Russia. This means that a reduction in demand for coal will be reflected proportionally in the output of the Polish mining sector, releasing factors of production that were previously engaged in that sector (see also the discussion on imported coal in Section 4.2).

Figure 5.3. Coal production vs coal consumption in Poland and selected other EU countries

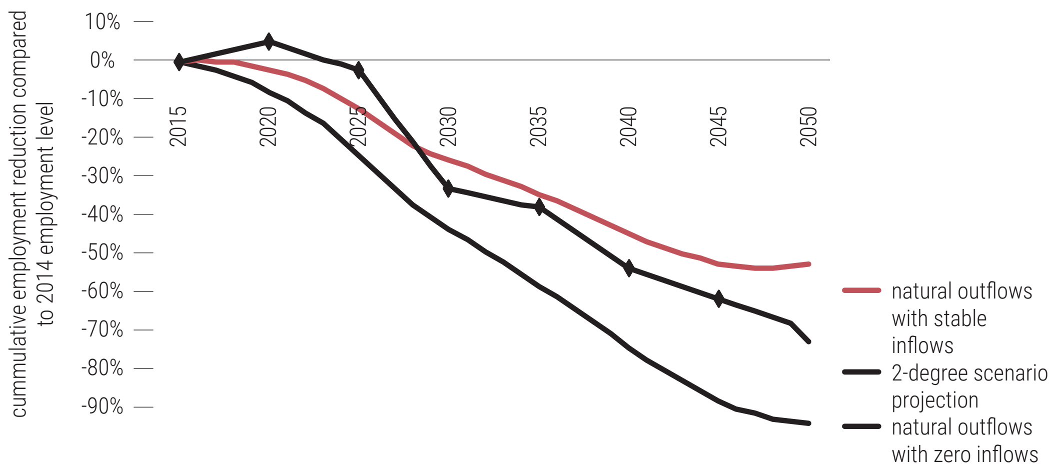


Source: IBS own calculations based on stats.IEA. Data for 2014.

Decarbonisation does not necessarily imply a significant decline in employment – a reduction in employment in the mining sector could be achieved mostly by a hiring freeze and natural attrition.

The opposition towards labour restructuring can be strengthened by the experience of the past transition, which was not fully successful: many miners left the labour force instead of finding new employment. Whether or not the future transition will generate the same problems depends on the speed of the transition. The past transition involved mass lay-offs concentrated over a short period of time. If the transition involves lay-offs that are smaller and spread over a longer period of time, then most of the reduction in employment could be achieved by natural attrition. There are a number of workers in the sector who will retire in the next two decades. A report on coal transition in Poland (Witajewski-Baltvilks et al. 2018) indicates that under a hiring freeze, a phase-down of the coal sector spread across three decades would involve no lay-offs (see Figure 5.4)

Figure 5.4. Scenarios of employment reduction in the hard-coal sector due to outflows through retirement by 2030



Note: In the first scenario (grey line) employment change is due to outflows through retirement and stopping new inflows. In the second scenario (red line) it is assumed that new inflows would be at a constant level as the number of students in mining classes would be fixed at the 2015 level. The assumptions for the evolution of the Polish economy under the two-degrees scenario are outlined in Witajewski-Baltvilks et al. 2018.

Source: Witajewski-Baltvilks et al. 2018.

Witajewski-Baltvilks et al. (2018) indicates that if lay-offs are necessary, then laid-off workers can be employed in the industrial sector in the Silesia region, where unemployment is currently low (5%). Additional demand for labour can be created by putting in place a large-scale thermal retrofit project, which is needed to improve air quality in the region (Lewandowski et al. 2018).

If the revenue is used to lower distortionary income tax, the negative effect of carbon tax on employment will be smaller and, in some cases, it could become positive. This prediction, known in the literature as the double dividend, was studied, among others, by Babiker et al. (2003; for several world regions including the US and some European countries), Faehn et al. (2009; for Spain), Takeda (2007; for Japan) and OECD (2018; for the global economy).

Concluding remarks and policy implications

Recent studies suggest that the risk of decline in employment under the decarbonisation pathway is manageable. The mitigation of the risk requires the state to play an active role. First, the government should clearly communicate to workers and firms in the mining sector that the scale-down of the sector is inexorable. This signal is important to prevent a large inflow of labour to the sector. If the inflow is limited, the fall in employment will be achieved by natural attrition and the costs of transition will be low. Second, macroeconomic studies suggest that the fall in employment associated with decarbonisation can be small if the government uses tax revenues from emissions to reduce the rates of other distortionary taxes. For instance, using the revenue from CO_2 emission permits to reduce the rate of the income tax could increase the demand for workers in the other (i.e. non-mining) sectors of the economy.

6. Relative importance of risks – Fuzzy Cognitive Map

ALEXANDROS NIKAS AND HARIS DOUKAS

In this section we illustrate some potential consequences of the two pathways using a Fuzzy Cognitive Map (FCM): a diagram of cause-effect relationships that link policies with economic growth, produced following the engagement of stakeholders to assess the strengths of these relationships. The process of quasi-quantifying the relative importance of the risks using the stakeholder-driven FCM approach was carried out during a stakeholder workshop held in Warsaw in October 2017.

6.1. Methodology

Knowledge embedded in stakeholders and participatory processes can significantly help to bridge knowledge gaps in transition studies (Kampelmann et al., 2017). Fuzzy cognitive mapping is a quasi-quantitative modelling technique that attempts to model and represent a group of stakeholders' knowledge of a particular issue in diagrammatic form, thus allowing for ad hoc structures and flexibility to add the desired level of detail and complexity (Kosko, 1986). The elements that form the system under examination are connected by means of cause-and-effect relationships. Simulations of the derived model through artificial network techniques capture how causal propagation across the system reacts to induced shocks and assumptions formulated by stakeholders and/or data. The methodology helps experts to assess complex problems and reach difficult decisions primarily using their own knowledge by facilitating the extraction of this knowledge and using it to drive simulations and reach conclusions that would otherwise be challenging for these experts to reach on their own.

FCMs have long been used for policy analysis (Vergini and Groumpos, 2017), mostly regarding environmental and energy planning, as well as for other applications (Groumpos, 2010), including transitions and resilience (Olazabal and Pascual, 2016), but have been underexploited in the domain of climate policy-making, in which the vast majority of scientific studies focus on climate-economy modelling. However, there have been instances of linking models with FCMs, in an effort to bring stakeholders closer to modelling analyses and to utilise the knowledge embedded in them in order to meaningfully inform the models (van Vliet et al., 2010; Mallampalli et al., 2016). In this report, we use the FCM methodology discussed in (Nikas and Doukas, 2016) as recently applied in assessing energy-efficiency strategies (Nikas et al., 2018c) and selecting decarbonisation pathways in the Dutch power sector (Nikas et al., 2018b).

