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ENERGY RESEARCH

Impact of Russia-Ukraine war on European gas markets: can Europe cope without Russian gas?

3rd March 2022

Agenda

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I. How important is Russian gas in Europe?

II. Where are we now with Russian gas and what happened to gas prices?

III. What could happen in markets in the next 2-3 years? We examine three scenarios:

1. Nord Stream 2 delayed to 2025
2. Disruption to Russian gas via Ukraine combined with Nord Stream 2 delayed to 2025
3. Halt in all Russian gas to Europe

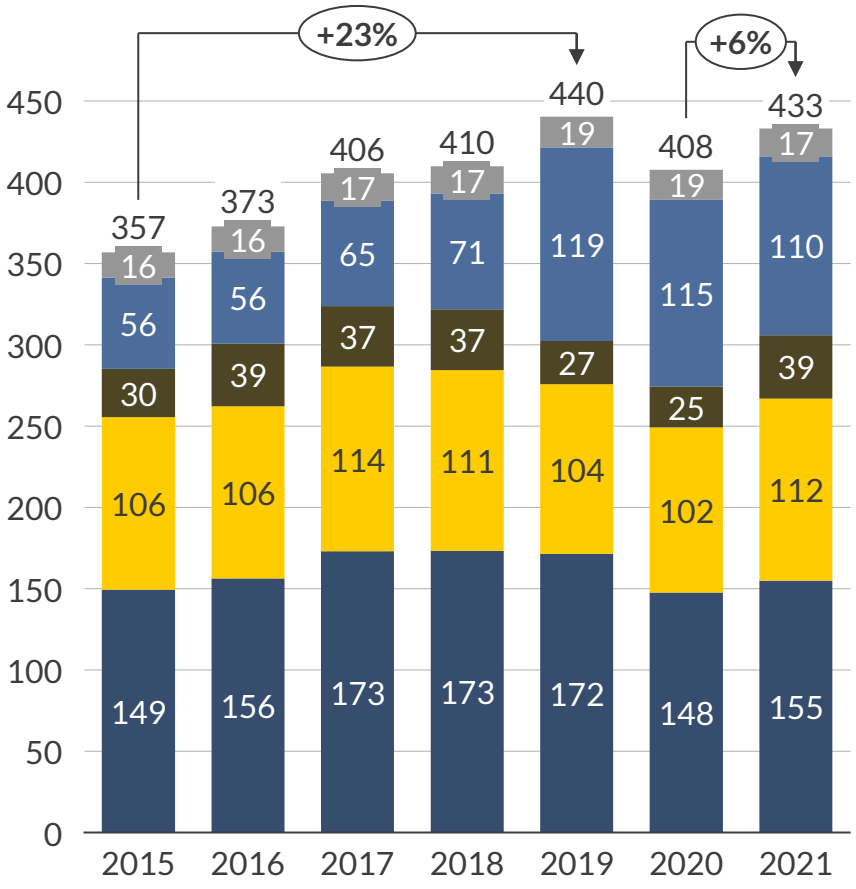
IV. Could Europe cope without any Russian gas this coming winter?

V. What are the policy implications for governments from this crisis?

Russia meets around 30-40% of gas demand in Europe and is the largest single supplier

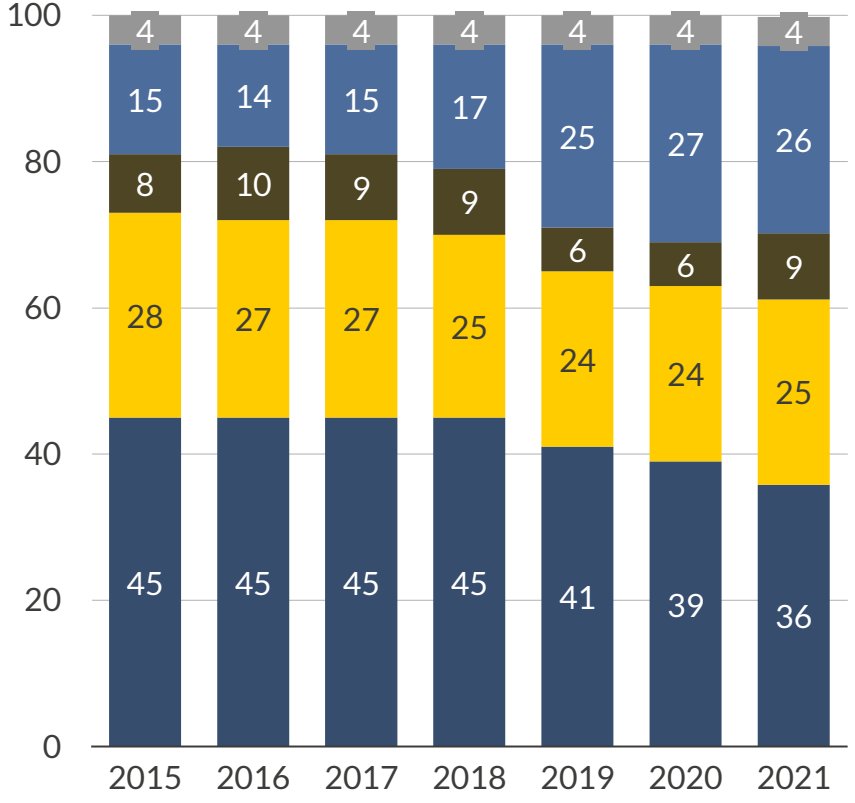
Gross European gas imports[1]

bcm



Percentage of European imports[2]

%



Russia Piped | Norway Piped | Africa Piped | LNG | Other

1) Includes Baltic states. 2) LNG import composition in 2021 by exporting country: US 25%, Qatar 23%, Russia 15%, Nigeria 13%, Algeria 12%, Norway 4%, Other 8%.

Sources: Aurora Energy Research, BP Statistical Review of World Energy 2021

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- Europe's gas demand is met through three primary sources, of which Russia is the largest single supplier. The share of Russian gas has been consistently above 35% on an annual basis
- European gas imports from Russia increased steadily year-on-year between 2015 and 2019, before dropping 7% in 2020 due to weak gas demand and prices due to the pandemic
- As a share of European imports, Russian pipeline supply slightly reduced in 2021 to 36%
- Russia also accounted for 15% of LNG imports to Europe in 2021

Russian gas flows into Europe declined in 2020, but have been increasing in the last week of February

