

The Road to 2°C: Challenges and Impacts of the Energy Transition

*Disclaimer: Aurora is not saying that 1.5°C target can't or won't happen,
instead forecasting the scenario for a different potential outcome*



Aurora provides market leading forecasts & data-driven intelligence for the global energy transition

A U R  R A

Power markets



Renewables



Storage



Electric vehicles



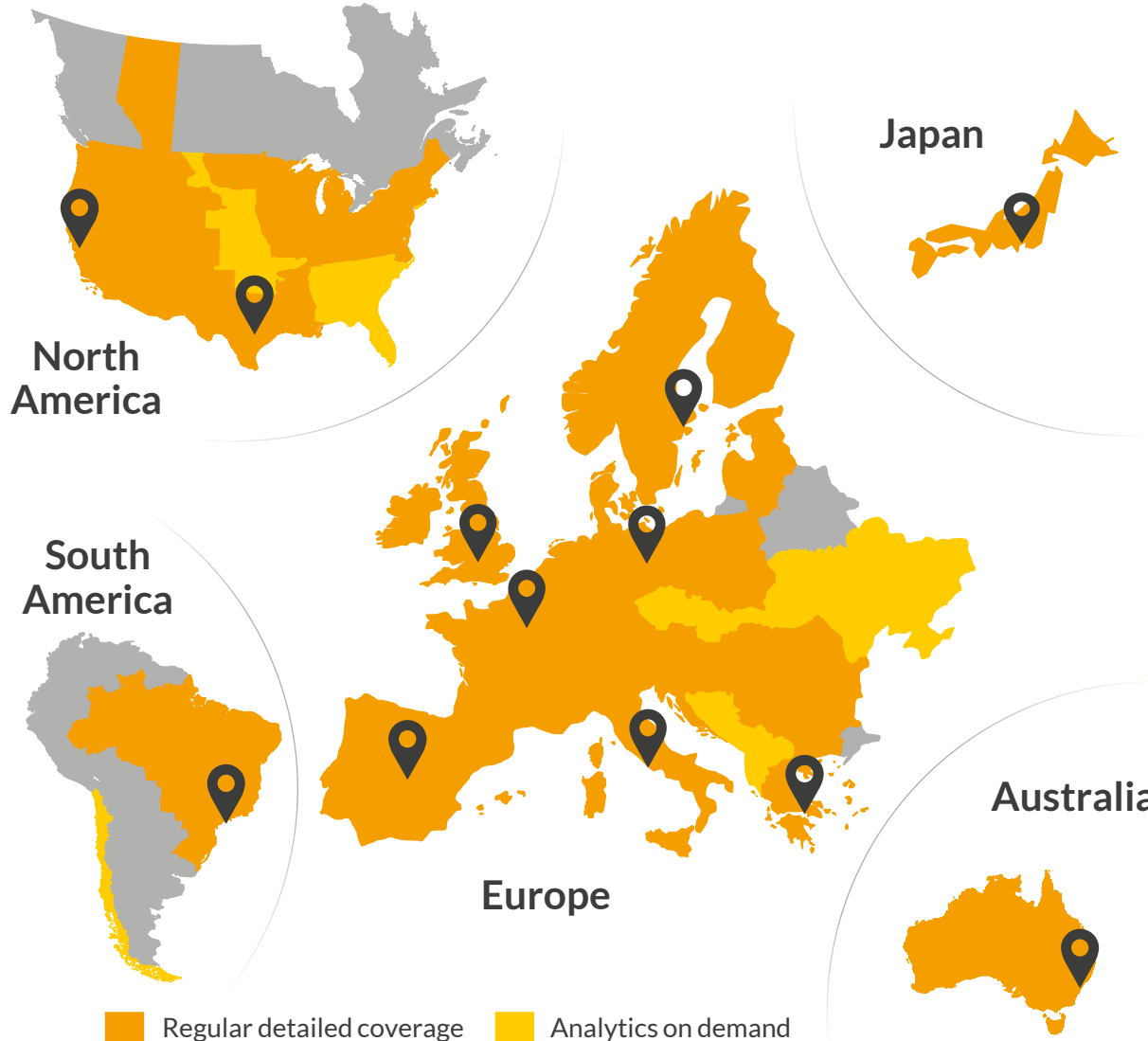
Hydrogen



Carbon



Natural gas



12 Offices

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Paris | Sydney | Austin | Oakland
Rome | Stockholm | Tokyo
São Paulo



