WHAT COUNTRIES LIKE POLAND CAN LEARN FROM CHINA'S ENERGY TRANSITION

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Summarize

The development of the energy sector in China is characterized by a unique combination of very rapid expansion of renewable energy sources and the continued dominance of coal as the foundation of the power system. The report shows that in 2024 China accounted for 34% of global renewable electricity production and invested more in this sector than Europe and the United States combined. At the same time, as much as 58% (!) of China's electricity still came from coal, which plays a stabilizing role in the system. China also dominates global energy technology supply chains - it manufactures the majority of photovoltaic panels, wind turbines, and batteries, giving it a cost advantage and significant influence on the global market. China's model of energy transition is therefore based on maximizing the growth of renewables while simultaneously maintaining coal as a key balancing element, ensuring security of supply amid rising energy demand. Should Poland draw conclusions from this approach?

KEYWORDS: coal, Chinese energy mix, renewable energy sources (RES), coal, energy transition, renewable energy supply chains

1. Introduction

Since the United Nations Earth Summit held in Rio de Janeiro in 1992, the global community has increasingly directed its energy systems toward decarbonization, placing particular emphasis on reducing the role of coal in electricity generation. This long-term shift, which accelerated notably after 2015, is clearly reflected in the evolution of the global electricity mix: the share of coal-fired power generation has steadily declined, while renewable energy sources (RES) have expanded their contribution year after year.

The data for the period 2015–2024 illustrate this transition. The share of electricity generated from coal decreased from 39% in 2015 to 34% in 2024, whereas the share of RES increased from 23% to 32%. Minor adjustments also occurred in other technologies: natural gas fell from 27% to 25%, and nuclear energy declined from 11% to 9% (Fig. 1). These percentage changes should be interpreted carefully, as the absolute volume of electricity generated worldwide continues to grow due to rising global demand. The expansion of nuclear power remains limited because of the long construction times and high capital requirements associated with nuclear facilities.

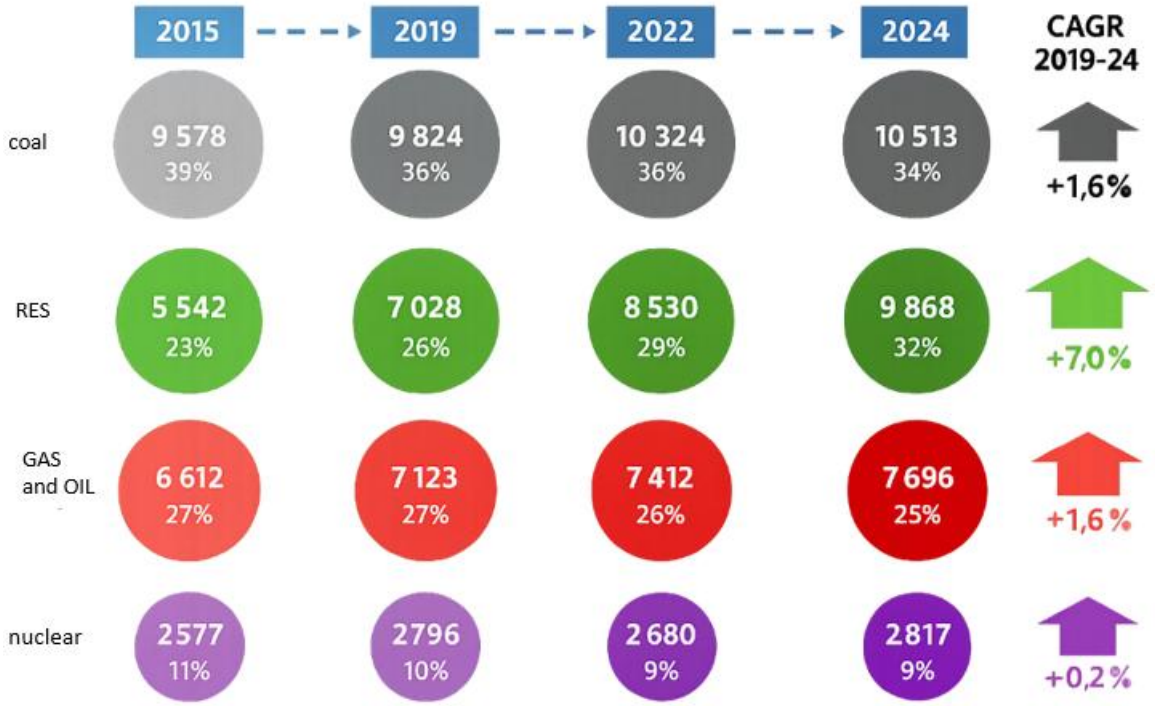


Fig. 1. Global production of energy by source in 2015-2024 [TWh]. Source: [1]
Rys. 1. Światowa produkcja energii elektrycznej w latach 2015-2024 [TWh]. Źródło: [1]

A subsequent figure presents the structure of the global energy mix in 2024 and compares it with the mixes of selected major economies, including among others China and the European Union. This article focuses in particular on the Chinese energy mix, given China's decisive influence on global energy trends.

