# Assessment of domestic demand for solid fossil fuels by 2040 as a result of the capacity market implementation

# Abstract

The capacity market is a relatively new mechanism in Poland, and its impact on the demand for hard coal and lignite has not been studied so far. The analysis of changes in coal consumption in the power generation system in the future is particularly crucial as solid fossil fuels still constitute the dominant role in electricity production, and the implementation of the capacity market has caused a diametrical change in the operating of the energy market.

The main purpose of the doctoral dissertation was formulated as follows: Quantitative assessment of the impact of the capacity market implementation on the demand for solid fossil fuels for electricity production by 2040. In the context of the assumed goal, the following research hypothesis was developed: The demand for solid fossil fuels will decrease by 2040 regardless of the structure of the electricity market; however, as a result of the introduction of the capacity market, the dynamics of these changes will decrease.

Solving the research problem required the employment of appropriate methodology. The method used to study fuel and energy systems is system analysis, whose tools for quantitative analysis assessment are mathematical models. A technical and economic model of the Polish power generation system was developed, formulated as a linear programming problem, which was then implemented in the MATLAB. In order to analyze the impact of the capacity market implementation on the demand for solid fossil fuels used for electricity production, two theoretical research scenarios have been developed: (i) REE scenario which reflects the operating of the energy-only market and (ii) RM scenario which mimics the functioning of the dual-commodity market, in which the capacity market operates parallel to the electricity market. The impact of the capacity market implementation on the demand for solid fossil fuels for electricity production was studied based on (i) the share of hard coal and lignite in the structure of available capacity in the power generation system, (ii) the percentage of solid fossil fuels in the structure of electricity production, and (iii) the volume of demand for solid fossil fuels for electricity production for the developed research scenarios. Moreover, electricity prices were also compared depending on the structure of the market.

The analysis of the results led to the formulation of conclusions, among which the most important are:

* The decarbonization of the Polish power generation system is inevitable by 2040. Hard coal demand in the analyzed period decreases by 86.9% under the REE scenario and by 87.9% under the RM scenario. In the case of lignite, demand is reduced by 91.8% under the REE scenario and by 93.0% under the RM scenario. Research results indicate that the introduction of the capacity market causes a delay in the decarbonization process of the energy sector. A slowing down of the withdrawal process of hard coal-fired units is observed, especially in the years 2021–2030 and in the years 2031–2032 in the case of lignite-fired units.
* The demand for hard coal from the power generation system is decreasing regardless of the research scenario. However, the dynamics of these changes is different. There are seven periods for which there are specific differences between the demand for hard coal in the analyzed scenarios:
	+ 2021–2024: the demand for hard coal under the RM scenario decreases from 37.2 million Mg to 32.3 million Mg and is higher than the demand under the REE scenario by an average of 9.7%;
	+ 2035–2026: the demand for hard coal under the RM scenario is 31.4 million Mg and 31.3 million Mg and is higher than the demand under the REE scenario by 7.8% and by 10.2%;
	+ 2027–2029: the demand for hard coal under the RM scenario decreases to 21.9 million Mg. However, the differences between the scenarios increase to 19.2% in 2029;
	+ 2030: the demand for hard coal under the RM scenario is significantly reduced to 17.9 million Mg, which is 13.7% more than under the RM scenario;
	+ 2031–2033: the demand for hard coal is reduced to 12.0 million Mg; the differences between the scenarios are much lower and are on average at 1.2%;
	+ 2034: the demand for hard coal is the same under both analyzed scenarios and amounts to 11.8 million Mg;
	+ 2035–2040: the demand for hard coal demand is reduced to 4.5 million Mg under the RM scenario in 2040; it is lower by 7.6% compared to the REE scenario.
* The introduction of the capacity market does not significantly impact the shutdown of lignite-fired generating units. In the first ten years of the analysis, the volume of capacity available in the system is the same for both scenarios; the demand for lignite decreases in the analyzed period regardless of the scenario considered. There are also specific periods for which characteristic differences between the scenarios are observed:
	+ 2021–2030: the demand for lignite in both analyzed scenarios decreases from 59.4 million Mg to 50.2 million Mg;
	+ 2031–2032: the demand for lignite is reduced from 47.0 million Mg to 31.1 million Mg; in this period the highest differences between the scenarios of 47.0% and 31.1% are present;
	+ 2033–2034: the demand for lignite is reduced to 21.3 million Mg under the RM scenario and is slightly higher than the demand under the REE scenario;
	+ 2035–2036: the demand for lignite decreases from 18.0 million Mg to 13.6 million Mg in both analyzed scenarios;
	+ 2037–2040: the demand for lignite decreases and in 2040 reaches 4.1 million Mg under the RM scenario; it is then 14.3% lower than under the REE scenario;
* The operating of the capacity market ensures that reserves of achievable capacity in the power generation system are available. As a consequence, energy security is improved. The implementation of the capacity remuneration mechanism, therefore, ensures the stability of supply during the decarbonization process of the Polish power generation system;
* The capacity market introduction also means lower electricity prices in each year analyzed. Electricity prices under the REE scenario are from PLN 265.13 to 359.58 / MWh, and electricity prices under the RM scenario are at the level of PLN 203.12 to 323.04 / MWh. Although the price of electricity under the RM scenario is lower from 8.15% to 35.14% compared to the prices obtained under the REE scenario, it does not necessarily mean lower total purchase costs of electricity for the consumers, because the costs of operating the capacity market are transferred to final users.

The research carried out in this dissertation is the first research on the quantitative assessment of the impact of the capacity market implementation on the demand for solid fossil fuels for electricity production. Since the capacity market was introduced in Poland relatively recently, the results of the analyses and the conclusions drawn on their basis constitute a significant contribution to the national discussion on the legitimacy and consequences of implementing capacity remuneration mechanisms.