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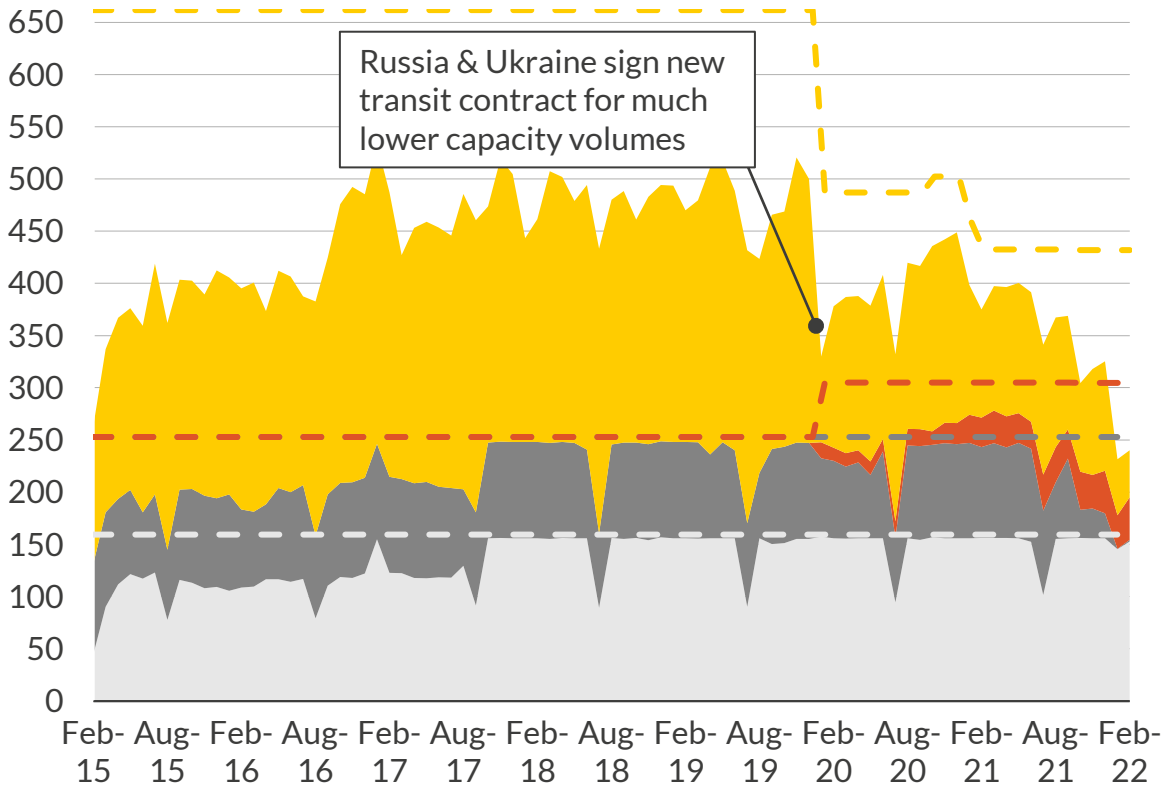
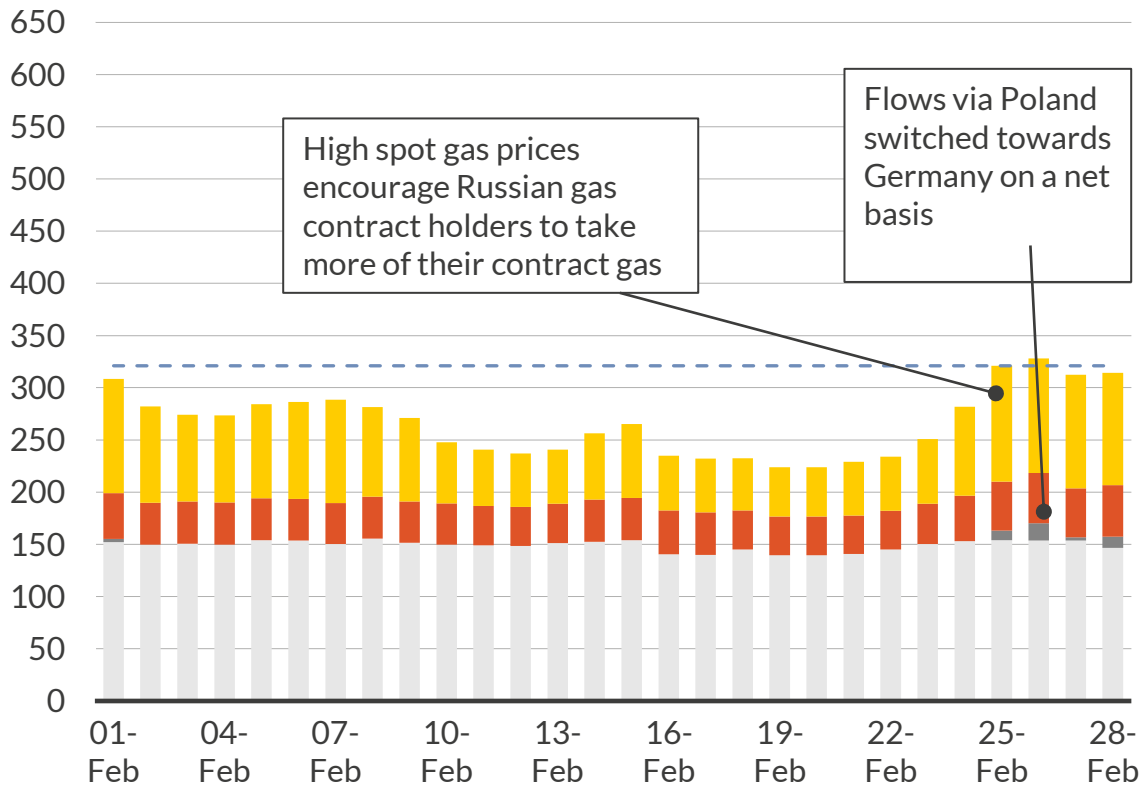
Average monthly Russian gas deliveries to Europe[1] since February 2015

mcm/d



Daily Russian gas deliveries to Europe[1]

mcm/d



Ukraine transit
Yamal-Europe
Nord Stream 1 capacity
TurkStream capacity
25 Feb flows
TurkStream
Nord Stream 1
Yamal-Europe capacity
Ukraine transit capcaity

1) Shown capacities (dashed lines) are cumulative, starting from Nord Stream 1, Yamal-Europe, TurkStream and Ukraine. Other marginal routes, including about 15.7mcm/a of additional capacity at the Belarus-Poland border were excluded. This is excluding Turkey and the Baltics vs capacity

Source: Aurora Energy Research

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Developments in European gas markets since Russia's military invasion

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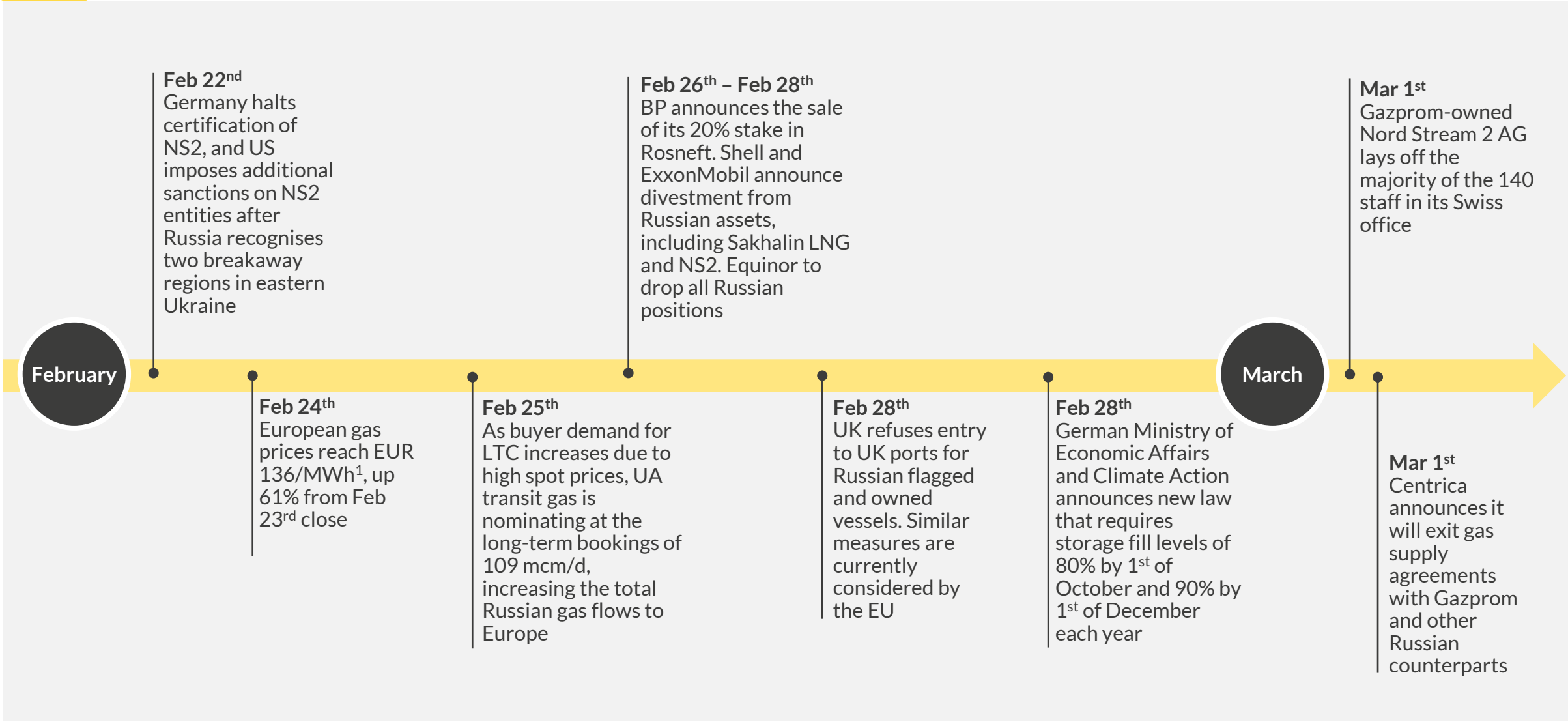

Timeline is not exhaustive. 1) TTF front-month contract

Source: Aurora Energy Research

Gas and power prices reacted to news of the Nord Stream 2 suspension, war in Ukraine, and Western sanctions