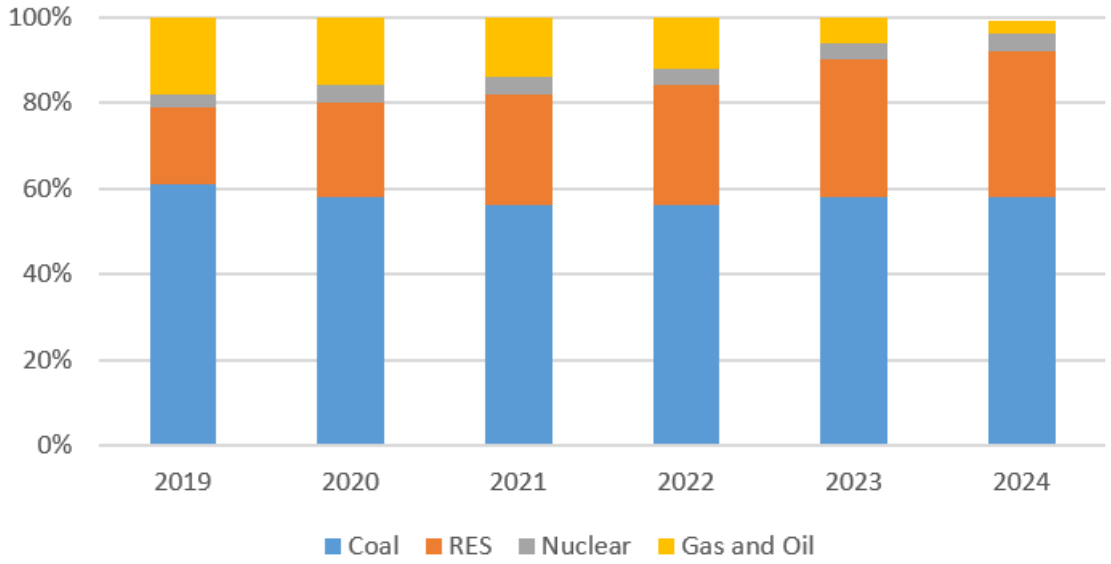


Fig. 2. Energy mix in China in 2019-2024. Source: own elaboration based on [1] [2] [3] [4]

Rys. 2. Mix energetyczny w Chinach w latach 2019-2024. Źródło:opracowanie własne w oparciu [1] [2] [3] [4]

China's energy mix has undergone significant transformation over the past five years (Fig. 2), driven by policy ambitions for carbon peaking and neutrality, rapid technological innovation, and regional disparities in resource endowment. Understanding the percentage shares of coal, oil, natural gas, renewables, and nuclear energy is critical for evaluating progress, informing policy, and guiding future research. The period 2019–2023 is especially relevant, marking the implementation of the Renewable Portfolio Standard (RPS), acceleration of wind and solar deployment, and ongoing debates about data consistency and reporting accuracy [5]. During that all years is visible that also China is going forward RES, but still coal remines as one of the most important source. In 2024, China's electricity generation mix was dominated by coal at 58%, while renewables accounted for 34%. It is also important to highlight that in 2024 as much as 34% of all renewable electricity produced globally originated from China, making the country the world's largest generator of renewable energy. At the same time, China accounted for 55% of global coal-fired electricity generation, remaining the dominant producer of coal-based power worldwide. [1] This dual position means that China is simultaneously the global leader in renewable energy expansion and the largest coal-dependent electricity producer. The present article examines this apparent paradox and seeks to explain its underlying structural drivers as well as its implications for the global energy transition.

2. Global Energy consumption and China's economy in that prism

Between 1990 and 2024, the global map of energy demand underwent a profound transformation: the center of consumption shifted from mature economies toward emerging markets, particularly in Asia. In 2009, the United States experienced an economic downturn, and this was also the moment when China began to position itself as the world's largest energy consumer (Fig. 3). By 2024, China accounted for approximately 27% of global primary

energy consumption—the highest share worldwide—and its portion of global electricity demand reached roughly one-third. [2] [6].