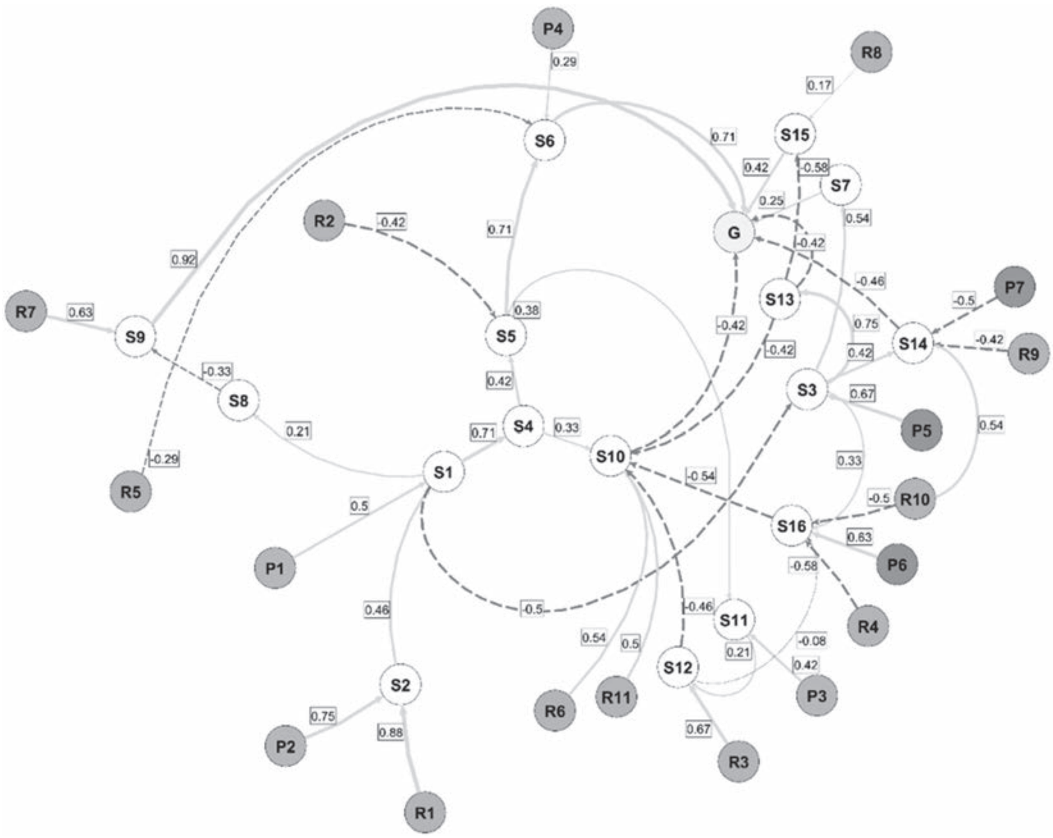
The FCM approach was carried out during a workshop entitled "Risks of low carbon transition in Poland" that took place in October 2017, in Warsaw. Eighteen Polish stakeholders, including representatives of private R&D firms in the power industry, stakeholders from public administration offices, and researchers, were engaged. In a dedicated session, stakeholders were informed about the scope and aims of the FCM methodology, guided throughout the process, and prompted to provide input. To this end, the preliminary modelling results associated with the two pathways were presented to the stakeholders by the researchers at the Institute for Structural Research (IBS). The process was supported by crisp system maps (Nikas et al., 2017) that helped frame our approach.

6.2. Mapping the knowledge of stakeholders

Before the workshop, researchers at the IBS had developed the FCM based on interviews, the literature, and their personal experience of studying the Polish power sector (Figure 6.1). The two pathways comprised seven policies in total. The coal-dependent baseline pathway consisted of political support for investments in coal, subsidies for R&D in coal technologies, and proper market design for domestic coal. The decarbonisation pathway, on the other hand, was based on RES auctions, the stability of RES support mechanisms, subsidies for R&D in renewables, and educational programmes and other labour policies aimed at helping mining workers adapt to a greener energy sector. Eleven uncertainties were selected, primarily drawn from studies focusing on relevant policies: the availability of foreign and domestic capital, barriers of entry for domestic firms, exogenous technological progress, gas and nuclear electricity costs, the extent to which miners will be able to adapt, gas prices, international relations, the EU's attitude towards climate action, international coal prices, costs of domestic coal extraction, and the price of EUA. These uncertainties are salient both in the Polish domestic debate and the international academic debate on the consequences of decarbonisation that could be relevant for Poland; it should be noted that the list explored in this report is incomplete and requires further investigation. While constructing the FCM, the authors considered the various factors that linked the selected policies and uncertainties to long-term economic growth through cause-and-effect relationships.

Stakeholders were each given a questionnaire, in which they were asked to assess the sign (i.e. positive if a positive change to one factor leads to a positive change of another factor, negative if a positive change to one factor leads to a negative change to another factor) and importance of each one of the identified relationships among the interlinked concepts of the FCM. Their input was quantified in [-1, 1] and a mean weight was calculated for the whole group of stakeholders in order to construct one global FCM (Figure 6.1). The grey circles denote the various factors at play: RES-boosting policies, coal-supporting policies and uncertainties, while white circles denote all other system concepts. The circle denoted by the letter *G* is the end goal. Furthermore, positive relations between factors are indicated by solid lines of variable thickness depending on the weight attached to them, while negative relations are shown using dotted lines.

Figure 6.1. FCM resulting from the Polish decarbonisation debate



Notes: Starting from the policy instruments and uncertainties, the identified causal propagation to the end goal, i.e. G = Long-term economic growth, includes the following system concepts:

R1 = Availability of foreign and domestic capital, R2 = Barriers of entry for domestic firms, R3 = Exogenous technological progress, R4 = Costs of gas and nuclear, R5 = Non-adaptability of miners, R6 = Price of gas, R7 = International relations, R8 = European attitude towards mitigations, R9 = International coal prices, R10 = Costs of domestic extraction, R11 = Price of permits,

P1 = Market mechanism for intermittent RES, P2 = Stability of support policies, P3 = Subsidies for RES R&D, P4 = Switch in schooling oriented on new (green) jobs, P5 = Political support for investment in coal power plants, P6 = Subsidies for coal technologies R&D, P7 = Market design for domestic coal,

S1 = Intermittent RES deployment, S2 = Sufficient finance, S3 = Insistence on coal, S4 = Demand for RES installations, S5 = Demand for RES installations by domestic producers, S6 = New (green) jobs, S7 = Traditional jobs, S8 = Demand for gas, S9 = Energy security, S10 = Energy system costs, S11 = Foreign progress absorption capacity, S12 = Long-run reduction in RES installation costs, S13 = GHG emissions and pollution, S14 = Import of coal, S15 = International reputation and finance, and S16 = Competitiveness of coal electricity.

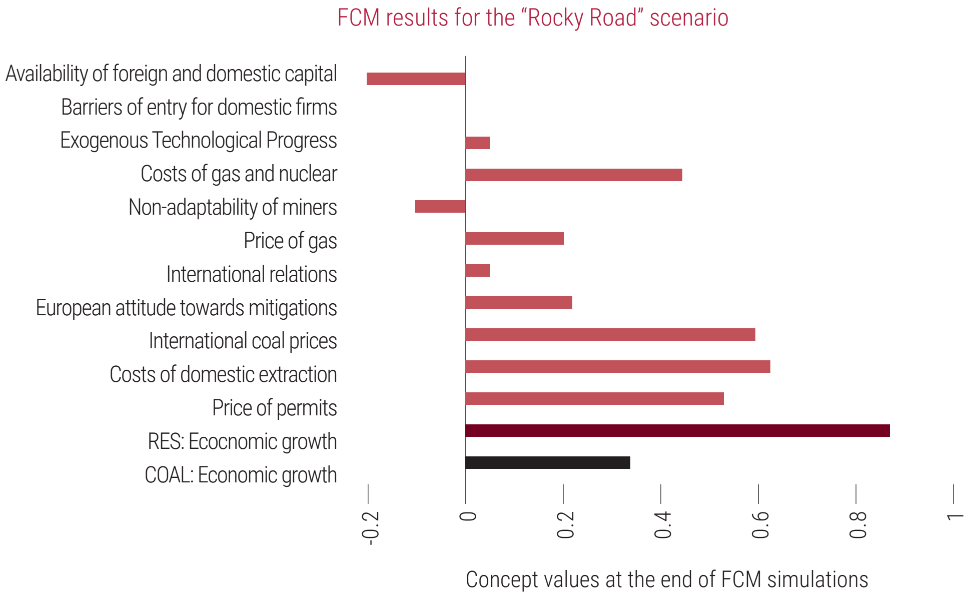
6.3. Simulations

The two pathways were simulated to capture their relative performance against five different socioeconomic scenarios describing different levels of mitigation and adaptation challenges. The first scenario, the 'Green road', is an optimistic scenario featuring low challenges overall; the second scenario, 'Middle road', describes a world with intermediate climate action challenges; the third scenario, 'Rocky road', describes a pessimistic future in which both mitigation of and adaptation to climate change are considered difficult; the fourth scenario, 'Divided road', features high adaptation challenges but assumes that mitigation is relatively easier; while the fifth scenario, 'Fossil-fuelled road', features high mitigation but low adaptation challenges. These scenarios and the factors describing them are borrowed from the Shared Socioeconomic Pathways literature (O'Neill et al., 2017).

The results show that, from the involved stakeholders' perspective, there are important channels through which policies supporting RES deployment may have a positive effect on economic growth. Channels transmitting the positive effect of policies supporting coal consistently appear to be weaker across all five socioeconomic scenarios, according to the FCM model.

