

# Poland Energy Review 2024

Overview and conclusions

April 2024



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## Introduction

This Report was prepared by Arthur D. Little, an international strategic consultancy.

The report covers three main areas critical to understanding the **energy transition path in Poland**. These areas are as follows:

- 1) **Challenges of the electricity mix in Poland** - an analysis of the challenges faced by the Polish electricity system, including potential development scenarios, renewable energy sources, and the increasing consumption of electricity
- 2) **Role of natural gas in the context of decarbonization** - an analysis of the current state of the market, development plans, and a detailed analysis of natural gas consumption and pricing in Poland
- 3) **Coal usage in the face of the energy transition** - an analysis of market trends and regulations regarding coal consumption, as well as a detailed analysis of coal consumption and pricing in Poland

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# Poland transitions to renewables, but faces challenges in meeting electricity demand and supply, e.g. replacement of coal-fired capacity and more frequent Dunkelflaute

## EXECUTIVE SUMMARY – ELECTRICITY MARKET

### Poland's transition to sustainable energy sources

- Poland is **transitioning from coal-reliant to more sustainable sources**, with renewable energy sources providing nearly 25% of annual domestic electricity production in 2023, up from around 9% in 2018
- **The rapid growth in RES<sup>1</sup> is primarily due to rising photovoltaic and wind capacity.** PV production increased from 0.7 TWh in 2019 to 13.2 TWh in 2023, driven by a national rooftop PV support scheme and emerging larger PV farms. Wind production also grew from 12.3 TWh in 2019 to 22.1 TWh in 2023
- **The 2023 increase in renewable generation in Poland has driven a sharp drop in estimated CO2 emissions volumes.** Compared to 2015, Poland's estimated CO2 emissions in 2023 dropped by 21%

### Increased electricity consumption in the long-term

- **Consumption and production of electricity in Poland has remained relatively flat in recent years**, despite changes in the generation mix and increasing prices. After 2015-2018 growth, Poland's electricity consumption remained rather steady, mostly driven by improvements in the country's energy efficiency, as well as the Covid-19 pandemic and subsequent recovery period
- Growing energy efficiency in Poland leads to a lower need for energy per unit of GDP. However, Polish electricity **consumption is expected to rapidly increase by 2040, driven by electrification of transport, heating and industrial production**

### Energy mix challenges

- Growing consumption of electricity is expected to introduce **challenges to the energy mix**
  - As Polish electricity production relies more and more on the energy generated by renewable sources, the **energy mix faces periods of oversupply, especially during summer, and deficits in electricity production in winter seasons**
  - Consequently, an energy generation mix that leans more heavily on renewable energy sources **emphasizes the necessity for a balancing power generation capacity**, which could be achieved through the utilization of **natural gas**

# Natural gas may be a key player in energy transformation and decarbonization, with the path and pace of progress yet to be defined

## EXECUTIVE SUMMARY – GAS & COAL MARKETS

### Natural gas as a transitional fuel for Poland's energy transformation

- **Natural gas appears to have potential in replacing coal-fired generation capacity** and acting as a transitional fuel over the next 10-15 years, **aiding in the stabilization of renewable energy sources**
- Consequently, gas consumption in Poland may increase in the near future, primarily driven by its **role in decarbonization**, with factors such as decarbonization targets, **regulatory measures**, increasing **electricity demand**, and balancing requirements
- On the other hand, natural gas can face **negative demand and supply shocks** (seen in e.g., price volatility). Furthermore, the gas industry's position could be affected by the anticipated **emissions trading system, which is expected to include gas by 2027**

### Improving gas market stability and independence via new infrastructure

- **Poland has successfully transformed its gas supply infrastructure and achieved independence from Russian gas** through strategic investments in the Baltic Pipe and expansion of the LNG terminal in Swinoujscie. While Poland has one of the lowest gas import dependency ratios in the EU, its limited storage and regasification capacities may still impact supply stability to some extent
- **Gas prices have stabilized at significantly lower levels compared to 2022** and the price spike caused by the war in Ukraine. This provides greater security and stability for both household and industrial users and is expected to drive demand up in the mid-term. However, it should be noted that similar price spikes in the future, as seen in 2022, cannot be ruled out due to the relatively unstable geopolitical and macro-economic environment

### Challenges and opportunities for coal reduction

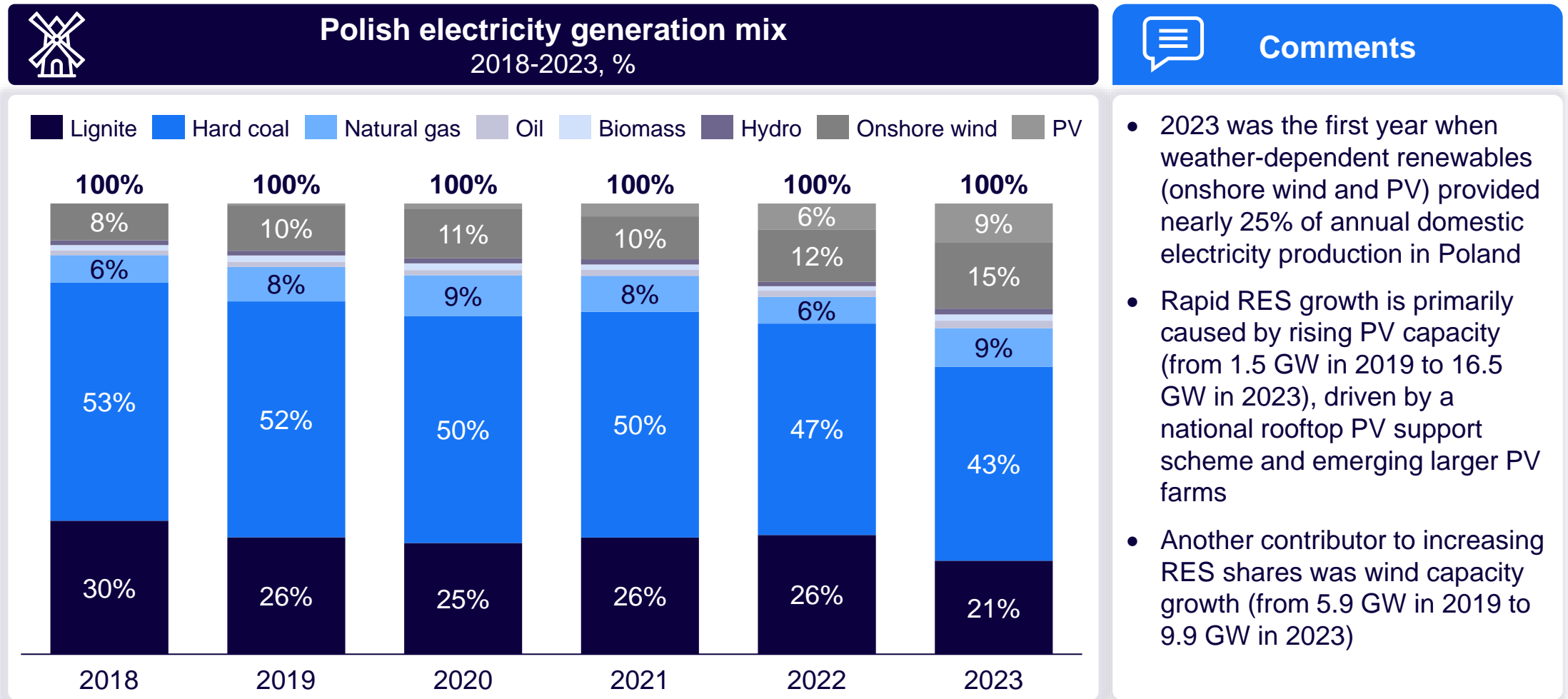
- **Poland is facing growing pressure to reduce its coal consumption and accelerate decarbonization efforts**, both on the EU and national level. While the transition of household users from coal-fired systems to gas boilers and heat pumps has accelerated in recent years, the transition of industrial coal users has been slower due to the lack of economically viable alternatives
- Although **energy transformation and decarbonization** are becoming a fact in Poland, the exact path and pace towards achieving these goals are still being determined, with **coal likely to be gradually phased out** in the coming years, with full decommissioning by 2049

# CONTENTS

1	Electricity mix challenges in Poland	7
2	Natural gas in the context of decarbonization	23
3	Coal usage in the energy transition	38
4	Glossary and sources	53
5	Appendix - supporting analyses	59

# ELECTRICITY MIX CHALLENGES IN POLAND

# Polish electricity generation mix transitions from coal-based, towards more diversified, with ~25% of electricity generated in 2023 coming from RES



- 2023 was the first year when weather-dependent renewables (onshore wind and PV) provided nearly 25% of annual domestic electricity production in Poland
- Rapid RES growth is primarily caused by rising PV capacity (from 1.5 GW in 2019 to 16.5 GW in 2023), driven by a national rooftop PV support scheme and emerging larger PV farms
- Another contributor to increasing RES shares was wind capacity growth (from 5.9 GW in 2019 to 9.9 GW in 2023)



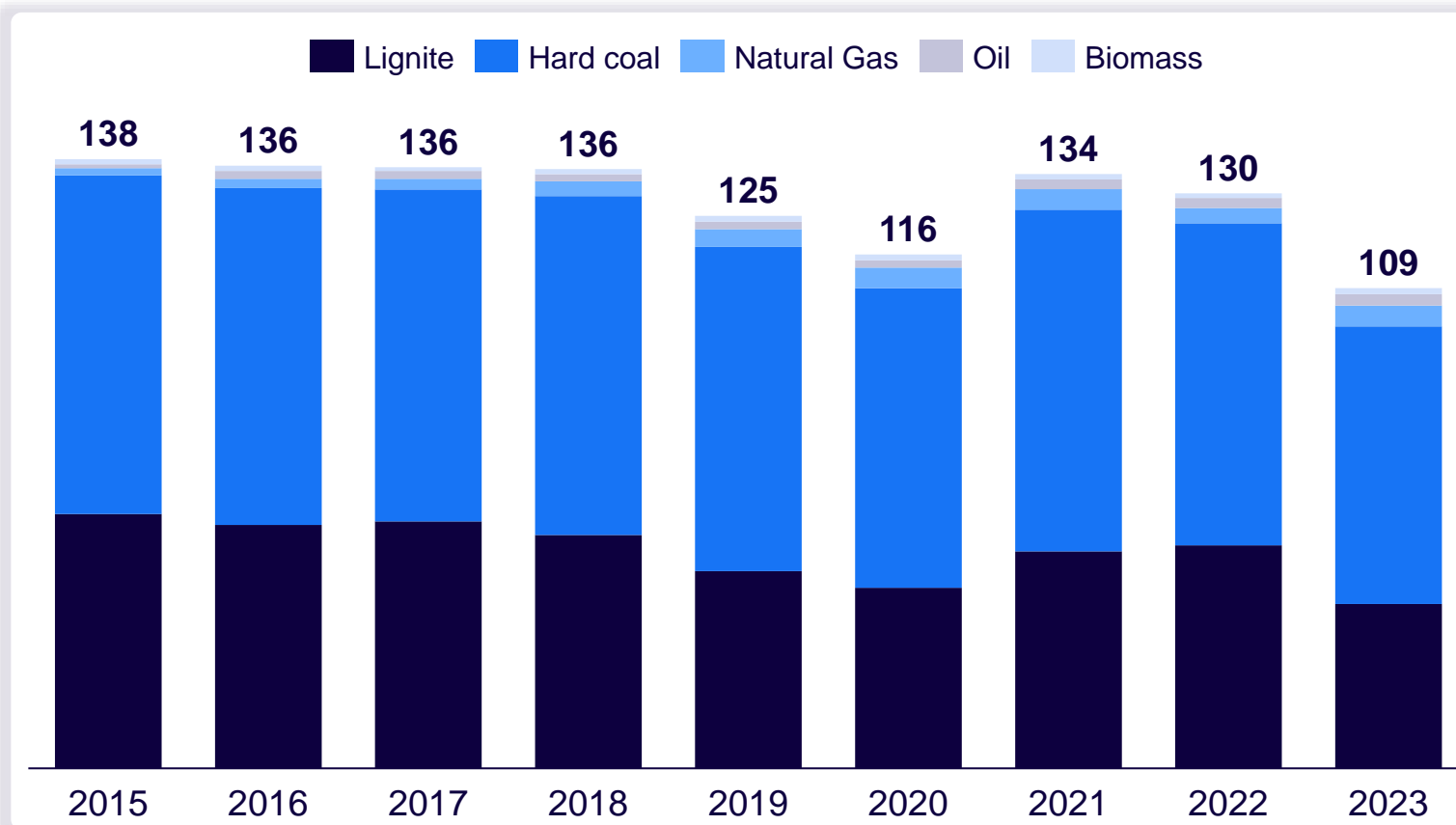
## The 2023 increase in renewable generation in Poland has driven a sharp drop in estimated CO<sub>2</sub> emissions



### CO<sub>2</sub> emissions from domestic electricity production 2015-2023, Mt



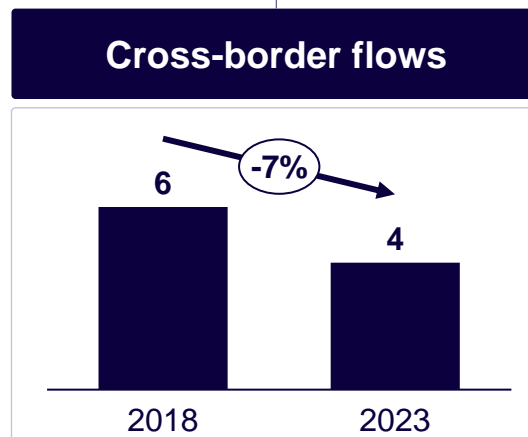
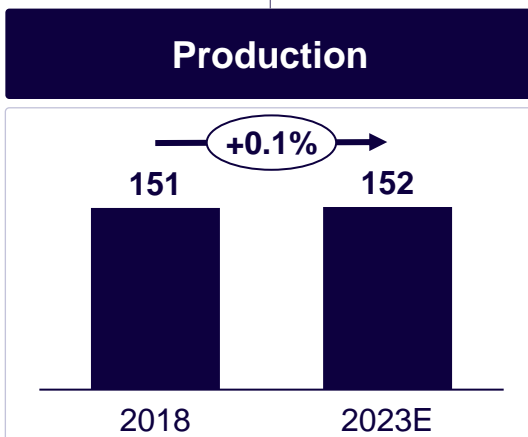
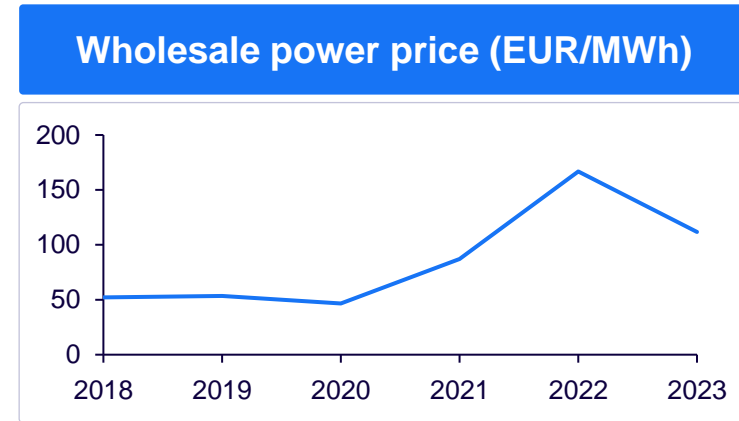
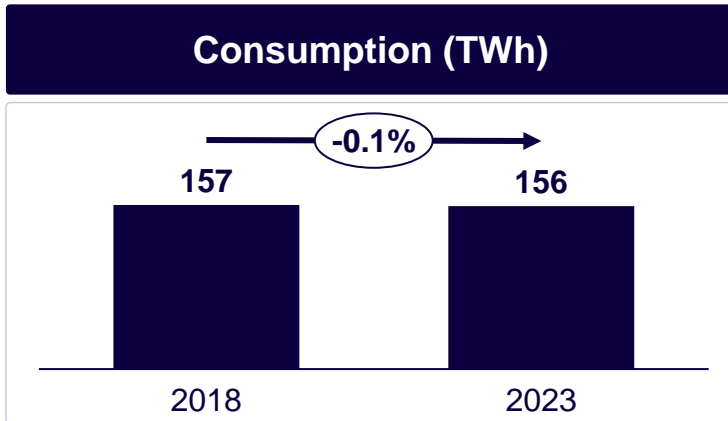
#### Comments



- Poland's estimated CO<sub>2</sub> emissions in 2023 dropped by 21% compared with 2015
- Decrease in emissions is driven by the increasing volumes and shares of renewable generation, mostly replacing output from the most emission-intensive coal-fired plants with low efficiencies (~34-37%)

# Consumption and production of electricity in Poland has remained relatively flat in recent years, despite changes in the generation mix and price volatility

🔍 Deep dives on each segment on following slides



## Despite changes in the generation mix and economic development, Polish electricity consumption has remained constant in recent years



### Poland's net electricity consumption

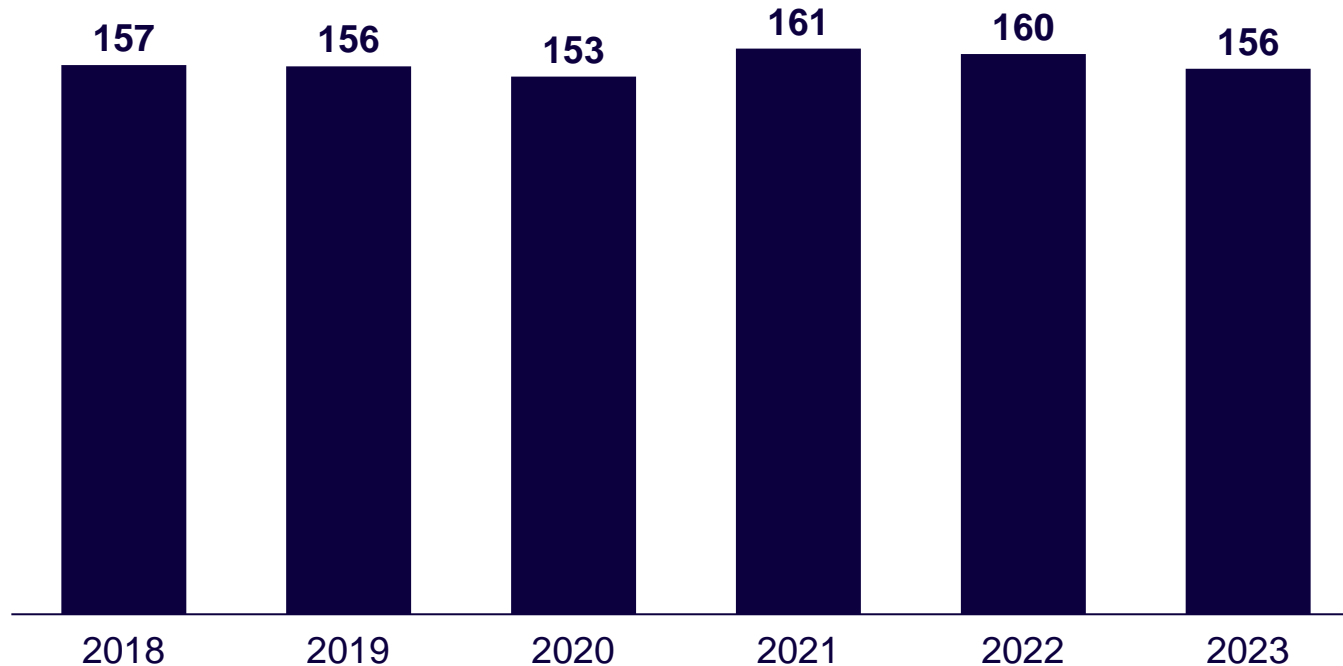
2018-2023, TWh



### Comments

CAGR  
'18-'23

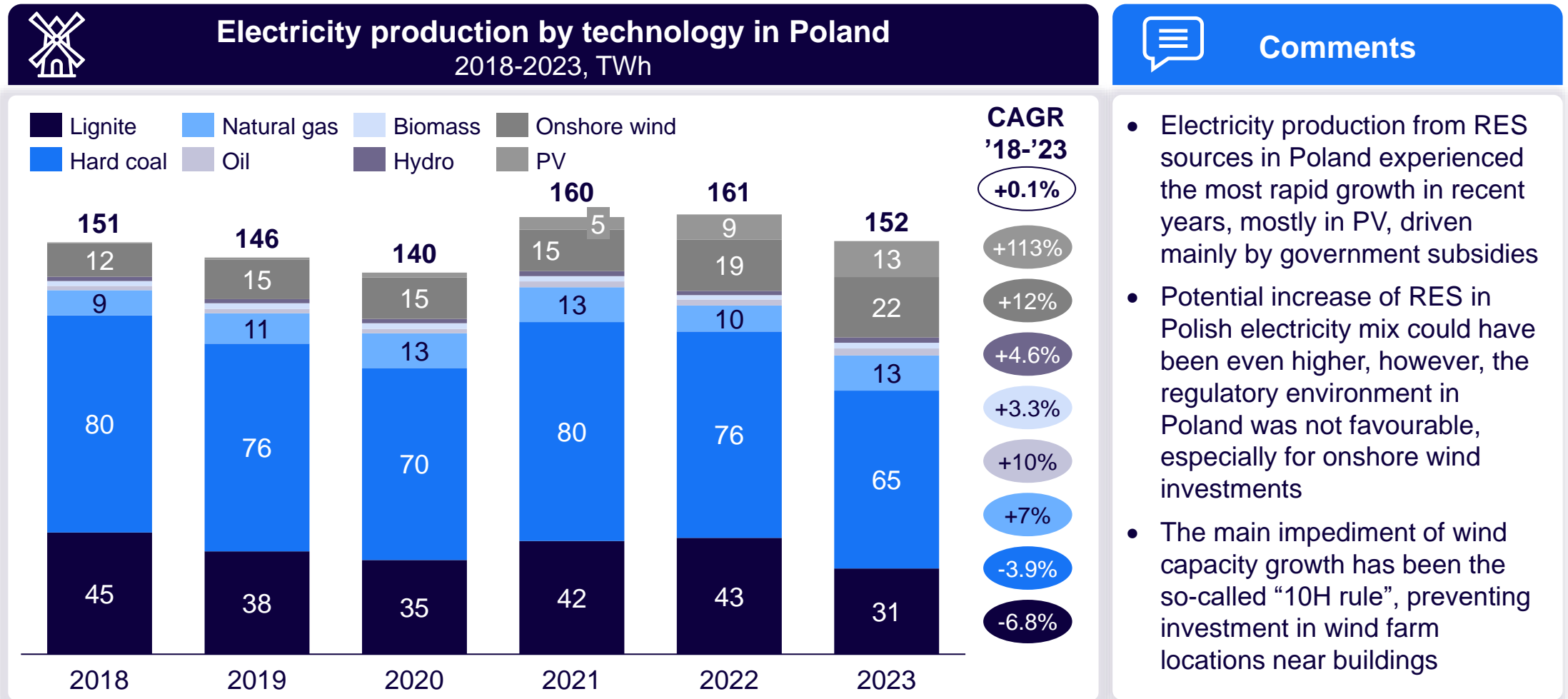
0%



- After 2015-2018 growth, Poland's electricity consumption has remained rather steady, mostly driven by improvements in the country's energy efficiency, as well as the Covid-19 pandemic and subsequent recovery period
- Growing energy efficiency in Poland leads to lower need for energy per unit of GDP. A phenomenon also observed in other developed EU countries



## The share of RES in Polish energy generation mix increased from ~9% in 2018 to ~25% in 2023, driven mostly by the increase of onshore wind and PV

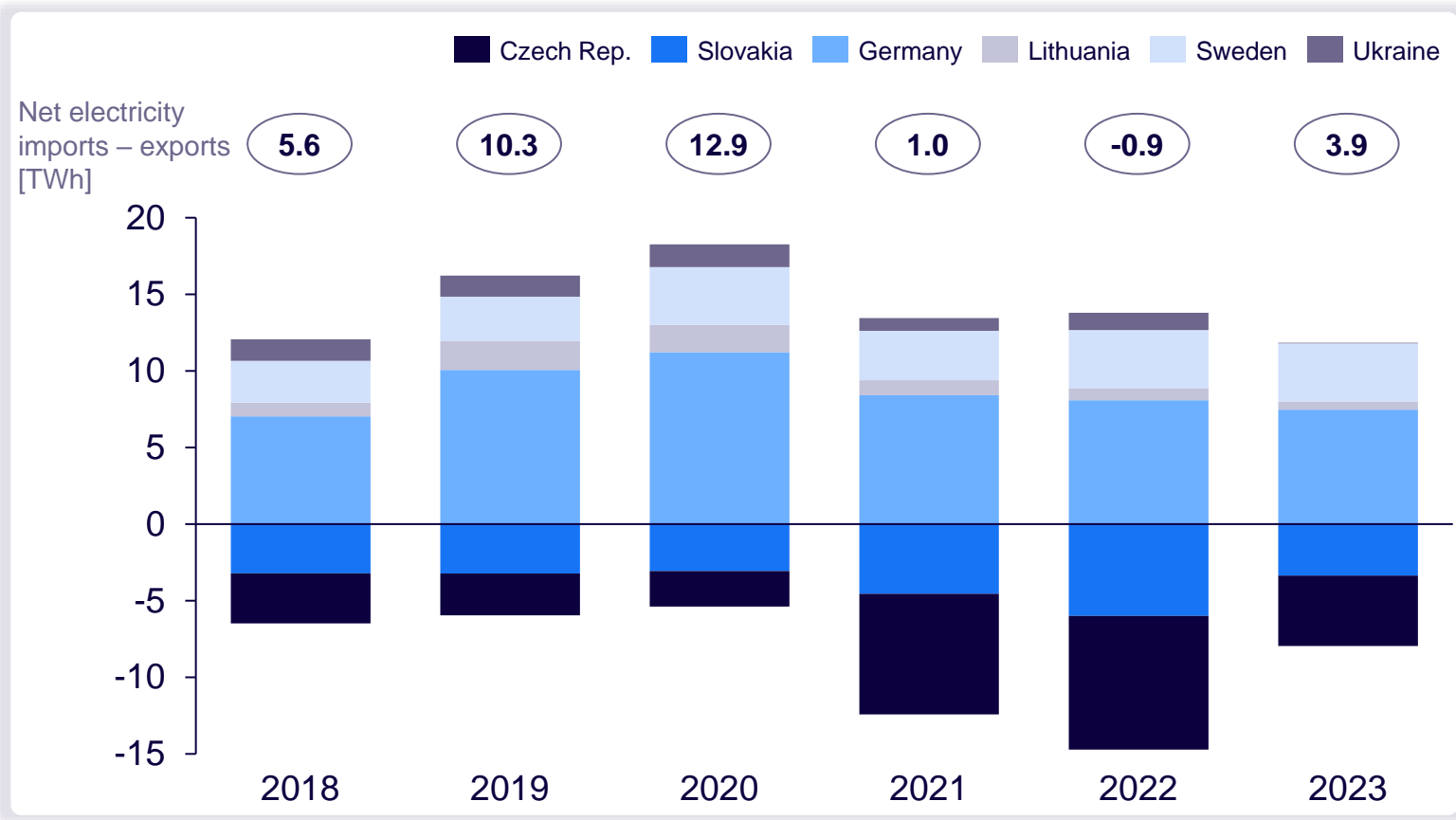




## Germany is the main exporter of electricity to Poland, followed by Sweden, while Poland exports power to the Czech Republic and Slovakia