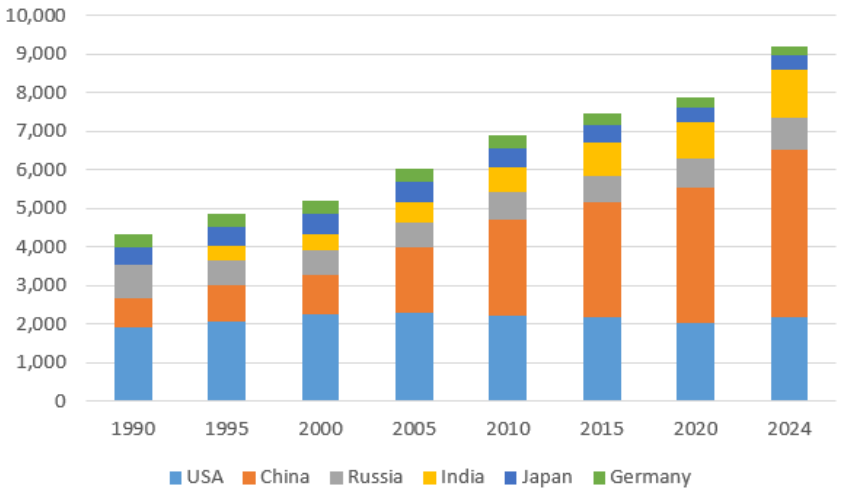


Fig. 3. Global energy consumption in fife selected countries [Mtoe]. Source: own elaboration based on [7]

Rys. 3. Światowa konsumpcja energii elektrycznej w pięciu wybranych krajach (Mtoe). Źródło: opracowanie własne na podstawie [7]

In the figures below, trend lines illustrate how electricity consumption (Fig. 4) and GDP (Fig. 5) have evolved in the United States and China over time. The data clearly show that U.S. electricity consumption has been increasing at a slower pace and has become progressively less correlated with GDP growth, indicating an ongoing decoupling of economic expansion from energy use and a steady decline in the energy intensity of the U.S. economy. This suggests that GDP growth in the United States is increasingly driven by services and high value-added sectors. In contrast, in China between 2020 and 2024 electricity demand grew faster than GDP, reflecting a period of intensified industrial development. As a result, China has emerged as both the world's largest consumer of electricity and the primary driver of global growth in power demand.

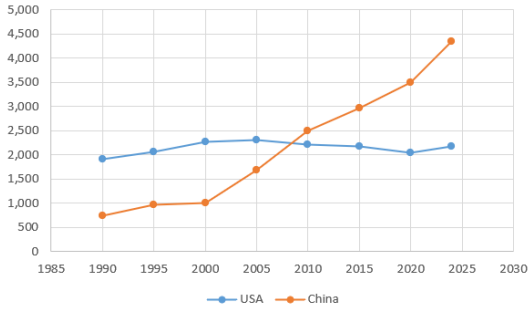


Fig. 4. Energy consumption in USA and in China [Mtoe]. Source: own elaboration based on [7]

Rys. 4. Konsumpcja energii w USA i w Chinach. Źródło: opracowanie własne na podstawie [7]

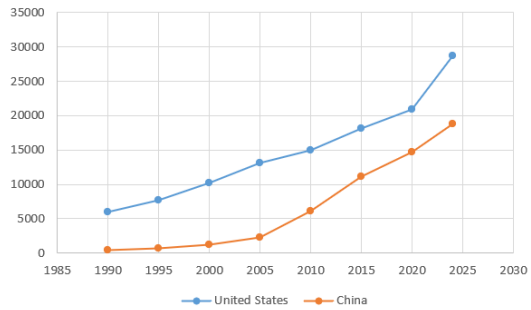


Fig. 5. GDP in USA and in China, Source: own elaboration based on [8]

Rys. 5. PKB w USA i w Chinach. Źródło: opracowanie własne na podstawie [8]

Given that China's industrialization is driven by highly energy-intensive sectors, such as heavy industry, basic materials processing, and large-scale manufacturing of electronic components, etc., its energy demand cannot be easily reduced or "relocated" without undermining the country's cost advantage. As a result, the strategic priority of Chinese energy policy is to maintain stable and low-cost energy supplies that ensure uninterrupted industrial production and preserve export competitiveness. Consequently, China must pursue a dual-track approach within its energy mix to safeguard the stability and security of its economy. On the one hand, it must continue to expand renewable energy sources (RES); on the other hand, it must retain a substantial share of coal in the power mix to guarantee system reliability and secure baseload capacity.

3. Energy mix in China and its dual-track

3.1. Investments and development of renewable energy supply chains in China and their global impact

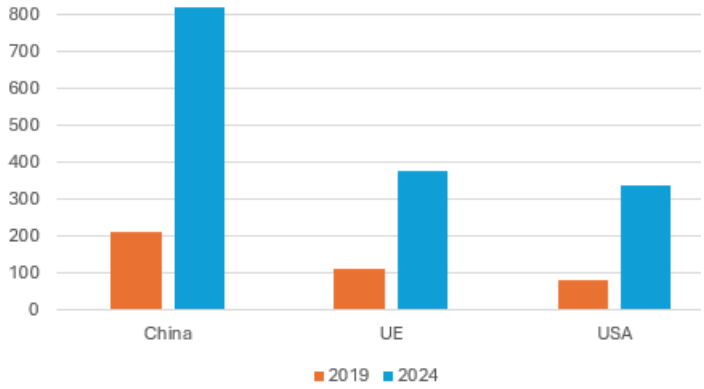


Fig. 6. Investment in RES in 2019 – 2024 [billion USD]. Source: own elaboration based on [1]