In particular, the analysis shows that the more catastrophic the scenario is considered to be in terms of mitigation and adaptation challenges, the worse the coal-oriented policy pathway performs compared to the decarbonisation pathway. In fact, in the 'Rocky' and 'Divided road' scenarios, in which adaptation challenges are expected to be significant, the gap between the impacts of the two pathways on long-term growth appears to grow (e.g. Figure 6.2). On the other hand, in both the 'Green' and the 'Fossil-fuelled road' scenarios, which assume low adaptation challenges in terms of economic growth, the two policy pathways are very close to each other in terms of their performance, but with the RES pathway again slightly outranking the coal-oriented one (e.g. Figure 6.3).

Figure 6.2. Uncertainty concept values and FCM results for the decarbonisation (green) and baseline (grey) pathways, in the 'Rocky road' socioeconomic scenario

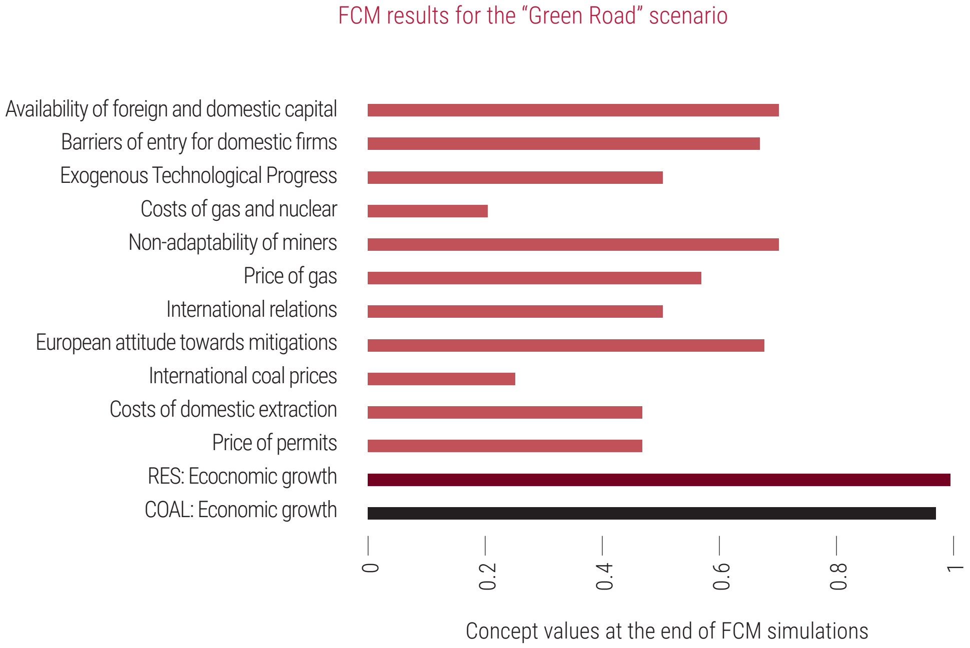


Notes: RES: Economic growth and COAL: Economic growth values reflect the effect of RES and coal-supporting policies on economic growth, respectively.

Another significant finding is that, among the seven policy strategies, only political support for coal plant investments appears to always affect economic growth adversely. All other policy strategies, when assessed individually, appear to have positive impacts on national economic growth, in most scenarios.

The FCM exercise reveals important channels that transmit the effects of policies supporting RES or coal on long-term economic growth. Since some of these channels are not considered in most economic models, predictions of those models may be biased. FCM simulations illustrate that, if these channels are taken into account, the prediction that the decarbonisation pathway is associated with smaller growth could be reversed.

Figure 6.3. Uncertainty concept values and FCM results for the decarbonisation (green) and baseline (grey) pathways, in the 'Green road' socioeconomic scenario



Notes: RES: Economic growth and COAL: Economic growth values reflect the effect of RES- and coal-supporting policies on economic growth, respectively.

PART 3

Implementation risks

Neither of the pathways defined in Part 1 could be implemented in a smooth manner without the adequate support of stakeholders. In this part we discuss such support as it pertains to three different levels. In Section 7 we explore the views of a group of experts on the transformation of the power sector, including representatives of the public sector, NGOs, and academia. In Section 8 we discuss support for the implementation of the pathways by citizens and local communities. In Section 9 we analyse under what conditions the pathways could gain the support of political parties and in which circumstances the issue of transformation could gain salience in political debate.

7. Stakeholders support

ALEKSANDER SZPOR

Internal and external pressure on energy transformation in Poland is expected to substantially affect Poland's future energy mix. Yet in the face of a lack of long-term energy policy strategies, the scope of possible scenarios is wide. To narrow down the number of possible scenarios, an analysis externalising the process of their formation was conducted. To that end, a survey of a group of experts participating in the public debate on low-emission transition in Poland was carried out. The participants were asked about perceived opportunities related to the future energy transformation, the main criteria for the selecting the components of the future energy mix, and its possible composition.

7.1. Basic information about the study

The study was conducted on 7 November 2017 during an open debate titled 'The Polish Energy Mix' organised by Procesy Inwestycyjne (Ltd), a company oriented towards creating discussion forums on the topic of transformation to a low-carbon economy.

A paper-based questionnaire was distributed among the debate participants. It contained seven questions. The first two questions were intended to identify the participants' status within the energy sector; the first was a closed question and the second was semi-open. The remaining questions were closed.

Fifty-three participants of the debate filled in the questionnaire. All of those surveyed answered the first question. For the second question, one of participants did not mark an answer and another one did not elaborate after marking the answer 'other'. For the third question, which was composed of three elements, one of those surveyed answered only with regard to one element. In the fourth question, twenty participants answered incorrectly (the most common mistake was attributing a value to all eight elements of the answer instead of only the five elements asked for) and three did not answer at all. In the fifth question, four participants did not answer at all, and nine surveyed answered incompletely or incorrectly (their answers did not add up to 100). All of those surveyed answered the sixth question and one participant did not answer the seventh question.

The aim of the survey was to discover their relation to and interest in the future energy transformation in Poland in the context of the EU's climate and energy policy.

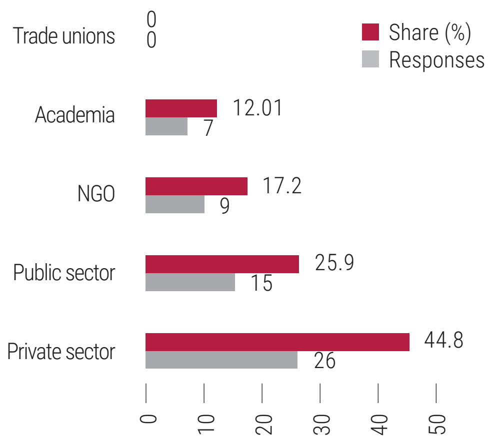
7.2. Results of the survey

Participants professional profiles

QUESTION 1. Please indicate the area of your professional activity (it is possible to choose more than one answer)

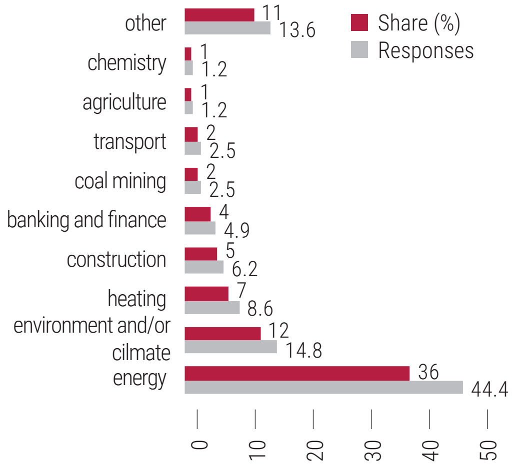
The most commonly indicated area of professional activity (Figure 7.1.) was the private sector – around 45% (26 answers), followed by the public sector – around 26% (15 answers). The NGO sector was indicated by around 17% (10 answers), and academia by around 12% (seven answers). Among those surveyed, no one indicated a trade union.

Figure 7.1. Area of professional activity, number and share of responses (%)



n: 53; multiple choice option, total number of responses: 58

Figure 7.2. Sector of professional activity, number and share of responses (%)



n: 52; multiple choice option, total number of responses: 81

Most respondents chose one area. Five respondents chose two answers. Among these five, two indicated the public and private sectors, one indicated public sector and NGO, one indicated the public sector and academia, and one indicated NGO and academia.