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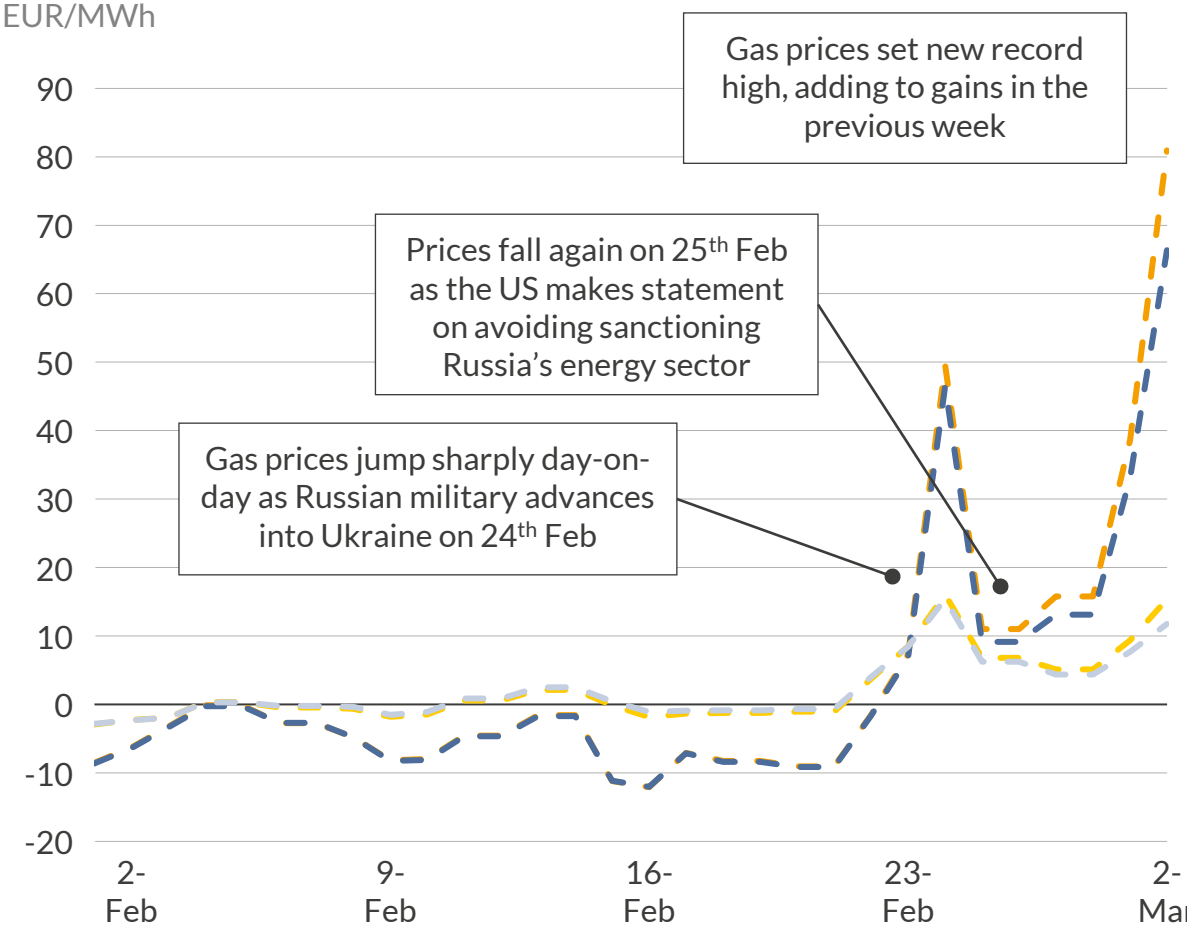
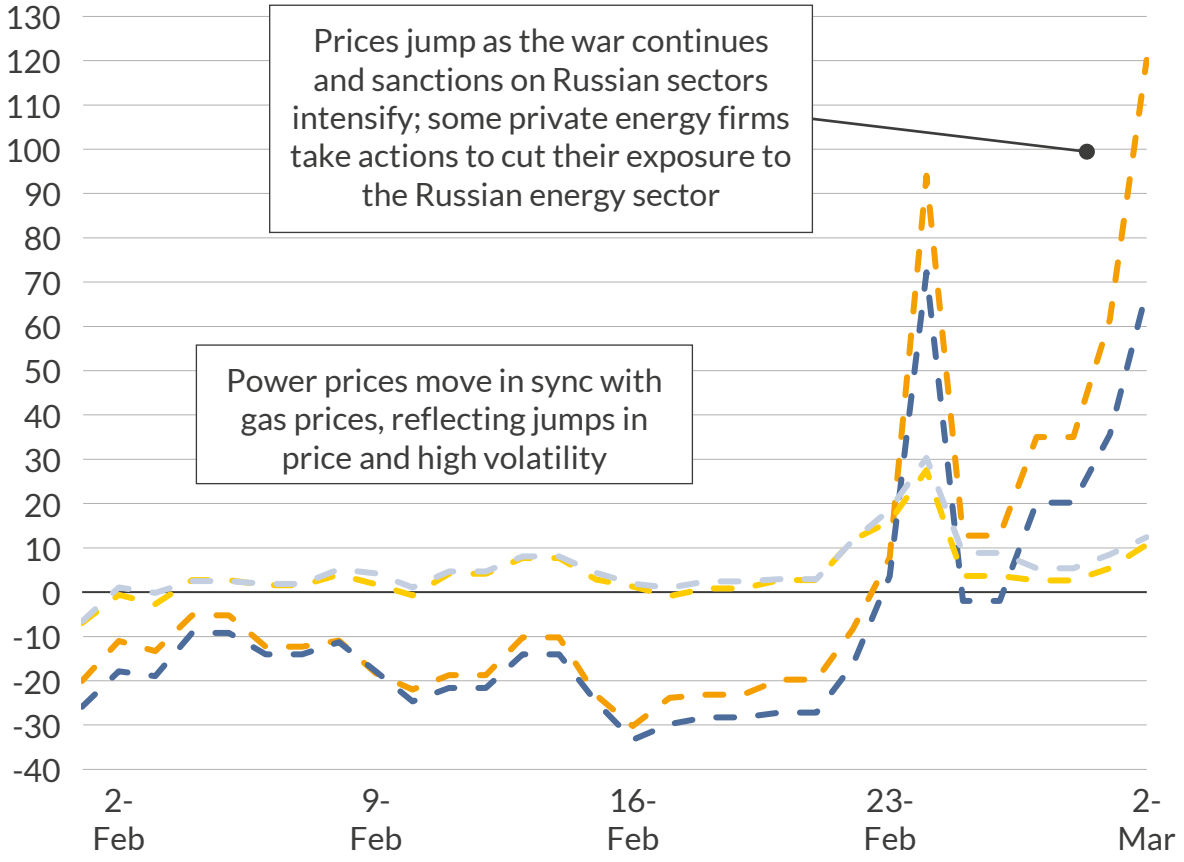
Cumulative daily change in Dutch TTF forward prices[1,2]
EUR/MWh



Cumultive daily change in German baseload power futures[2]
EUR/MWh



Summer 2022 — Winter 2022-23 — Summer 2023 — Winter 2023-24

1) ICE TTF futures 2) EEX German baseload power futures 2) Summer prices for delivery in April-September, winter prices for delivery in October-March

Sources: ICE, EEX

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We examine the impact on markets of three Russian gas scenarios