← → **Cross-border flows: imports (+) and exports (-) from Poland**  
2015-2023, TWh

**Comments**

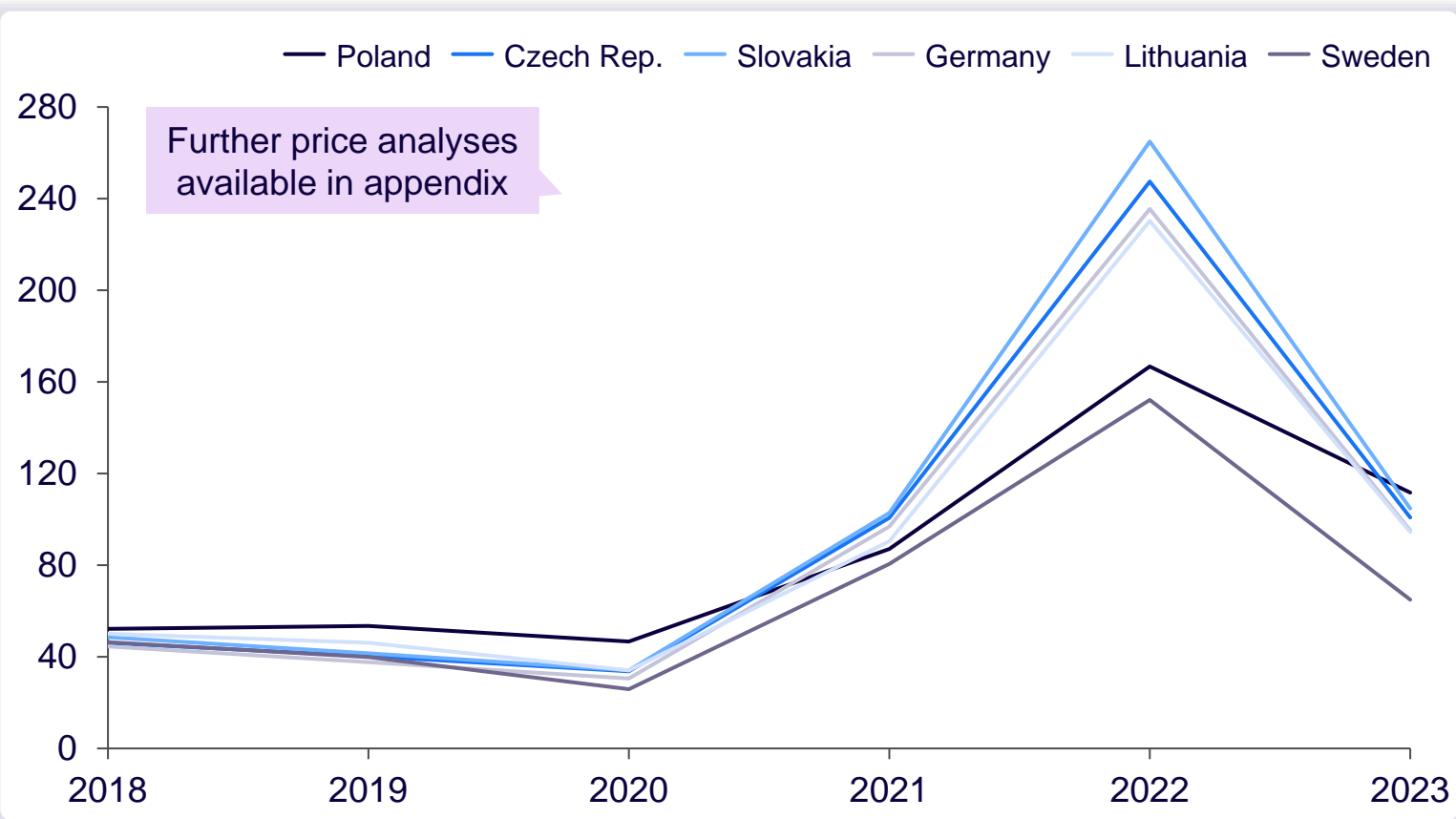


- Germany continues to be the main exporter of power into Poland
- Some German electricity imports transit Poland to Czechia and Slovakia
- Poland and other Central European countries still have lower interconnection capacities than Western Europe
- For example, interconnection capacity between FR-ES and FR-DE is around 2.8-3 GW while DE-PL, DE-AT or DE-CZ is around 1.5 GW each

# Power prices in Poland and neighbouring countries follow similar patterns, although differences persist between countries, mainly due to interconnector capacity

**DA<sup>1</sup> wholesale power prices in Poland and its neighbours**  
2018-2023, EUR/MWh

**Comments**



Further price analyses available in appendix

- In 2022, DA<sup>1</sup> electricity prices in Poland were the second lowest compared to its neighbours, mainly due to record high natural gas prices in Germany
- The relationship changed in 2023, when gas prices dropped
- Poland and CEE are generally higher-priced than Western Europe, due to weaker interconnector capacity

1) DA – Day Ahead  
Source: ENTSO-E; IJ

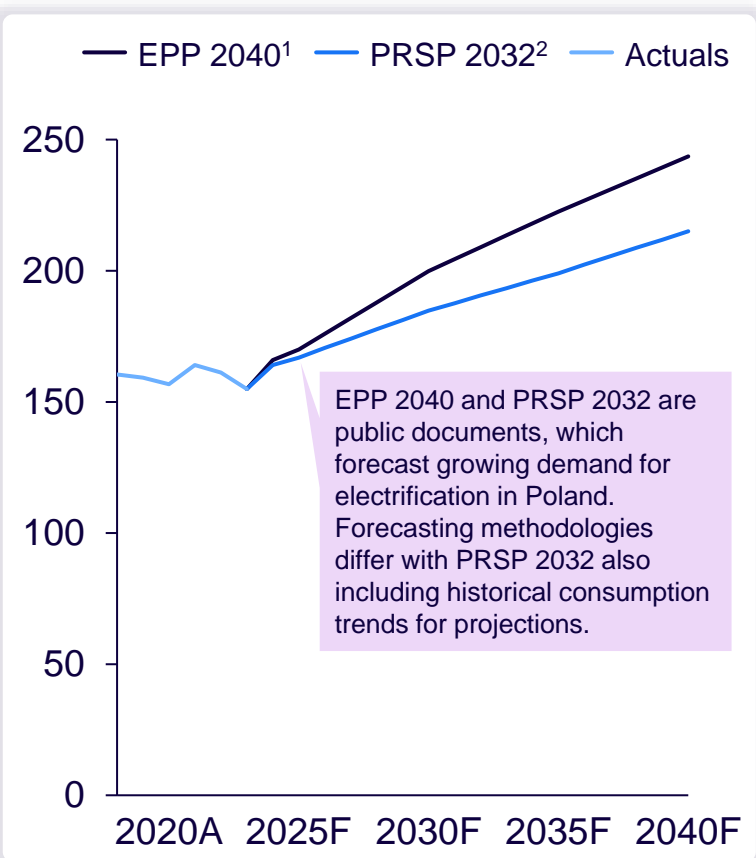
# Changes in the Polish electricity mix come with challenges driven by expected increase in consumption and integrating RES into the power system

		Deep dives on following slides		Description	
Demand side	1	Increasing electricity consumption		Polish electricity consumption is expected to <b>rapidly increase by 2040</b> , driven by growing penetration of <b>electrification of transport, heating and industrial production</b>	
	2	Evolving capacity mix		Apart from growing consumption, Polish energy mix is evolving from reliance on fossil fuels towards renewable sources of energy, with potential to <b>achieve more than 50% energy generation from renewable sources by 2040</b>	
Supply side	3	Weather-dependent output		As Polish electricity production relies more and more on the energy generated by renewable sources, the energy mix faces <b>periods of oversupply</b> , especially during summer, and <b>deficits in electricity production</b> in winter seasons	
	4	Declining prices of RES-generated energy		Renewable energy sources provide <b>cheaper electricity compared to fossil fuels</b> because they don't require external fuel sources. However, during <b>oversupply periods</b> , prices can reach <b>negative numbers</b> , as Polish electricity grid lacks storage capacity and the <b>overproduced energy must be utilized</b>	
	5	Lack of network capacity		The rapid growth of PV capacity and the stable growth of onshore wind capacity have led to the <b>exhaustion of the connection capacity of distribution and transmission networks in Poland</b> , as evidenced by the refusal of operators to issue connection conditions	

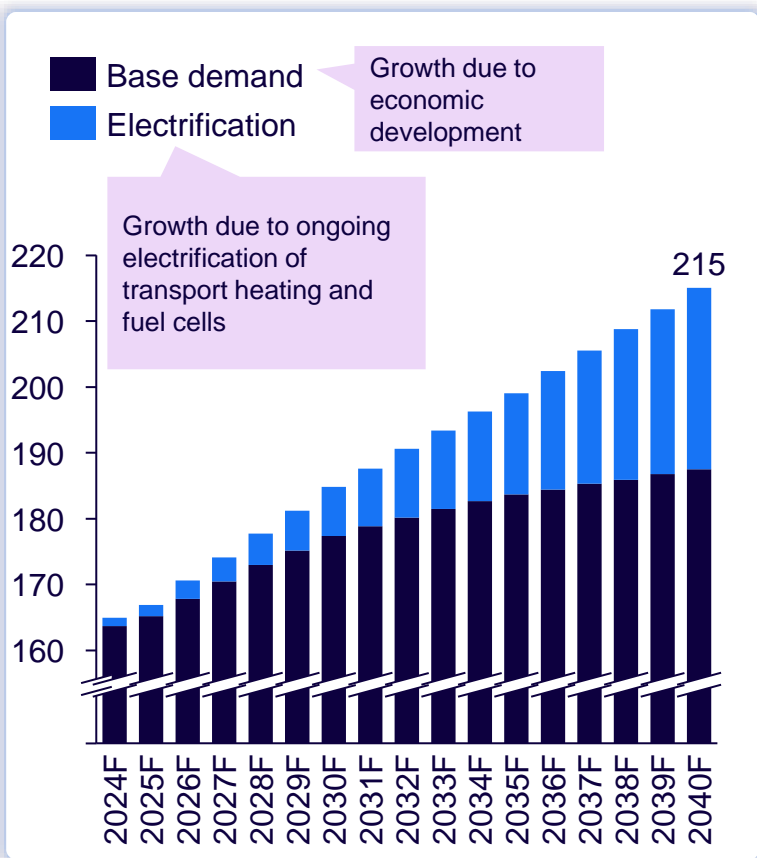
01

# In the coming years, demand for electricity in Poland is expected to increase significantly, from ~156 TWh in 2023 to ~215 TWh in 2040

**Expected net electricity consumption growth in Poland to 2040, TWh**



**Expected electricity demand growth by area, TWh**



**Comments**

- By 2040, the demand for electricity in Poland will increase significantly, driven by the expected economic growth of the country, which, despite increasing energy efficiency, will be associated with a growing base of energy demand
- Strong growth of Poland's electricity consumption is expected to be driven not only by economic growth but also by other emerging drivers such as:
  - Electric vehicles
  - Heat pumps and aircon
  - Electrolysers
  - Industry electrification

1) EPP 2040 – latest scenario / version shown, accounting for war in Ukraine from Jun 2023

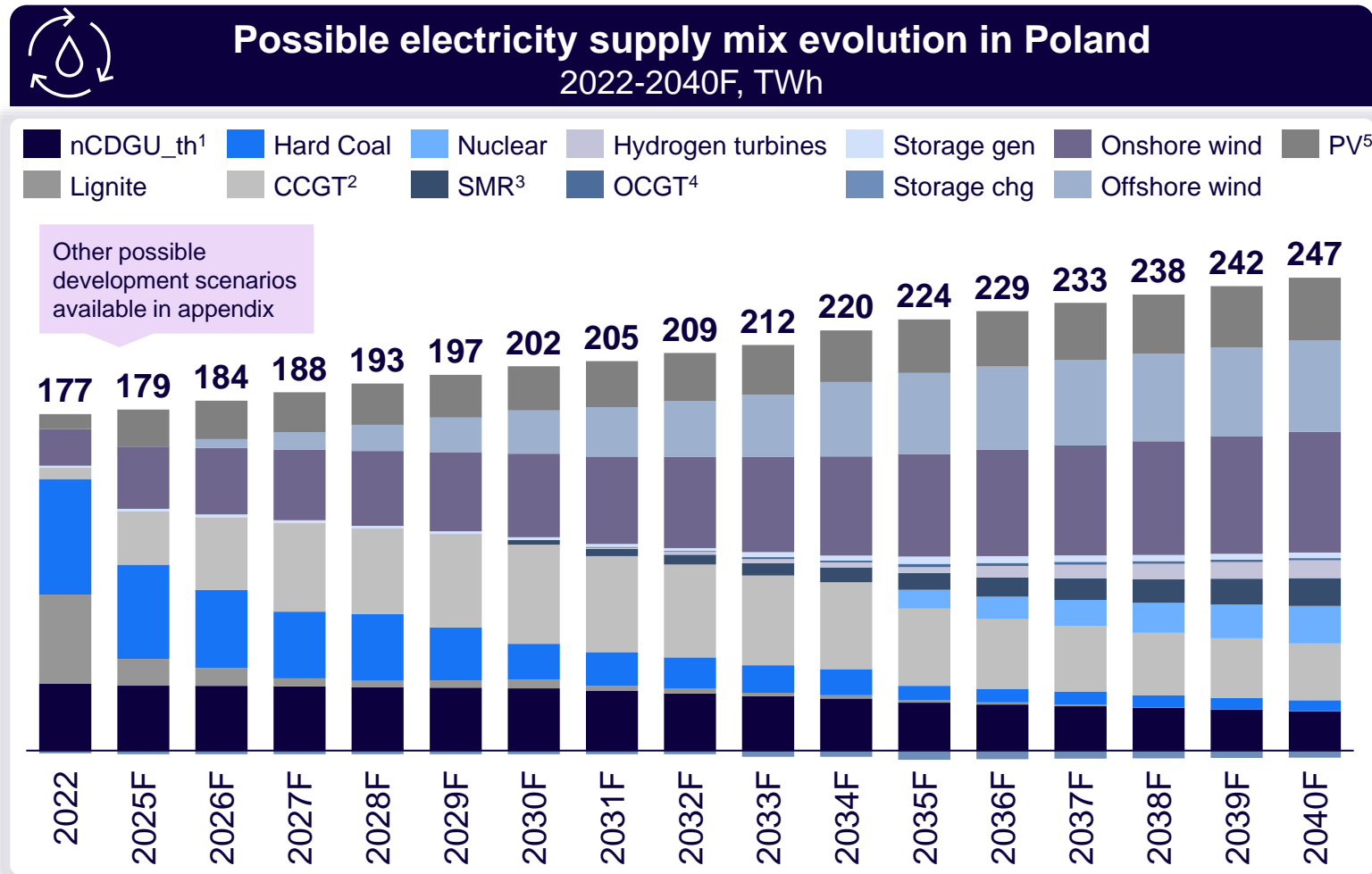
2) PRSP 2032 – base scenario shown, PRSP 2032 includes also rapid growth scenario, with consumption in between EPP 2040 and base PRPS 2032 scenario

Source: Poland's Energy Policy 2040; PSE's Network Development Plan (PRSP 2032); URE; IJ



02

# The Polish electricity mix is expected to evolve into a system dominated by wind and solar generation by 2040



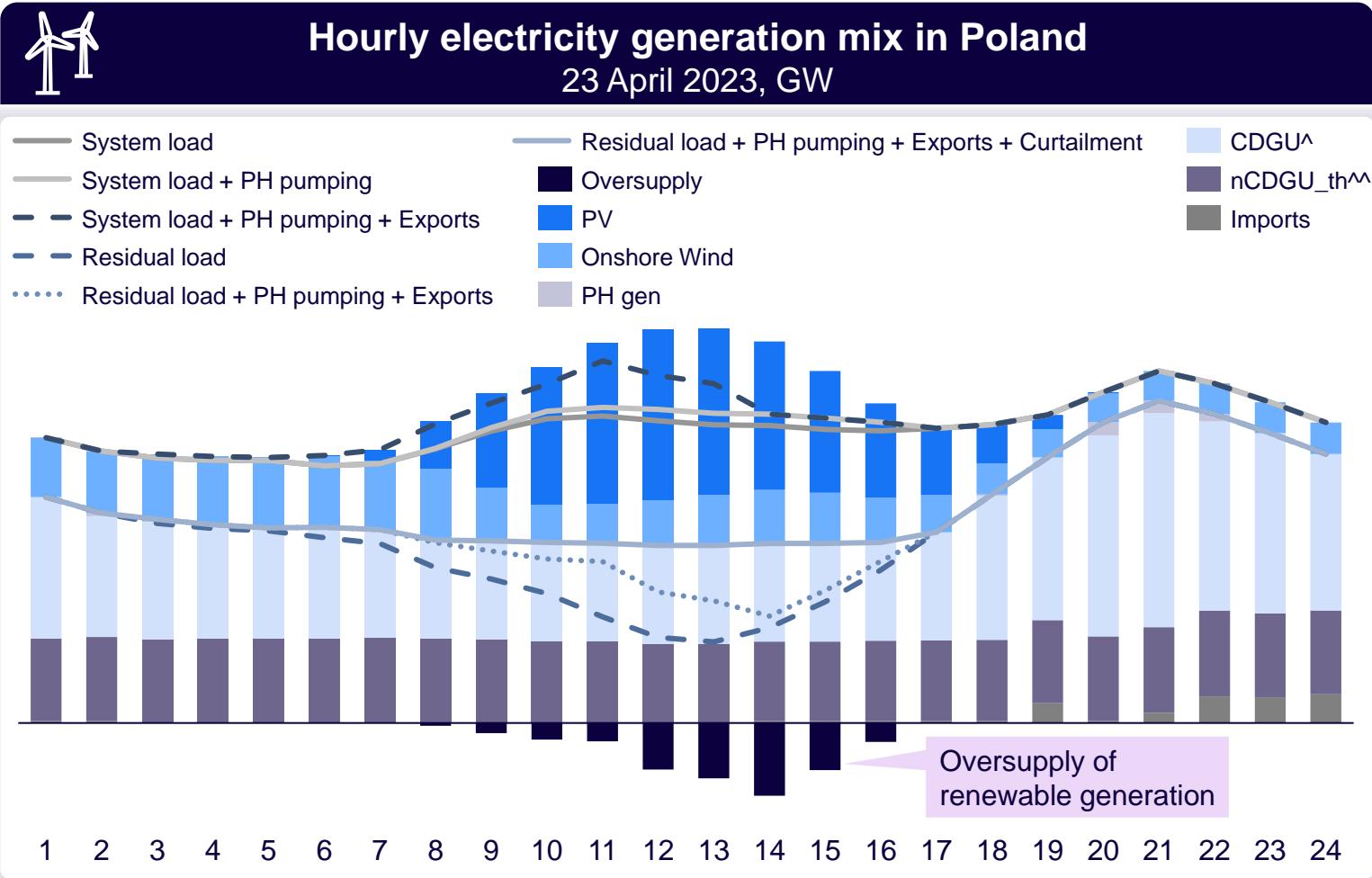
**Comments**

- Despite numerous technical challenges related to integration of weather-dependent renewables in the system, our modelling shows that Poland's electricity supply is likely to evolve into a mix dominated by renewable energy sources
- The modelled scenario shows that:
  - The share of renewables in total power generation may reach 59% by 2040
  - Possible emissions reductions by 2040 (compared to 2005) may reach 83%

1) nCDGU – Non-centrally dispatched generating units; power plants or generators that are not directly controlled by a central dispatching authority; 2) CCGT – Combined Cycle Gas Turbine; 3) SMR – Small Modular Reactor; 4) OCGT – Open Cycle Gas Turbine; 5) PV - Photovoltaics  
Source: IJ model

03

# The increasing share of electricity generated by renewables leads to a temporary oversupply of energy, highlighting need for increased storage or export capacity



## Comments

- Prior to 23 Apr 2023, only wind oversupply had been subject to curtailment by the PSE<sup>1</sup> due to system balancing and security
- On 23 Apr, the first case of PV generation curtailment was observed, as a last-resort measure after exhausting the pumping of storage and exports
- The curtailment was necessary to maintain spinning reserves from CDGUs<sup>2</sup> for downward frequency control (FCR<sup>3</sup>/FRR<sup>4</sup> reserves)
- The event highlighted the need for more storage or export capacity, or development of elastic demand (e.g. electrolysers)

1) PSE – Polish transmission system operator (Polskie Sieci Elektroenergetyczne S.A.); 2) CDGU – Controllable Distributed Generation Units; 3) FCR – Frequency Containment Reserve; 4) FRR – Frequency Restoration Reserve  
Source: ENTSO-E; PSE; IJ

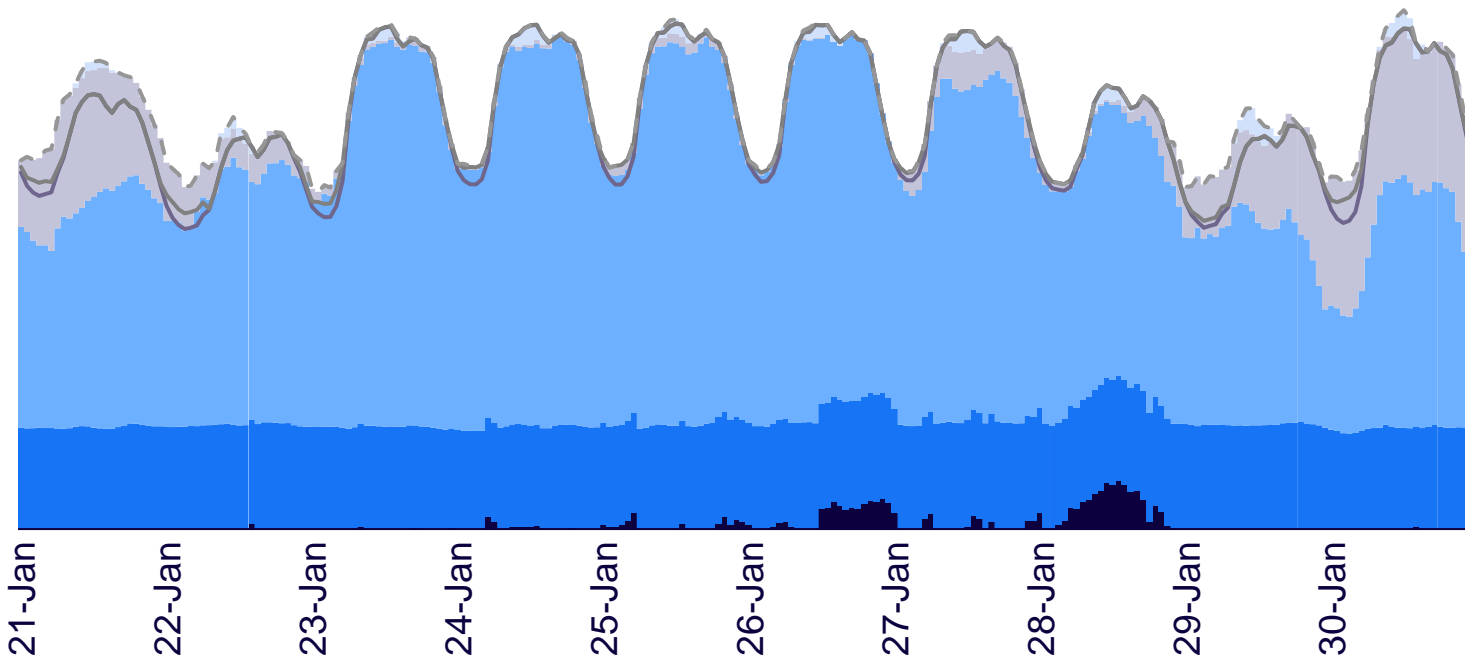
03

In contrast to oversupply periods during sunny days, winter months are a challenge to reliability of supply in high-demand and low-wind/low solar periods



**Electricity generation in Poland**  
Hourly, 21 January – 30 January 2023, GW

— System load  
— System load + PH pumping  
- - System load + PH pumping + Exports  
■ Imports  
■ nCDGU\_th^  
■ CDGU^  
■ Onshore Wind  
■ PV



### Comments

- Jan 2023 provides an illustration of renewable power generation draught (Dunkelflaute<sup>1</sup>) in the Polish power system (KSE)
- Low wind output<sup>2</sup> persisted for a period of consecutive 98h across 23rd to 27th Jan 2023
- PV generation was also very modest, on average 580 MW (5% of installed capacity)
- In addition to the very limited renewable supply was high demand, typical for winter season in Poland
- The KSE has to rely on dispatchable thermal generation, imports or Demand Side Response (DSR) on days like these

1) Dunkelflaute – a period of time in which little or no energy can be generated with wind and solar power; 2) Below 700 MW, or below 8% of installed capacity  
Source: ENTSO-E; PSE; IJ