QUESTION 2. Please indicate the sector of your professional activity (it is possible to choose more than one answer)

The most commonly indicated sector of activity (Figure 7.2) was energy – around 44% (36 answers), the environment or climate – 15% (12 answers), heating – 9% (7), building and construction – 6% (5), banking and finance – 5% (4), coal mining – 3% (2), transport – 3% (2), agriculture – 1% (1), chemistry – 1% (1). The answer 'other' was indicated by around 14% (11), of which consulting was chosen by 5% (4) and 1% (1) each gave: technology transfer; structural funds; statistics; business self-government; economics; economy. One interviewed (1%) indicated the answer 'other' but without naming it. One respondent failed to answer this question.

The majority of respondents (32) indicated only one sector of professional activity. Two sectors were indicated by 10 respondents, three sectors were indicated by six respondents and four sectors were indicated by two respondents.

Relationship to the future energy transformation in Poland

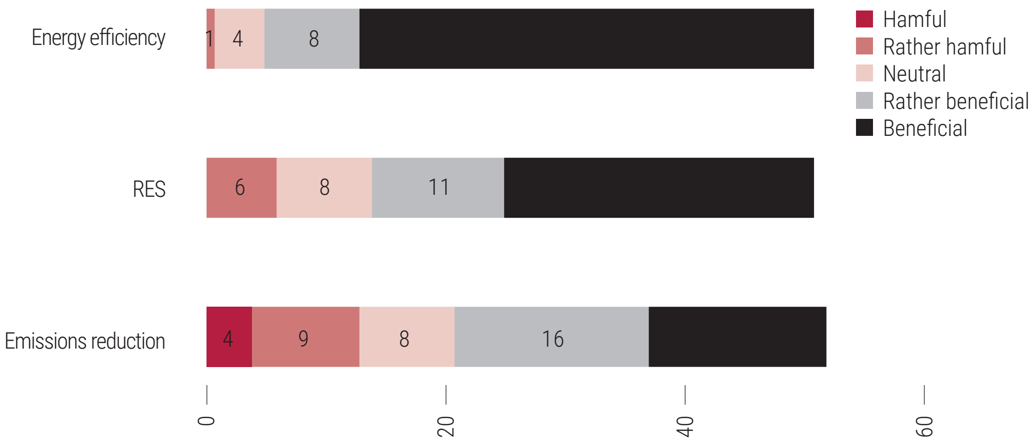
QUESTION 3. In your opinion, what impact will the accomplishment of the three main EU climate-policy goals included in climate and energy package for the years 2020 and 2030 have on the development of the Polish economy?

The respondents believed that the accomplishment of the three goals included in the climate and energy package would have a positive impact. The most negatively assessed goal of the package was the limitation of GHG emissions (Figure 7.3). Four surveyed assessed it as having a negative impact, nine as having a rather negative impact, eight as neutral, sixteen as rather positive, and fifteen as positive. (The average score was 3.6)

The impact of the second of the goals – increasing the share of RES in the energy production – was not assessed as negative by anyone. Six surveyed assessed it as having a rather negative impact, eight as neutral, eleven as rather positive and sixteen as positive. (The average score was 4.1)

The majority of those surveyed (38) assessed the impact of the third goal of the package – improvement of the energy efficiency – as positive. Eight surveyed assessed it as rather positive, four as neutral and one as rather negative. No one assessed it as negative. (An average score of 4.6)

Figure 7.3. The number of individual assessments for particular goals of the package

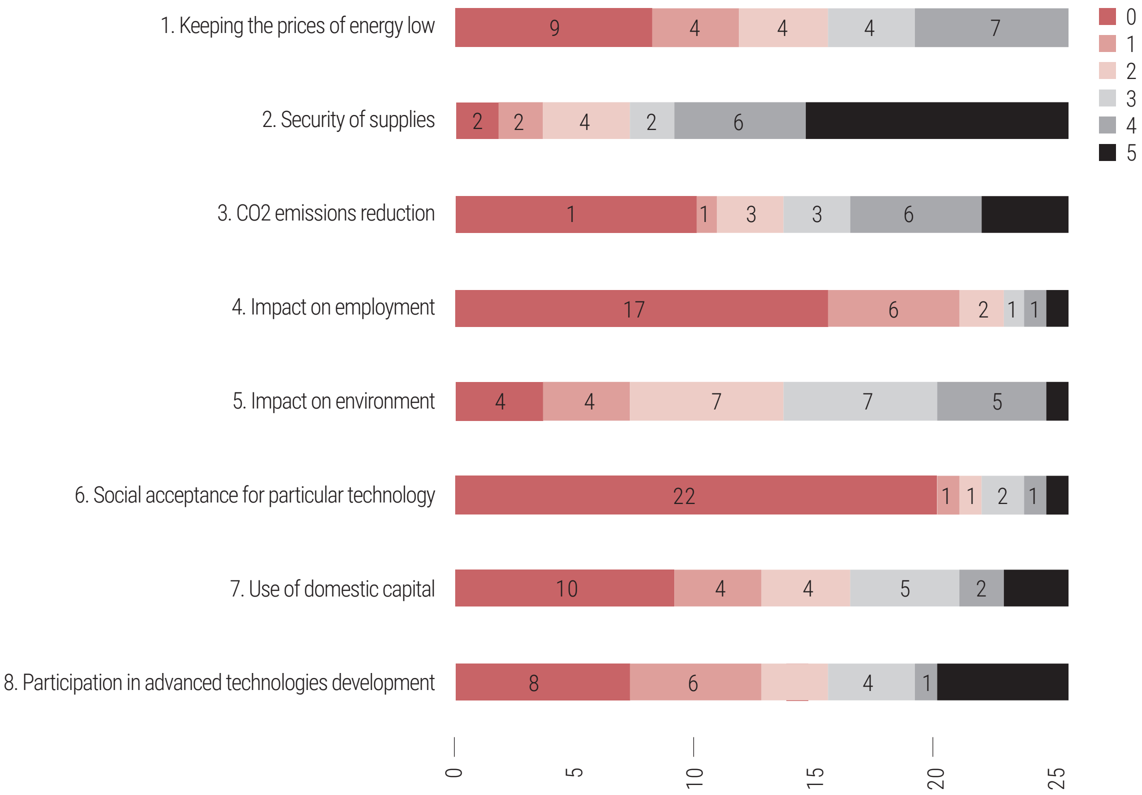


QUESTION 4. What, in your opinion, should be the most important criteria when choosing the best options for the energy-sector transformation in Poland? Please choose the 5 most important criteria and attribute to them a value from 1 to 5, where 1 is the least important criterion and 5 is the most important criterion (each value can be attributed only once).

According to the respondents, the most important criterion is the security of energy supply (Figure 7.4). Twenty-six respondents indicated that this is one of the five most important criteria The second was the impact on environment (among the top five criteria for 24 respondents), participation in advanced technologies (for 20 respondents), keeping the prices of energy low (for 19 respondents), and the use of domestic capital (for 18 respondents). According to the stakeholders, the least important criteria were CO_2 emission reductions (17), the impact on employment (11) and social acceptance for particular technology (six).[7]

[7] For the sake of simplicity this measure can be deducted from the number of non-attributions (zeros) which is negatively correlated with the importance of each criterion.

Figure 7.4. Distribution of answers on the importance of the criteria for energy-sector transformation in Poland



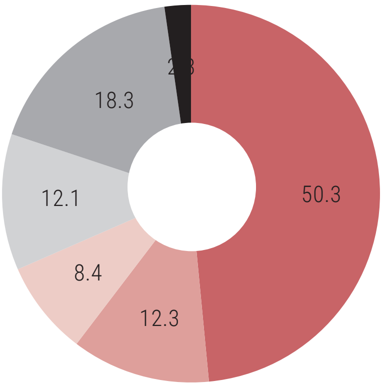
1 = the least important, 5 = the most important, 0 = lack of indication
n: 28

QUESTION 5. In your opinion, from which sources should electricity be produced in Poland in 2030 and in 2050? Please indicate the answers below, attributing to each source a percentage of the total production (so that the sum of the answers is 100%).