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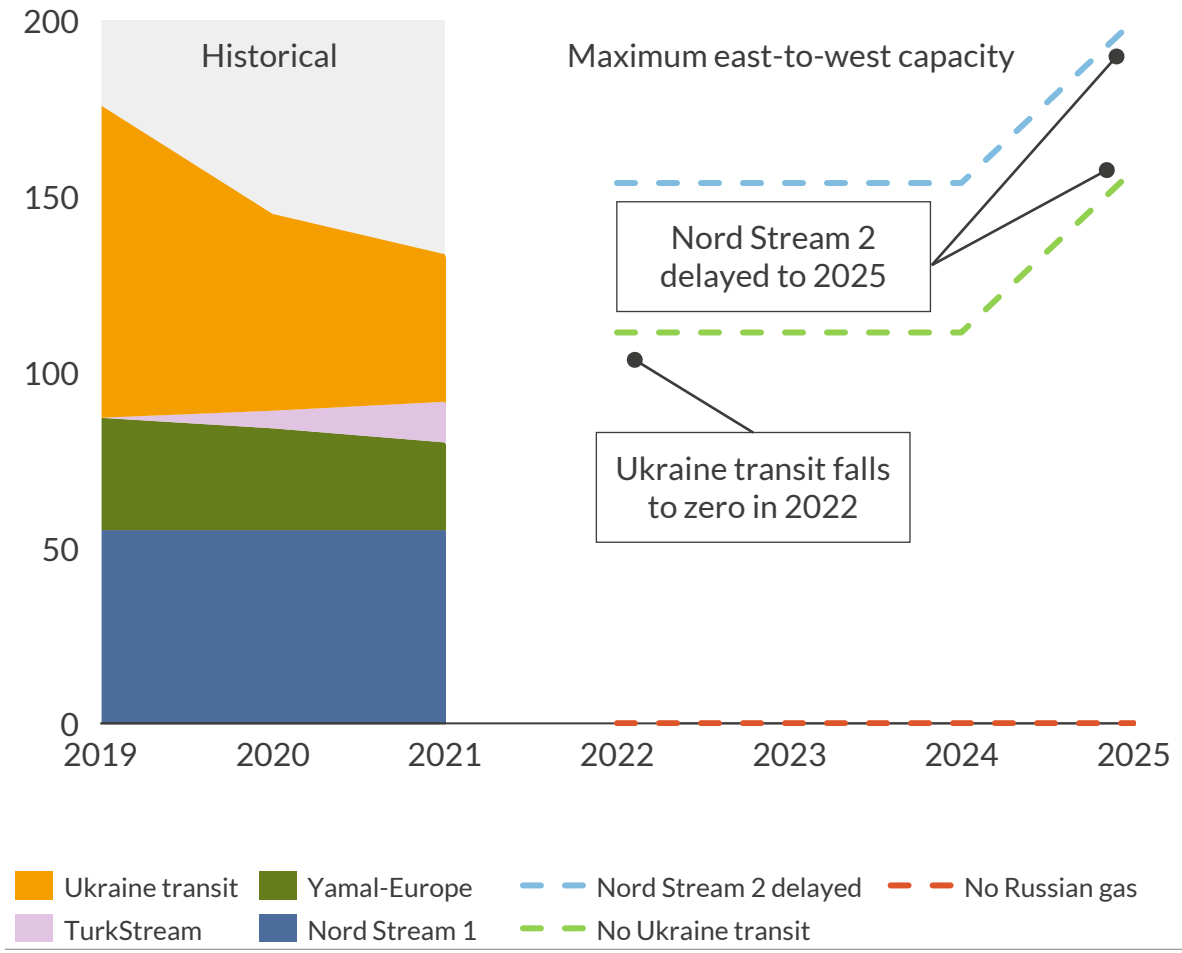
Historical flows 2019-21[1], total capacity under three scenarios[2]
bcm/a



In this analysis we look at three Russian gas scenarios

1. Optimistic: There is a de-escalation of conflict between Russia and Ukraine and only a two-year delay to Nord Stream 2. This scenario is most similar to a return to the situation before the Russian military incursion into Ukraine. This is the most optimistic of the three scenarios.

2. No Ukraine transit: Russian gas to Europe is constrained significantly until 2025 because of a complete halt to Ukrainian transit flows. NS2 is also suspended until 2025, but other routes remain available

3. Drastic: No Russian gas flows to Europe along any route

1) As published on 4 May 2021 on EOS 2) Nord Stream 1 flows are reduced below capacity of 55bcm/a from 2025 because of regulatory restrictions along its downstream Opal pipeline connection, but only when Nord Stream 2 starts operations

Source: Aurora Energy Research

1 2 In the scenario without Ukrainian transit, Russian flows fall below 2020-2021 levels, and under estimated contract levels

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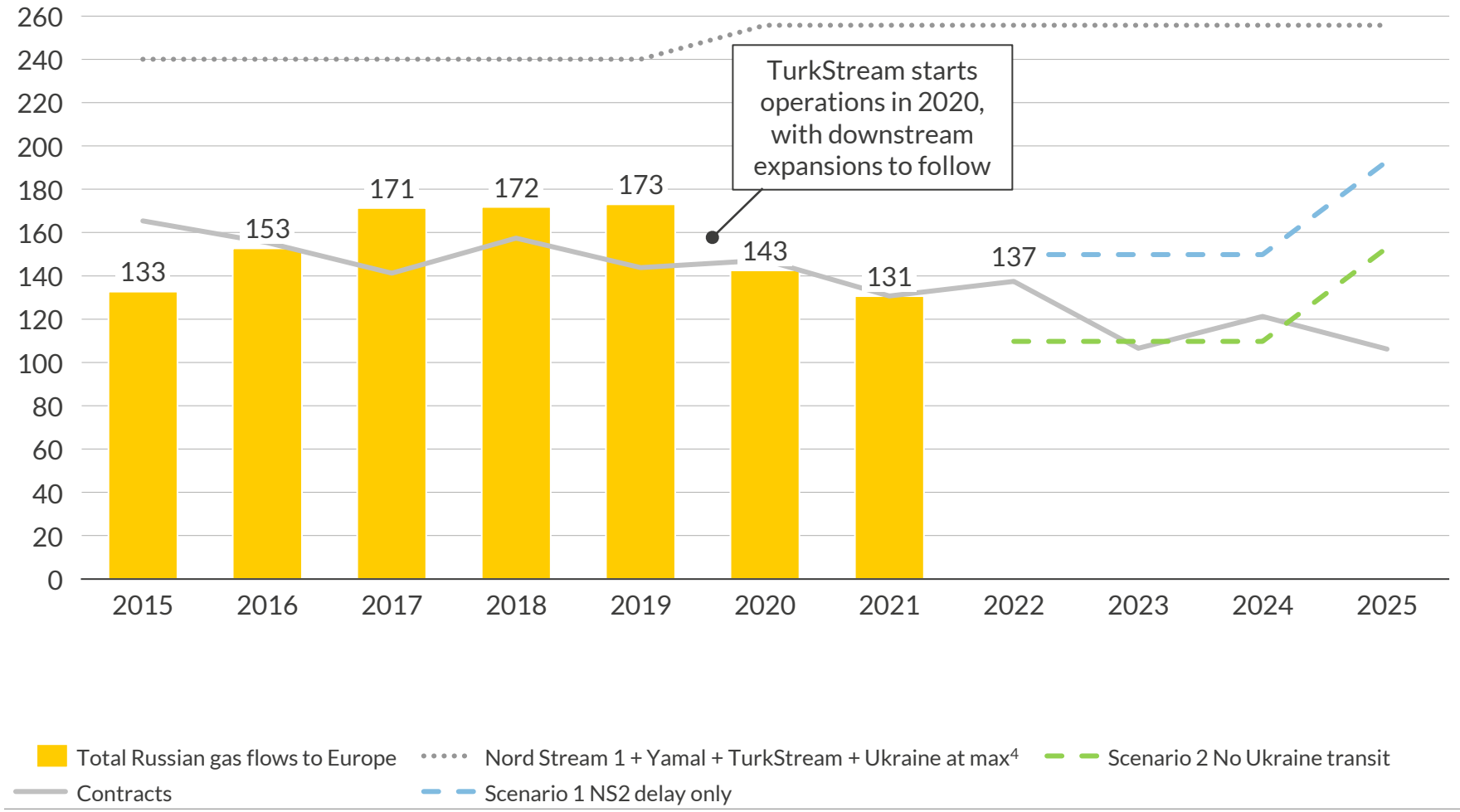
Russian gas deliveries[1] would not fit into Nord Stream 1, TurkStream and Yamal[2] alone

bcm



1) Excluding Turkey and the Baltic States. 2) Capacity at Polish-Belarussian border used. 3) Downstream regulatory restrictions would keep combined NS1 and NS2 flows below capacity. 4) Ukraine max capacity based on transit capacity provided by Ukrainian network operator TSOUA, which is partially mothballed.