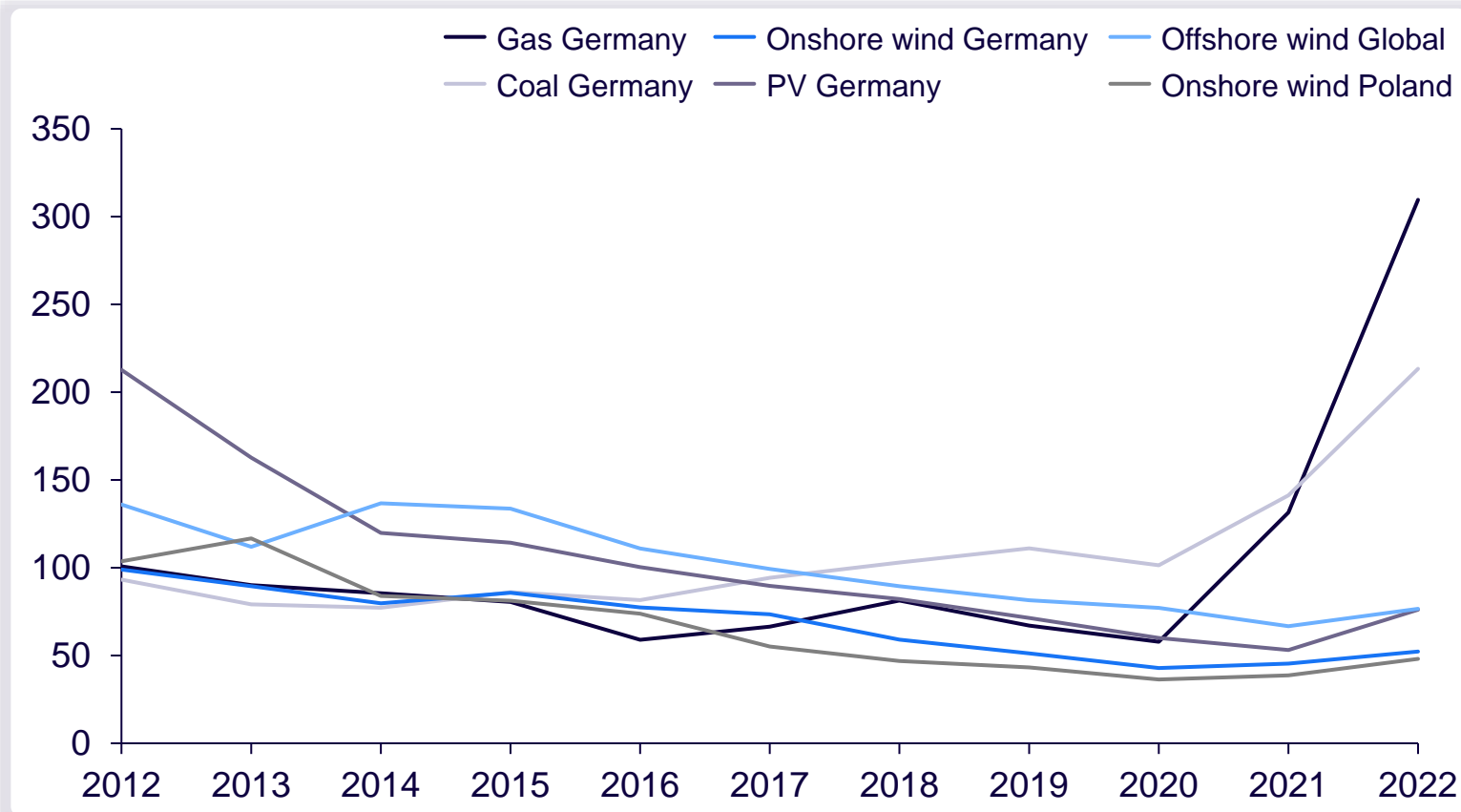
04

## Renewable technologies have become more economic than coal or gas fired generation ...



### LCOE<sup>1</sup> of RES compared to the cost of coal and gas generation

2015-2022, EUR/MWh<sup>2</sup>



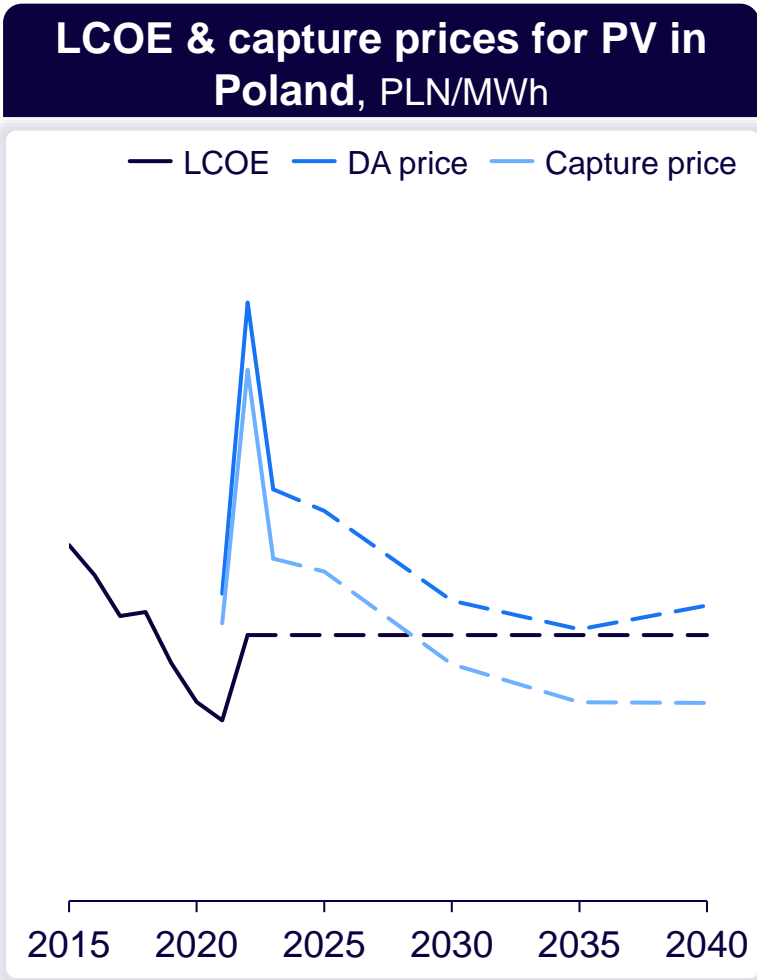
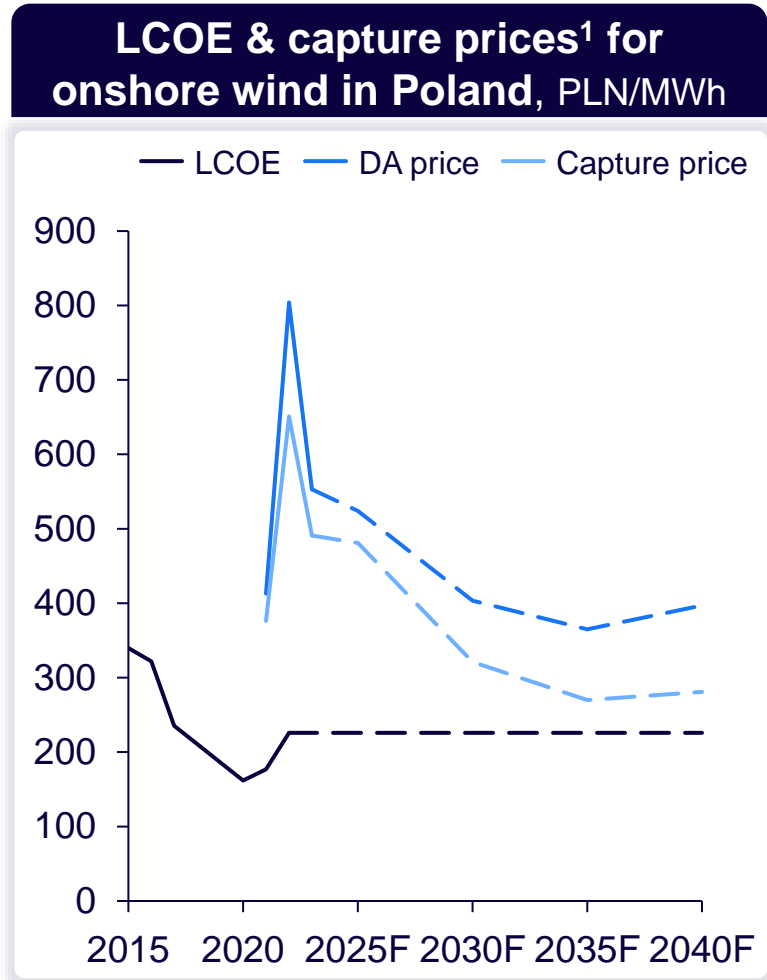
### Comments

- Onshore wind is currently the most mature and cheapest technology on an LCOE basis
- After years of progressive drops, the LCOE of PV went up in 2022, driven by supply chain disruptions following the Covid-19 pandemic
- While experiencing a similar downward trend as other renewables, Offshore wind remains relatively more expensive
- Renewables have become significantly cheaper on the LCOE basis than coal and gas-fired generation

1) LCOE – Levelized Cost of Electricity; 2) Converted from USD  
Source: IRENA; ECB; IJ

04

...however, the effect of increasing renewables on spot power prices can be a double-edged sword for renewable investment economics



### Comments

- Wind or solar generation has no fuel or CO<sub>2</sub> cost, allowing for low prices of generated electricity
- In periods of high renewable output, spot power prices are suppressed and often reach zero or negative levels (the latter being an expression of technical challenges with system balancing and flexibility)
- Low spot prices in the long run will translate into even lower capture prices for individual technologies, which may undermine the business case of further investments (“cannibalization”)

1) Average electricity price that a RES project achieves throughout a given period of time  
Source: IRENA; PSE; IJ

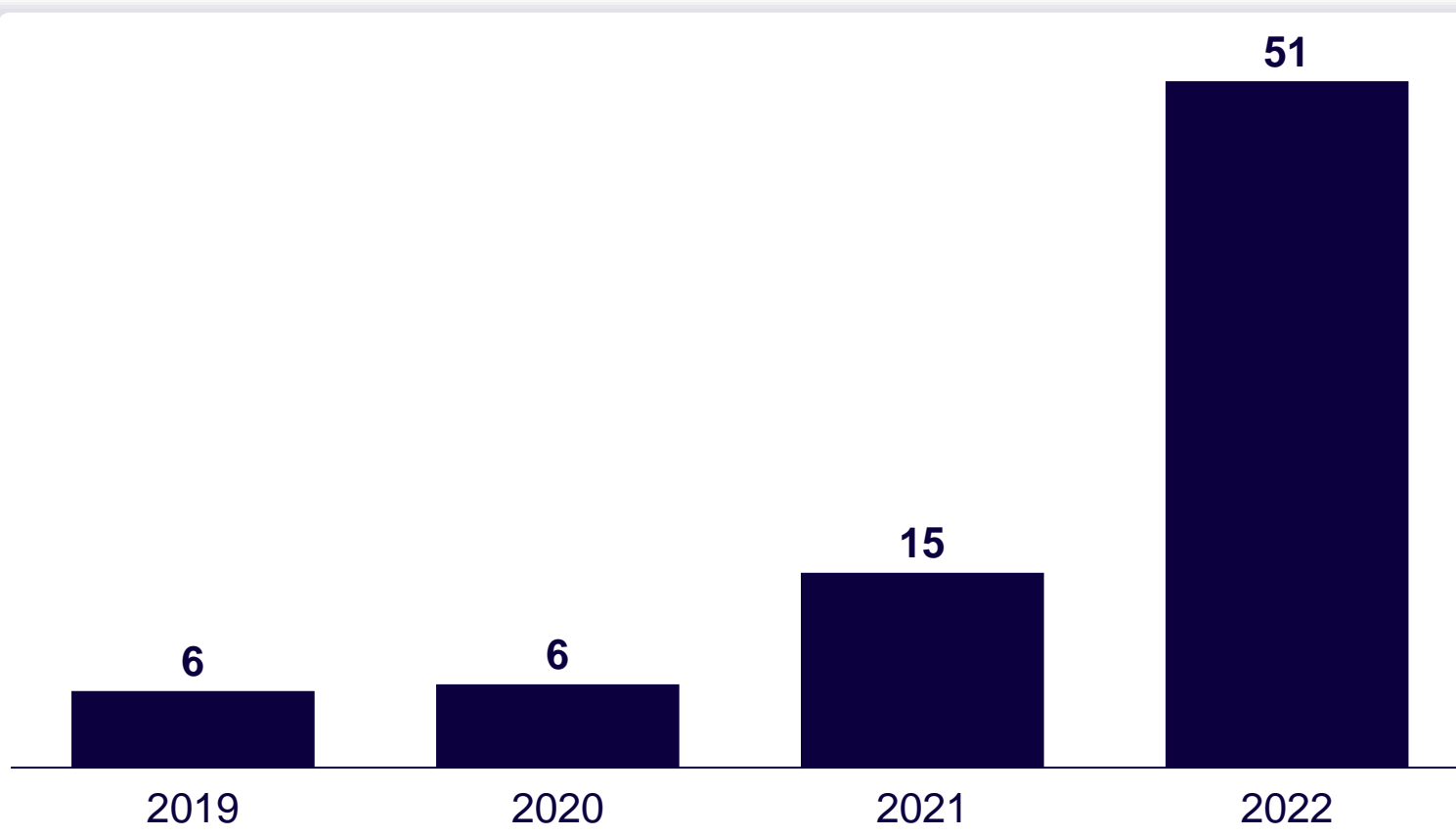
05

Development of RES resulted in a surge of connection applications, however due to a lack of transmission and distribution network capacity, many are being rejected



### Network connection arrangements refusals in Poland

2019-2022, GW



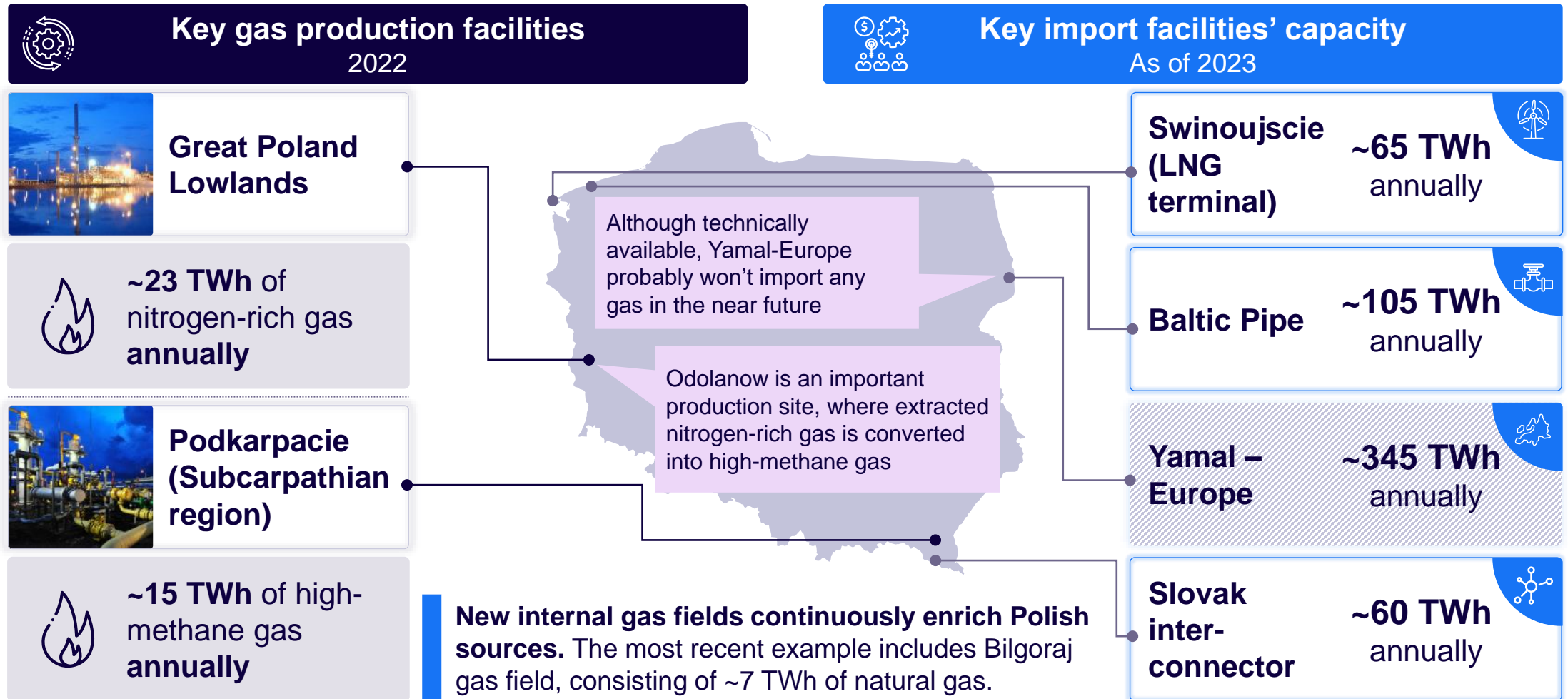
### Comments

- According to the Polish transmission system operator, Poland has zero MW of connection capability to the transmission network (as of November 2023)
- Data collected by the Polish Energy regulator (URE) show that over 51 GW of new connection applications were rejected in 2022 due to lack of technical or economic conditions

# NATURAL GAS IN THE CONTEXT OF DECARBONIZATION

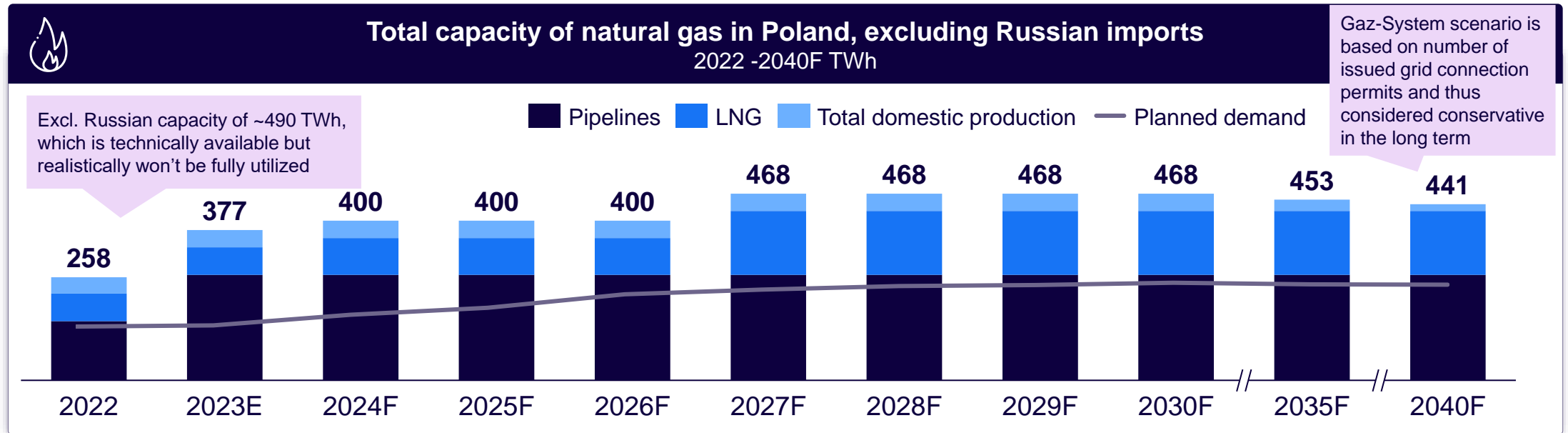
# Poland mainly relies on imported natural gas sources, with domestic production accounting for ~20-25% of the national demand

*NON-EXHAUSTIVE*





# Polish gas supply infrastructure is currently being transformed to become independent from Russian gas



## KEY INVESTMENTS

### Expansion of LNG terminal Swinoujscie

The only operational LNG terminal in Poland, which is currently in the process of expansion (construction of a new storage tank and a new jetty)

**By 2024, increase in capacity from 69 to 92 TWh**

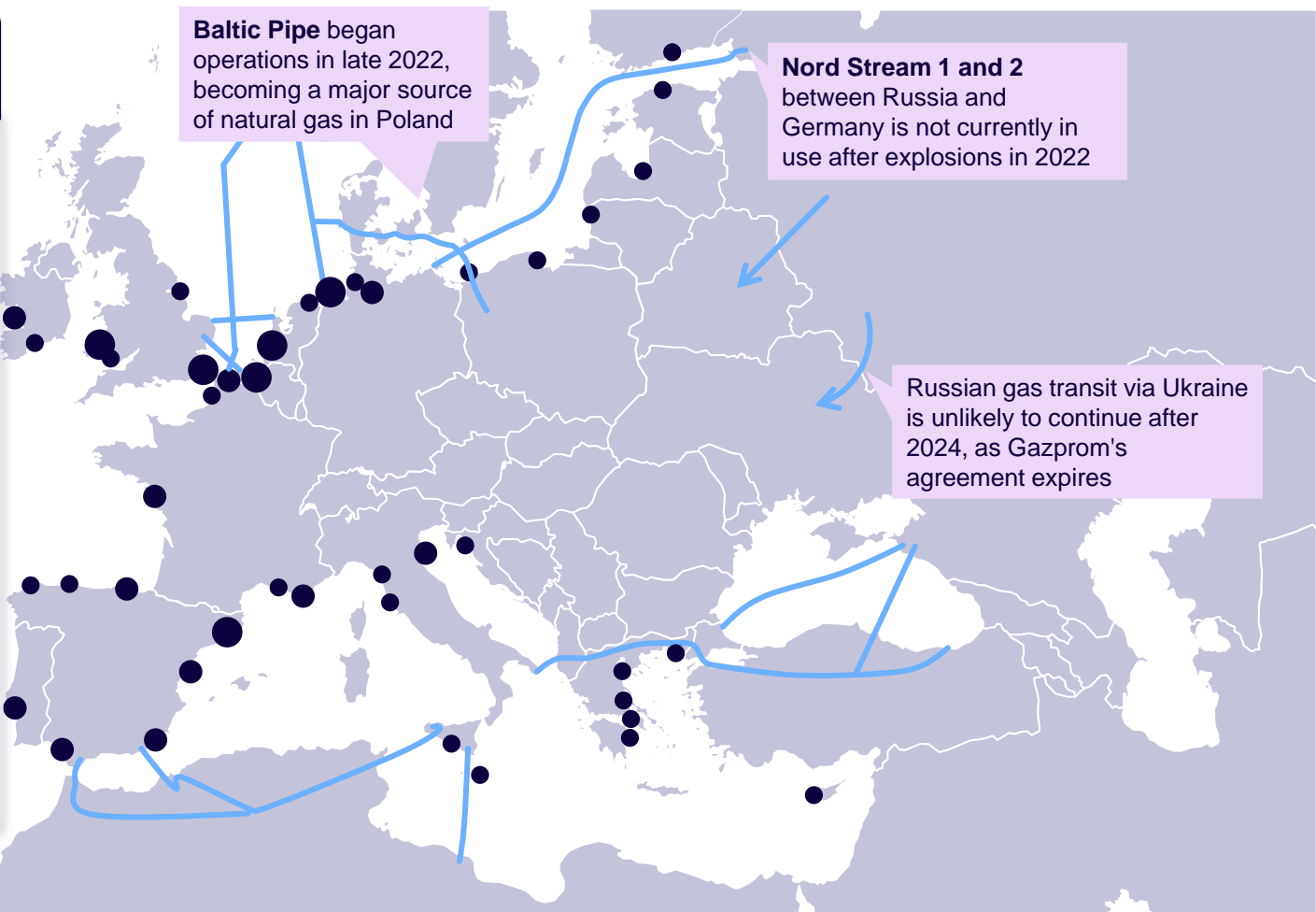
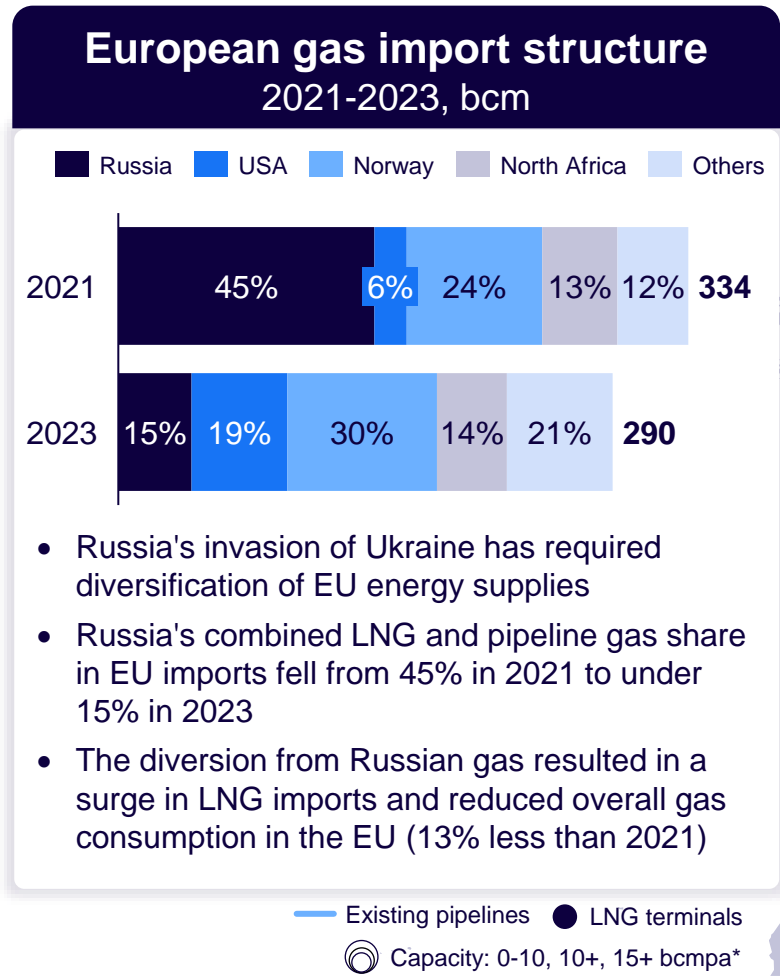
### FSRU<sup>1</sup> Gdansk

FSRU is a LNG storage ship, that is capable of regasification of LNG onboard and then supplying gas network directly