The surveyed indicated that electricity production in 2030 should be based on coal as the main fuel (around 50%), and 18% from RES such as wind, water, and solar. 12% should be provided by gas and also 12% biofuels. The share of nuclear should be at the level of 8% and 2% should come from other fuels. (Figure 7.5)

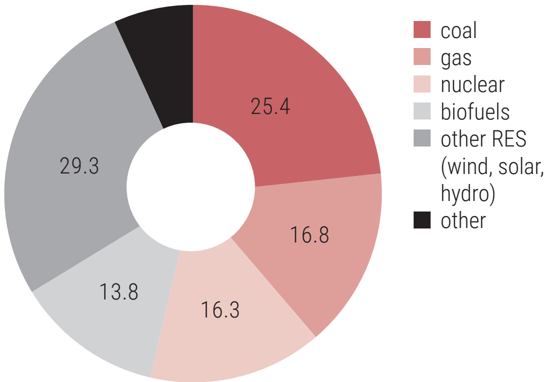
In 2050 the electricity production – in the opinion of those surveyed – should be based first and foremost on RES (around 29%). Coal should be responsible for 25% of the mix, gas for 17%, nuclear energy 16%, biofuels 14%, and other sources 7%. (Figure 7.6)

Figure 7.5. Electricity production mix in 2030 based on the arithmetic average from individual responses



n:41

Figure 7.6. Electricity production in 2050 based on the arithmetic average from individual responses

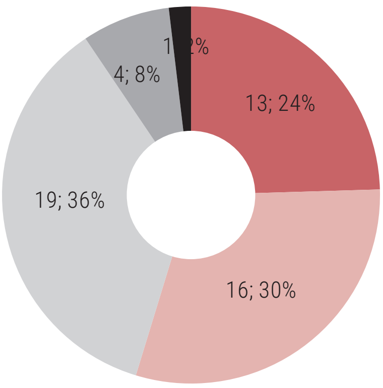


n:48

QUESTION 6. How would you assess the quality of research indicating that human activity is the main cause of climate change? Please indicate the closest corresponding answer to your views.

The largest group of surveyed (19) indicated that the results of the research presenting human activity as the main cause of climate change are subject to uncertainty and they should be improved before they are taken into consideration. (Figure 7.7) Sixteen of those surveyed indicated that the results of the research are subject to uncertainty, and that they should be further improved and taken into consideration cautiously. Thirteen respondents expressed their view that the results are convincing and four said that the research results are tendentious and untruthful. One person did not have an opinion in this matter.

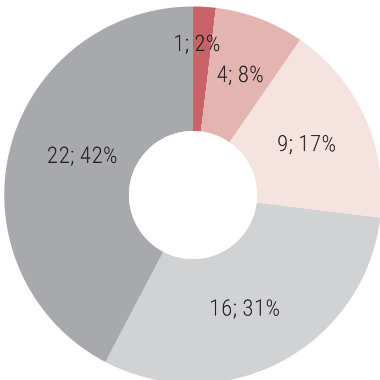
Figure 7.7. Distribution of answers (1–5) to question 6 presented in both values and in percentages



- 1 - are convincing
- 2 - are subject of uncertainty so they should be futher improved and taken into consideration cautiosly
- 3 - are a subject of uncertainty so they should be improved before they will be taken into consideration
- 4 - are tendentious and untruthful
- 5 - no opinion

n:53

Figure 7.8. Distribution of answers (1–5) to question 7 presented in both values and in percentages



- 1 - not important
- 2
- 3
- 4
- 5 - very important

n:52

QUESTION 7. What importance for the future development of Poland should the establishment of low-carbon transformation have as the strategic priority in domestic policy? Please assess this using a scale from 1 to 5, where 1 is not important and 5 .

The average score among those surveyed in relation to assessing the importance of the transformation to a low-carbon economy as the strategic priority in the domestic policy was 4.04 (in the scale 1-5). (Figure 7.8)

7.3. Summary and interpretation of the results

The group of surveyed stakeholders was internally diversified both in terms of their area and sector of professional activity. As for the area, the private sector was indicated the most common, with the public sector in second place. As for the (economic) sectors in which they worked, energy, including heating, was indicated by more than half of the total number of respondents. The next two largest groups were the construction and environment sectors. Although the group of respondents was diversified, the lack of trade union representatives seems significant and may have had an important impact on the results.

Security of supplies is a major concern in the Polish debate on energy transformation.

The majority of stakeholders positively assessed the impact of climate and energy package on the Polish economy. The energy-efficiency target was assessed as positive (beneficial or rather beneficial) by the largest share of the surveyed), and the reduction of CO_2 emissions earned the smallest share (yet was still an issue for the majority of respondents).

In the question related to eight proposed criteria for the selection of the energy transformation pathways, security of supply was indicated by the highest number of participants among their top five. Additionally, this criterion was also chosen as the most important by the highest number of participants. Other important criteria were the impact on the environment, participation in the development of advanced technologies, and keeping the prices of energy low.

As for the future energy mix, those surveyed indicated a process of gradual phase-down of coal and the development of RES. Between 2030, when coal will constitute half of the energy mix, and 2050, its share will be reduced by a factor of two. In the meantime, the share of nuclear will increase by the same factor, from 8 to 16%. The role of biofuels will remain almost constant, whereas the share of other RES will increase by a third. These answers suggest that the decarbonisation pathway discussed in Part 1 of the report would find support among stakeholders.

A quarter of those surveyed regarded research indicating human activity as the main source of climate change as unconditionally credible. More than a quarter expressed the view that the research should be further improved and taken into consideration with caution. Both groups combined constituted slightly more than a half of those interviewed. The largest group (35%) indicated that in their view the research is a subject of uncertainty, so it should be improved before it is taken into consideration. Less than a tenth of respondents indicated that the research is tendentious and untruthful.

Those surveyed agreed that establishing low-carbon transformation as the strategic priority in domestic policy is important.

8. Implementation risk at the local level[8]

ANDRZEJ CEGLARZ

In this section we discuss the potential support for the implementation of the selected energy technologies by citizens and local communities. We focus on: transmission infrastructure (the extra-high-voltage, 200-750 kV, and high-voltage, 110 kV, transmission lines), the creation of new coal mines (in the case of baseline scenario requiring resources for coal-fired power plants), and selected technologies of renewable energy sources (wind and solar). The analysis is based on a literature review.

8.1. Framing the problem

Regardless of which scenario is implemented until 2050 in Poland (the coal-based baseline pathway vs the RES-based decarbonisation pathway), substantial investments into new energy infrastructure are essential. The main reasons for this include growing electricity demand, the push for decarbonisation from the EU, as well as fact that existing infrastructure is ageing. Such investments will represent a challenge not only in relation to the additional costs required, but also due to social reluctance towards the installation of large energy infrastructure at the local level and an unstable regulatory framework.

There are well-documented and analysed cases of public opposition towards the installation of energy infrastructure and its drivers worldwide (see: Cain and Nelson, 2013; Ciupuliga and Cuppen, 2013; Cohen et al., 2014; Friedl and Reichl, 2016; Ruud et al., 2011; Vorkinn and Riese, 2001). While the academic discussion about the meaning of social acceptability of energy infrastructure is ongoing and scholars are constantly developing new dimensions in this area (see: Batel et al., 2013; Cohen et al., 2014; Dermont et al., 2017; Devine-Wright et al., 2017), their conclusions frequently share a similar critique of insufficient, top-down decision-making processes regarding the building and siting of infrastructure (Aas et al., 2014; Batel and Devine-Wright, 2015; Keir et al., 2014; Whitton et al., 2015). Although in some cases such a top-down approach is changing, and some companies are beginning to implement innovative approaches that involve and empower affected stakeholders (Komendantova and Battaglini, 2016; Komendantova et al., 2015; Späth and Scolobig, 2017), these new approaches still might be not enough to address public concerns if the regulatory system remains unclear and unstable (Battaglini et al., 2012).

The topic of social acceptability of energy infrastructure in Poland (including the development of participatory planning procedures) has recently gained attention from scholars and policy-makers, but it remains insufficiently regulated by law. If the lack of acceptability of energy infrastructure and the demands of citizens at the local level remain ignored, problems may arise when it comes to the full implementation of any of 2050 scenarios: no matter what direction Poland's overall energy policy will take, the infrastructural investments will need to take place at the local level.