500+

market experts



750+

subscribing companies



150+

transactions supported in 2022

- I. The state of play**
- II. Aurora's Global Two Degrees scenario forecast**
 - 1. Emissions
 - 2. Total energy use and electrification
 - 3. Fossil fuel market fundamentals
- III. Implications for investors and policy makers**
- IV. Key takeaways**

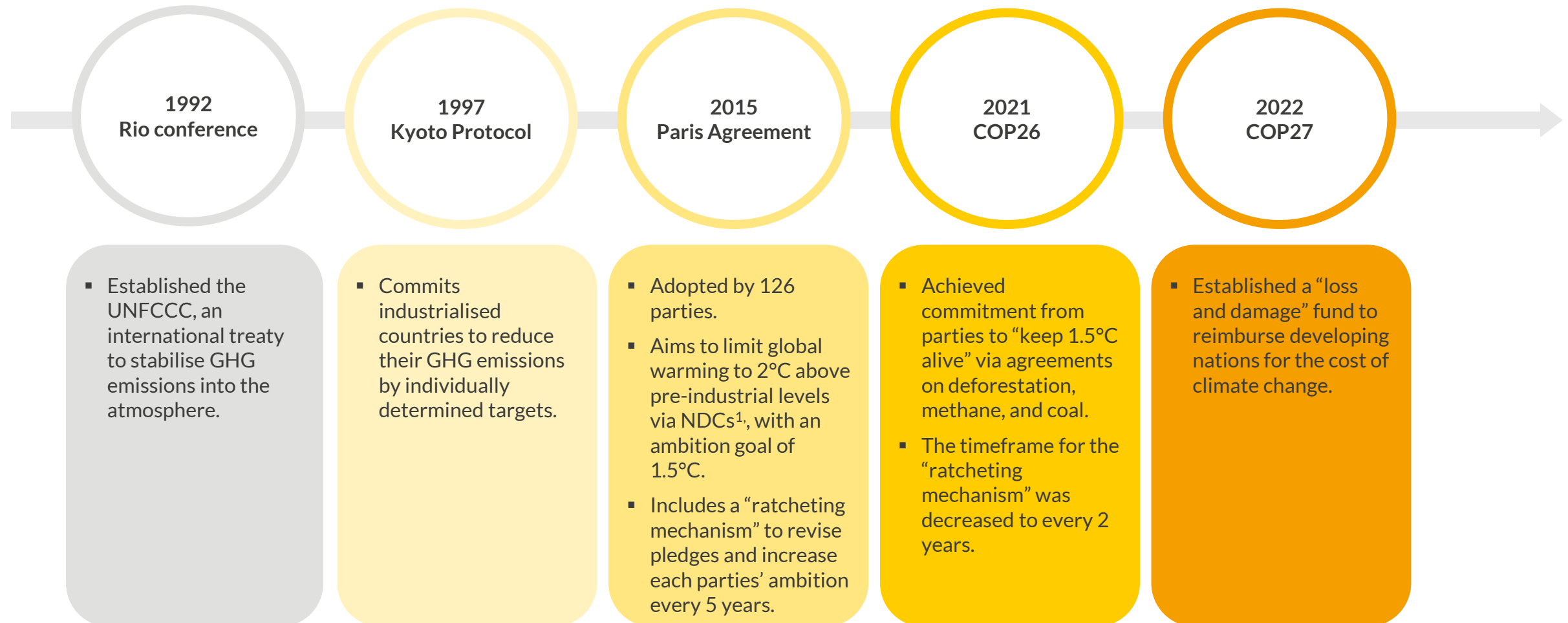
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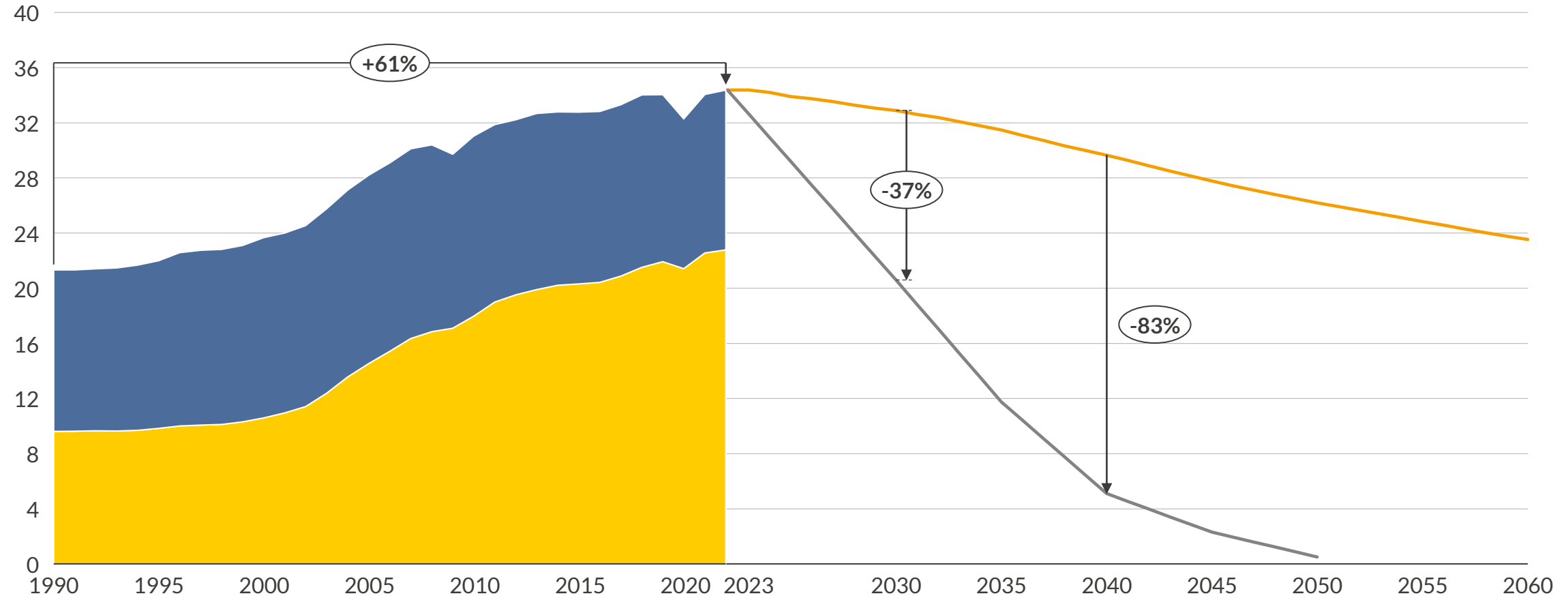
The ambition to limit global warming has increased through a series of international agreements over the last 30 years...