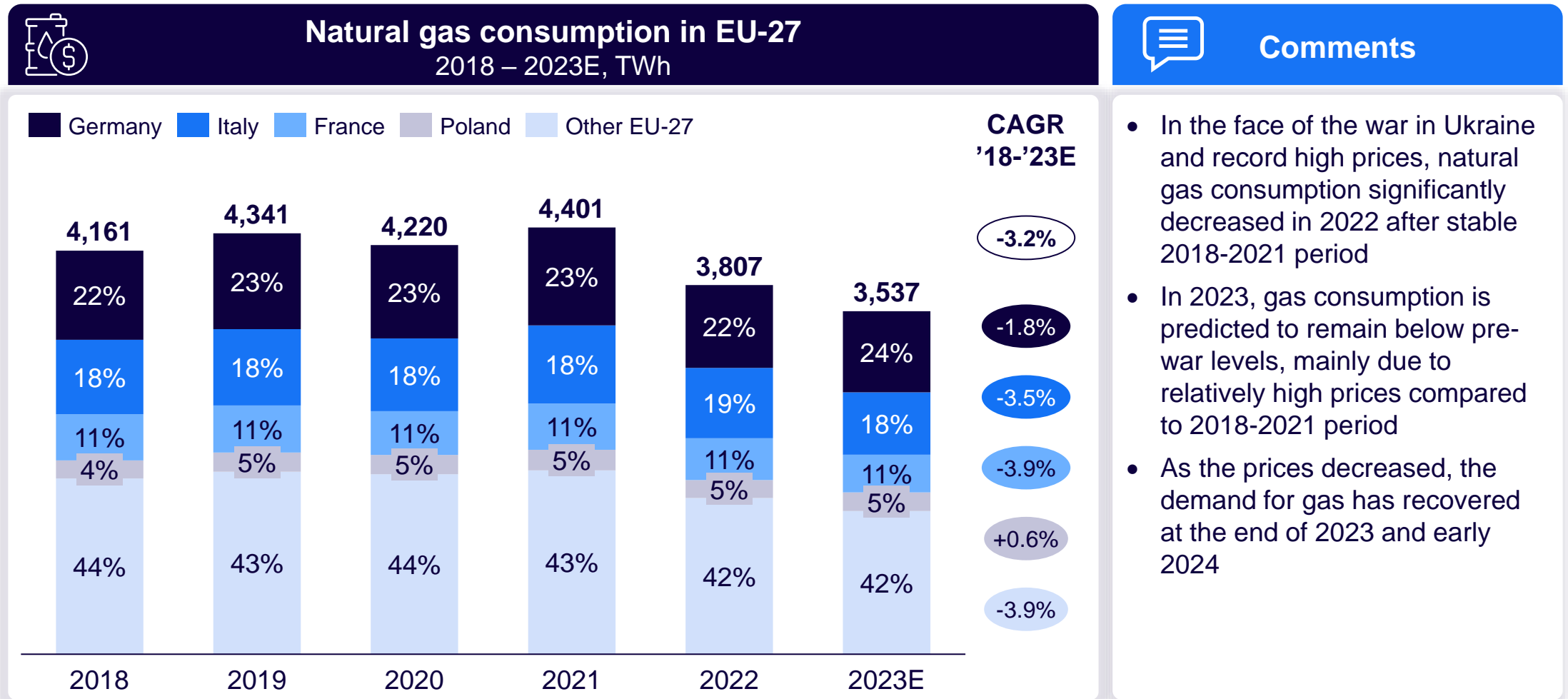
**Operational by 2027**      **Capacity: 69 TWh**

1) FSRU – Floating Storage Regasification Unit  
Source: PGNiG; IJ; Arthur D. Little

# The Russian invasion of Ukraine influenced European gas import flows, with Russian share declining from 45% in 2021 to 15% in 2023

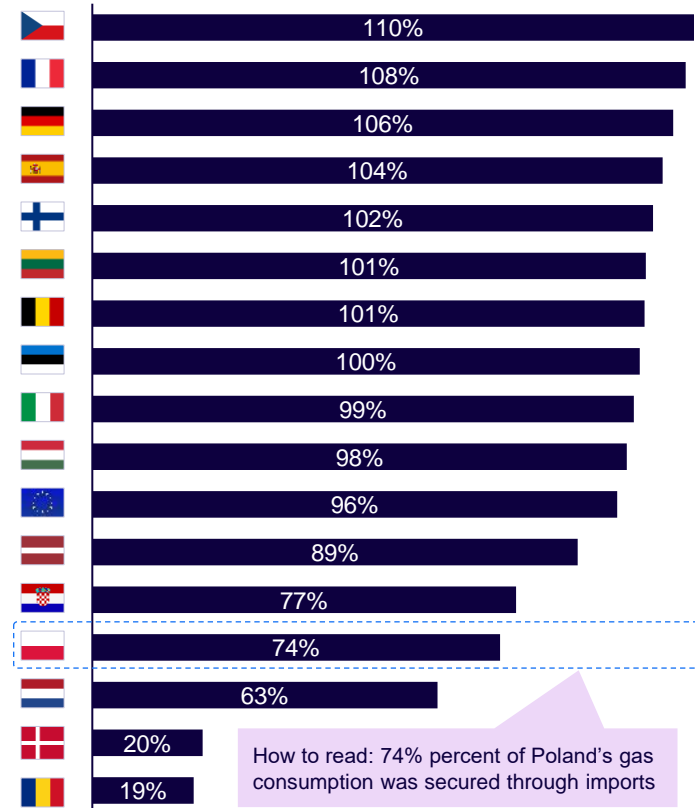


# The rise in gas prices and supply instability following the war in Ukraine led to lower gas consumption in the EU in 2022, with no significant recovery anticipated for 2023

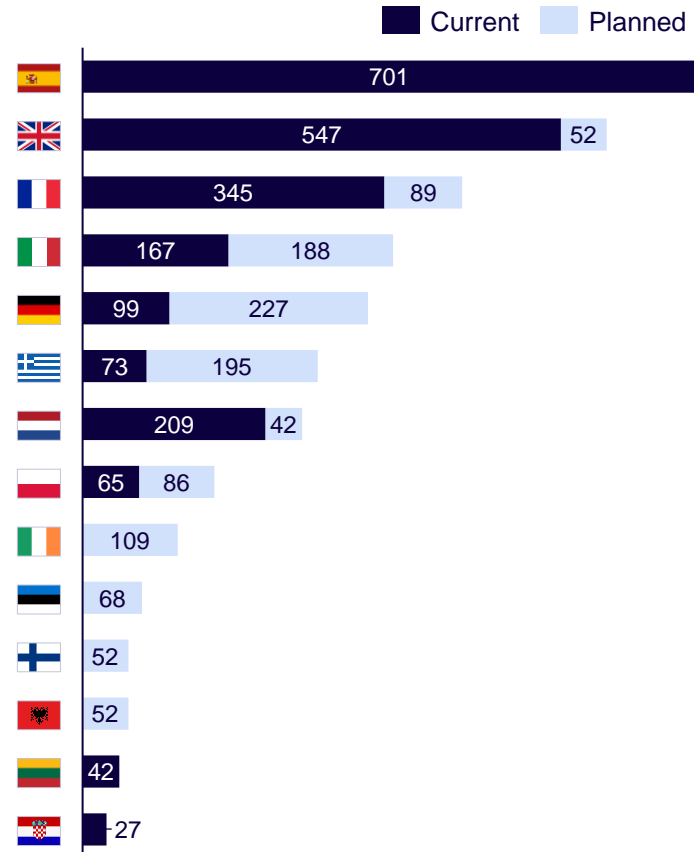


# Poland has one of the lowest gas import dependency ratios in the EU, however its low storage and regasification capacities reduce supply stability to some extent

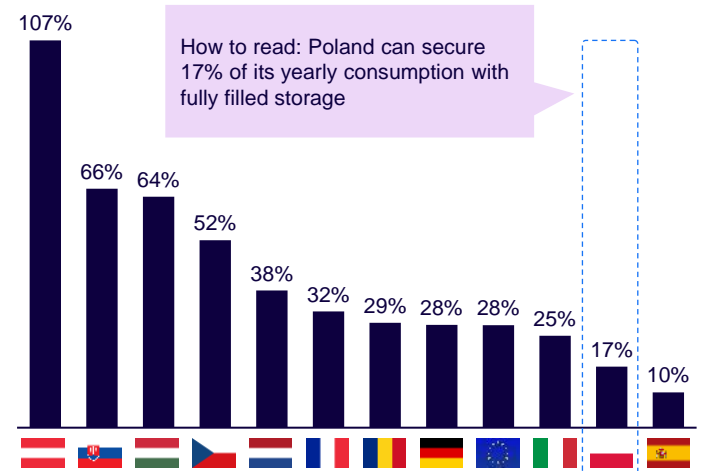
## Import dependency (imports-exports)/consumption, 2022



## Regasification capacity TWh, 2023
















## Storage-to-consumption ratio %, 2022



## Comments

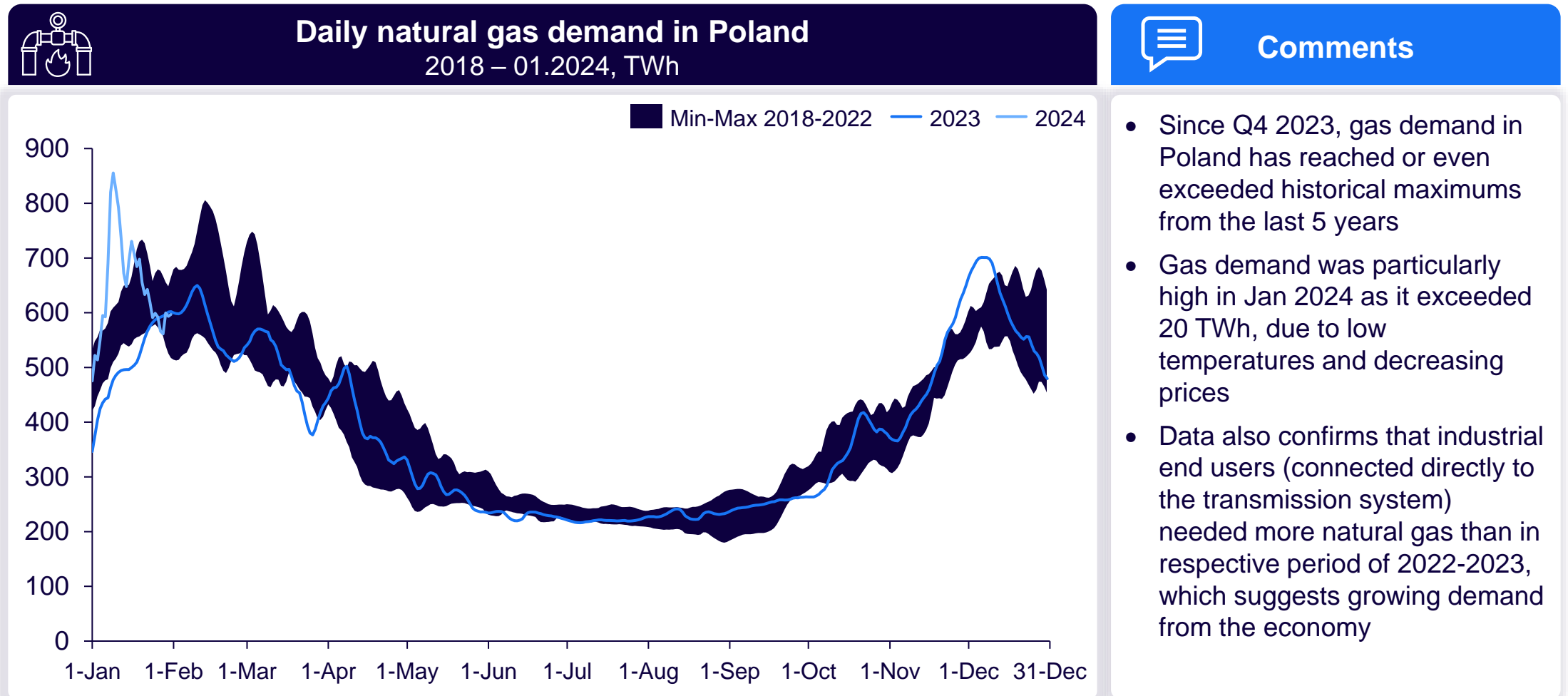
- Poland's relatively **low gas import dependency** has a **positive impact** on the country's supply security, however **increasing regasification and storage capabilities** are still **critical challenges** to be faced

## Polish gas consumption is expected to grow, mostly due to its role in the energy transition... but volatile gas prices and improved efficiency may dampen demand

		 Description	Importance	Impact
 Demand drivers	<b>1</b> Decarbonization goals & regulations 	Both European and Polish <b>regulations</b> require reduction of coal in the coming years with gas being a natural <b>transition fuel</b> before moving to nuclear power	High	
	<b>2</b> Growing electricity demand and balancing needs 	In the face of supply <b>instability of RES</b> and lack of <b>sufficient electricity grid capacity</b> , increasing electricity demand will be <b>balanced with more stable sources such as natural gas</b>	Medium	
	<b>3</b> Instability of gas prices 	Start of full-scale war in Ukraine exposed significant <b>instability of natural gas prices</b> , which may fluctuate depending on the macro environment (e.g. global LNG prices)	Medium	
	<b>4</b> Improving energy efficiency 	<b>Gas-fueled equipment</b> is getting more and more <b>energy efficient</b> , which means that consumption per unit will be gradually decreases, both for B2C and B2B (industrial) users	Low	
 Supply drivers	<b>5</b> Long-term security of gas supply 	After cutting <b>Russian gas imports to zero</b> in 2022, <b>adjusting supply structure</b> in Poland continue, in order to ensure energy security, e.g. via LNG infrastructure, Baltic Pipe and new pipeline interconnections	High	

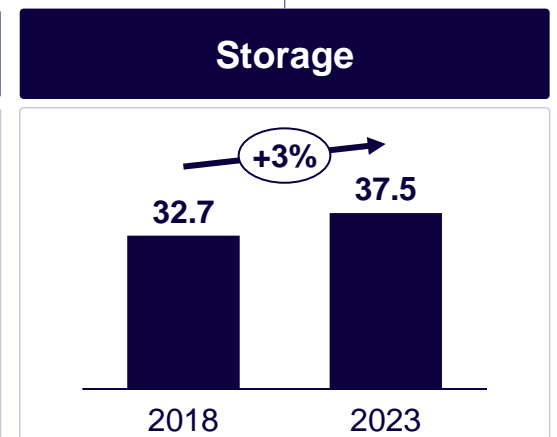
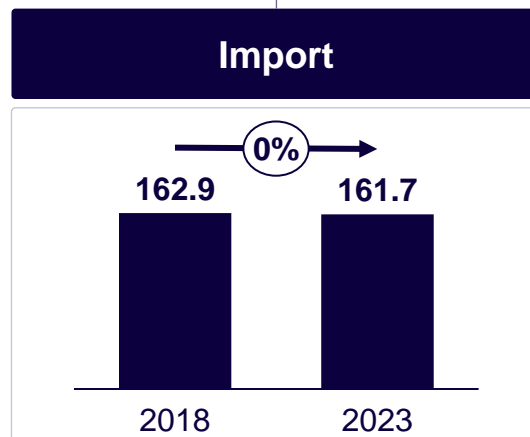
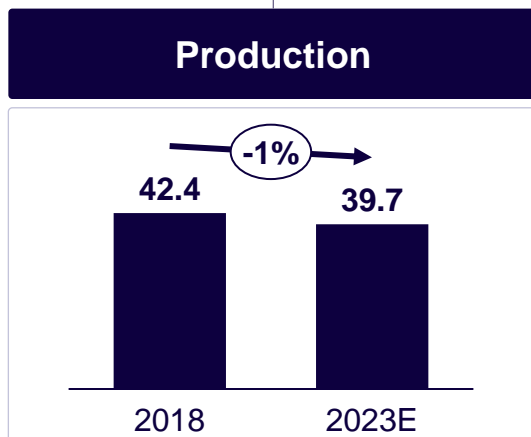
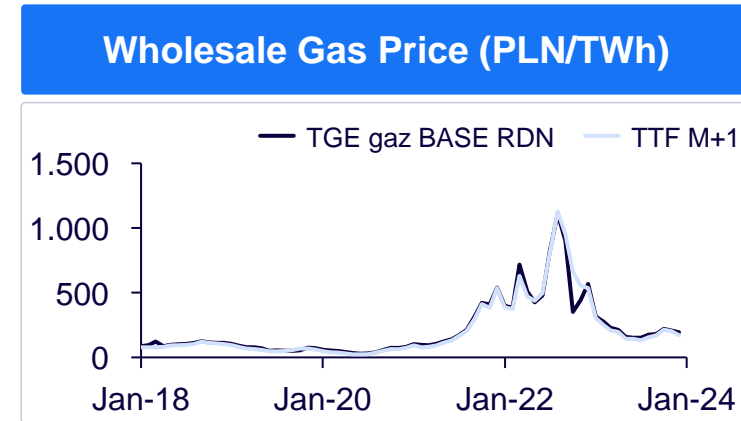
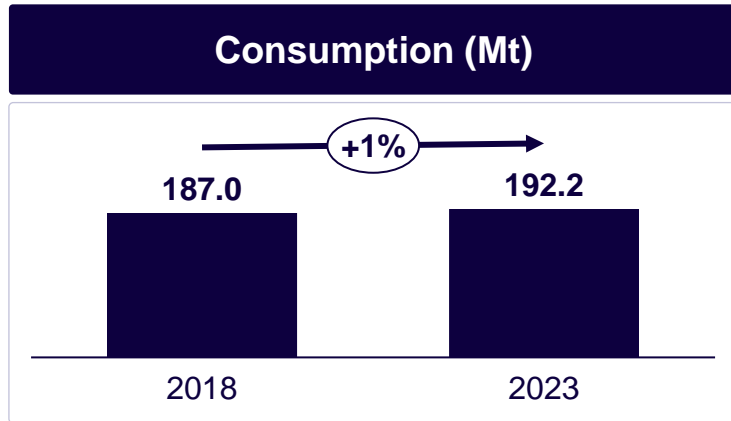
 Positive  Negative

**Demand for natural gas in Poland has been relatively high in Q4 2023 and at the beginning of 2024, which suggests the market has come back to pre-war levels**



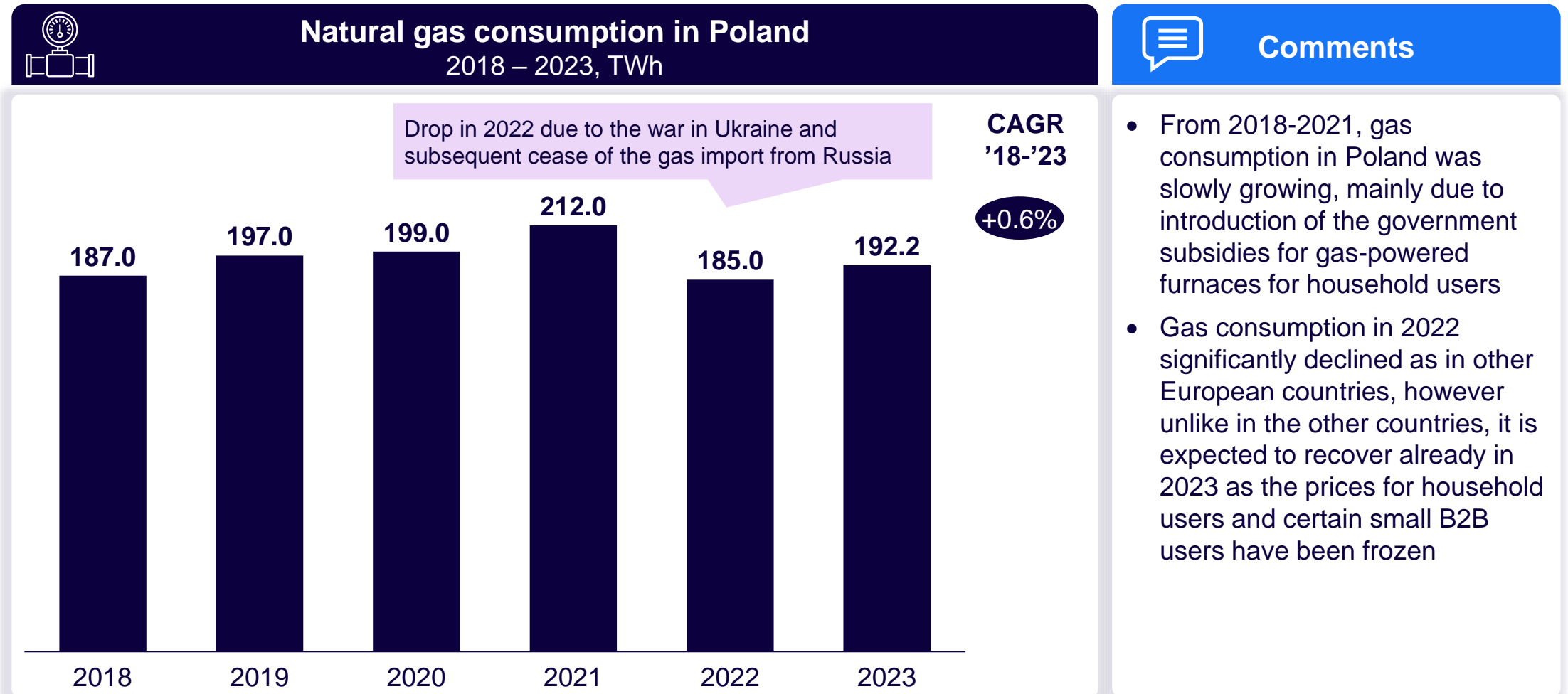
# Consumption of natural gas in Poland is on track to return to pre-war levels, despite change in supply structure and temporary surge in prices

🔍 Deep dives on each segment on following slides



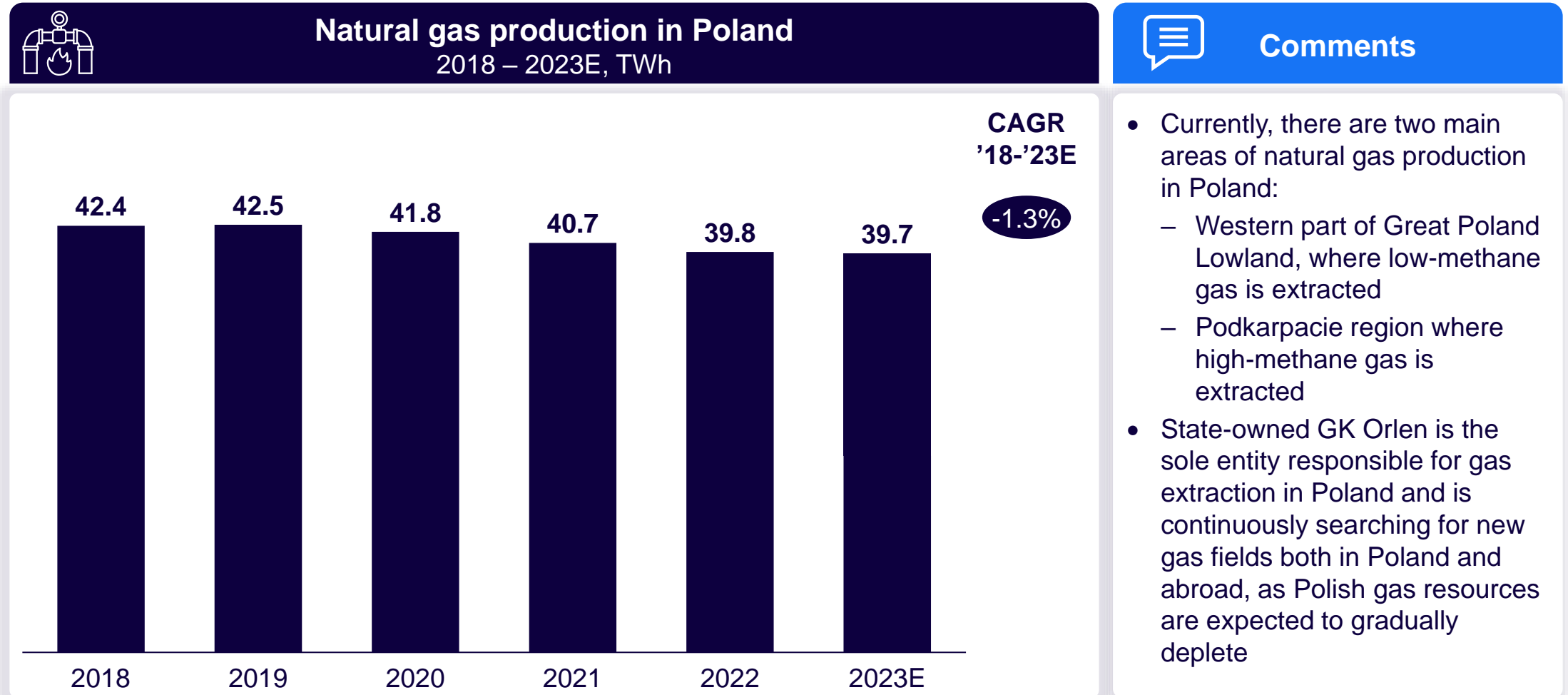
1) TGE gaz BASE RDN – the price of natural gas in Poland on the Day-Ahead Market (spot); 2) TTF M+1 – European forward gas price index  
 Source: URE; ARE; Eurostat; Gas Storage Poland; TGE; NBP; GK ORLEN; PGNiG; investing.com; Arthur D. Little