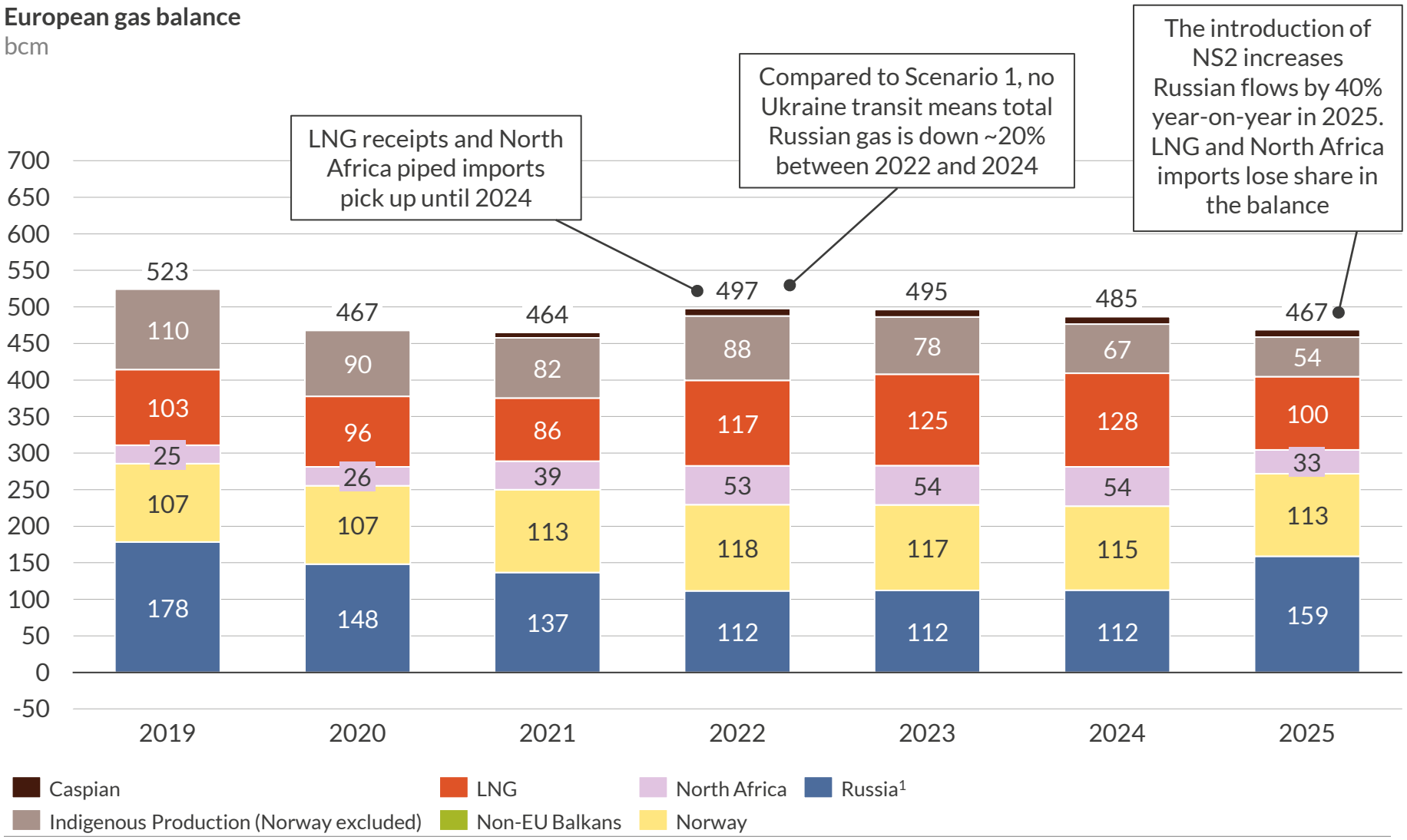
Source: Aurora Energy Research

Historical gas flows are higher than capacity without Ukraine

- Aurora estimates that European countries have 137bcm/a in total of pipeline supply contracts with Russia for 2022
- In Scenario 1, a delay to Nord Stream 2 will still result in enough capacity to meet 2021's Russian gas flows and contracted supply
  - This would still keep gas flows lower than in 2016-19
  - Gazprom could still send 5.5bcm/a more through Ukraine, in addition to its 40bcm/a long-term booking, but auctions for this capacity are suspended
- In Scenario 2, losing the Ukraine route means capacity would be below the estimated contract level by nearly 20bcm in 2022
- Nord Stream 1 is already used at available[3] capacity

2 A complete loss in Ukrainian transit boosts LNG and North African imports, until NS2 starts in 2025

European gas balance
bcm



1) Excluding Turkey and Baltics

Source: Aurora Energy Research

Total Russian gas is down ~20% compared to the first scenario

- LNG sendout increases yearly before reaching up to 128bcm in 2024
- Piped imports from North Africa are at 80% of pipeline capacity between 2022-24 before slowing down with the introduction of NS2
- Russian, Norwegian and Caspian flows are at relatively stable levels between 2022 and 2024 without much upside available
- Compared to scenario 1, there is a ~2bcm drop in gas demand in 2023, driven by fuel-switching economics
- A drop in Russian gas means less is exported from the west to Ukraine, risking a supply shortage. This is despite there being enough west-to-east pipeline capacity to fill its supply gap.

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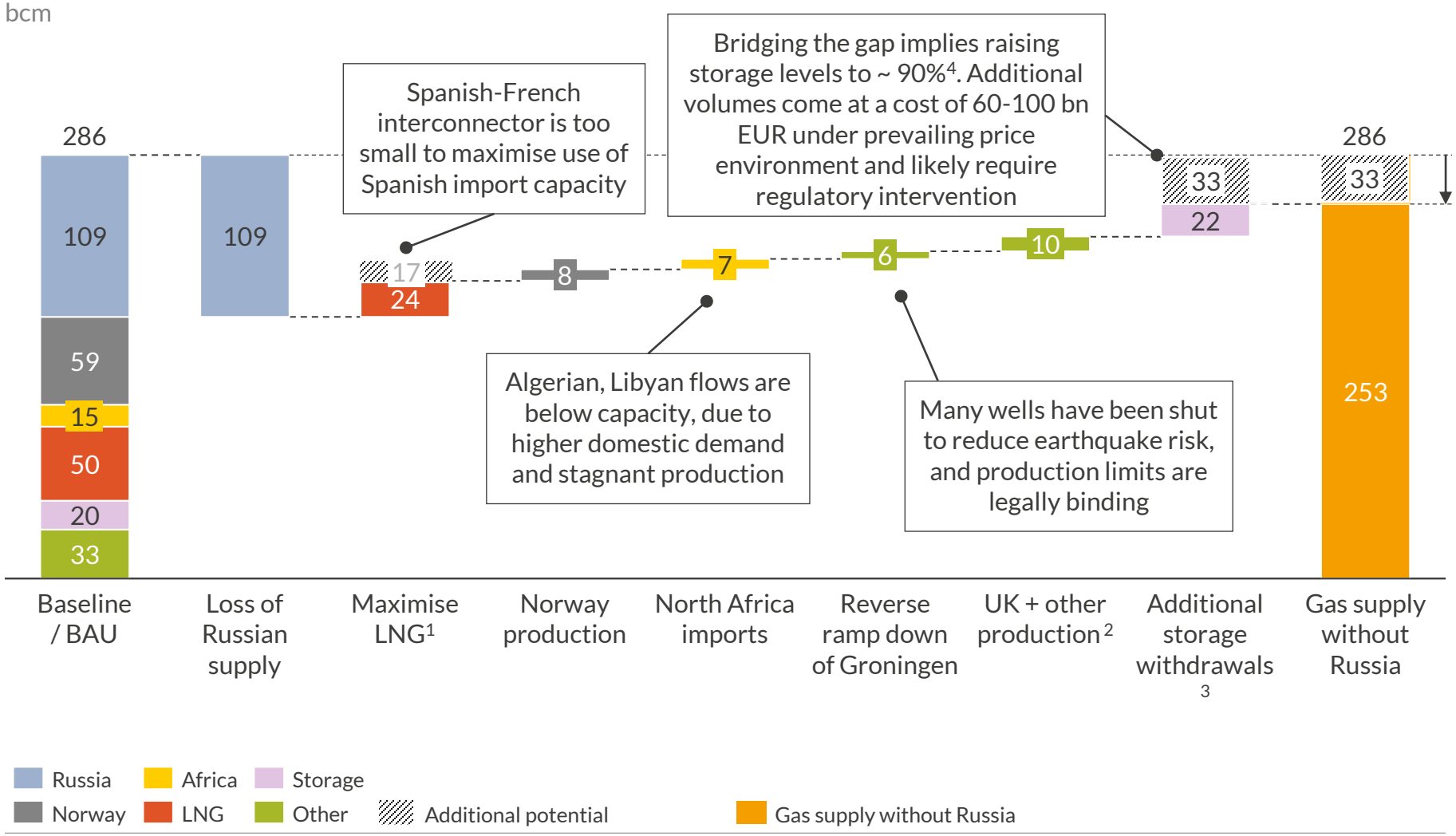
3 Coping next winter without Russian gas requires storage refill at cost of >60bn EUR, likely requires regulatory intervention