Selected international climate agreements



1) Nationally Determined Contributions (NDCs) are commitments by individual countries to reduce their national emissions in line with the goals of the Paris Agreement.

...despite greater ambition, emissions have increased substantially in the last 30 years, and the gap to a 1.5°C target has grown even wider

Annual global carbon emissions from combustion¹GtCO₂

■ Non-OECD ■ OECD — Apr-23 Central — IEA Net Zero Emissions

1) Do not account for process emissions (e.g., clinker production in cement industry), methane and other greenhouse gases equivalent carbon emissions.

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A new scenario where global leading economies reach carbon neutrality is compared with Aurora's Central view

In Aurora Central scenario most countries' carbon neutrality pledges are missed. The aim of this report is to explore what the implications on energy markets could be should leading global economies respect their carbon neutrality pledges instead; we therefore design a scenario, Global Two Degrees, whereby most leading global economies become carbon neutral by 2050 or 2060 and contrast this outlook for energy markets with that of Central.

Aurora Central scenario



Central reflects Aurora's view of how energy markets could evolve based on current governments policies and likely future policies based on the current market sentiment. Decarbonisation efforts are hindered by lack of cooperation and short-term energy security concerns.



The global GHG emission trajectory is compatible with a median temperature rise of 2.3-2.5°C by 2100. No countries are forced to reach carbon neutrality by the end of the forecast.



The rate of licensing and developing new fossil fuel projects reflects our current view based on current policies and market development.



Global GDP is 102% larger in 2060 than today. Emerging and developing economies account for 59% of the global GDP by 2060.

Aurora Global Two Degrees scenario



Coordinated and immediate action is needed by leading global economies to drive the energy transition. Several emerging and developing economies react to the new market conditions accelerating their decarbonisation efforts.



The global GHG emission trajectory is compatible with a median temperature rise of 2°C by 2100. G7 countries, the whole EU, Brazil and China need to reach carbon neutrality by 2050 or 2060.



Financing and developing fossil fuel projects is more challenging than in Central, particularly in advanced economies targeting net zero.