The following analysis of this risk will cover recent developments in Poland in the social acceptability of energy infrastructure, including the potential conflicts around it and features of the decision-making processes. It will discuss selected RES technologies (wind and solar), high-voltage (110 kV) and extra-high-voltage (200–750 kV) transmission lines, and the creation of new coal mines in the baseline pathway that require resources for coal-fired power plants. However, it shall not consider other socially controversial energy technologies or resources, such as nuclear power or shale gas, which could also lead to social conflicts and a lack of acceptability (see Lis and Stankiewicz, 2017; Mrowinski and Stadnicki, 2014; Szulecki et al., 2015).

8 The results of this section are based on a literature review and interviews with four stakeholders from the government, political advisory, and industry sectors. The authors would like to express their gratitude to the stakeholders for their time and for providing important inputs that greatly contributed to this section

8.2. Acceptability of transmission infrastructure

One of the most contested forms of energy infrastructure globally are high and extra-high voltage transmission power lines. The lack of acceptability of such grids results from health concerns (related to electromagnetic fields), environmental risks, visual and noise impacts, the loss of property values, land-use attributes, and psychological stigma (Cain and Nelson, 2013; Cotton and Devine-Wright, 2012). Although the broad public and affected stakeholders are often aware of the need for new power lines and there are ways of addressing many of abovementioned reasons behind existing negative attitudes, public opposition still persists, partly because of the perceived inadequacy of the stakeholder engagement and participation processes undertaken by the Transmission System Operators (TSOs) and the public authorities (Keir et al., 2014; Porsius et al., 2016).

Existing investigations (Cieszkowski, 2017; Dołęga, 2014) highlight mistakes related to the planning procedures and participation processes made by the Polish TSO, Polskie Sieci Elektroenergetyczne (PSE), and by the local municipalities. This is in line with the opinion of the biggest Polish protest group, an association of at least 13 local municipalities and many civil initiatives in central Poland, which have blocked a 400 kV power line Kozienice-Ołtarzew, and whose protests have gained national attention. As one activist put it, 'We are not against the line, we are against incompetent and non-transparent decisions being made behind the back of society' (SGKKO, 2018). Currently, PSE is pursuing several projects that together constitute the biggest investment programme in its history. Any delay would generate significant additional costs and negatively influence the modernisation and restructuring of the whole domestic power transmission system.

The lessons learned from the Kozienice-Ołtarzew case led to an internal change of the Polish TSO and resulted in the development of a comprehensive investment decision-making scheme. Previously, project preparation, planning, and permitting had been commissioned to various subcontractors. In May 2017, PSE established an internally Central Investment Unit that would be responsible for all steps in the project investment, including monitoring of the construction stage when that task is subcontracted to an external company. This reorganisation has helped to avoid an unclear division of responsibilities and perceived non-transparency. Additionally, PSE has developed a new communication and stakeholder-involvement approach that explains in detail the need for power lines, the decisions behind selected lines, and the expected environmental impact. This change has given PSE a higher level of control over the investment and increased its credibility in the perception of stakeholders.

One can highlight three important characteristics of the interactions between TSO and stakeholders in Poland. First, the most challenging and time-consuming issue in a (mandatory) stakeholder participation process are the negotiations on the transmission easement. This legal mechanism, which is enshrined in Polish legislation, guarantees a company permanent legal title to land while it is carrying out an investment in and later maintenance of transmission infrastructure. It determines the compensation quotas for stakeholders whose property a transmission line would run through. These quotas are calculated using a different method from that based on selling rights, and this difference and its misinterpretation often leads to disputes. Second, unlike in many West and Nordic European countries, the environmental and landscape impacts do not play such an important role in the stakeholder engagement process. This also results from (big) environmental NGOs not having enough capacities to deal with environmental impacts of the development of new transmission power lines. If environmental and landscape issues are discussed during the decision-making process, they are mostly raised either by single individuals or by locally based NGOs and citizen initiatives. In this context, the fulfilment of environmental protection and nature conservation measures takes a very institutionalised form, which the General Directorate for Environmental Protection (with its restrictive environmental standards) oversees. From the perspective of the TSO, the most important aspect that determines the general approach to environmental protection is related to the power lines' proximity to residential buildings. When it comes to taking siting decisions, this aspect is especially challenging, due to the very dispersed character of residential development in Poland. Third, the shape of stakeholder participation and engagement processes fully depends on the approach developed and applied by PSE – which is neither regulated nor recognised by the Energy Regulatory Office (Urząd Regulacji Energetyki), and specific rules relating to its design (e.g. environmental, ownership, permitting, and stakeholder empowerment issues) are covered by various dispersed and uncoordinated pieces of legislation.

8.3. Acceptability of new coal mines

Although according to some stakeholders Poland might need to import substantial amounts of coal from abroad (Forum Energii, 2017), following the coal-based pathway until 2050 would still require decisions to be taken about the siting of new coal mines. Existing studies show relatively high social support for extracting coal from new mines, including both hard coal and lignite (Badera and Kocoń, 2014; Forum Energii, 2017). However, some stakeholders note that they only take into account a small range of selected geographical areas and they do not discuss in a comprehensive way the strongly contested social, health, economic, and environmental impacts of lignite and hard-coal mines (see for example: StopKopalni, 2018). Additionally, building new coal-fired power plants might turn out to be unprofitable in future if the costs of alternative technologies keep falling, the prices of coal on international market are low, and the costs of CO_2 allowances under the EU Emission Trading System increase. This raises questions about their overall investment potential (Zasuń, 2016, 2018). Nevertheless, notwithstanding issues related to the profitability of new coal-fired power plants and coal-mining sites, existing planning and decision-making procedures are thought to be insufficient, non-participatory, and conflictual (Badera and Kocoń, 2014).

8.4. Acceptability of RES installations

The most controversial and contested technological solutions for local societies are: high-voltage transmission lines, the construction of new coal mines, especially open-pit lignite mines; and renewable energy system installations such as onshore wind turbines.

Although in Poland the public generally supports RES as a preferred source of energy (Gwiazda and Ruszkowski, 2016), this is not entirely reflected at the local level. Over recent years, the most publicly discussed controversies related to the siting of infrastructure have concentrated around renewable energy sources, especially wind energy. In 2007–2014, local conflicts around wind energy took place in over 100 municipalities throughout the country (Bednarek-Szczepańska, 2016; Bednarek-Szczepańska and Dmochowska-Dudek, 2017). The phenomenon of the 'national-local gap' is not new (Bell et al., 2005; Bell et al., 2013), and while it requires adjustments taking into account place-based elements (Batel and Devine-Wright, 2015), such an approach could help explain specific features of the opposition to wind energy in Poland. This opposition is characterised by ad hoc activities, mostly directed against other neighbours inside a community or, less often, against other communities, that would profit from the siting of a wind turbine on their land (Bednarek-Szczepańska, 2016; Dmochowska-Dudek and Bednarek-Szczepańska, 2018). This implies that the most important factor behind a lack of acceptability of the (wind) energy infrastructure in Poland lies in the feeling of community injustice and non-fairness (see: Gross, 2007). Indeed, while analyses show that there is still untapped wind-power potential in Poland, barriers are formed due to the insufficient and non-transparent planning, permitting, and participatory procedures (Brzezińska-Rawa and Goździewicz-Biechońska, 2014; Igliński et al., 2016). This was also reflected in two reports published by the Supreme Audit Office (NIK, 2014; 2016, but see also; PSEW, 2016). These developments have contributed to wind energy and turbines a becoming a significant political issue, which resulted in the introduction in 2016 of legislation strictly limiting the development of new wind farms in built-up areas and on land of significant environmental value. In consequence, up to 90% of new and ongoing wind-energy investments have been blocked, which has substantially slowed down the dynamic growth of wind-energy capacity (by almost 700% in 2005–2016) (Piszczatowska, 2016; PSEW, 2017).

In contrast to this, solar energy is considered in Poland to be the most accepted form of renewable energy technology (IEO, 2017). However, although since 2014 it has become the most dynamically developing source of energy in Poland (Skłodowska, 2018), the share of the electricity coming from solar energy is exiguous and as of 2016 it amounted to around 200MW, which is 2.3% of RES capacity and 0.5% of the capacity of the national power system (IEO, 2017). As such, Poland is one of the lowest generators of solar power in the EU (Derski, 2017). This outcome is a result not only of the different geographical and weather conditions determining solar irradiation levels, but also the unfavourable support system and unstable regulation in past years (Derski, 2017; IEO, 2017). The Polish government has announced ambitious plans to develop solar energy, but continuously ongoing changes within the regulatory system might negatively affect the realisation of these plans (Skłodowska, 2018).