European supply measures required in event of no Russian gas supply in the period October 2022 – March 2023

bcm



1) Includes maximum increase in pipeline flow from Spain to France 2) Includes Romania and Poland 3) Assumes withdrawals in winter 2022-23 are in line with the lowest since 2015 (winter 2018-19) 4) Initial 22bcm fills storage facilities to 60% at start winter 2022-23, additional 33bcm fills storage to 90%, assumes stocks would end winter at 20%

Source: Aurora Energy Research

- European wholesale gas customers would need to compete on the LNG spot market to secure significant additional volumes, at a substantial cost
- Norway, the UK and elsewhere have limited scope to increase production
- The Dutch Groningen field is planned to be primarily shut in winter 2022-23, but if kept online, it could add some supply
- The gap left after these options is 33 bcm (12%) of projected supply for winter 2022-23 but could be reduced further depending on the level of storage going into winter
- Ensuring sufficient storage levels before next winter likely requires regulatory intervention given high risk for storage operators
- Gas infrastructure, especially for west-to-east flows may become a major constraint

Europe could pursue a range of options to reduce short term gas demand – but most carry significant economic, political or carbon costs

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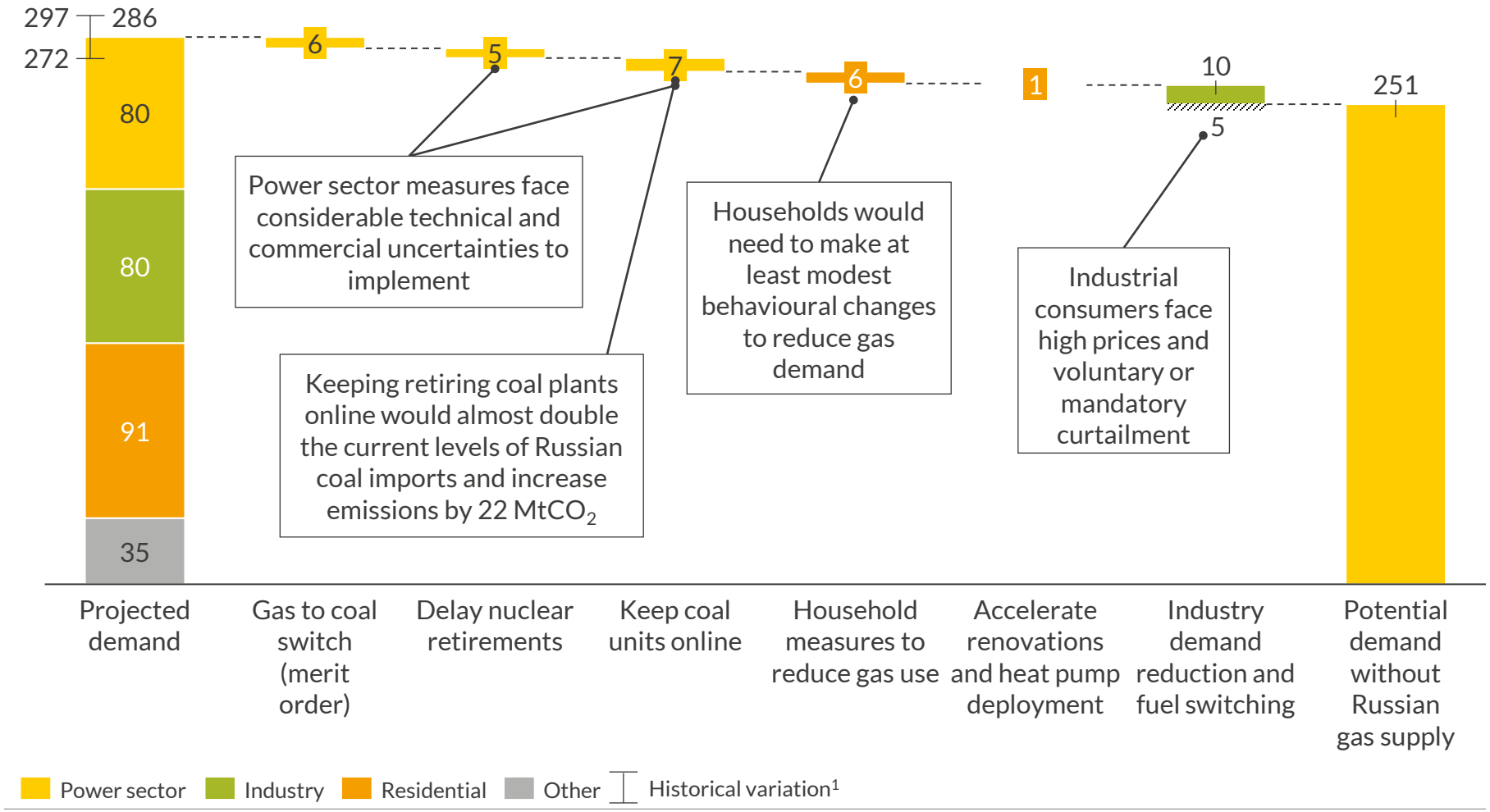
	Policy option	Short term feasibility	Reduction of EU gas demand	Barriers and limitations	Risks of implementation	Medium term feasibility
Power sector	Delay nuclear retirements (~8 GW across Germany, Belgium, UK)	◑	< 5 bcm	▪ Plants need to deviate from existing decommissioning schedules	▪ Difficulty sourcing fuel supplies from non-Russian sources by next winter	◔
	Keep coal plants online and revert recently retired capacities (~17 GW across Germany, Italy, UK, Iberia, France)	◕	>7 bcm	▪ Plants need to deviate from existing decommissioning stages ▪ Increased coal demand (~13Mt) must be secured from suppliers	▪ Switching from Russian coal grades may not be feasible for all plants ▪ Setback to decarbonisation efforts (~22MtCO_2e increase in emissions)	◑
	Accelerate renewables deployment	◔	<1 bcm	▪ Long term planning and development process, high cost	▪ Limited short term impact ▪ High RES costs in short term	◕
Residential	Behaviour change or price-induced demand response[1]	◔	4 bcm	▪ Consumer and political acceptability – effect on standard of living	▪ Requires coordinated demand reduction campaign ▪ Social licence	◔
	Accelerate renovations and heat pump deployment	◔	>1 bcm	▪ Insufficient incentives at present to encourage faster deployment ▪ Supply chain disruptions/limitations	▪ The time period until next winter limits the retrofits that can realistically be implemented	◕
Industry	Industry consumption reduction and fuel switching	◑	10-15 bcm	▪ Limited amount of industrial players can rapidly switch boiler fuels from gas to coal or oil	▪ Loss of production and resultant economic impacts ▪ Setback to decarbonisation efforts	◕

1) Modelled as a 1°C reduction in space heating, 10% less hot water use

Source: Aurora Energy Research

Demand could be reduced by up to 14%, but requires concerted effort by regulators, industry and consumers

European demand reductions required in event of no Russian gas supply in the period October 2022 – March 2023
bcm



1) Based on historical demand since 2011

Source: Aurora Energy Research

- 25 GW of nuclear and coal plant closures across Europe can be delayed to offset ~12 bcm of gas demand but are subject to considerable technical and commercial uncertainties
- Increasing coal-fired power generation will require an additional ~13 mt coal, almost doubling the current level of Russian imports
- Residential gas demand could fall either as a result of higher prices or through active campaigns to improve efficiency or change behaviour
- Industrial demand reductions of ~5-10% are only possible in the short term through fuel switching or curtailment of production
- A colder or warmer than average winter would materially affect the supply-demand imbalance and thus the reductions needed