Rys. 6. Inwestycje w RES w latach 2019 – 2024 [mld USD]. Źródło: opracowanie własne na podstawie: [1]

As previously mentioned, the share of renewable energy sources (RES) in China's energy mix has reached 34%, and additionally, in the global energy mix, approximately one-third of all renewable electricity generated worldwide comes from China. Since 2019, the share of RES in China's energy structure has been increasing steadily by around 1–2 percentage points per year. All these indicators clearly show that China is the global leader in renewable energy development. This position is closely tied to China's significant and rapidly growing investments in the RES sector in recent years. Chinese investments in renewables have equaled the combined investments of the EU and the United States since 2019 (Fig. 6). In 2024, global capital expenditures on renewable energy reached 771 billion USD, with China alone accounting for 376 billion USD, almost half of all worldwide RES investments [1]. This prompts an important question: Where exactly has China invested these resources? Crucially, China is not focusing solely on expanding generation capacity. Instead, the country is investing strategically and comprehensively across entire supply chains. This includes raw materials, manufacturing

capacity, processing stages, technological development, and large-scale deployment of RES infrastructure. China holds dominant and often majority shares in nearly all stages of the global renewable energy value chain (Fig. 7), from photovoltaic production and battery materials to component manufacturing and system integration. These investments demonstrate that China's leadership is not accidental—it is the result of long-term industrial planning, vertical integration, and prioritizing control over critical technologies and materials essential for the global energy transition.

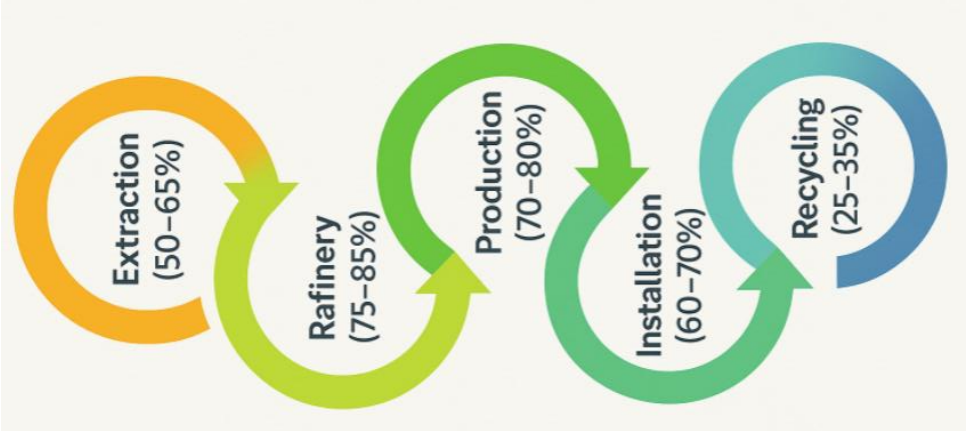
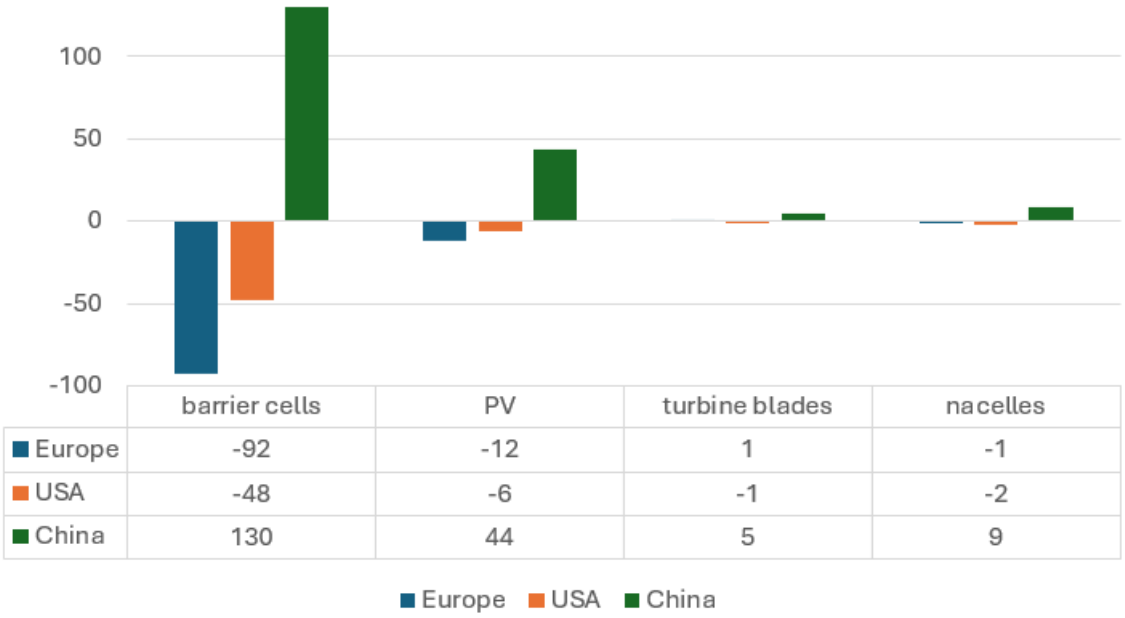