## Lower gas prices and increased security of supply enabled gas consumption in Poland to recover slightly in 2023



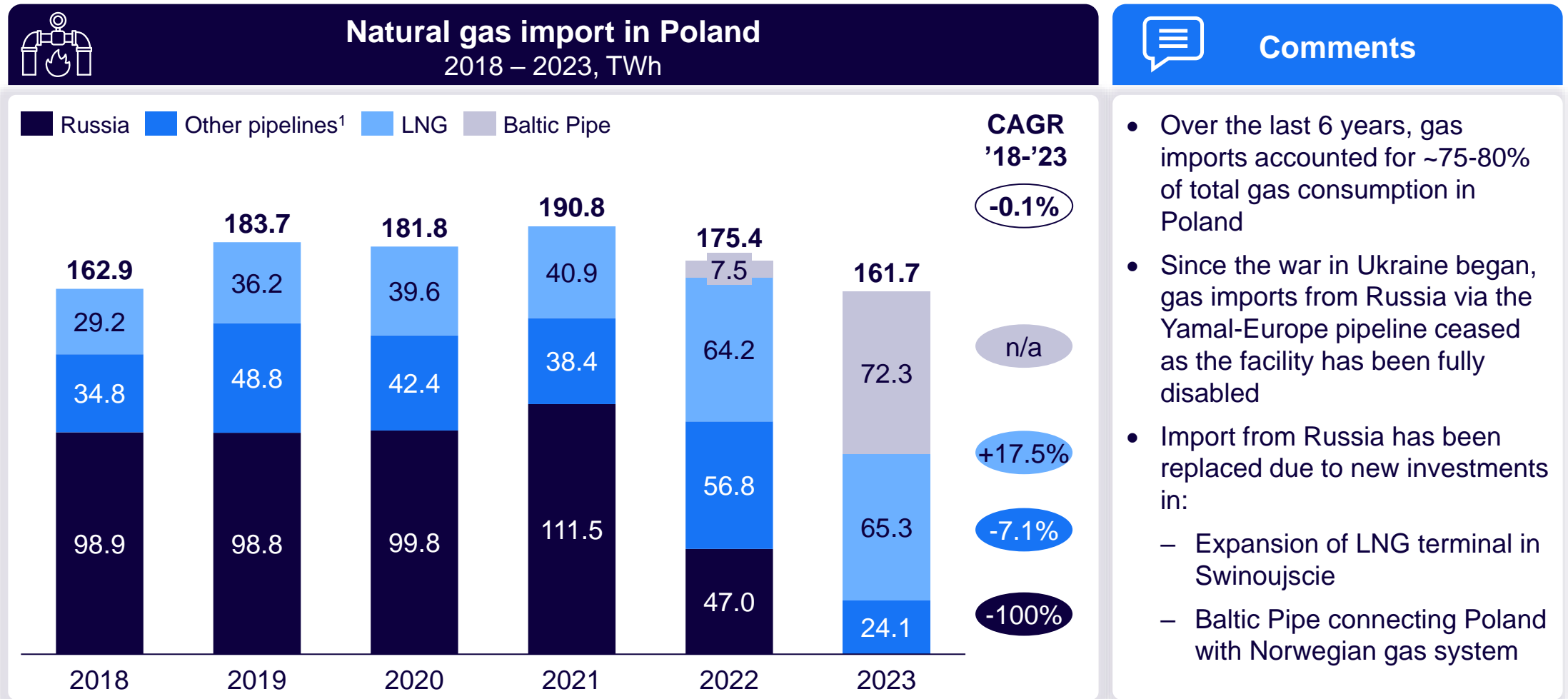


Poland's domestic gas production has oscillated around 40 TWh in the recent years, which covers ~20-25% of the demand, being one of the highest ratios in the EU





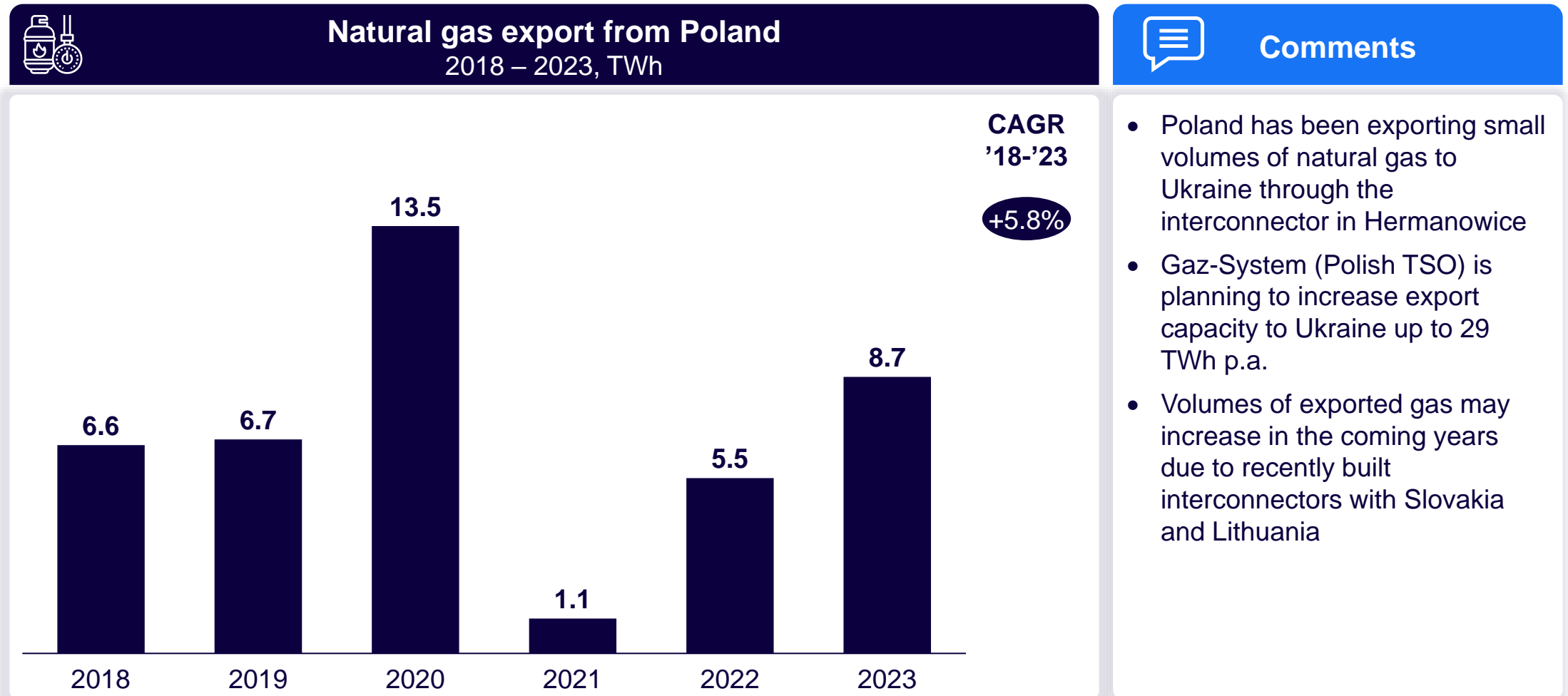
## Over the last 6 years, gas import in Poland switched from mostly Russian gas to a more diversified structure with LNG terminal and Baltic Pipe being key contributors



1) Pipelines connecting Poland with Germany, Czechia, Slovakia, Ukraine and Lithuania  
 Source: URE; GK OLREN; PGNiG; ENTSOG; Arthur D. Little

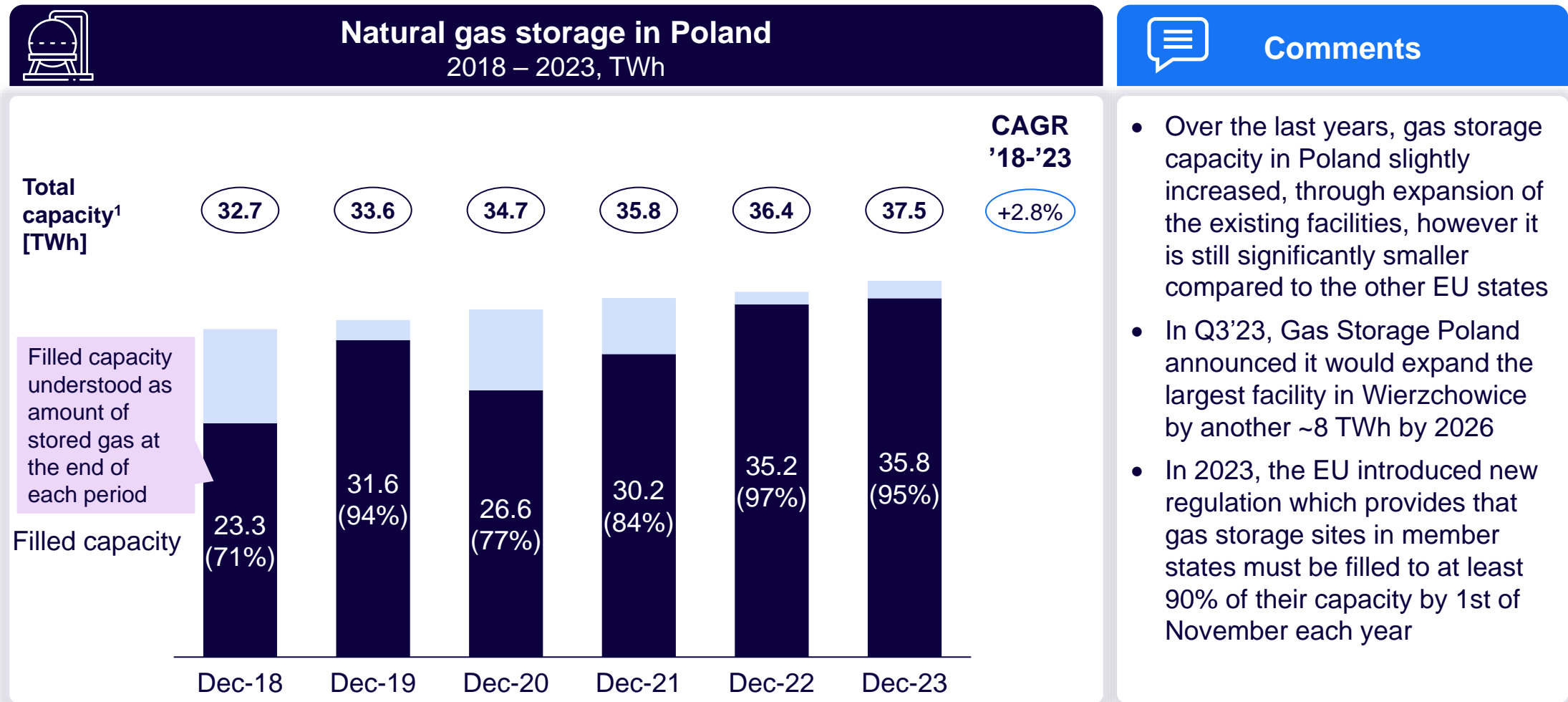


## Gas exports play only a limited role in the Polish gas market, with minor volumes transmitted to Ukraine





## Gas storage capacity and the volume of stored gas in Poland has been successively expanding in order to prepare for possible demand/supply fluctuations

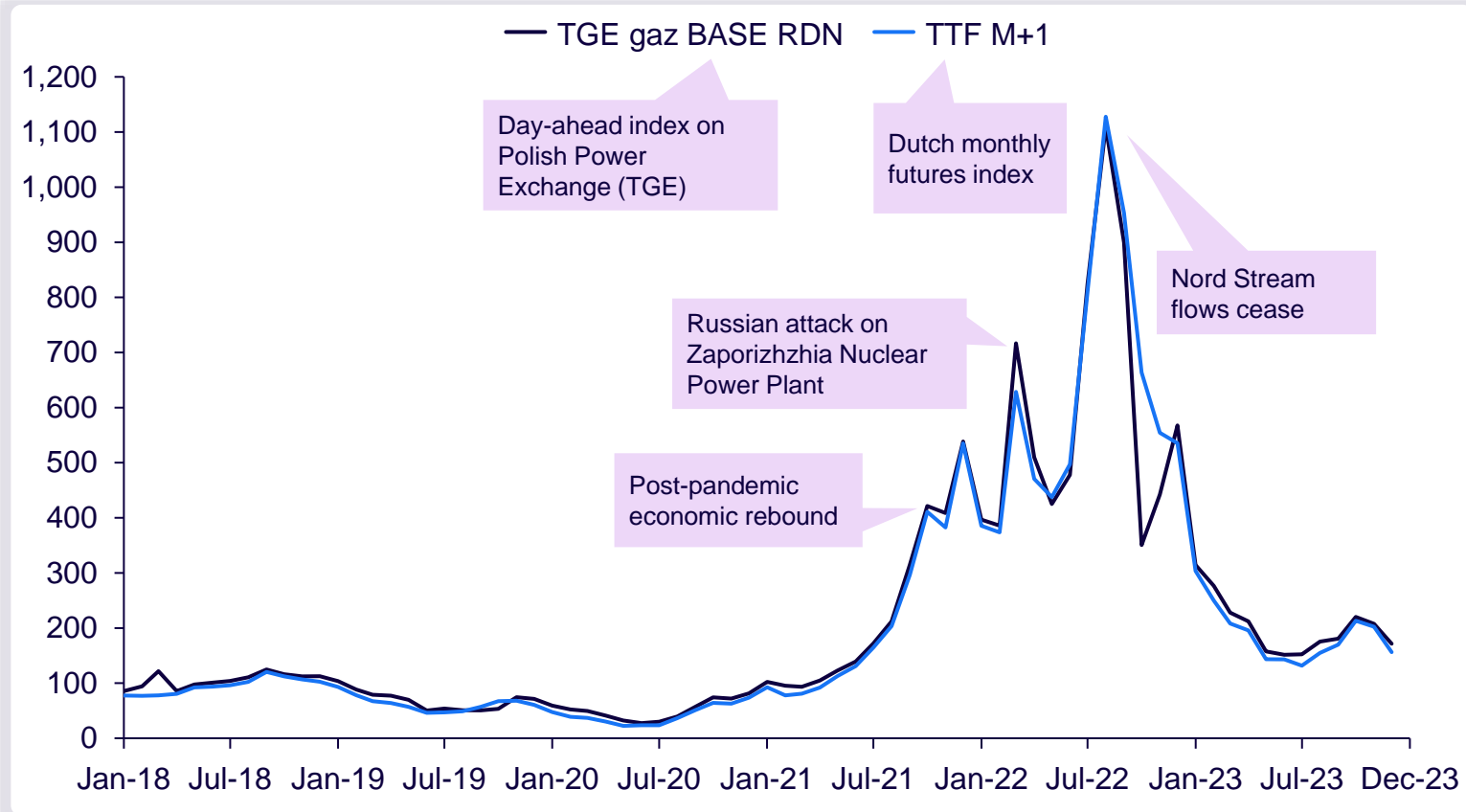


1) Capacity at the end of the period, e.g. there was storage capacity of 37.5 TWh at the end of 2023  
Source: Gas Storage Poland; Arthur D. Little

## As of Dec 2023, wholesale gas prices in Poland and the TTF index traded in the Netherlands almost returned to the pre-war and pre-Covid-19 pandemic levels



### Natural gas prices in Poland 2018 – 2023, PLN/MWh

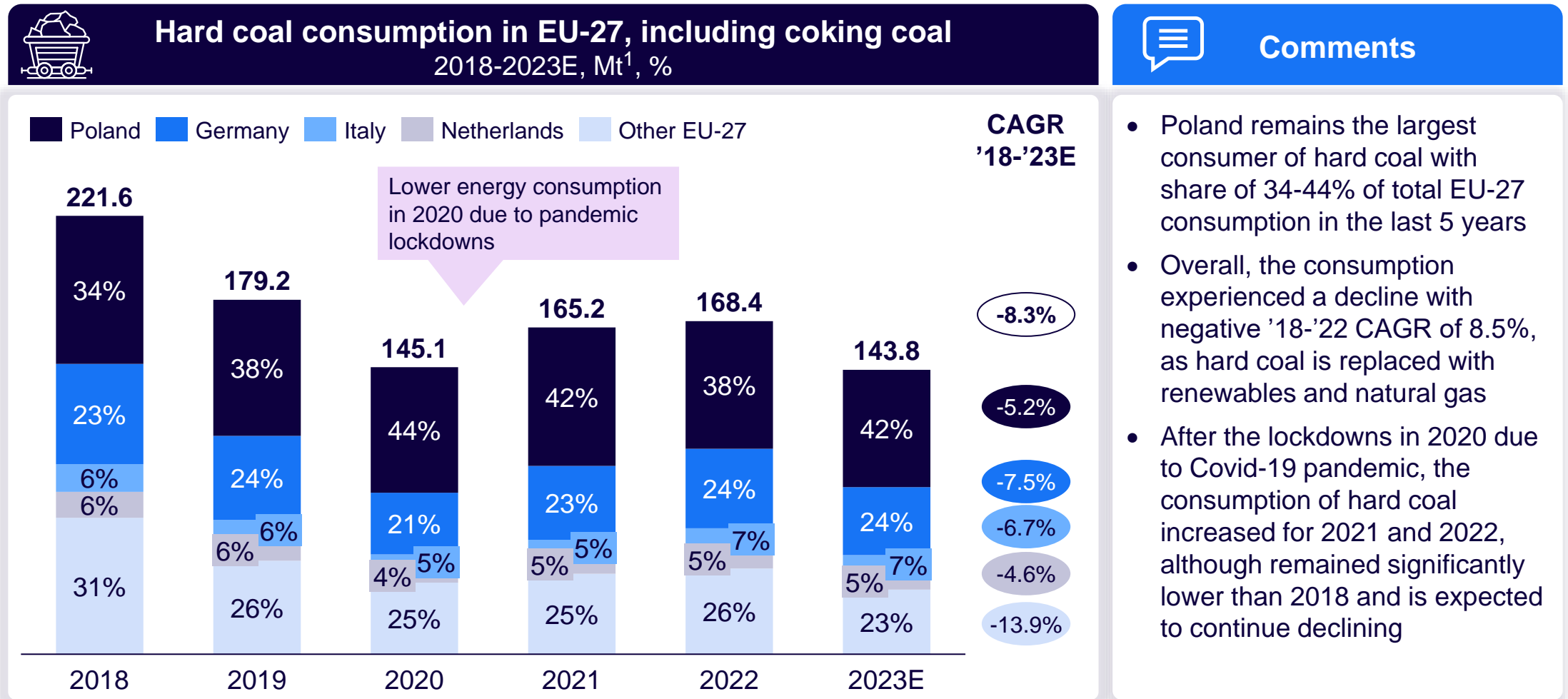


### Comments

- Wholesale gas prices on the Polish Power Exchange (TGE) have been consistently correlated with the main European gas index TTF
- After significant increase following the war in Ukraine, the prices started to decrease and as of Dec 2023 they have come back to the levels from 2021
- In the short term, gas prices are expected to stabilize closer to pre-war levels as European countries mostly managed to replace Russian supply with other sources

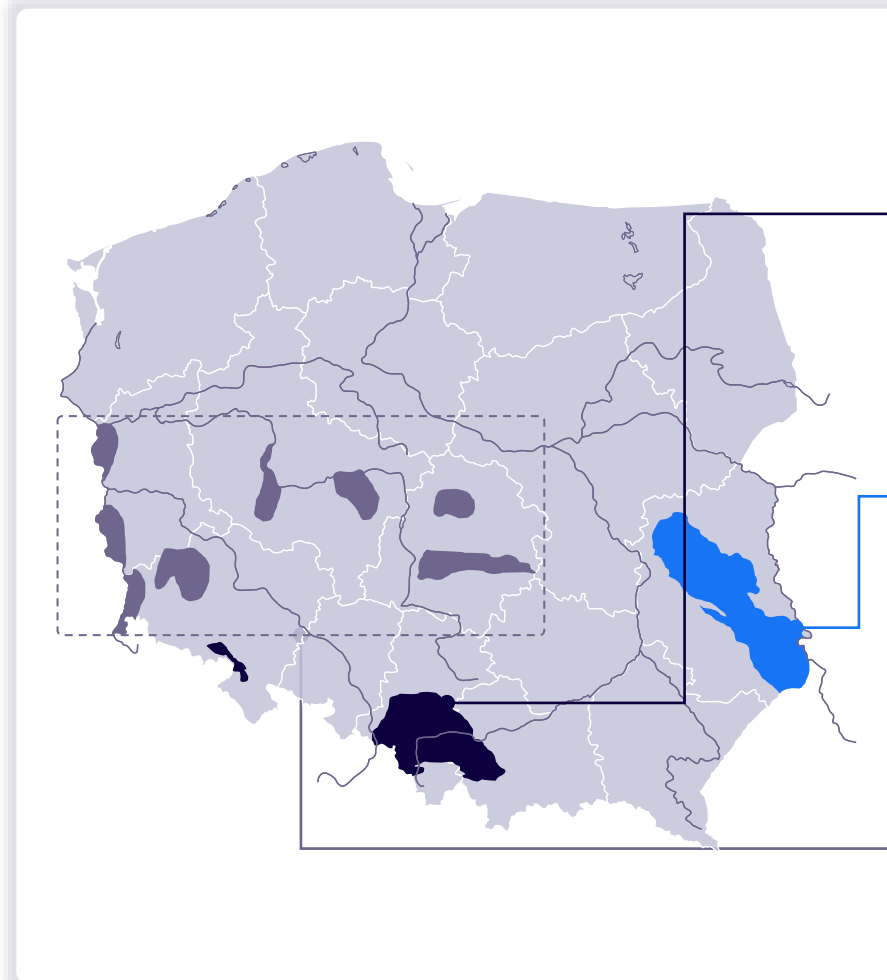
# COAL USAGE IN THE ENERGY TRANSITION

## In line with environmental policies, the consumption of hard coal in EU-27 countries declines, with Poland remaining the largest EU coal consumer



1) Mt – million metric tons  
Source: Eurostat; Arthur D. Little

## Polish production of coal is located in five main areas, with two hard coal extraction basins and three lignite production areas



### Hard Coal Production In Poland

#### Upper Silesian Coal Basin

- Estimated coal reserves<sup>1</sup>: **50-55 Gt<sup>2</sup>**
- Number of operating mines: **26**

**~40Mt**  
Annual production

#### Lublin Coal Basin

- Estimated coal reserves: **10-12 Gt**
- Number of operating mines: **1**

**~7Mt**  
Annual production

### Lignite Production In Poland

#### 3 Main Production Areas

- Estimated coal reserves: **20-25 Gt**
- Number of operating mines: **5**

**~40Mt**  
Annual production

1) As of 31/12/2022; 2) Gt – gigatons  
Source: Polish Geological Institute; Arthur D. Little



# Polish demand for hard coal is shrinking, driven by regulations, alternatives and shift in household usage, with decreasing competitiveness impacting supply

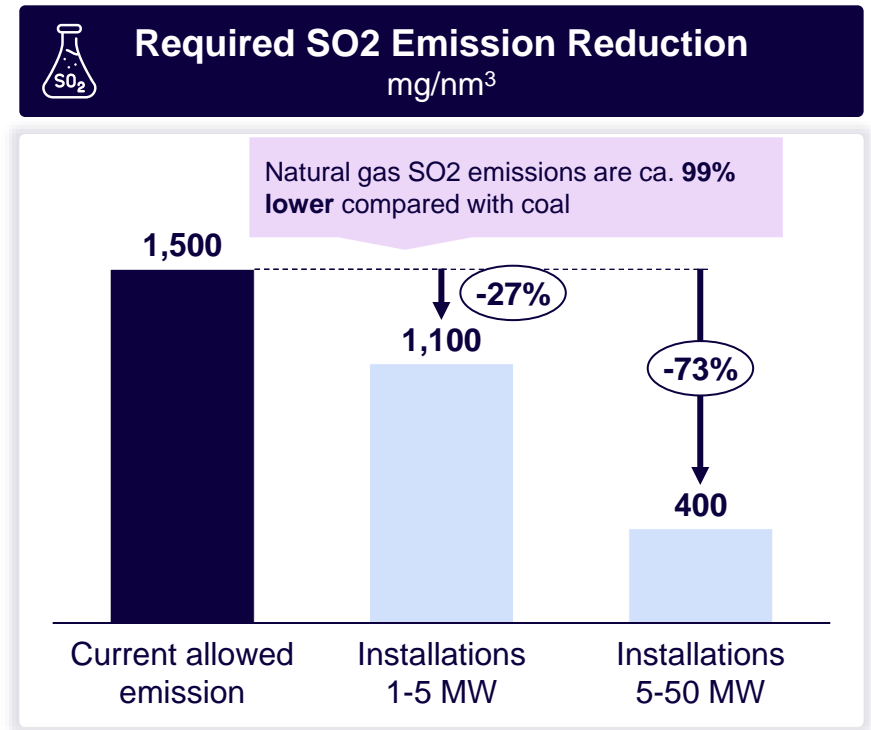
Deep dives on following slides		Description	Importance	Impact
<p><b>Demand drivers</b></p>	<p><b>1</b></p> <p><b>Low emissions regulations</b></p>	<p>EU and Polish regulations mandate a <b>decrease in coal usage</b> in the upcoming years, with the ultimate objective of <b>fully substituting coal</b> with energy sources that have low or zero emissions</p>	High	
	<p><b>2</b></p> <p><b>Investments in alternatives</b></p>	<p>In line with Polish plans to phase-out coal, the Polish government <b>invests heavily</b> in support to roll-out of <b>more environmentally friendly energy sources</b> like gas and nuclear</p>	High	
	<p><b>3</b></p> <p><b>Shift in household usage</b></p>	<p>Households, which historically accounted for a <b>significant portion of coal consumption</b>, are gradually <b>transitioning</b> their heating systems to <b>natural gas and heat pumps</b>, encouraged by subsidies</p>	Medium	
<p><b>Supply drivers</b></p>	<p><b>4</b></p> <p><b>Decreased competitiveness of Polish coal</b></p>	<p>As coal extraction continues in Polish mines, the process becomes increasingly <b>difficult and costly</b>. Decreasing competitiveness in relation to alternative sources of energy</p>	High	

Positive Negative

01

# The EU's MCP Directive<sup>1</sup> will require many small and medium industrial businesses to switch from using coal as a primary energy source

Overview of MCP Directive		
Definition	Objective	Process stages (compliance dates)
EU Directive from 2015 concerning SO <sub>x</sub> , NO <sub>x</sub> and dust emission in plants with a rated thermal input 1-50 MWth	Significant SO <sub>2</sub> reductions, depending on the size of the combustion plant (vide chart on the right)	2025 – installations with a capacity exceeding 5 MW 2030 – installations between 1 and 5 MW