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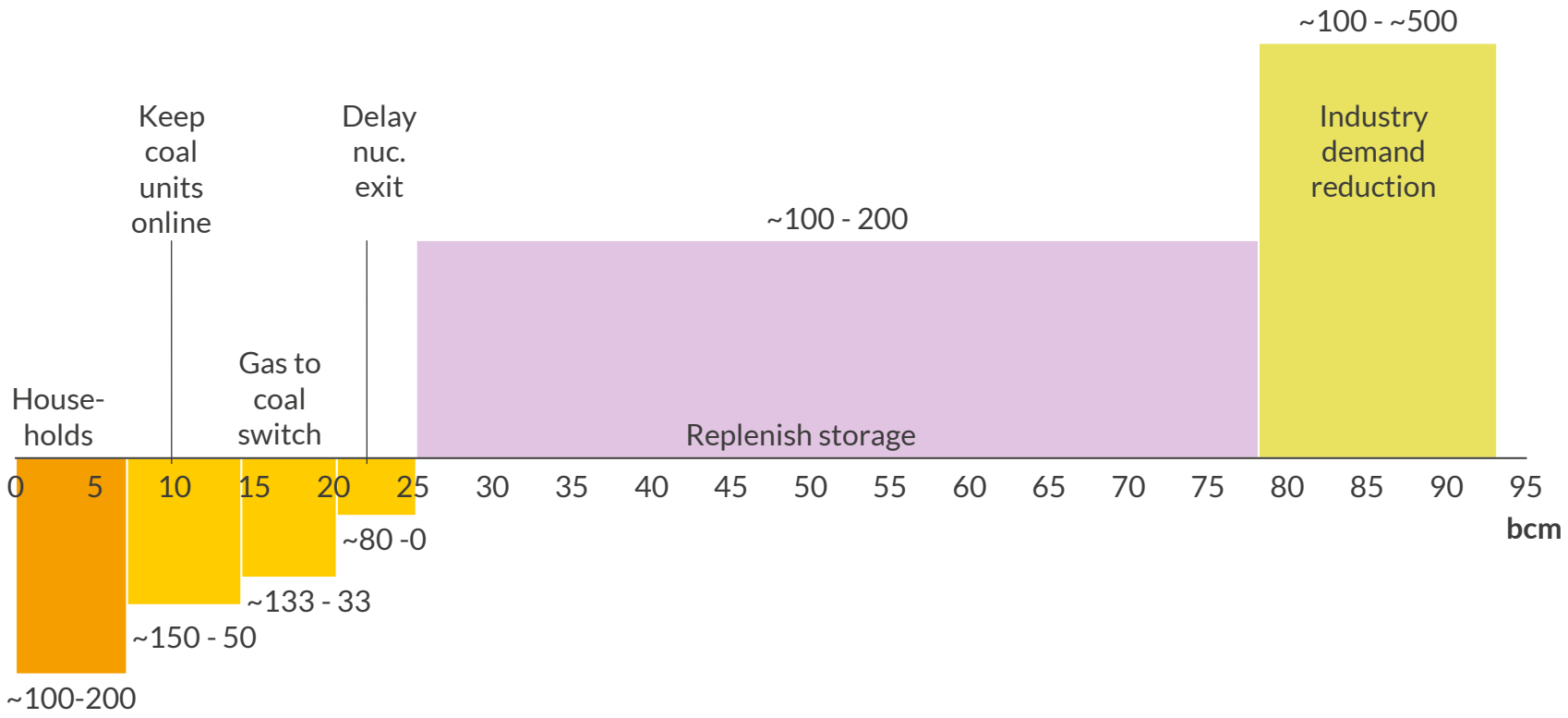
Gas demand savings in power sector and households save money; filling gas storage will be costly

Relative cost to address natural gas supply gap (first estimate)
EUR per MWh of natural gas avoided or stored



Total cost EUR bn	**-14** to **-7**	**-11** to **-4**	**-8** to **-2**	**-4** to **-0**	**60** to **100**	**20** to **70**

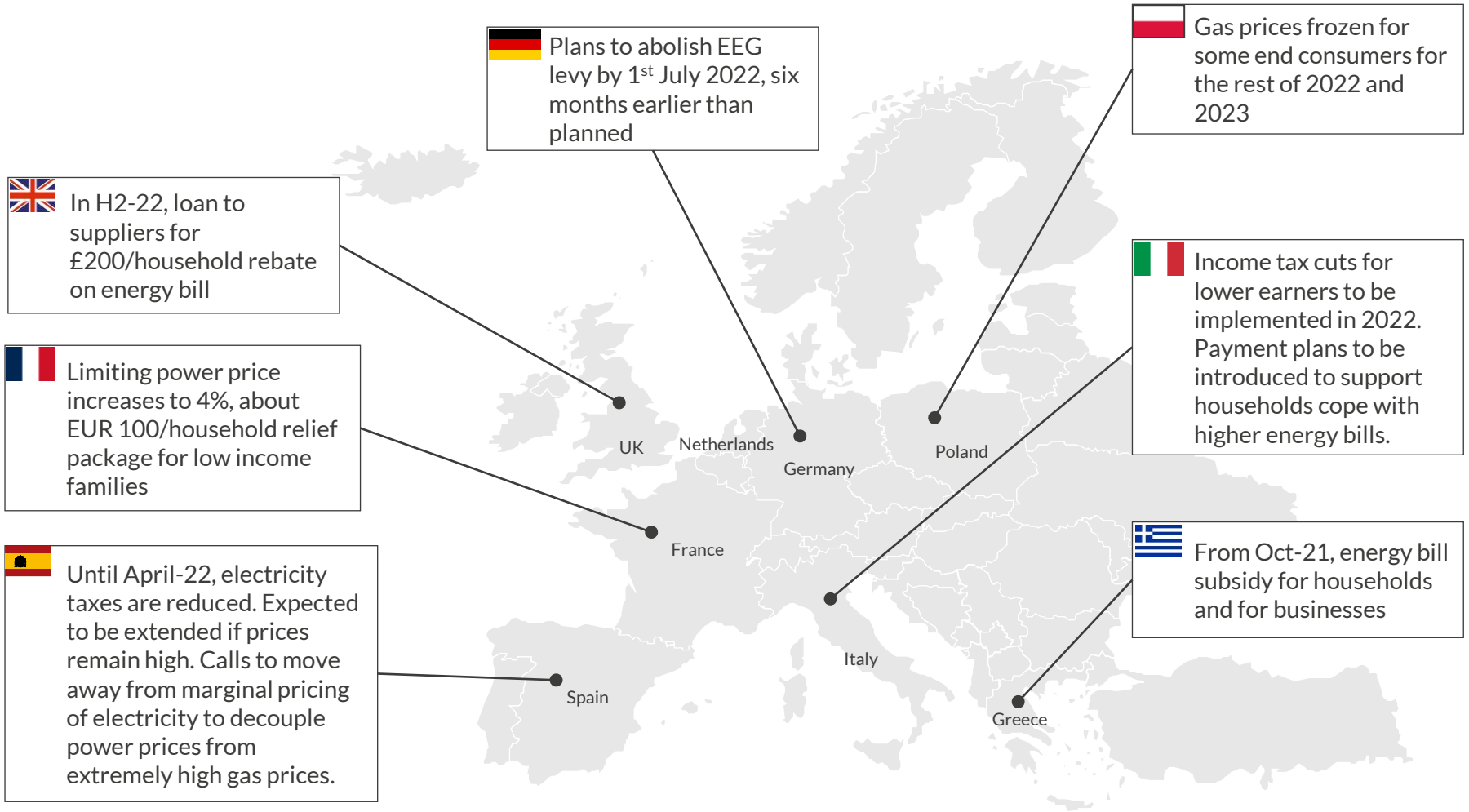
1) Assumed hard coal price: 300 EUR/t

Source: Aurora Energy Research

- Household demand reductions offer the most economical option as reduced gas consumption directly translates to savings
- Replacing gas by coal[1] and nuclear in power benefits from delta in fuel cost, but would partly require reactivation cost
- Cost of additional carbon emissions are not taken into account as EU economy is able to reuse these for mitigation measures
- Storage replenishment is directly linked to gas prices - Cost calculations assume gas price of 100-200 EUR/MWh, higher prices are possible and would exacerbate both savings as well as cost for storage
- Cost for industry demand reduction assumes production interruption of 1%-3.5% of industry GDP over winter which offsets energy savings by an order of magnitude

Governments had already responded to high energy prices with tax reductions, subsidies and price controls; more will be needed

Selected government measures to tackle high wholesale and retail energy prices



Source: Aurora Energy Research

Since 2021, many governments in Europe introduced energy subsidies. Further rises in wholesale prices will put more pressure on public budgets

- Countries across Europe have enacted measures to reduce the impact of high wholesale energy prices on households and industry
- Some of these were enacted in 2021, in response to rising gas and power prices
- Wholesale prices are rising again in 2022. Extending or even increasing these subsidies will become costly to public budgets
- High wholesale prices also creates risks for solvency of energy suppliers if unhedged. Governments may need to step in to mitigate risk of supplier failure.