Fig. 7. Chinas participation in global RES value chains. Source: own elaboration
Rys. 7. Udział Chin w światowych łańcuchach dostaw RES. Źródło: opracowanie własne

China has achieved a clear global competitive advantage in the renewable energy sector. Its manufacturing capabilities in renewable energy technologies and energy storage far exceed domestic demand. An analysis of the supply–demand balance in European, U.S., and Chinese markets (Fig. 8) shows that both Europe and the United States face significant shortages of battery cells, photovoltaic (PV) modules, and wind-turbine components, while China possesses substantial production surpluses in all these categories. In the PV segment, domestic demand absorbs only about 55% of China's manufacturing capacity, meaning that the remaining production volume alone is equivalent to 55% of the rest of the world's total demand. This gives China the potential to dominate virtually every foreign PV market. A similar situation can be observed in the battery sector: approximately 80% of output is consumed domestically, yet the remaining surplus still corresponds to around 38% of demand outside China. In the wind-energy segment, the proportions are more balanced, but China continues to maintain an excess production capacity of roughly 20% of global foreign demand for wind-turbine components [1].



	barrier cells	PV	turbine blades	nacelles
Europe	-92	-12	1	-1
USA	-48	-6	-1	-2
China	130	44	5	9

Fig. 8 The difference between supply and demand of selected renewable energy technology elements (GW). Source: own elaboration based on [1]

Rys. 8 Różnica pomiędzy podażą a popytem wybranych elementów technologii RES (GW)

Altogether, these factors demonstrate that China plays an almost decisive role in global RES value chains, exerting significant influence over the final pricing and competitiveness of renewable-energy technologies on international markets (Fig. 9).

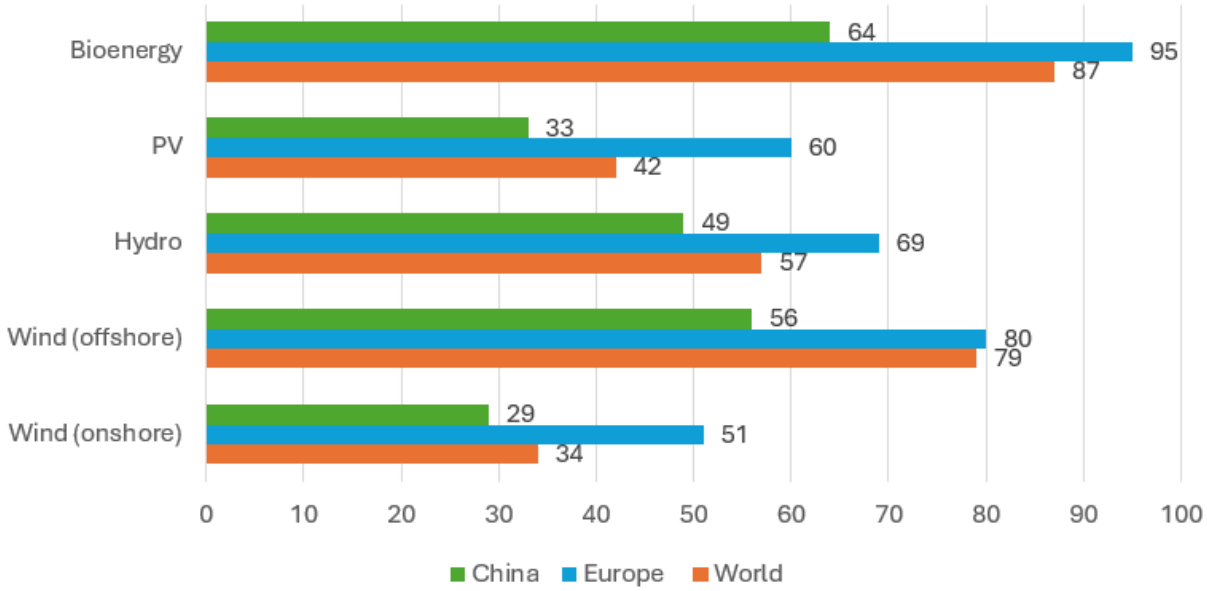


Fig. 9 Average unit cost of electricity (LCOE) of individual renewable energy technologies in 2024 (USD/MW). Source: own elaboration based on [1]