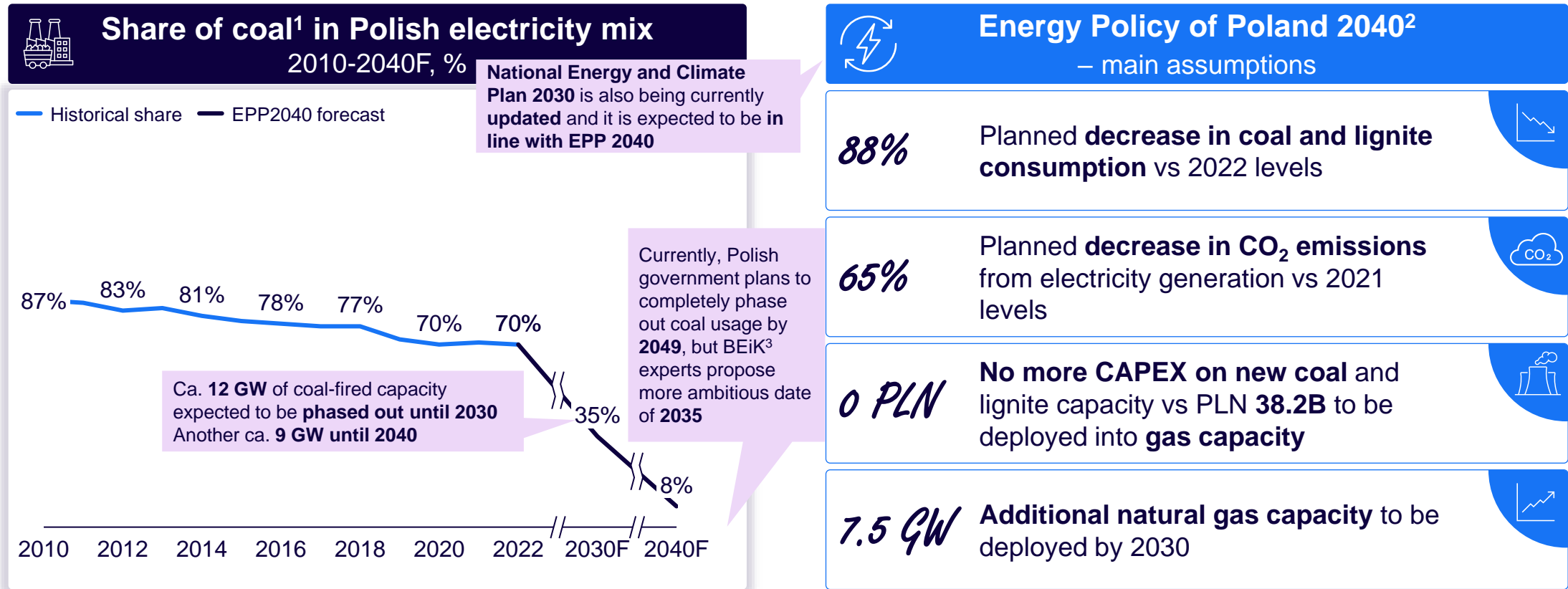


The introduction of the MCP Directive means that many industrial energy consumers will be forced to **switch from coal to less polluting energies, e.g. natural gas systems, which are long-term solution (beyond 2040) as they can also use biomethane as a fuel source** without significant modifications

1) MCP Directive - The Medium Combustion Plant Directive  
Source: MCP Directive; European Commission; KOBiZE; Arthur D. Little

02

# The share of hard coal in the Polish electricity mix is expected to gradually decline, as it is replaced by more environmentally friendly alternatives



**Limited improvement** in reducing share of coal in the electricity mix since 2010 will require Poland to significantly **intensify decarbonization efforts** in the coming years in order to meet ambitious goals of the Energy Policy of Poland until 2040

1) Including lignite; 2) Based on principles for the update of EPP 2040, from Mar '22; 3) BEiK – Expert Council on Energy Security and Climate  
Source: Energy Policy of Poland 2040; IJ; Arthur D. Little

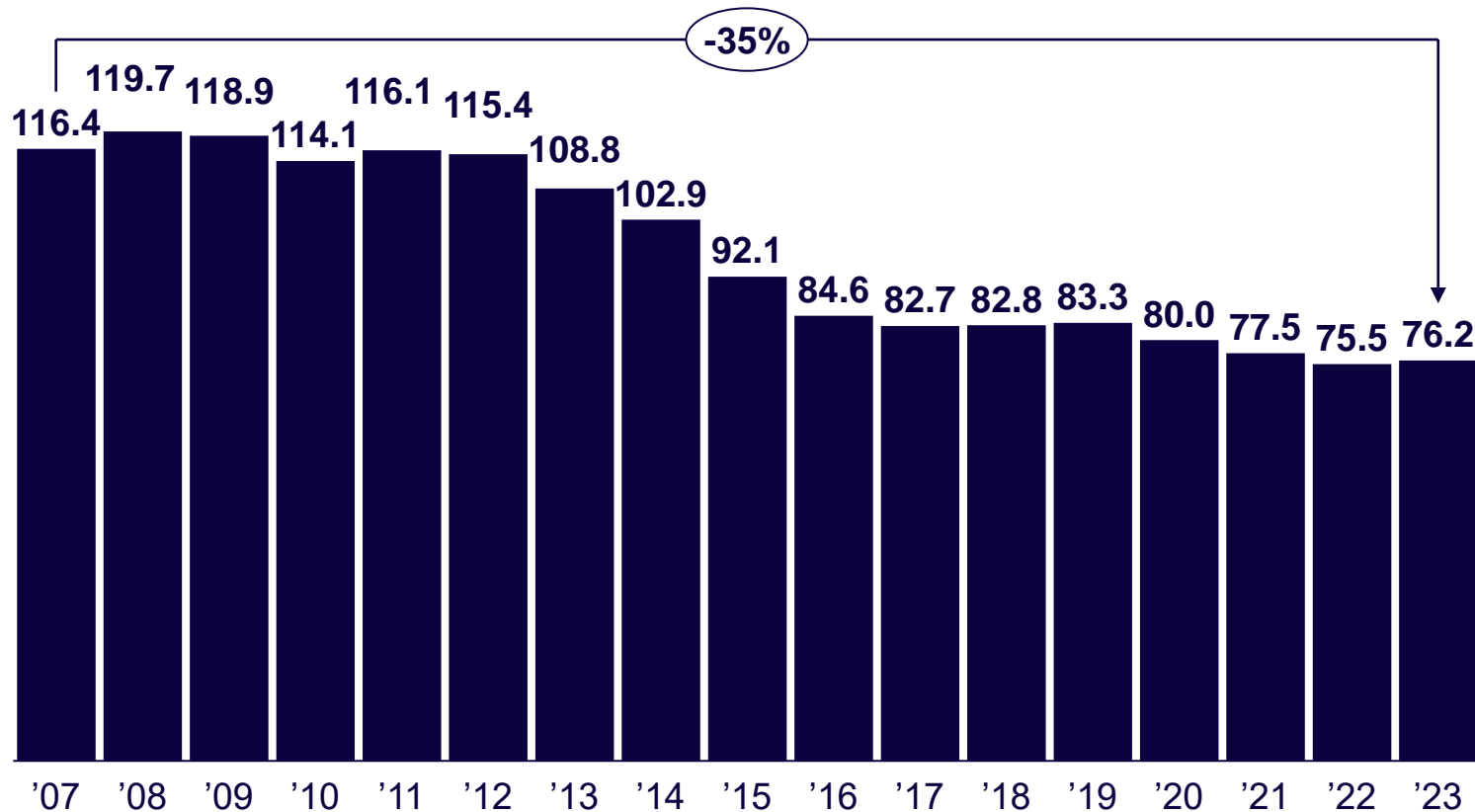
02

## Shrinking role of hard coal can also be visible in the number of FTEs employed in the Polish mining industry



### Employment in the hard coal mining industry in Poland

2007-2023<sup>1</sup>, K of FTEs



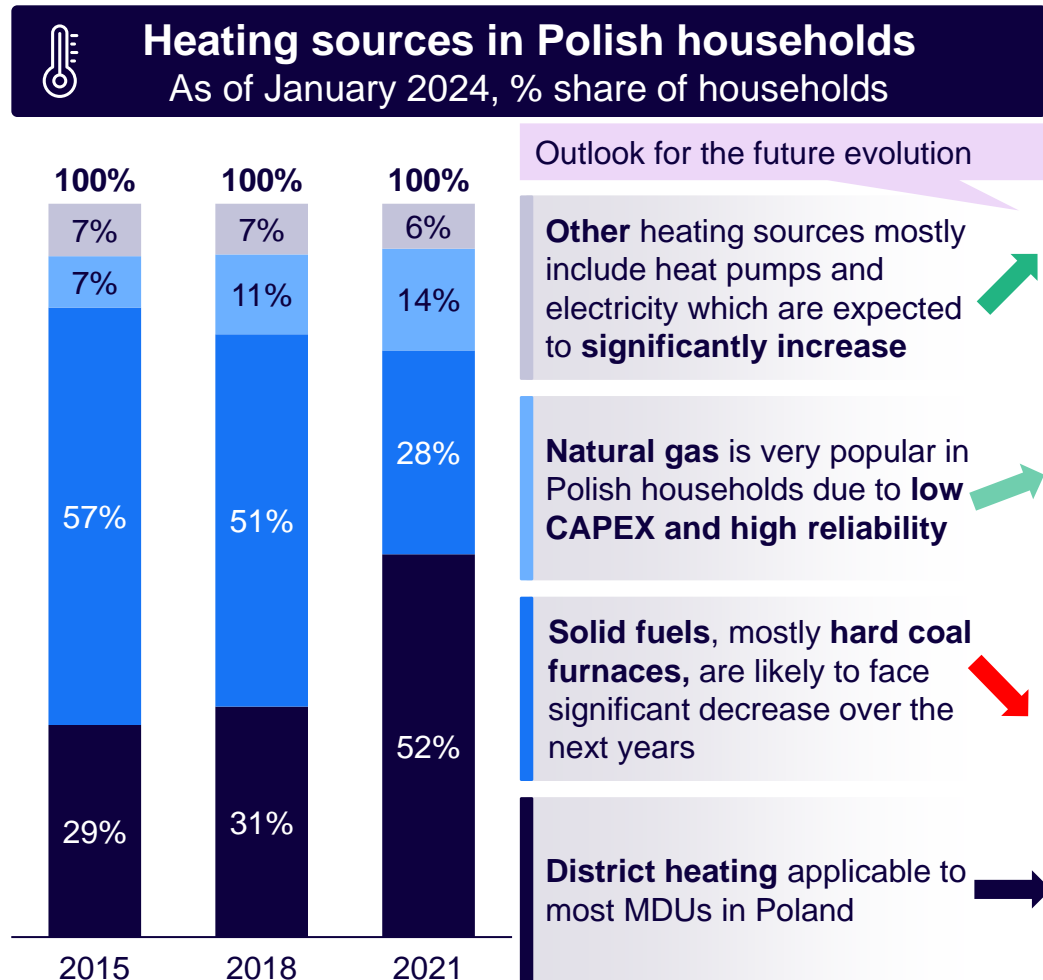
### Comments

- Over the last 15 years employment in the hard coal industry in Poland decreased by ~35%, primarily caused by:
  - Decreasing profitability of coal production due to low availability of deposits
  - Poland's increasing decarbonization efforts
- In addition to the decreasing employment, the average productivity<sup>2</sup> has been also decreasing, which affects the unit labor costs even more

1) Employment level at the end of each period; 2) Understood as amount of coal produced per FTE  
Source: ARP; Arthur D. Little

03

# Household demand for hard coal is expected to steadily decrease, especially given progressing bans on coal-fired furnaces in Polish cities



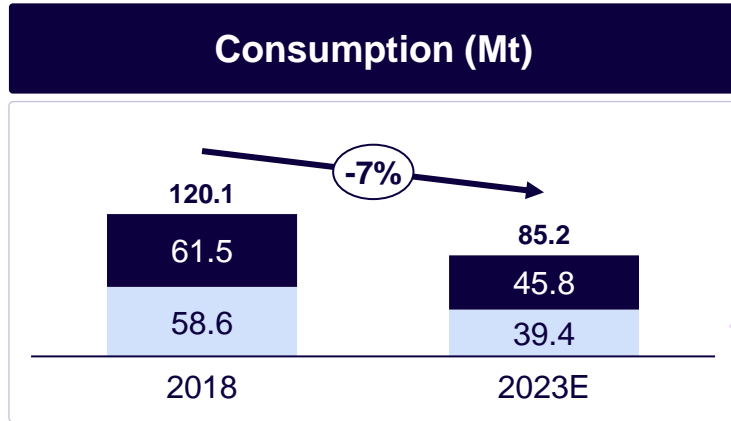
**Bans on coal-fueled systems in Polish cities**

- Krakow**  
Ban from September 2019
- Warsaw**  
Ban from October 2023
- Wroclaw**  
Ban to be introduced in July 2024

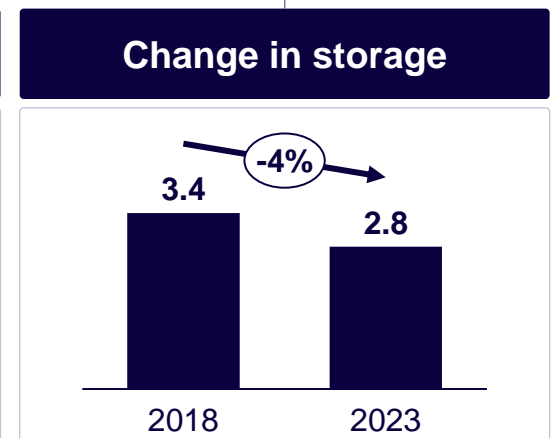
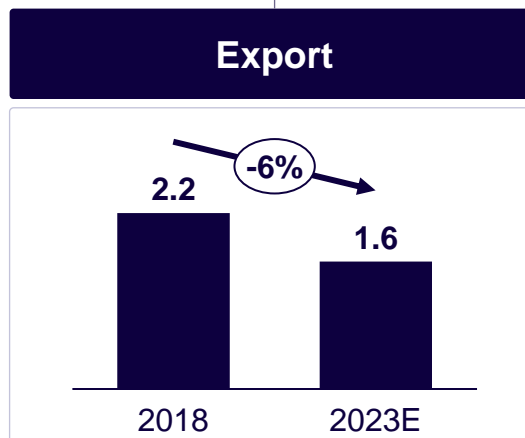
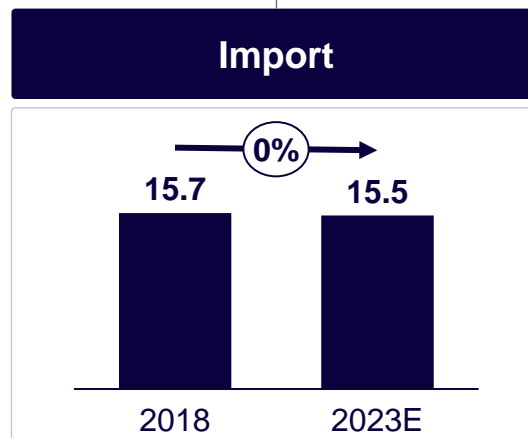
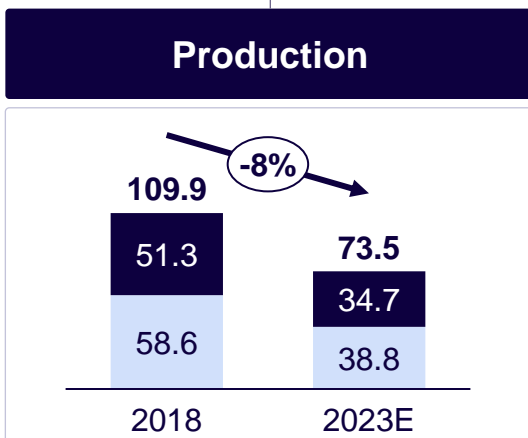
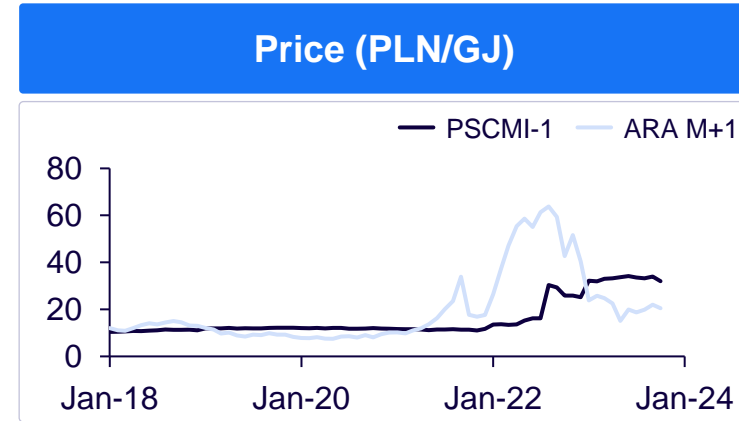
# Polish coal consumption '18-23E has declined with a CAGR of 7%, due to production decline and lower exports

🔍 Deep dives on each segment on following slides

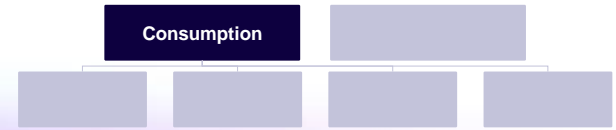
■ Hard coal ■ Lignite



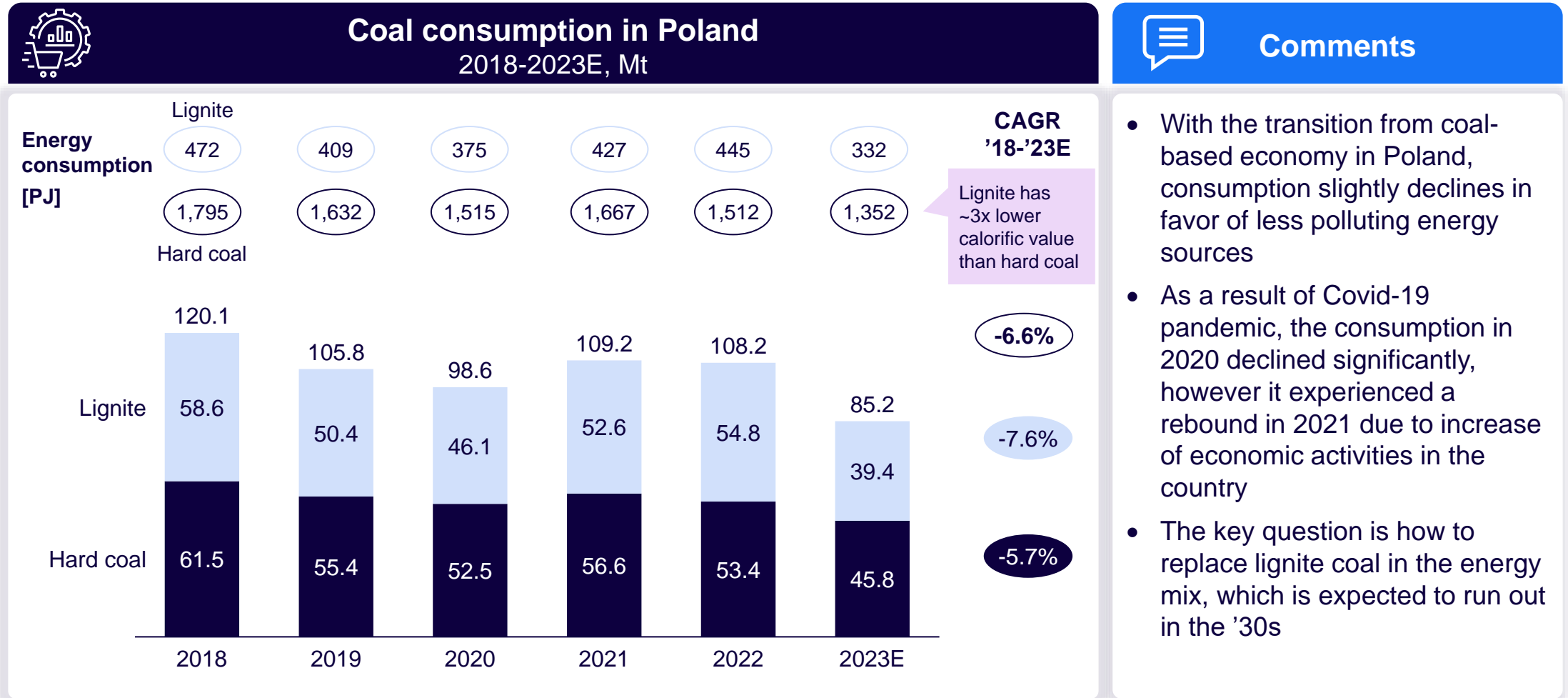
Lignite is consumed directly by the nearby mines and therefore is not stored, imported nor exported



1) PSCMI-1 – Polish Thermal Coal Market Index 1; 2) ARA M+1 – European hard coal futures price index (month ahead)  
 Source: Source: Eurostat; ARE; GUS;ARP; Stooq; Arthur D. Little

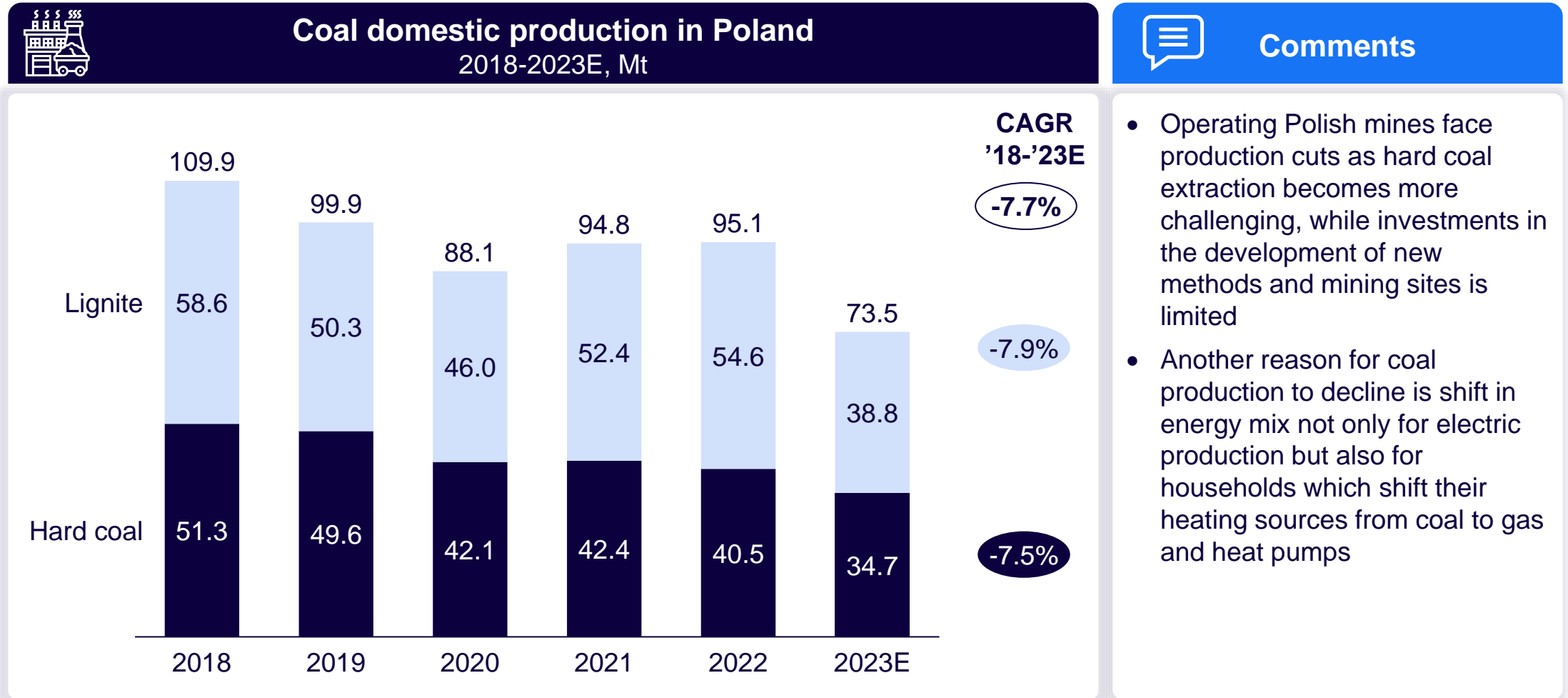


**2018-2023E consumption of both hard coal and lignite in Poland decreased, with lignite declining at a faster rate of 7.6% p.a., while hard coal decreased by 5.7% p.a.**





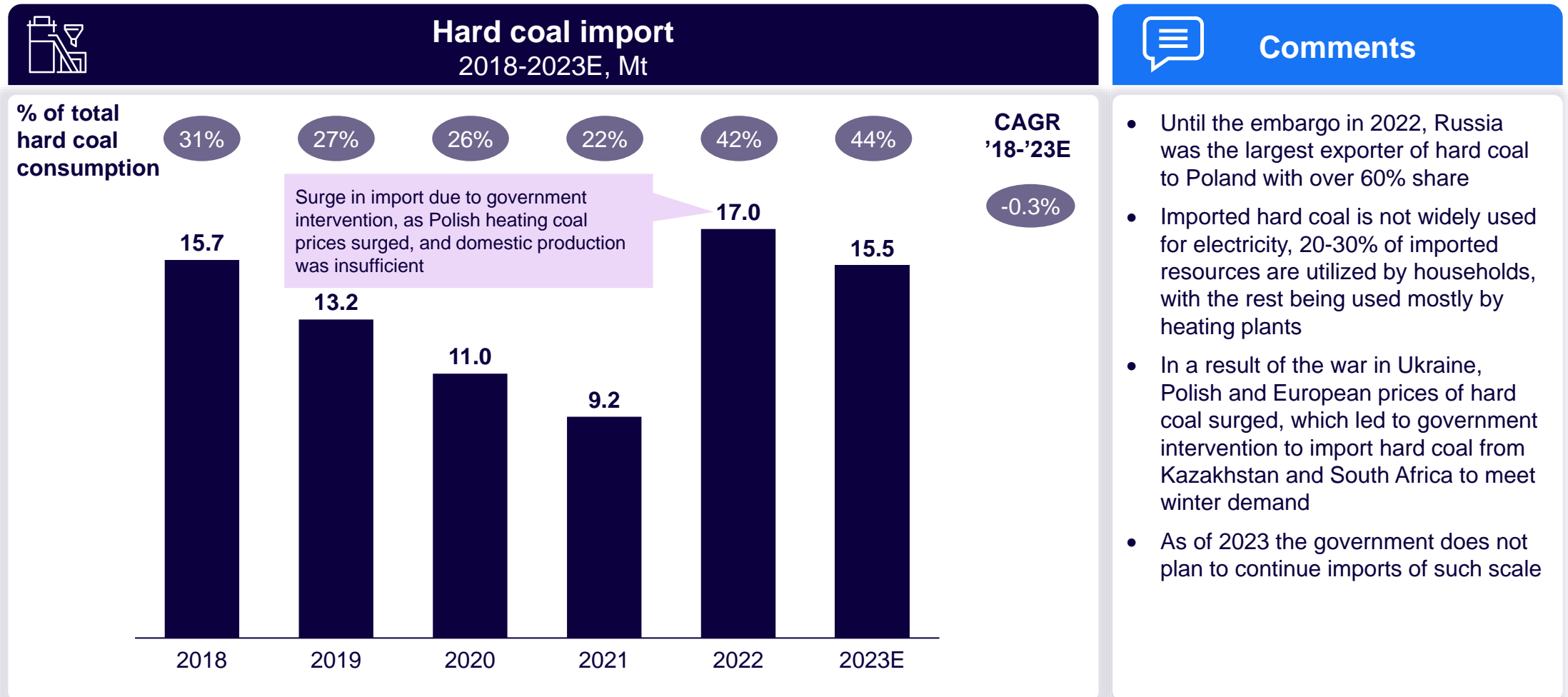
## Domestic coal production declines following the shift in energy mix and increasing difficulties to extract coal from Polish mines, both for hard coal and lignite