Europe can mitigate a disruption or complete halt to Russian gas imports through supply- and demand-side measures, but it would come at a cost

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- Russian energy imports are key for European supply, accounting for 30-40% of total gas imports in Europe, and over 75% in some countries in the east and south
- The ongoing invasion of Ukraine has raised the threat of supply disruptions, and driven gas and power prices up sharply
- Europe and the US have responded, introducing severe sanctions. Gas and other energy imports have continued but the risk of disruption presents significant challenges

In our optimistic scenario with only a delay to NS2 until 2025, LNG imports reach closer to maximum regasification capacity, but drop again once NS2 is online. Overall, there is enough gas in Europe

Should Ukraine gas transit stop from 2022, and NS2 be delayed to 2025, Europe could compensate with a strong rise in LNG and African pipeline imports, but there may be insufficient western supply for Ukraine

- In the extreme case where Russian gas imports cease, this would leave a 109 bcm gap in projected supply next winter
- An increase in alternative supply could make up for over 70% of this shortfall, including higher LNG and other pipeline imports and an increase to indigenous production
- Storage would play a key role in meeting winter demand, but could require an initial investment of EUR 60-100 billion and likely require Government intervention

- Demand could be reduced by up to 14%, but would require concerted and coordinated efforts by regulators, industry and consumers
- Households could meaningfully reduce gas consumption (and bills) through immediate modest behavioural changes
- Power plant operators face technical and commercial challenges to secure alternative fuel supplies, especially if Russian coal imports also cease
- Industrial demand reductions of ~5-10% are only possible in the short term through fuel switching or curtailment

Source: Aurora Energy Research

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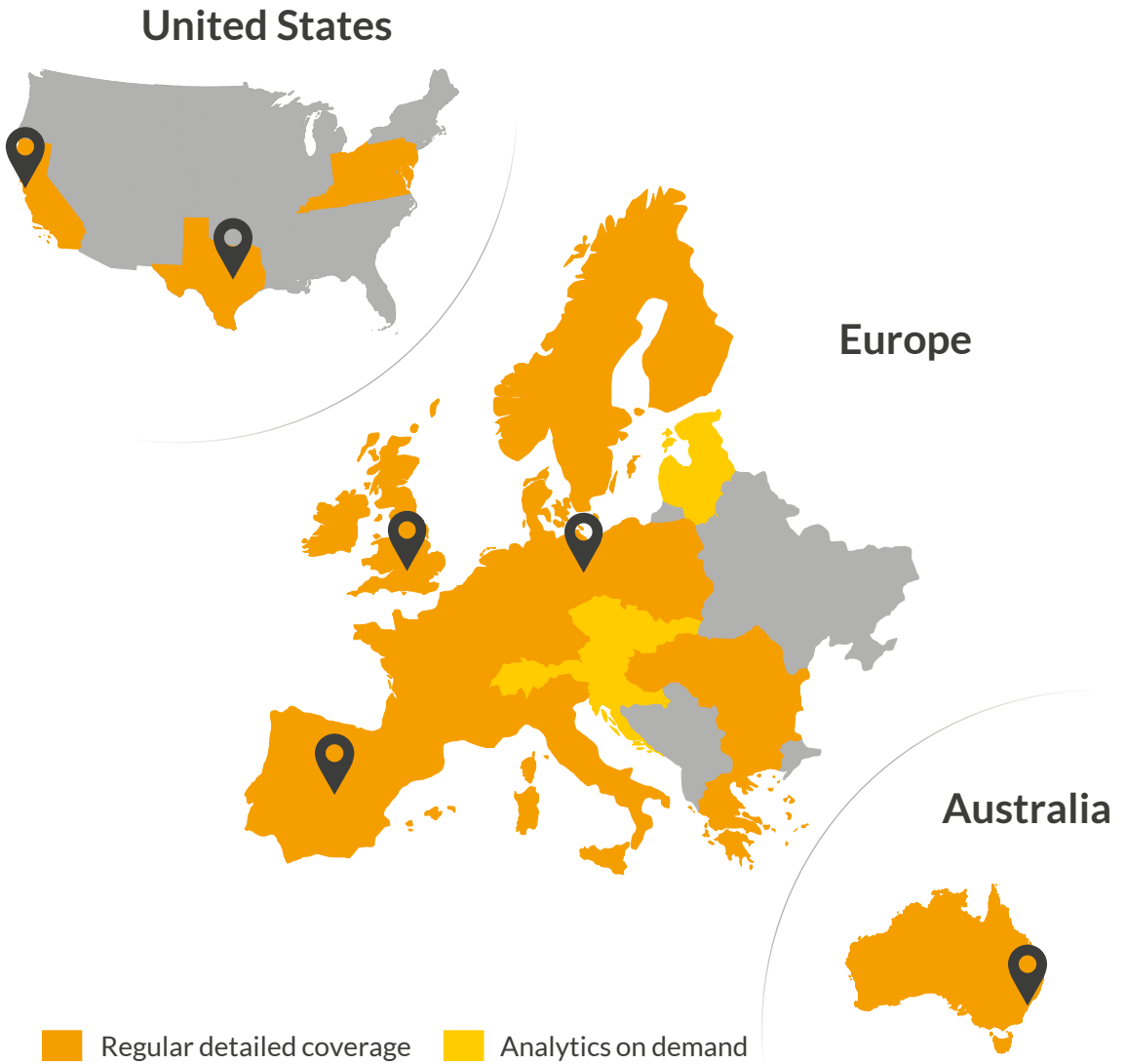
- Storage
- Electric vehicles
- Hydrogen H_2
- Carbon CO_2
- Natural gas



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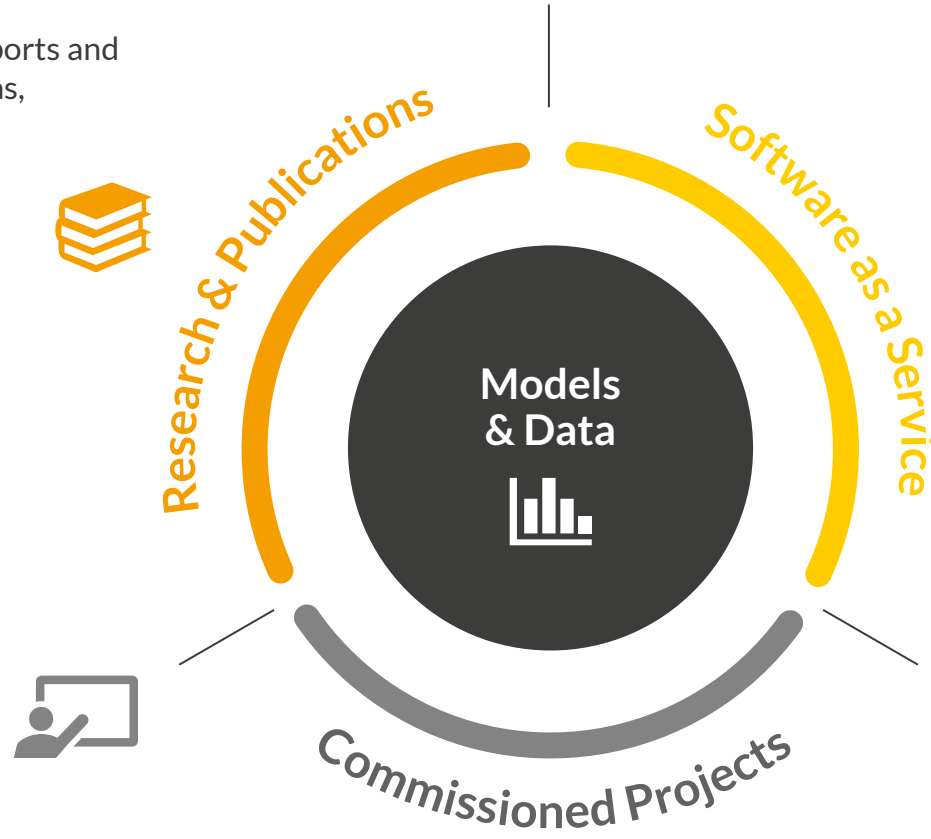

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