8.5. Concluding remarks

All of the examples described above show that, regardless of which energy pathway is implemented in Poland until 2050, building any new electricity-related infrastructure can be challenged by a lack of acceptability at the local level. Since all of the presented technological choices have their pros and cons, the social responses towards them are determined not only by their physical characteristics, but also by the way in which decisions about a specific investment are taken. In this manner it is clear that currently existing laws and procedures in Poland regarding the decision-making processes in the aspect of the electricity infrastructure remain insufficient.

Decision-making processes that are perceived by citizens as exclusive and non-transparent, and characterised by a top-down approach and non-compliance, can lead to an increase in public opposition, which, in turn, can trigger an unstable environment for investors. A lack of social acceptability will likely gain in strength in the future, especially due to increasing affluence levels in society and growing demands to realise higher-level needs, such as participation in and co-ownership of decision-making processes (and, of course, ownership of the energy infrastructure itself).

It appears that the current research is not sufficiently focused on understanding stakeholder engagement and decision-making processes regarding energy infrastructure in Poland. Insufficient research can be both the result of and the reason for insufficient use of evidence-based recommendations in the policy-making process. It is important to further investigate the Polish specificity of described processes and mechanisms in the context of international research progress (such as was carried out in research by Dmochowska-Dudek and Bednarek-Szczepańska, 2018) and to cross-fertilise it with research on governance, participation, and decision-making and policy-making processes in other sectors, such as the advanced level of research on nature conservation (Cent et al., 2014; Maczka et al., 2016; Niedziałkowski et al., 2018; Niedziałkowski et al., 2016; Pietrzyk-Kaszyńska and Grodzińska-Jurczak, 2015). This would enable a comparison of the results with outcomes obtained elsewhere and to adjust any lessons learned to Polish conditions.

9. Salience of climate change among political parties

BAIBA WITAJEWSKA-BALTVILKA

In this section we describe the factors that shape political party competition on climate-change and environmentalism issues. We focus on socioeconomic inequality, public opinion, and the strength of trade unions. We describe the key findings from the quantitative study on political parties' positions in 22 European countries during electoral campaigns, as well as two case studies: Poland in 2011 and Germany in 2013.[9]

Political parties' preferences on climate policy are important for at least two reasons. First, political parties and, in particular, party leaders, are key actors in shaping public policies at both the national and international level. They can either hinder or propose climate-change mitigation policies (e.g. Birchall, 2014; Harrison, 2010 & 2012; Jensen and Spoon, 2011). Second, political parties play an important role in shaping people's attitudes by either trying to justify unpopular climate-mitigation policies or arguing against them (e.g. Brulle et al., 2012; Steenbergen et al., 2007).

Political parties express less interest in environmental issues in countries with high inequality and when the economy is in recession.

The literature on party politics and climate change identifies the following key factors to explain the conditions on which political parties tend to compete on climate change and environmentalism.

First, political parties tend to talk about environmentalism and climate change less when inequality increases (Witajewska-Baltvilka, 2018). This might be due either to other issues becoming more important for voters or

[9] The section is the summary of the paper: Witajewska-Baltvilka, B. (2018). Political parties and climate change policy: why do parties sometimes talk about it, but sometimes keep silent. *IBS Working Paper 05/2018*. http://ibs.org.pl//app/uploads/2018/09/IBS_Working_Paper_05_2018.pdf [date of access: 08.11.2018]

because of the associated costs of environmental protection and climate-change policies, which disproportionally affect the poorest citizens. Interestingly, and somewhat unexpectedly, economic conditions, as measured by real GDP per capita, do not seem to determine party issue competition on environmentalism and climate change (Witajewska-Baltvilka, 2018). However, as Carter, Ladrech, and Little (2014) argue, events such as economic crises can negatively impact countries' incentives to implement various climate policies.

Second, more favourable public opinion on the environment is associated with the issue of environmentalism or climate change having a higher salience for a party (Witajewska-Baltvilka, 2018). Indeed, one of the key reasons why political parties did not talk about environmentalism or climate change either in Germany 2011 or in Poland 2013 was the relatively low salience of these issues among voters. None of the major political parties tried to highlight climate change or environmentalism as one of its key campaign issues (i.e. to increase its salience among voters) despite the fact that, for example, in Poland there was a window of opportunity due to it having the EU presidency. However, given the strong reverse causality between public opinion and party issue salience, as often discussed in the literature, one should treat the explanatory power of this factor with caution (Witajewska-Baltvilka, 2018).

Third, some institutional factors such as patterns of inter-party competition/dynamics also seem to play a role, but this factor appears to be vaguely defined. As Carter and Jacobs (2013) argue, '[p]arty politics, especially where party competition generates a "competitive consensus", can be important for both initiating and prolonging policy change in parliamentary systems' (Carter and Jacobs, 2013: 125). Hence, weak competition, as well as certain patterns of coalition incentives, can help explain why climate policy does not appear on the agenda of political parties (Carter, Ladrech and Little, 2014). Here, the role of the party leadership is crucial.

Fourth, fuel dependency and the role of coal-industry business groups is yet another factor that shapes party issue competition on environmentalism and climate change. As Lachapelle (2013) argues, countries with substantial exports of mineral fuels are less likely to implement any type of climate policy. Indeed, a Polish 2011 case study clearly points to a 'fuel-dependency narrative'. Voters believe that turning away from coal and introducing alternative sources of energy would create an economic downturn and unemployment and, at least partly, such a narrative is sustained by coal-industry companies. In Germany, where the production of coal is lower, further transition towards clean energy is supported by all political parties, and the opposition from coal industry does not seem so strong (Witajewska-Baltvilka, 2018).

Finally, in countries with stronger trade unions, party competition on environmentalism and climate change is lower (Witajewska-Baltvilka, 2018). As already argued in the literature and demonstrated by a few case studies (e.g. Ladrech, 2011; Carter, Ladrech, and Little, 2014), trade unions seem to be particularly concerned about losing jobs, which may accompany changes in production and consumption and the implementation of climate-change policies. The Polish 2011 case study approves this. As already mentioned, the transition to carbon-free energy is regarded as threat to the national economy by trade unions.

To summarise, such factors as socioeconomic inequality, the strength of trade unions, and public opinion levels appear to be the most important factors shaping competition between parties when it comes to climate-change and environmentalism issues. The lower the socioeconomic inequality, the more environmentally friendly public opinion is, and the weaker the trade unions are, the more likely it is that political parties will give prominence to environmental and climate-change policies.

Conclusions

In this paper we examined the evolution of the power sector and the economy under two alternative pathways: the baseline pathway, which assumes no constraints on emission reduction, and the decarbonisation pathway, which assumes a threefold reduction in emissions. Our analysis predicts that the least-cost option under the constraint of emissions reduction involves the gradual replacement of coal with a mix of onshore wind, nuclear, natural gas, biogas, and biomass. In contrast, if we abandon the emissions reduction constraint, the least-cost option involves a moderate decline in the consumption of coal, mostly after 2030. Over the projected period (2015–2050) the decarbonisation pathway requires more capital expenditure (necessitated by a larger scale of investment in the construction of RES installations and gas power plants) than the pathway with no emission reduction constraints.

The macroeconomic analysis indicates that the baseline pathway is associated with higher GDP and consumption than the decarbonisation pathway. That is because the additional investment required in the decarbonisation pathway crowds out investment in the other sectors of the economy, such as services, particularly in the short term. However, the difference in GDP and consumption between both pathways is very small and should not be a decisive factor for policy-makers.

The key results do not change if we perform the analysis for alternative assumptions regarding the evolution of EU ETS prices and intermittent renewable energy costs, as well as the availability of nuclear technology. Low EU ETS prices result in some growth in coal use in the unconstrained pathway (instead of nuclear energy deployment), but do not have a significant influence on the optimal energy mix in the decarbonisation pathway. Surprisingly, the optimal mix in both pathways does not change substantially in the case of lower or higher trajectories of installation costs of major intermittent RES (solar PV, onshore and offshore wind). However, the installation costs do have an impact on the projected capital expenditure, and this is particularly important in the decarbonisation pathway, where a larger deployment of RES is assumed. Finally, in the absence of nuclear power in the energy mix, the role of offshore wind grows. Still, the substitution is not full, and as a result this scenario may lead to power shortages, particularly in the decarbonisation pathway.