## Hard coal import increased in recent years, fueled by the surge in prices of domestic hard coal following the war in Ukraine

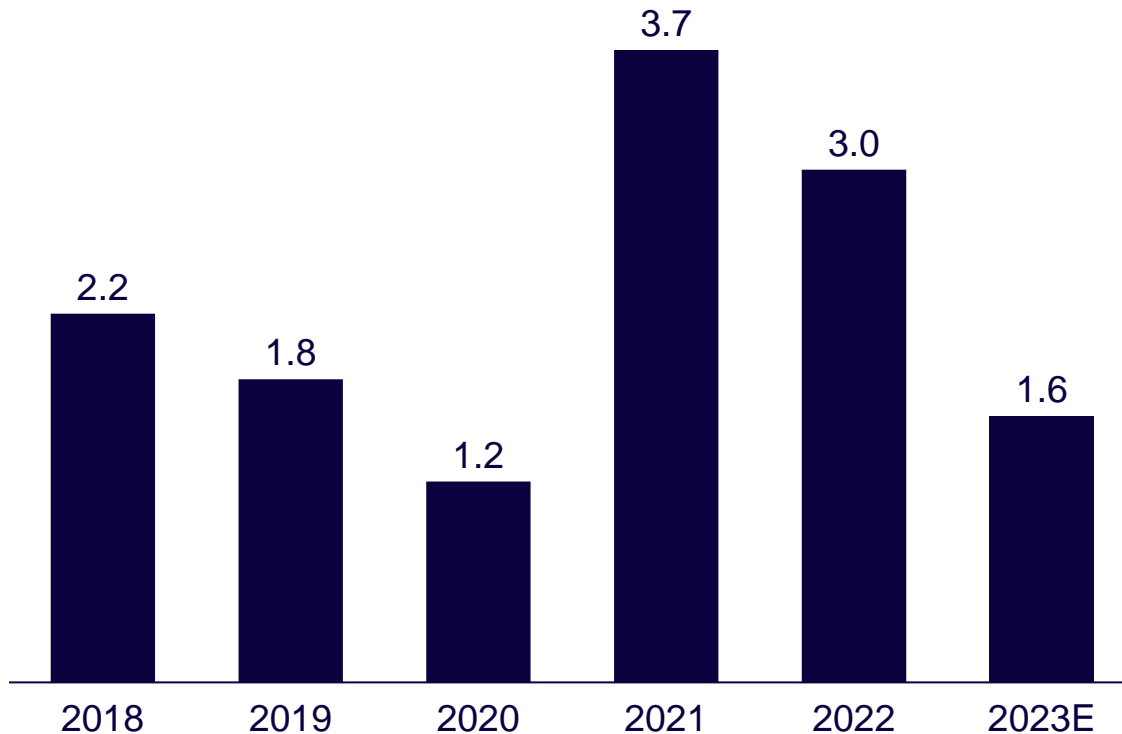




## Polish hard coal export rose in a result of post-pandemic economic rebound and increased shipping prices, which led European countries to look for local suppliers



### Hard coal export 2018-2023E, Mt



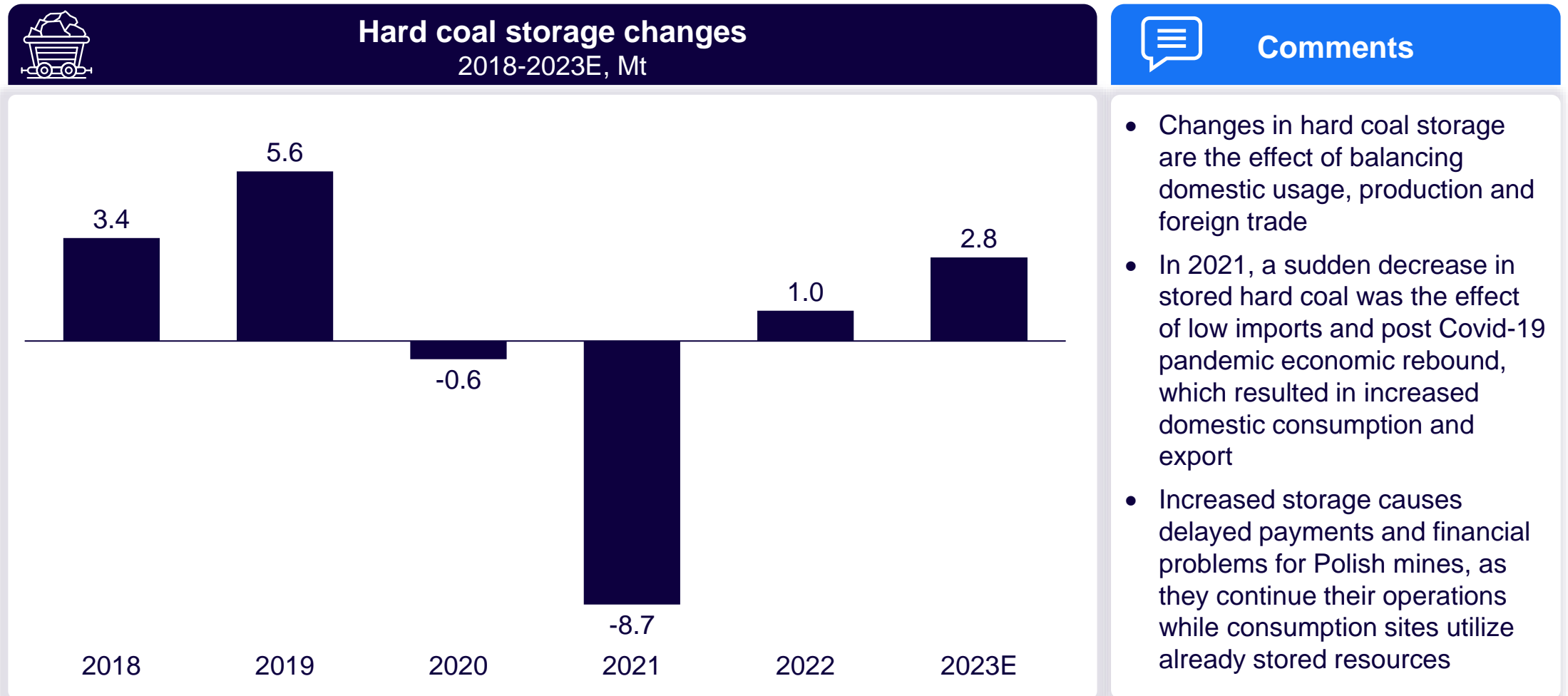
CAGR  
'18-'23E  
-6.3%



### Comments

- Between 2018 and 2020, there was a decrease in Polish hard coal exports. However, following the Covid-19 pandemic, energy consumption in Europe rose, leading to a higher demand for hard coal. Heightened European demand, coupled with rising shipping costs, contributed to an increase in Polish hard coal exports during 2021 and 2022
- As of 2022, the largest export markets for Polish hard coal included Germany, Ukraine and Czech Republic

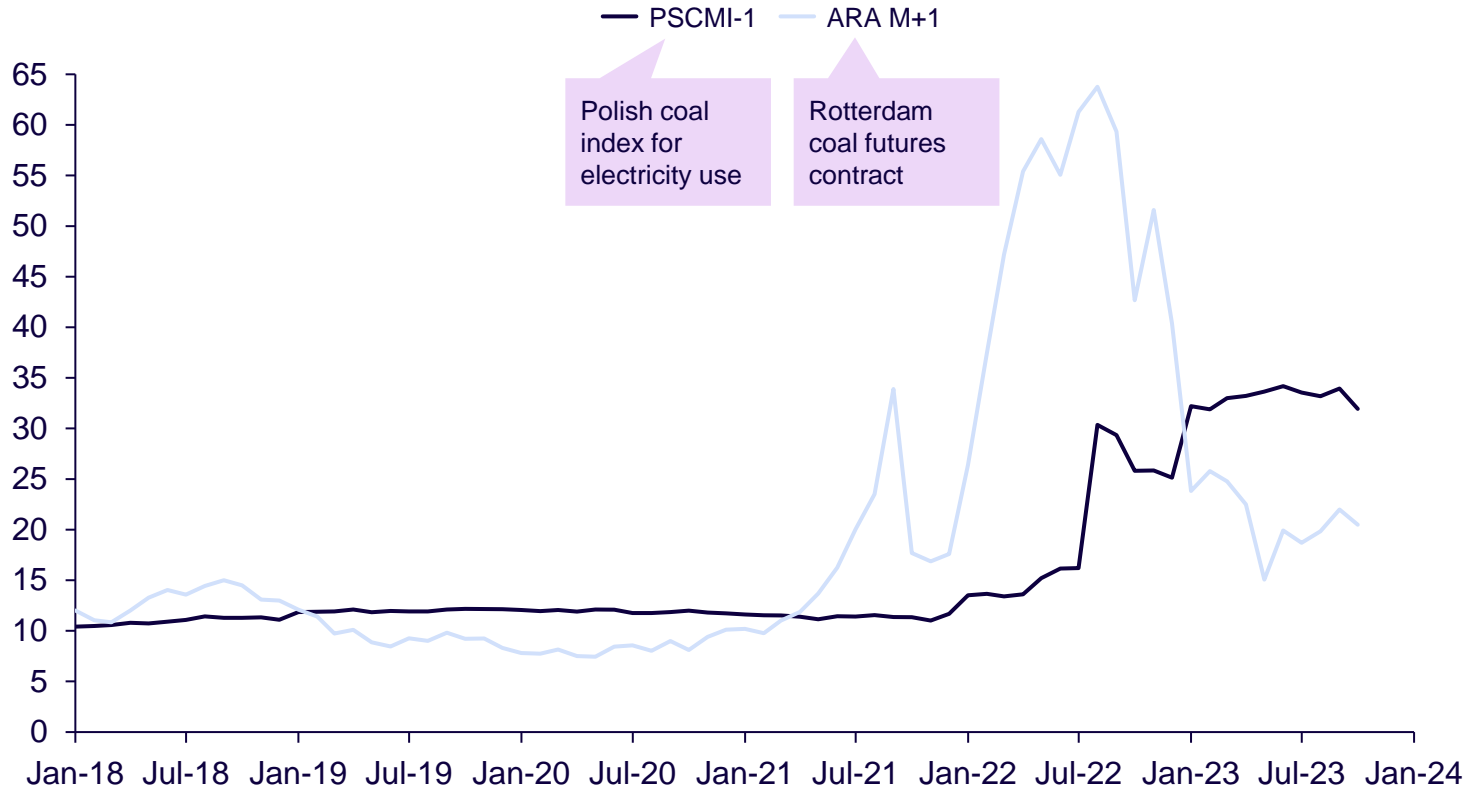
## The amount of stored hard coal fluctuated in recent years, with sudden decline in 2021 and gradual build up afterwards



## Geopolitical instability in recent years introduced rapid changes to previously stable prices of hard coal both on Polish and European markets



### Hard coal prices 2018-2023, PLN/GJ



### Comments

- As a market index ARA M+1 is characterized by a much higher volatility than regulated and partially steered by government PSCMI-1 prices
- In winter season of 2021 as gas prices in Europe rose, demand for cheaper alternatives surged, increasing also prices of ARA M+1, the trend intensified in 2022, following Russian invasion of Ukraine
- PSCMI-1 prices also experienced rapid increase in 2022 due to inflation pressures and unmatched production to demand for hard coal

# GLOSSARY AND SOURCES

## Abbreviations and definitions (1/3)

Name	Definitions
ARA Y+1/M+1	European hard coal futures price index (year/ month ahead)
BEiK	Expert Council on Energy Security and Climate
Capture price	Average electricity price that a RES project achieves throughout a given period of time
CDGU	Controllable Distributed Generation Units
CCGT	Combined Cycle Gas Turbine
DA	Day Ahead
DSR	Demand Side Response
Duck curve	Graph of power production over the course of a day that shows the timing imbalance between peak demand and solar power generation. When plotted on a graph the lines and curves form a distinctly duck-like shape.
Dunkelflaute	A period of time in which little or no energy can be generated with wind and solar power
EPP2040 SC_3	Poland's Energy Policy until 2040, priority Social Challenges in theme SC 3 safe, clean and efficient energy
FCR	Frequency Containment Reserve
FRR	Frequency Restoration Reserve
FSRU	Floating Storage Regasification Unit

## Abbreviations and definitions (2/3)

Name	Definitions
KSE	Polish Power System (Krajowy System Elektroenergetyczny)
LCOE	Levelized Cost of Electricity
MCP Directive	The Medium Combustion Plant Directive
nCDGU	non-Controllable Distributed Generation Units
OCGT	Open cycle gas turbine
PH	Pumped hydroelectricity
PRSP 2032	Transmission System Development Plan to 2032
PSCMI_1	Polish Thermal Coal Market Index 1, weighted average of transactions executed on the Polish thermal coal market, invoiced in a given calendar month
PSE	Polish transmission system operator (Polskie Sieci Elektroenergetyczne S.A.)
PV	Photovoltaics
RES	Renewable energy sources
SMR	Small modular reactor
SRMC	Short-run marginal cost
TGE	Polish Power Exchange (Towarowa Giełda Energii)

## Abbreviations and definitions (3/3)

Name	Definitions
TGE gaz BASE RDN	The price of natural gas in Poland on the Day-Ahead Market (spot)
TTF M+1	European forward gas price index (for the following month), for the Dutch Title Transfer Facility hub
URE	Energy Regulatory Office (Urząd Regulacji Energetyki)



## Sources (1/2)

### Sources

Industrial Development Agency (Agencja Rozwoju Przemysłu, ARP)

Agencja Rynku Energii (ARE)

Energy.instrat

Euracoal

European Network of Transmission System Operators for Electricity (ENTSOE)

European Network of Transmission System Operators for Gas (ENTSOG)

Eurostat

Gas Storage Poland

Gaz System

GK ORLEN

Statistics Poland (Główny Urząd Statystyczny, GUS)

Instytut Jagielloński

Investing.com

European Commission

## Sources (2/2)

### Źródła

The National Centre for Emissions Management (Krajowy Ośrodek Bilansowania i Zarządzania Emisjami, KOBiZE)

International Renewable Energy Agency (IRENA)

International Monetary Fund (IMF)

National Bank of Poland (Narodowy Bank Polski, NBP)

Polish Geological Institute (Państwowy Instytut Geologiczny)

Polish Coal Market (Polski Rynek Węgla)

Polskie Górnictwo Naftowe i Gazownictwo (PGNiG)

Stooq

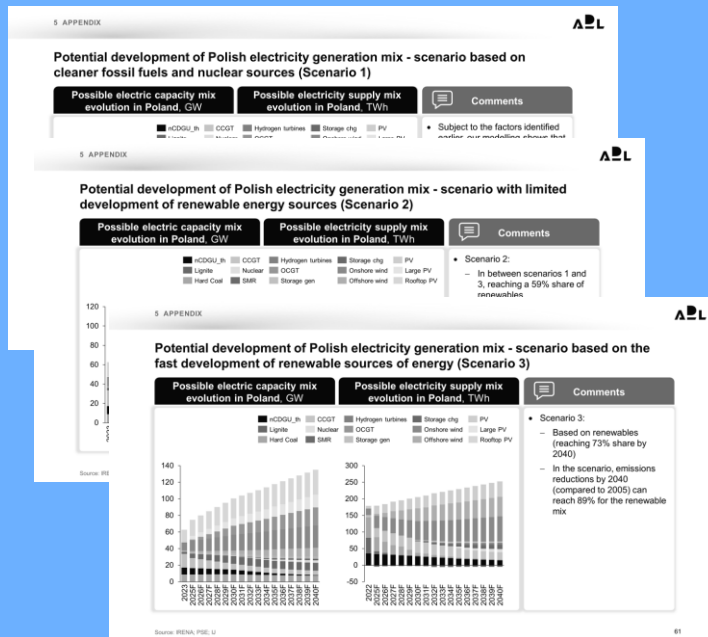
Polish Power Exchange (Towarowa Giełda Energii, TGE)

Energy Regulatory Office (Urząd Regulacji Energetyki, URE)

# APPENDIX - SUPPORTING ANALYSES

# Appendix - Potential developments of Polish energy generation mix

## Potential development of Polish energy mix



## Detailed analysis of electricity prices

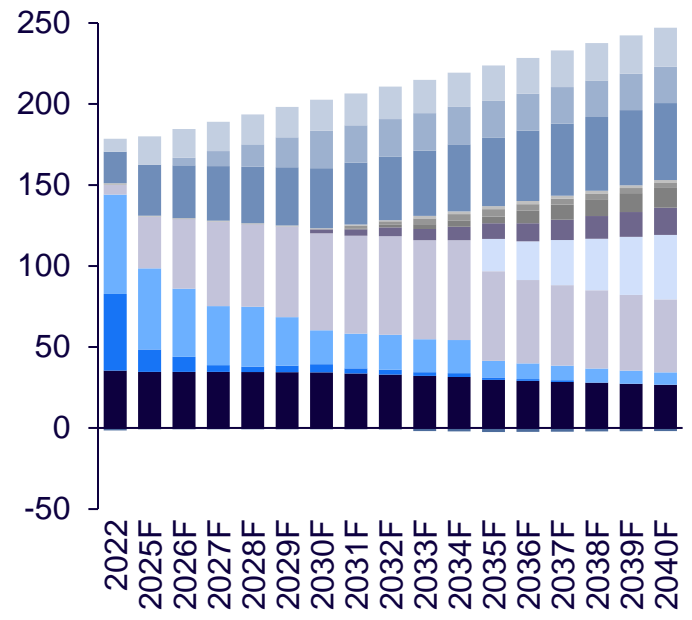
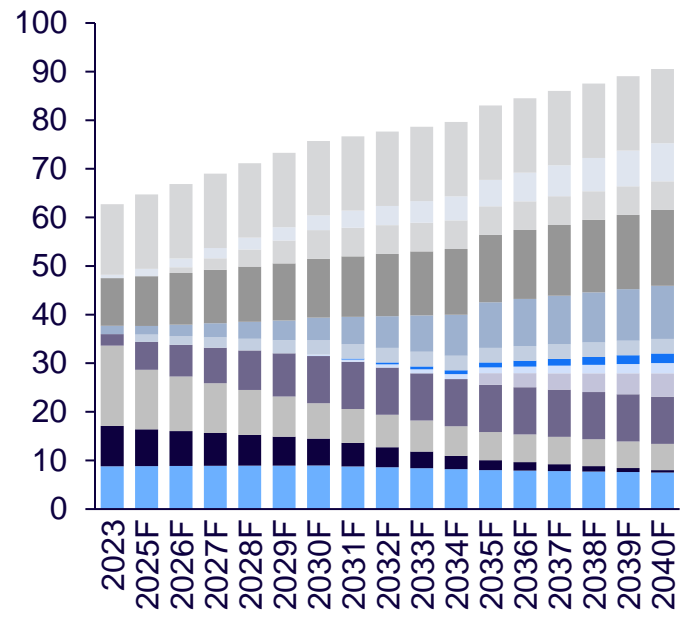
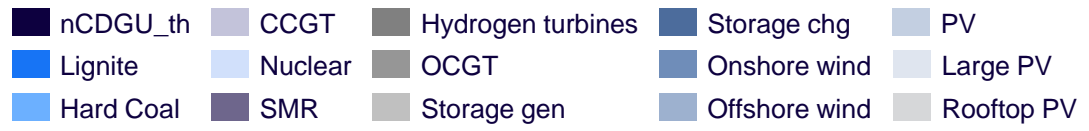


# Potential development of Polish electricity generation mix - scenario based on cleaner fossil fuels and nuclear sources (Scenario 1)

## Possible electric capacity mix evolution in Poland, GW

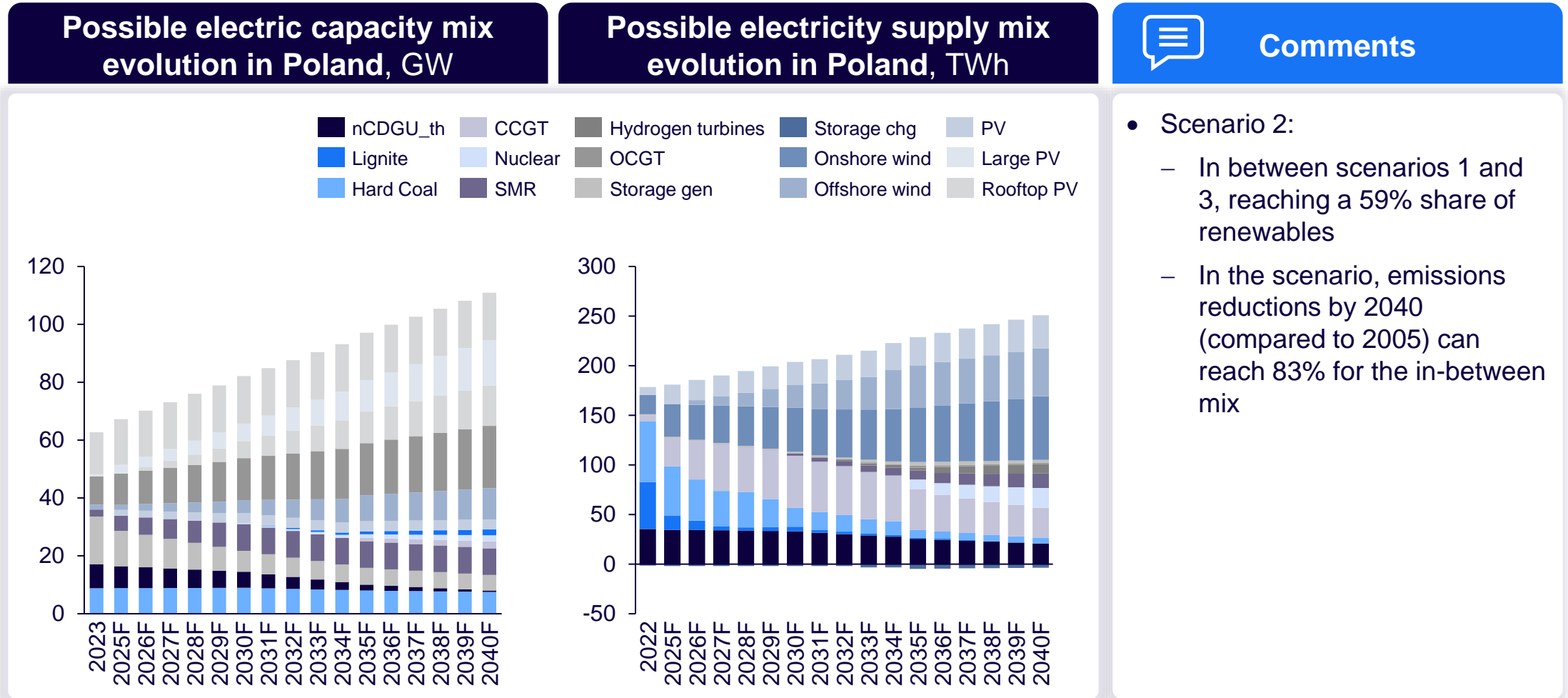
## Possible electricity supply mix evolution in Poland, TWh

## Comments



- Subject to the factors identified earlier, our modelling shows that Poland's electricity generation mix can evolve into 3 scenarios
- Scenario 1:
  - Based on cleaner fossil fuels (gas, hydrogen) and nuclear sources, with around 38% share of renewables in the long term
  - In the scenario, emissions reductions by 2040 (compared to 2005) can reach 76% for the fossil and nuclear mix

## Potential development of Polish electricity generation mix - scenario with limited development of renewable energy sources (Scenario 2)

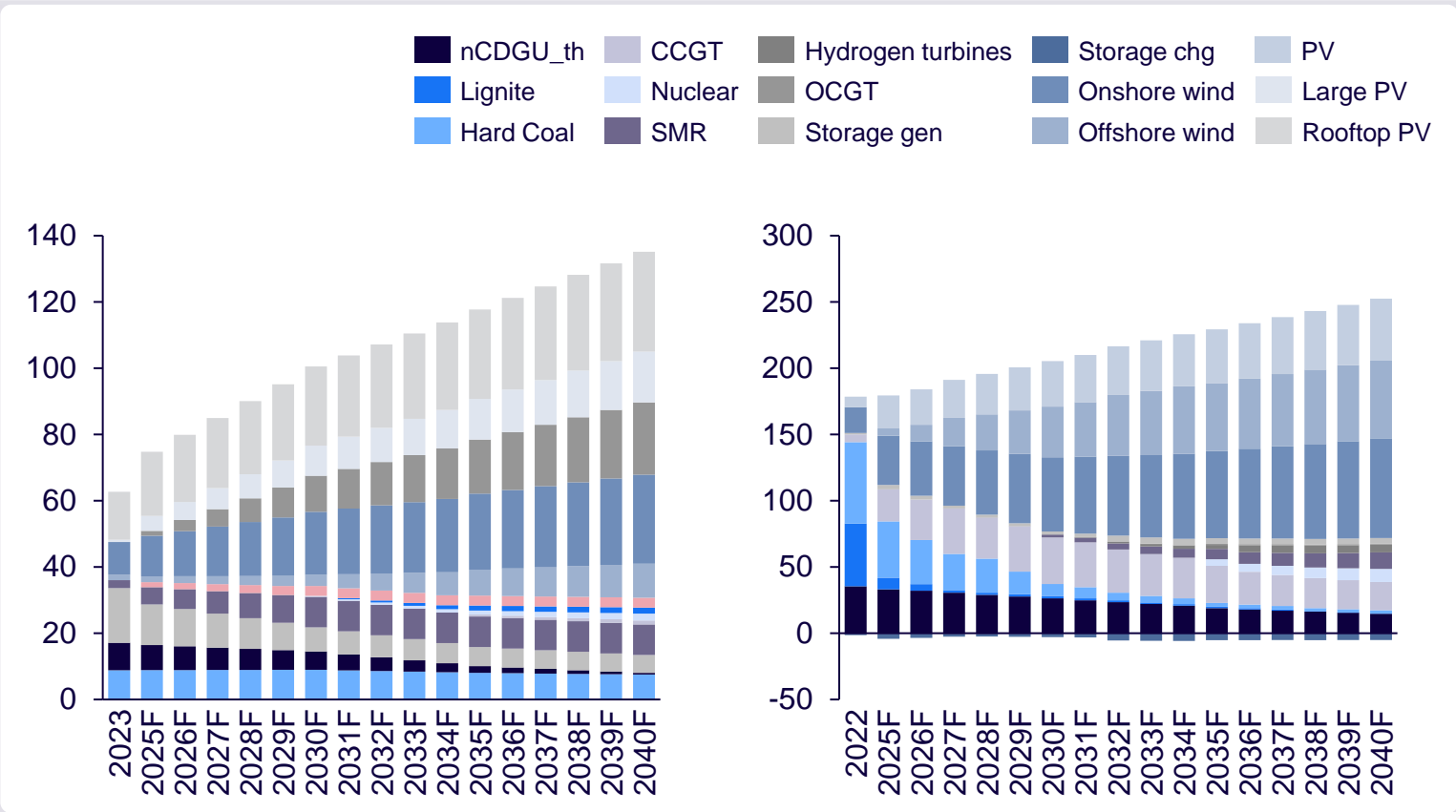


# Potential development of Polish electricity generation mix - scenario based on the fast development of renewable sources of energy (Scenario 3)