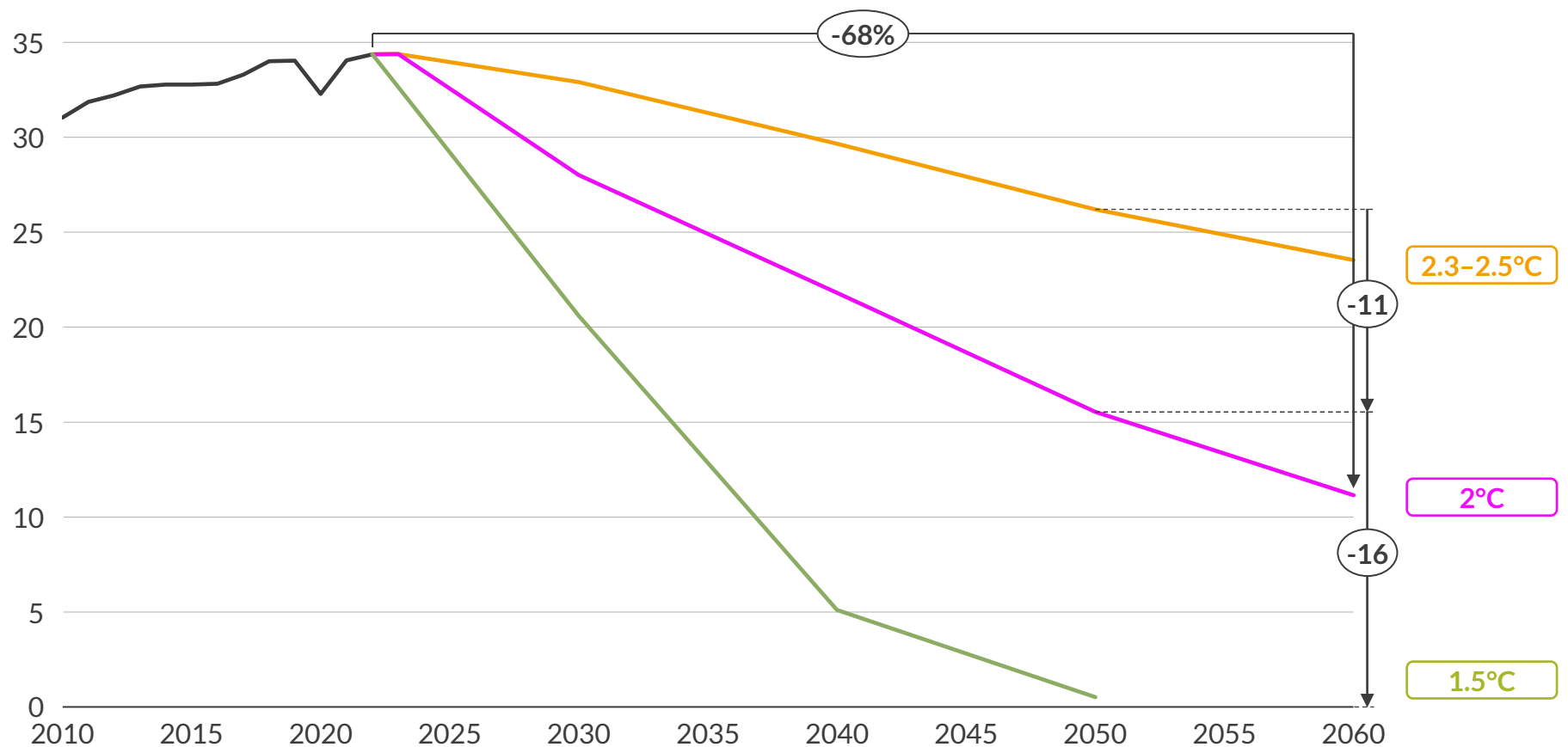


We assume global GDP growth to be equal to that of Central. Decarbonisation has no negative impacts on global economic output.

Disclaimer: Aurora is not saying that 1.5°C target can't or won't happen, instead forecasting the scenario for a different potential outcome

In Global Two Degrees, global carbon emissions from energy in 2060 are 68% lower than current levels

Annual global carbon emissions from combustion¹
GtCO₂