We find that the largest economic loss associated with the decarbonisation pathway is observed under the scenario of low ETS prices. However, even in that scenario, the loss is not significant (in 2030, GDP in the decarbonisation pathway is 2% lower than in the baseline pathway) and transitory (the difference in GDPs is close to zero in 2050).

In Part 2 we discussed the risks of both pathways that were not taken into account in the model simulations in Part 1 of our study. The risks associated with the decarbonisation pathway include the loss of stability in the energy system and energy security, technological dependency, and labour loss. The risks associated with the baseline pathway include the loss of international reputation, waste of R&D resources, and dependency on imported coal. Importantly, some risks associated with decarbonisation, such as a fall in employment and technological dependency, could be mitigated if the government communicates to firms and workers that the scale-down of the coal sector is inexorable given the global commitment to combat climate change. However, this will be accompanied by a simultaneous scale-up of the sector related to carbon-free technologies

In the last section we discussed some of the risks associated with the implementation of the decarbonisation pathway. We highlighted the risk of a lack of support or opposition towards decarbonisation by three groups of stakeholders: experts, citizens, and political parties. The survey among experts suggests that they support the decarbonisation at a pace similar to the one assumed under the decarbonisation pathway in this study. The energy transformation may be resisted by local communities if it involves investments that affect landscapes or, more generally, the well-being of citizens. Finally, political parties may not be interested in raising the topic of climate change, especially if there are other important issues on the agenda, such as economic growth or economic inequality.

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APPENDIX 1. Assumptions on the availability of natural gas

We assumed the import of natural gas for the use in the power sector has a cap at the level of 7.4bln m^3. This value was computed as follows. The total import of natural gas in 2015 was 12.6bln m^3. We assumed that the total import could increase by no more than 50%. Thus the cap on the total import of natural gas was assumed at the level of 18.8bln m^3. We assumed that the consumption of gas in the other sectors cannot be smaller than the current consumption (11.4bln m^3 in 2015). Thus the cap on the import of natural gas for the use in the power sector is at the level of 7.4bln m^3.

We assume that the domestic resource of natural gas available for the power sector is at the level of 10.9bln m^3. This value was computed as follows. Currently, the total domestic resource of natural gas is 121 bln m^3.[10] We assumed that the share of this resource available for the power sector is equal to the share of consumption of natural gas in the power sector in the total natural gas consumption.

10 Source: http://geoportal.pgi.gov.pl/surowce/energetyczne/gaz_ziemny

APPENDIX 2. Details of the method of the survey study and its limitations

DATE OF THE STUDY

The study was conducted on 7 November 2017 between 11.00 and 13.30.

TOOLS

A paper version of the questionnaire was distributed among the debate participants. The debate was organised by *Procesy Inwestycyjne (Ltd)* under the title "The Polish Energy Mix". The participants provided their answers to the questionnaire during (or shortly before and after) the debate. The questionnaires were collected at the end of the debate.

SELECTION OF PARTICIPANTS

The debates conducted by *Procesy Inwestycyjne (Ltd)* concentrate on topics related to low-carbon economy transformation. This particular debate was held at the Faculty of Civil Engineering at the Warsaw University of Technology (address: ul. Armii Ludowej 16, Warsaw).

Since its establishment in 2003, *Procesy Inwestycyjne (Ltd)* has organised several projects, consultations, and strategic communication campaigns oriented primarily towards the energy, gas, industry, construction, and IT sectors, as well as towards local authorities. It collaborates closely with stakeholders from the EU and Polish public administration, business organisations, and academia.

STRUCTURE OF THE QUESTIONNAIRE

Among the seven questions asked, two were designed with the purpose of identifying the participants (the first was closed and the second semi-open). The remaining five questions were closed. The fourth and the fifth questions were in tabular form.

LIMITATIONS OF THE STUDY

The study was conducted on a specific group that had gathered together to participate in a debate on low-carbon transformation in Poland. Even though the participants formed quite a diversified group in terms of their views on the topic, taken as a whole they can be perceived as being outside of the political mainstream, which in Poland is overall more sceptical towards the EU's climate and energy policy. To counterbalance this deficiency, the study could be conducted in a contrasting forum aimed at preserving the coal-mining sector.

The survey was originally designed for an online survey, which would better facilitate the selection of answers. However, due to its length and the relatively demanding structure of the questions, the results from the online survey were not successful in terms of responsiveness. Therefore, the authors decided to choose an alternative form of distribution involving personally handing out and collecting the surveys in order to achieve a more representative sample. As a result of this change from an online to a paper version, it transpired that question no. 4 was formulated in too complicated a manner, which translated into a low rate of correct answers. The same problem applied to question no. 5 also, albeit to a lesser extent.

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TRANSrisk project

The objective of the project is to understand the risks, uncertainties, and co-effects related to different climate-change mitigation pathways as well as to analyse public acceptance (or lack thereof) of low-carbon technology options. TRANSrisk aims to create a novel assessment framework for analysing the costs and benefits of transition pathways. The framework will integrate well-established approaches to modelling the costs of resilient, low-carbon pathways with a wider interdisciplinary approach including risk assessments. In addition, TRANSrisk aims to design a decision-support tool that will help policy-makers to better understand uncertainties and risks and enable them to include risk assessments as part of the creation of more robust policy design, thereby making it more robust. All of the research results from the project may be found at transrisk-project.eu.

IBS is collaborating with several acclaimed European research institutes as part of the TRANSrisk project, including the University of Sussex, Cambridge Econometrics, the University of Graz, and the National Technical University of Athens.

List of TRANSrisk publications by IBS (from the oldest):

1. Sawulski, J. (2017). Structural analysis of the offshore wind innovation system in Poland. *IBS Working Paper 06/2017.*
2. Sawulski, J., Witajewski-Baltvilks, J. (2017). Optimal RES differentiation under technological uncertainty. *IBS Working Paper 07/2017.*
3. Witajewska-Baltvilka, B. (2018). Political parties and climate change policy: Why do parties sometimes talk about it, but sometimes keep silent. *IBS Working Paper 05/2018.*
4. Sawulski, J., Gałczyński, M., Zajdler, R. (2018). A review of the offshore wind innovation system in Poland. *IBS Working Paper 06/2018.*
5. Witajewski-Baltvilks, J. (2018). Green Growth and Taste Heterogeneity. *IBS Working Paper 07/2018.*
6. Witajewski-Baltvilks et al. (2018). Risks associated with the decarbonisation of the Polish power sector. *IBS Research Report 05/2018*.
7. Witajewski-Baltvilks, J., Fisher, C. (2018). Green Innovation and Economic Growth in a North-South Model. *IBS Working Paper. [forthcoming, available from authors upon request]*
8. Antosiewicz, M., van Vliet, O. (2018). Is a mix of wind and gas a good alternative to coal in Poland? *IBS Working Paper. [forthcoming, available from authors upon request]*
9. Baran, J., Szpor, A., Witajewski-Baltvilks, J. (2019). The labour costs of transition in coal-dependent economy. *IBS Working Paper. [forthcoming]*

TRANSrisk is a research project financed by the EU's Horizon 2020 programme (grant agreement no. 642260).

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About Institute for Structural Research (IBS)

The Institute for Structural Research (IBS) is an independent and politically neutral research foundation. Our research studies focus on economic analysis and evaluating the consequences of public policies in the following areas: labour markets, demography, education, family policy, public finance, as well as energy and climate. We rely on modern modelling, statistical, econometric, and IT tools. We take great care to ensure our research is objective and based on sound methodology.

Since our foundation in 2006, we have conducted almost 200 research projects for entities such as the World Bank, the OECD, various ministries, the Chancelleries of the Prime Minister and President of the Republic of Poland, the National Bank of Poland, and employers' organisations, as well as other associations and foundations. The Institute's research findings are generally available to the public, with two series of publications specifically responsible for their dissemination: *IBS Working Paper* and *IBS Policy Paper*. All articles, reports, and information about our projects and conferences may be found at ibs.org.pl.