Rys. 9. Przeciętny jednostkowy koszt energii elektrycznej (LCOE) poszczególnych technologii RES w 2024 (USD/MW). Źródło: opracowanie własne na podstawie [1]

As a consequence, the European energy sector—relying predominantly on its own, generally more expensive technologies—generates noticeably higher electricity production costs, despite the very favorable wind conditions in the northern part of the continent. In the case of solar photovoltaics, elevated unit costs are driven not only by higher capital expenditures but also by additional expenses related to transporting imported components from China, as well as local installation, grid-connection, land-preparation, and administrative procedures. The cost gap measured by the average Levelized Cost of Energy (LCOE) between Europe and China is particularly pronounced in solar power and onshore wind energy. Lower cost-effectiveness compared with China is also observed in European hydropower and bioenergy, largely due to the higher prices of locally manufactured technologies and the absence of large-scale deployment, which in China generates substantial economies of scale. Strong state support combined with massive scaling has driven a global decline in renewable-technology prices, reshaping cost structures worldwide. From China's perspective, however, renewable energy is not merely a tool for accelerating the energy transition—it is also a strategic pillar of industrial policy, strengthening the country's position in global value chains and shaping the competitiveness of renewable-energy technologies across international markets.

At this point, it is important to highlight two key issues. The LCOE calculated for renewable energy sources does not include several additional costs required to ensure that the system can operate reliably, such as system balancing costs, energy storage costs, capacity reserves, and the costs associated with expanding and modernizing transmission networks. Considering the investment outlays that must be made today to build renewable energy installations, the short-term LCOE still appears more favorable for electricity generated from conventional sources. As indicated by the authors of the article "Calculation and Monte Carlo uncertainty analysis of the levelized cost of electricity for different energy power generation in the smart grid under time scales", renewable energy installations achieve a lower LCOE only after approximately 20 years [9]. It is also worth noting that the operational lifetime of PV installations and wind farms typically ranges from 20 to 25 years.

3.2. *Coal in Chinese Energy mix*

The chart shown below (Fig. 10) illustrates global electricity generation from coal compared with coal-fired electricity generation in China. While global coal power output is slowing and its share in the worldwide energy mix is declining, China continues to exhibit steady growth. Figure 11 extends the perspective to the 2020–2024 period, confirming the same pattern. The data presented in both charts, combined with the fact that China invested 46 bln USD in coal-fired power generation in 2024 and in 2025 it was 54 bln USD in 2025 [10], indicate that China maintains a clear upward trend in the use and expansion of conventional (coal-based) energy sources.

According to the Global Energy Monitor report [11], China remains by far the dominant driver of new coal-fired capacity worldwide. In 2025, China accounted for 80% of all newly commissioned coal power capacity globally.

These figures clearly indicate that China maintains a clear upward trend in the use and expansion of conventional (coal-based) energy sources and that China continues to play the central role in global coal growth.

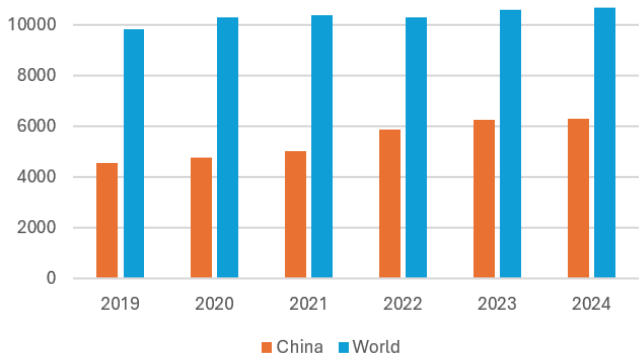


Fig. 10. Energy generation from coal in word and in China [TWh]. Source:own elaboration based on [6] [12] [13]
Rys. 10 Produkcja energii elektrycznej z węgla na świecie i w Chinach (TWh). Źródło: Opracowanie własne na podstawie [6] [12] [13]

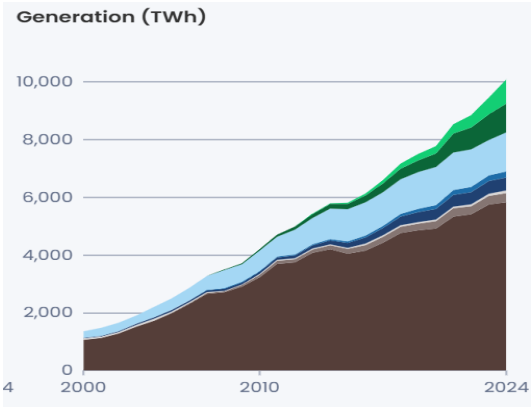


Fig. 11. Energy mix in China 2000-2024 (TWh). Source: [6]
Rys. 11. Mix energetyczny w Chinach 2000-2024 (TWh). Źródło: [6]