## Possible electric capacity mix evolution in Poland, GW

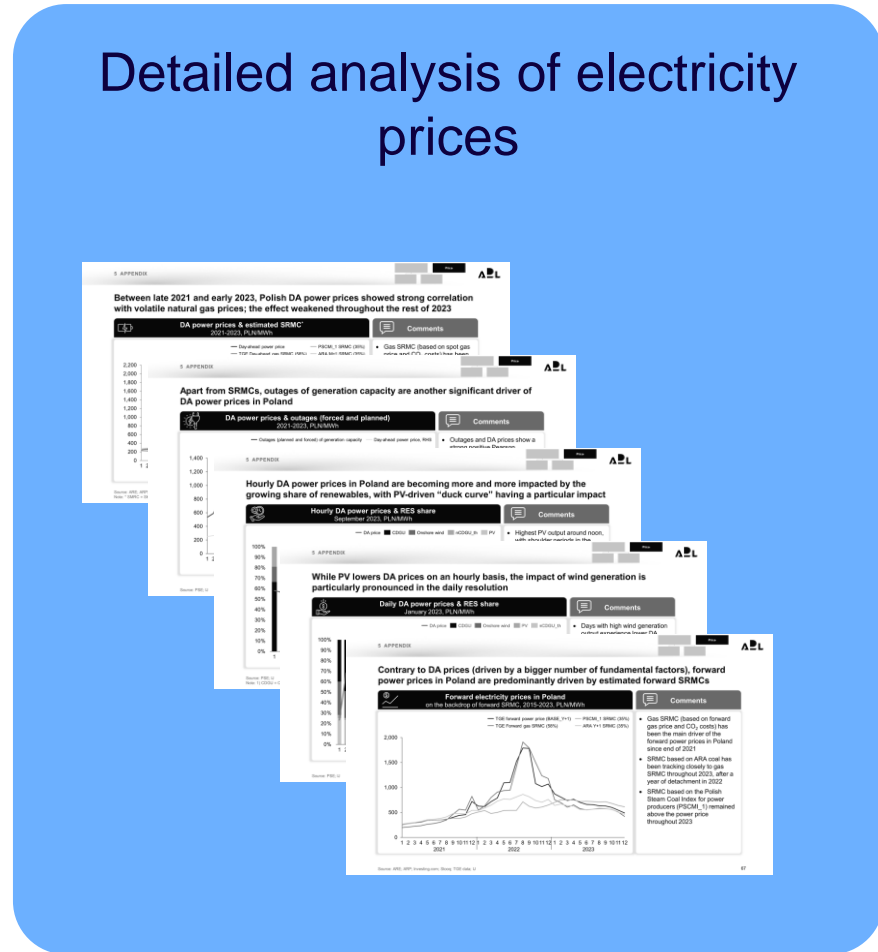
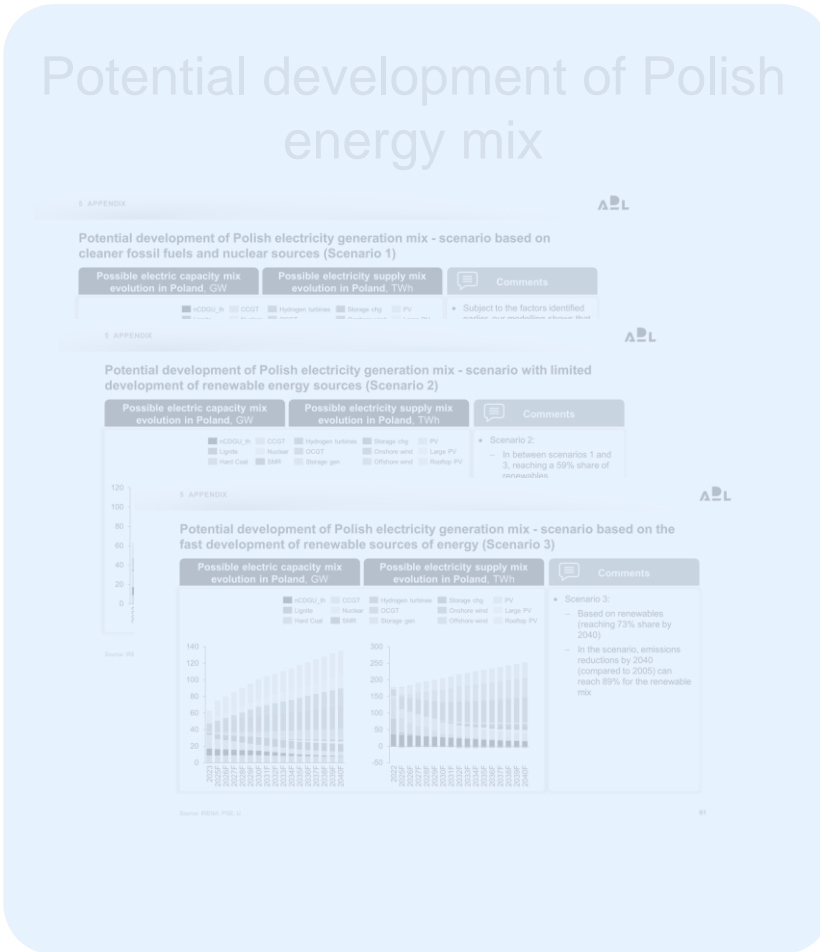
## Possible electricity supply mix evolution in Poland, TWh

## Comments



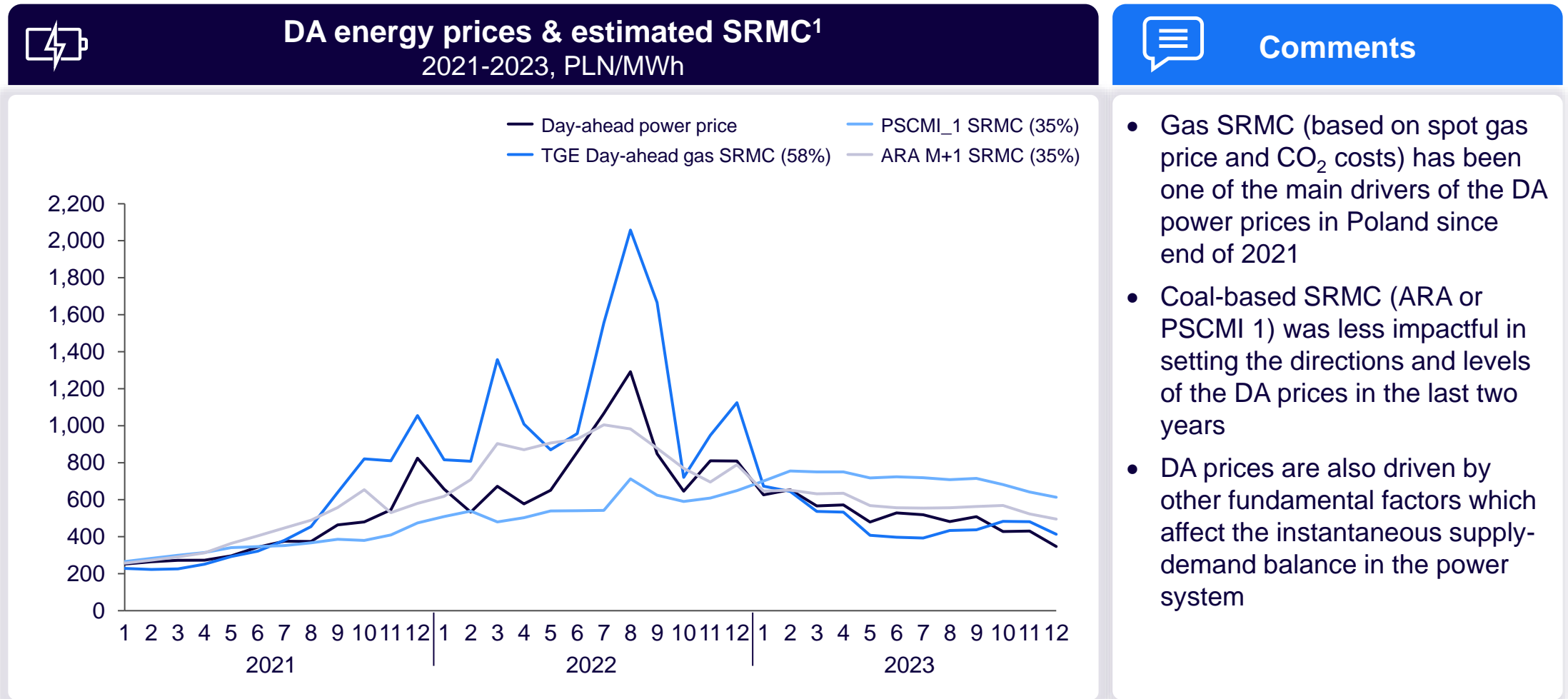
- Scenario 3:
  - Based on renewables (reaching 73% share by 2040)
  - In the scenario, emissions reductions by 2040 (compared to 2005) can reach 89% for the renewable mix

# Appendix - Detailed analysis of electricity prices





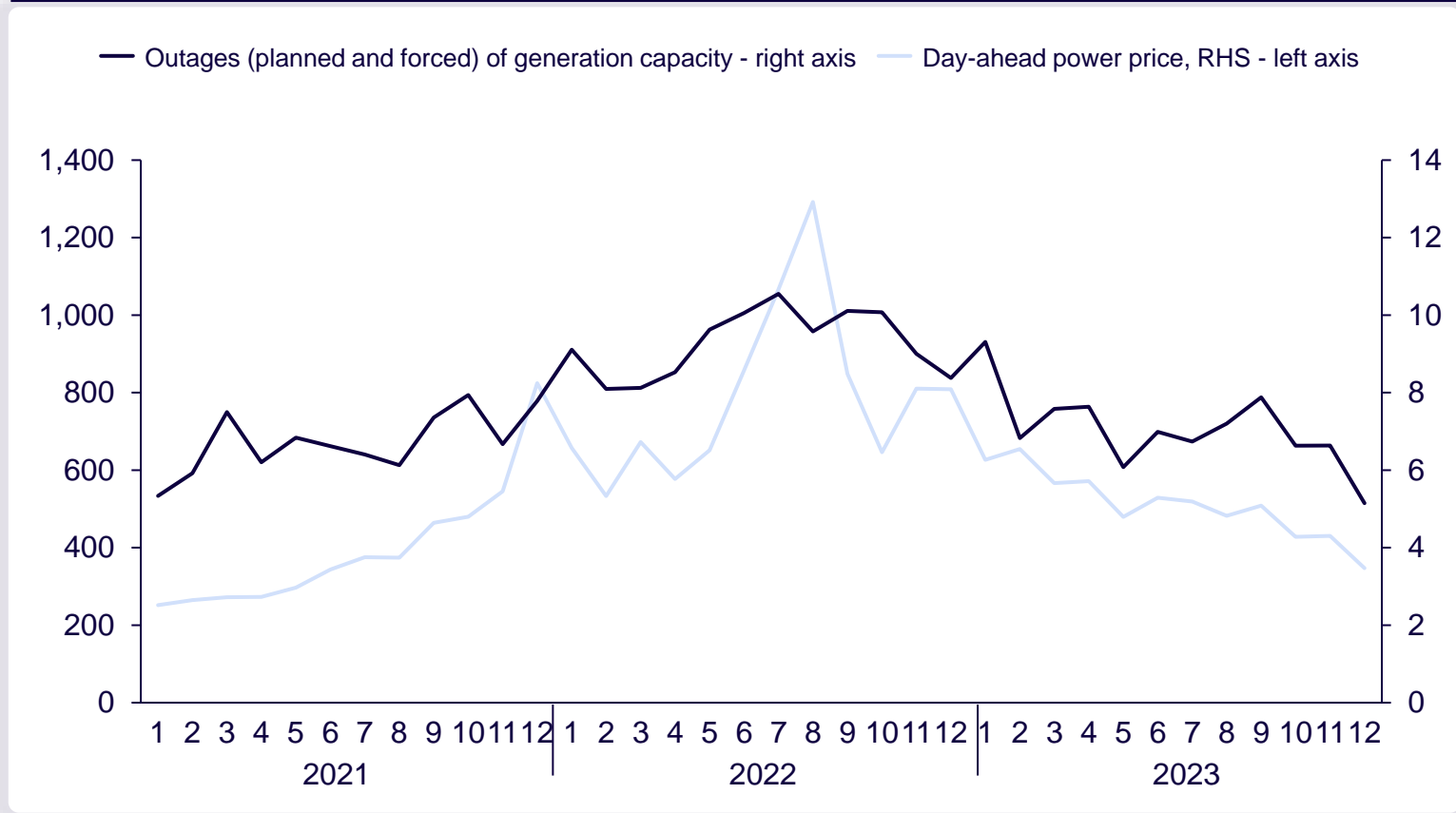
## Between late 2021 and early 2023, Polish DA power prices showed strong correlation with volatile natural gas prices; the effect weakened throughout the rest of 2023



1) SRMC – Short-run marginal cost  
Source: ARE; ARP; Investing.com; PSE; TGE; IJ

# Apart from SRMCs, outages of generation capacity are another significant driver of DA power prices in Poland

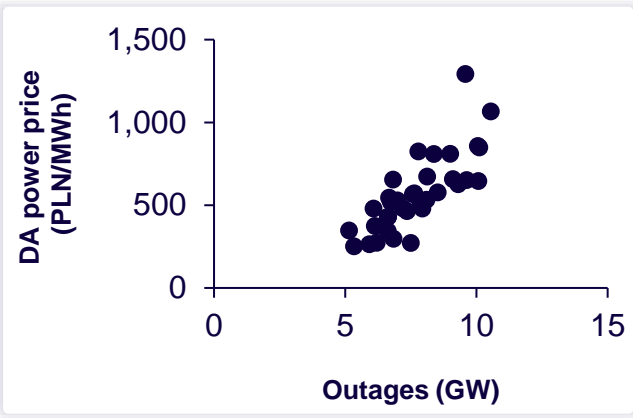
## DA power prices (PLN/MWh) & outages (forced and planned) (GW) 2021-2023



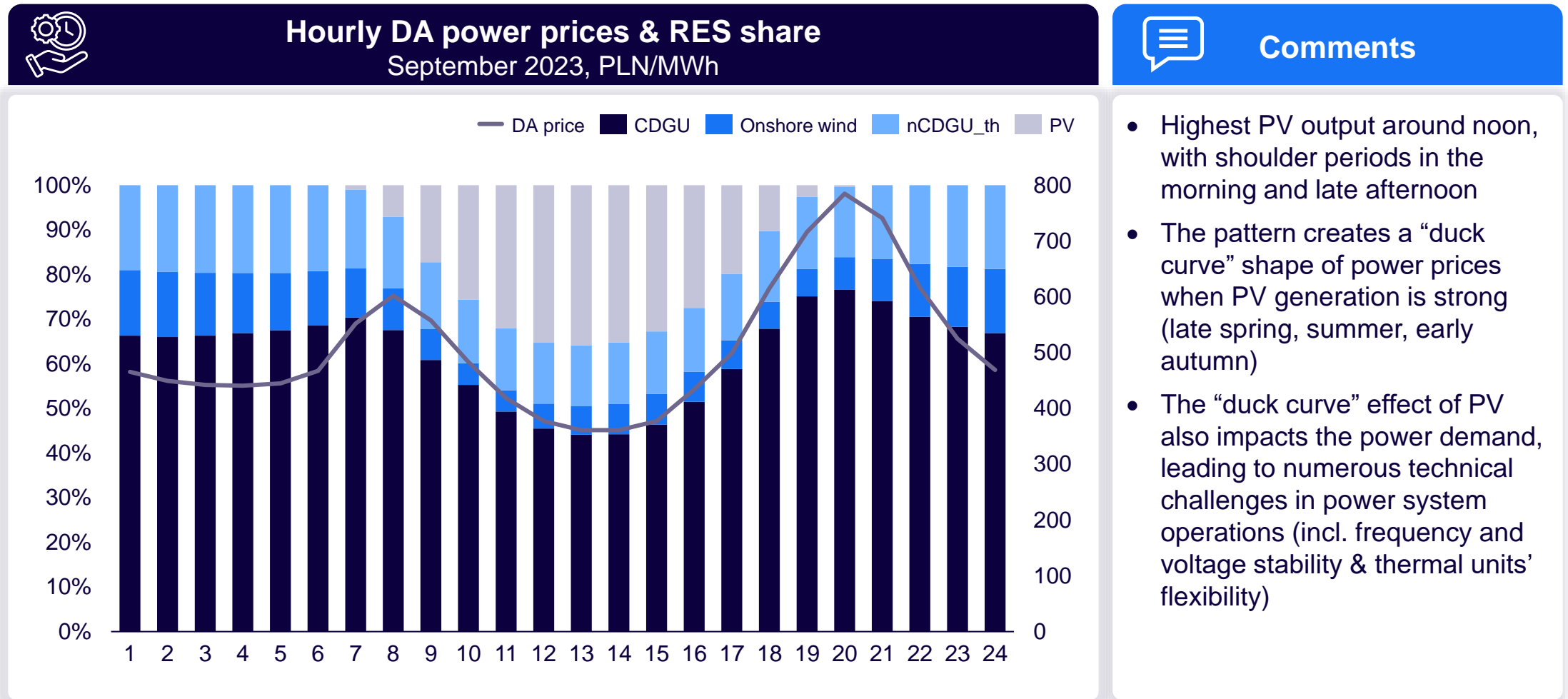
## Comments

- Outages and DA prices show a strong positive Pearson correlation coefficient (0.79)
- Higher outages result in a tighter system (capacity scarcity) and drive prices up

## DA power prices & outages (forced and planned), 2021-2023



# Hourly DA power prices in Poland are becoming more and more impacted by the growing share of renewables, with PV-driven “duck curve” having a particular impact

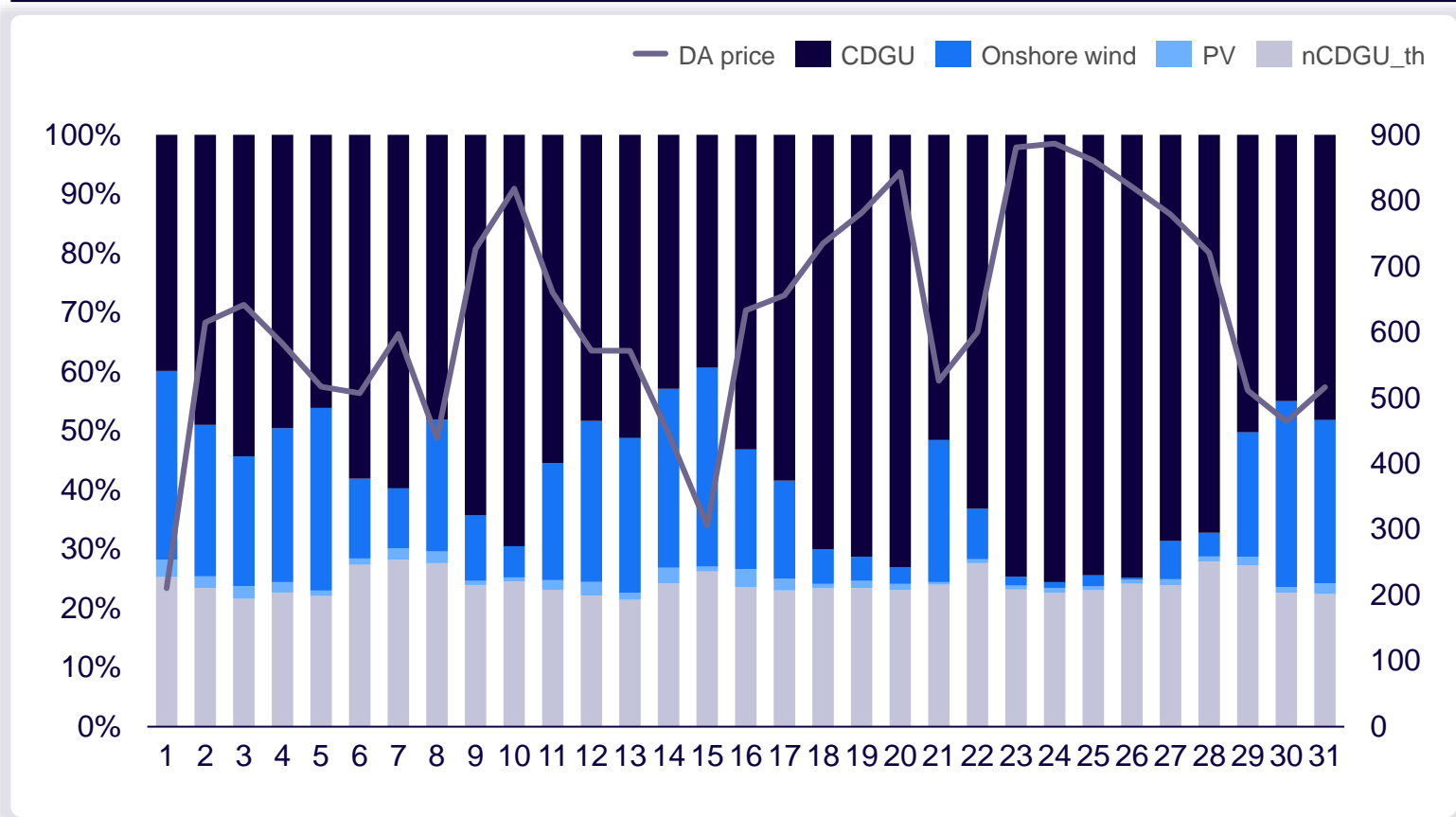


1) CDGU – Controllable Distributed Generation Units; 2) nCDGU – Non-Controllable Distributed Generation Units  
 Source: PSE; IJ

# While PV lowers DA prices on an hourly basis, the impact of wind generation is particularly pronounced in the daily resolution

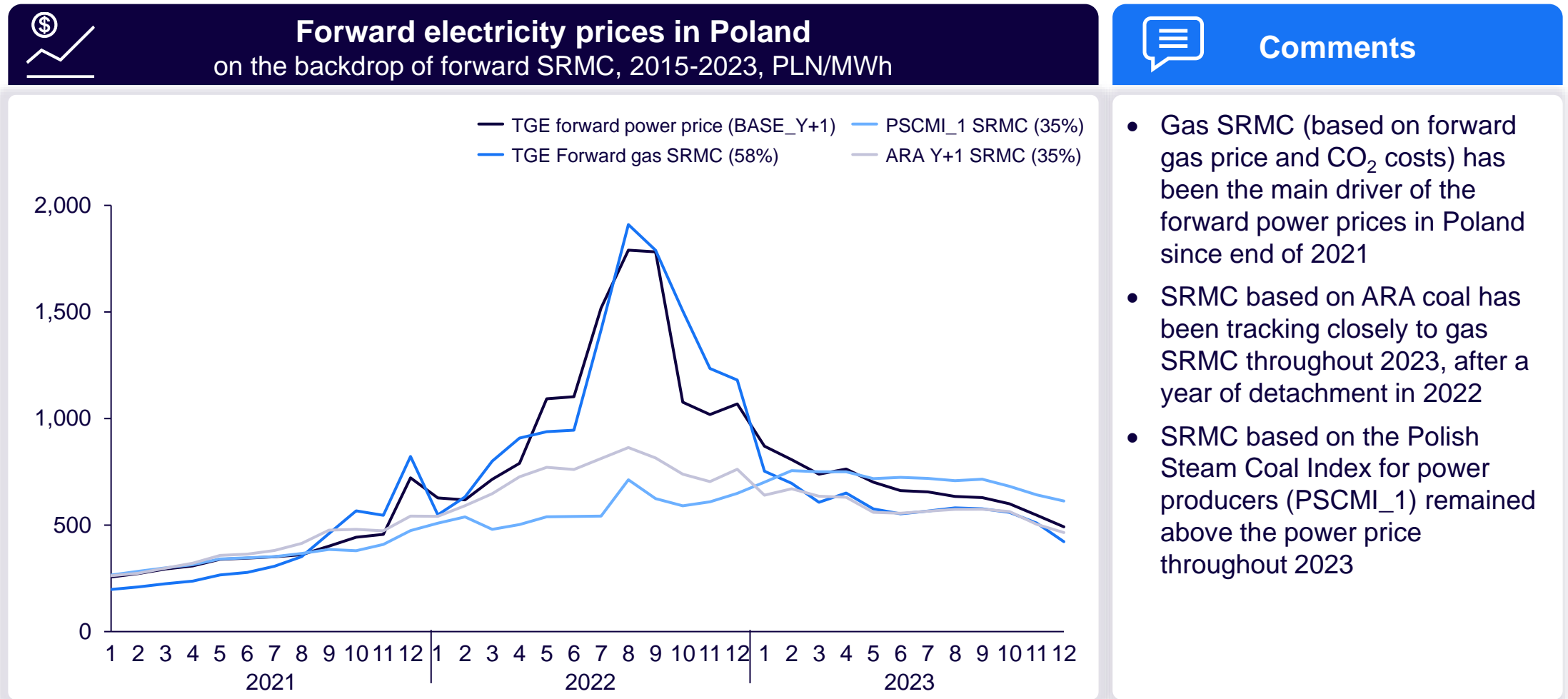
**Daily DA power prices & RES share**  
January 2023, PLN/MWh

**Comments**



- Days with high wind generation output experience lower DA prices than days with low shares of wind output
- The daily impact of wind (compared to hourly impact of PV) stems from the characteristic of these natural resources
- PV output is more variable across hours, while wind output levels generally changes more from one day to another

## Contrary to DA prices (driven by a bigger number of fundamental factors), forward power prices in Poland are predominantly driven by estimated forward SRMCs



**ARTHUR  LITTLE**

**THE DIFFERENCE**