— Historical — Apr-23 Central — Global Two Degrees — IEA Net Zero Emissions

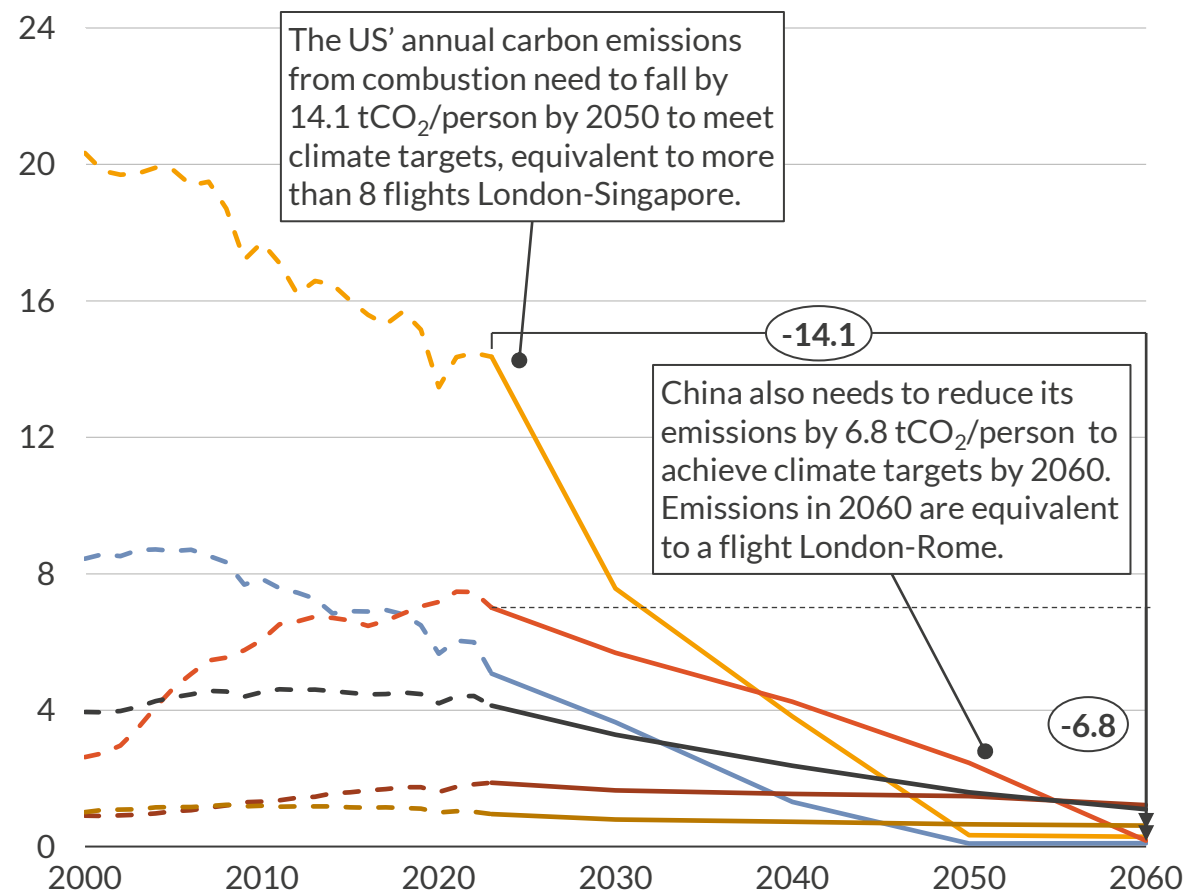
1) Do not account for process emissions (e.g. clinker production in cement industry), negative emissions technologies, methane and other greenhouse gases equivalent carbon emissions. 2) IPCC carbon budgets for CO₂-eq emissions from energy in 2015-2050 compatible with 2°C: 25th percentile = 908GtCO₂; 2°C 75th percentile = 1062GtCO₂; 90th percentile = 1136GtCO₂.