A primary reason why China maintains coal as a central component of its energy mix is that coal ensures a high degree of energy security. China possesses substantial domestic coal reserves and can therefore rely on its own resources to sustain electricity generation. Using domestically available production capacity allows the country to mitigate growing geopolitical risks - such as strategic rivalry with the United States, the potential disruption of maritime trade routes, or instability in the Middle East. In the context of geopolitical tensions, dependence on imported fossil fuels represents a major strategic vulnerability. Coal is thus not only an energy source but also an integral element of China's national security doctrine. Maintaining a high share of coal reduces the country's exposure to external supply shocks and sanctions.

Second important reason why China continues to operate and develop coal-fired power plants is the need to maintain the stability of its power system. It is well understood that renewable energy sources such as solar and wind power are highly dependent on weather conditions: at times the wind does not blow or the sun does not shine, while at other times strong winds or intense sunlight can generate sudden power surpluses. These fluctuations would be manageable if large-scale energy storage were widely available, but current storage capacity remains insufficient. As a result, such deviations lead to system imbalances, forcing countries either to import or to export electricity on short notice. For this reason, any country with a high share of renewables in its energy mix must retain access to conventional generation sources to prevent supply shortages. Some countries rely on gas-fired power plants for system stabilization, arguing that coal-fired units are not sufficiently flexible. However, the Chinese case demonstrates that coal plants can indeed serve as flexible assets when adequately modernized. Since 2021, 300 GW of existing coal-fired capacity in China has undergone flexibility retrofits [12]. New plants increasingly incorporate advanced boiler-side technologies—such as plasma ignition systems, upgraded coal mills, and combustion-stabilization solutions—which allow for safe operation at very low loads. At the same time, China has become a global leader in integrating energy-storage systems with coal units: hybrid configurations combining

flywheels and battery storage enable sub-second response times and ramp rates reaching 6.97% Pe/min, substantially enhancing their grid-regulating capabilities. Additional turbine-side upgrades—including HP–LP bypass systems, condensate throttling, and zero-output low-pressure cylinder technologies—support rapid load changes and allow for the effective separation of heating and electricity production in combined-heat-and-power plants. Through these coordinated measures, China's coal-fired power plants have become some of the most flexible and technically advanced in the world [14].

Another important aspect is the geographical distribution of coal mines, coal-fired power plants (Fig. 12), and industrial zones (Fig. 13). Historically, the location of coal deposits dictated where coal-fired power plants were built, and these plants subsequently attracted industrial development in their immediate surroundings. As a result, China's industrial base has become strongly concentrated in the eastern and southeastern regions of the country, particularly in the provinces of Shandong, Jiangsu, Zhejiang, and Guangdong, as well as in major economic hubs such as the Yangtze River Delta, the Pearl River Delta, and the Bohai Economic Rim. Together, these factors have led to the formation of deeply integrated industrial hubs, whose functioning continues to depend heavily on stable electricity supplies from coal-fired power plants.

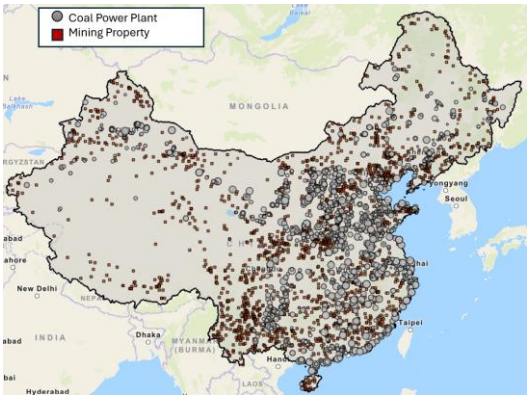


Fig. 12. Layout of coal power plants and mining properties. Source: [15]

Rys. 12. Rozłożenie kopalń węgla i elektrowni węglowych. Źródło: [15]

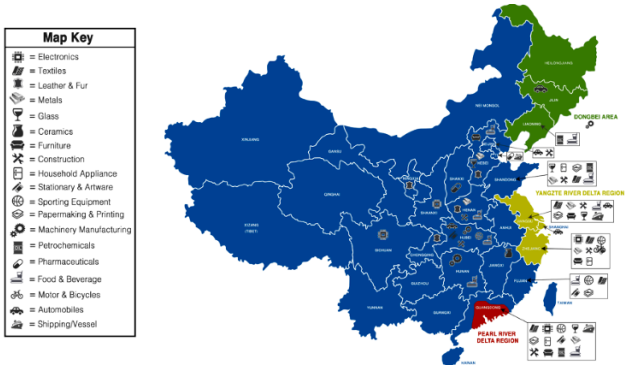


Fig. 13 Map of industry in China. Source: [16]

Rys. 13. Mapa stref przemysłowych w Chinach. Źródło:: [16]

Chinese authorities recognize that phasing out coal too rapidly would pose significant risks, including the destabilization of regional labor markets, declining revenues for local governments, and the emergence of large-scale stranded assets. In a centrally managed economy, socio-economic stability remains a key political priority, which means that the energy transition must proceed evolutionarily rather than revolutionarily.