Sources: Aurora Energy Research, IEA World Energy Outlook 2022, 2023 Energy Institute Statistical Review of World Energy

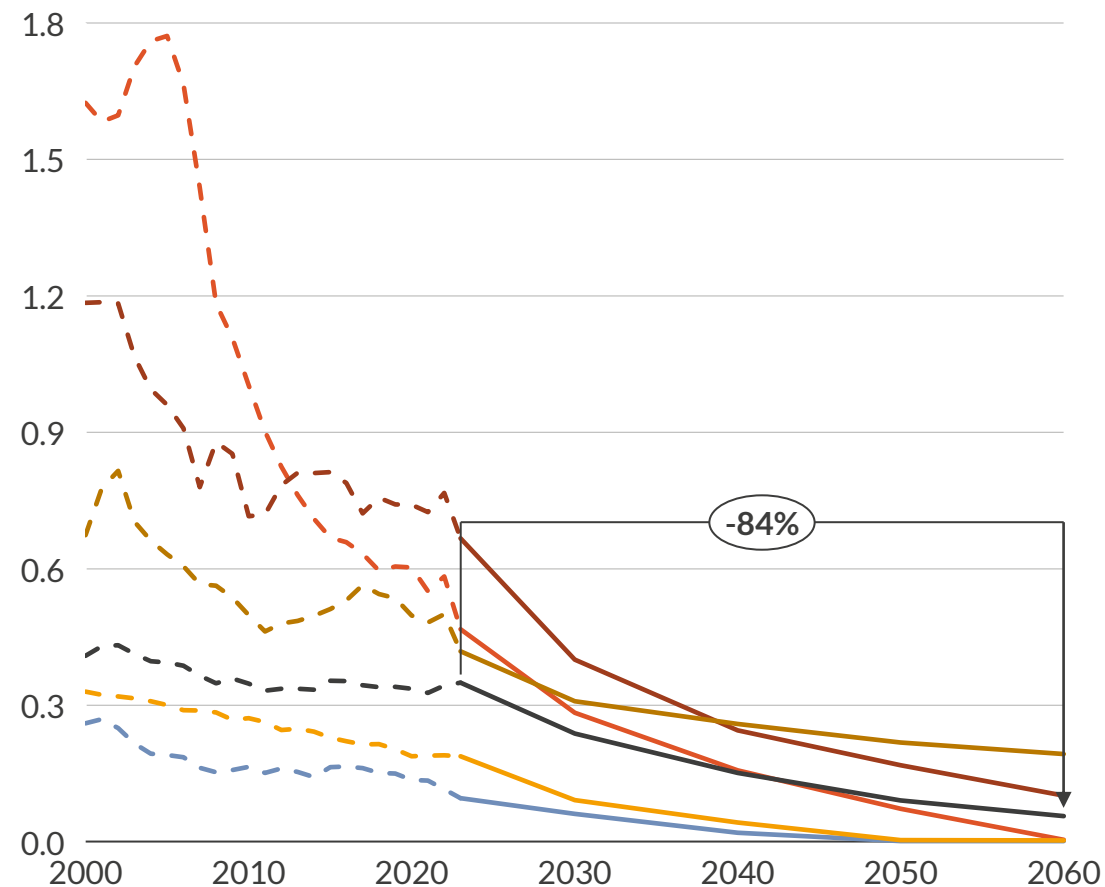
- Aurora's Central forecast is compatible with a global median temperature rise of 2.3-2.5°C in 2100 and would therefore miss the target set by the Paris agreement.
- Our Global Two Degrees scenario carbon emission trajectory is compatible with limiting the global median temperature increase to 2°C in 2100. Our forecast for cumulative equivalent carbon emissions from energy falls within the 25th and 75th percentile carbon budget values prescribed by the IPCC².
- For our forecast to be compatible with limiting the global median temperature rise to 2°C by the end of the century is of utmost importance that non-energy related emissions also fall with a speed at least equal to that of energy related emissions.

The carbon intensity of the global economy must drop by 84% by 2060 to limit the global median temperature rise to 2°C by 2100

Annual carbon emissions from combustion per capita¹
tCO₂/person



Regional carbon intensity of GDP in Global Two Degrees¹
kgCO₂/\$ (real 2022)



— Europe² — China — US — India — Non-OPEC Africa — World — History

1) Unabated emissions only. 2) Europe includes EU-27, UK, Norway, and Switzerland.

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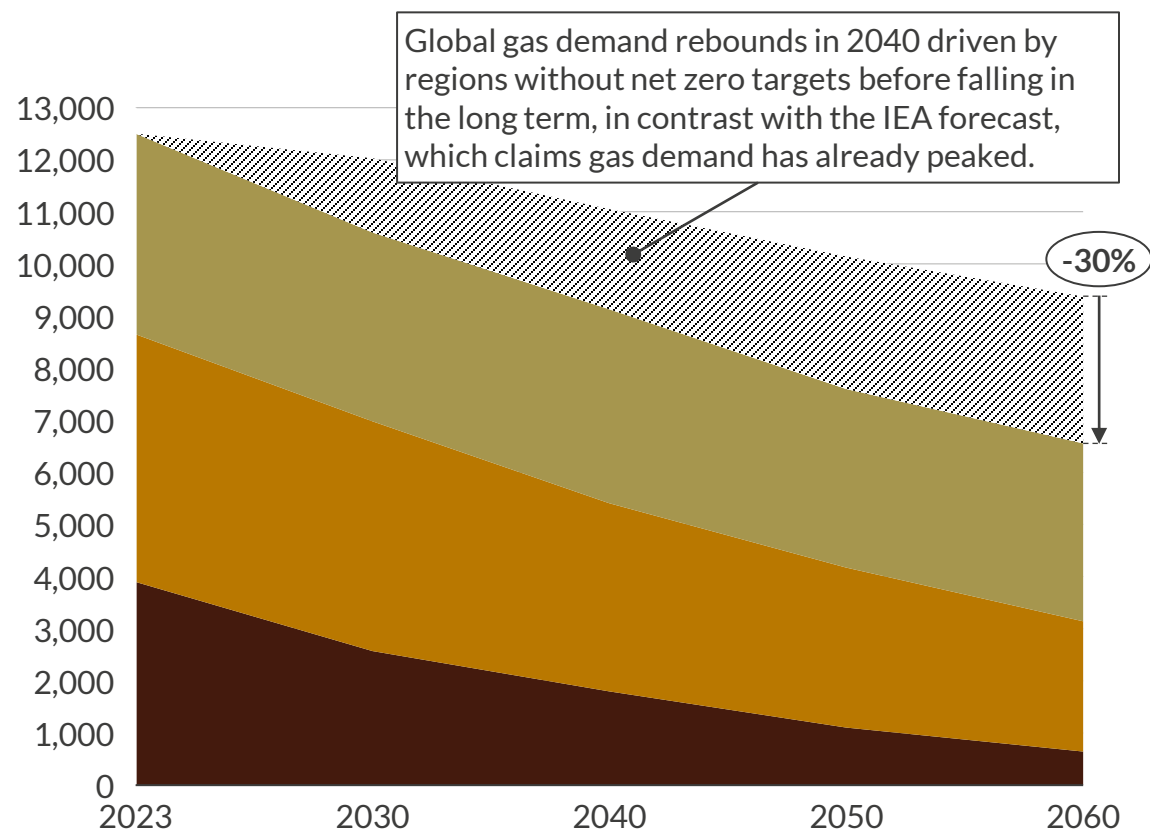