4. Conclusions

Today, most countries—following globally accepted principles of climate and energy policy - strive to reduce the share of electricity generated from conventional sources and increase the contribution of renewable energy. In China, however, the situation looks different: the country follows a distinctive dual energy model.

The aim of the article was to examine the apparent contradiction within China's energy mix, where the share of renewables is rising while energy production from conventional sources is also increasing. The authors demonstrate that this duality is driven primarily by the continuously growing energy intensity of the Chinese economy. For several years, China has been the most energy-intensive economy in the world, and such a high demand for electricity leaves no room for supply shortages. As a result, China expands its renewable energy capacity, but it does not "abandon" coal.

In 2024, China made the largest renewable energy investments globally (the largest in its history) amounting to 376 bln USD. At the same time, it invested 54 bln USD in the construction of new and modernization of existing coal-fired power plants. Importantly, Chinese investments in renewables were not limited to expanding generation capacity; they also focused on building and strengthening domestic, and thus global renewable energy supply chains. The article shows that China plays a dominant role at every stage of these chains, shaping the global renewable energy market and influencing the prices of renewable technologies, and consequently the cost of electricity generated from these sources. Renewable energy in China is significantly cheaper than in Europe, and globally we can observe declining LCOE values for RES largely due to China's market position. Nevertheless, the increase in renewable generation in China serves primarily to meet growing energy demand, not to replace existing coal-based capacity.

China is not moving away from coal. It continues to build new coal-fired power plants and modernize existing ones. Maintaining coal in the national energy mix is driven by economic and systemic factors rather than a lack of climate ambition. Key determinants include: ensuring energy independence regardless of geopolitical conditions; guaranteeing system stability in light of enormous electricity demand and the weather-dependent nature of renewables; regional considerations, as conventional plants are located close to industrial clusters; and employment - approximately 6 million jobs depend on the mining and conventional energy sector. Moreover, because coal-fired power plants already exist and renewable capacity must be built from scratch, current LCOE calculations still favor coal. Renewables will become cheaper only after about 20 years of operation. Affordable electricity ensures China's industrial competitiveness. The Chinese energy transition model is therefore based on pragmatism and a full accounting of system-level transformation costs. It is an evolutionary approach: in the short and medium term, coal will remain the backbone of the power system, while in the long run its importance will gradually decline as energy storage technologies advance, grid infrastructure is modernized, and low-emission generation capacity expands.

The conclusions drawn from the Chinese model may also be important for Poland. Like China, Poland possesses its own coal resources and maintains a relatively high share of coal in its energy mix. The Polish energy sector is

strongly interconnected with domestic industry and the labor market. For this reason, Poland's energy transition should be carried out gradually, ensuring the security of electricity supply. Renewable energy must be developed—this is inevitable, as coal reserves will eventually deplete—but, similar to China, Poland should also focus on building domestic renewable energy supply chains rather than solely expanding generating capacity. Additionally, existing coal-fired power plants should be modernized so they can continue to stabilize the power system. Once again, it must be emphasized: the energy transition should be evolutionary, not revolutionary.

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Czego państwa takie jak Polska mogą się nauczyć na przykładzie chińskiej transformacji energetycznej

Streszczenie:

W ostatnich latach Chiny stały się bezsprzecznym globalnym liderem rozwoju odnawialnych źródeł energii (RES). Państwo to odpowiada za 34% globalnej produkcji energii elektrycznej z RES. W roku 2024 globalne inwestycje w RES wyniosły 771 mld USD, a w tym same Chiny zainwestowały 376 mld USD [1]. Czyli ok. 50% globalnych inwestycji w RES poczyniły same Chiny. Przy tym ważny jest też fakt, że Chiny nadal pozostają największym na świecie producentem i konsumentem energii z węgla. W 2025 r. węgiel wciąż odpowiadał za 58% produkcji energii elektrycznej w Chinach. Powstaje więc zasadnicze pytanie: dlaczego kraj, który dominuje w produkcji paneli fotowoltaicznych, turbin wiatrowych i magazynów energii, nadal utrzymuje węgiel jako fundament swojego systemu elektroenergetycznego?

SŁOWA KLUCZOWE: węgiel, chiński mix energetyczny, RES, węgiel, transformacja energetyczna, łańcuchy dostaw RES