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Total fossil fuel demand falls by 50% from the 2020s in Global Two Degrees, as A U R ☀ R A does coal and oil demand, but gas demand remains robust

Global primary energy demand of fossil fuels in Global Two Degrees

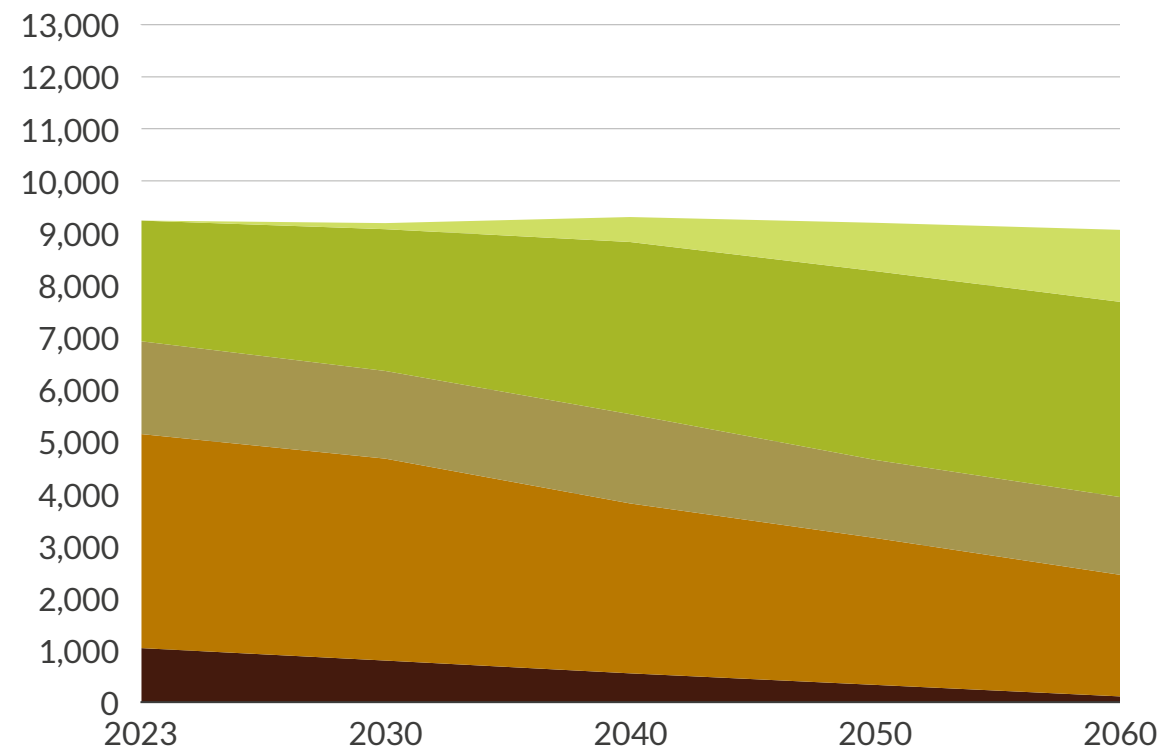
mtoe



Coal Oil Gas Extra fossil fuel demand in Central

Global final energy consumption in Global Two Degrees

mtoe

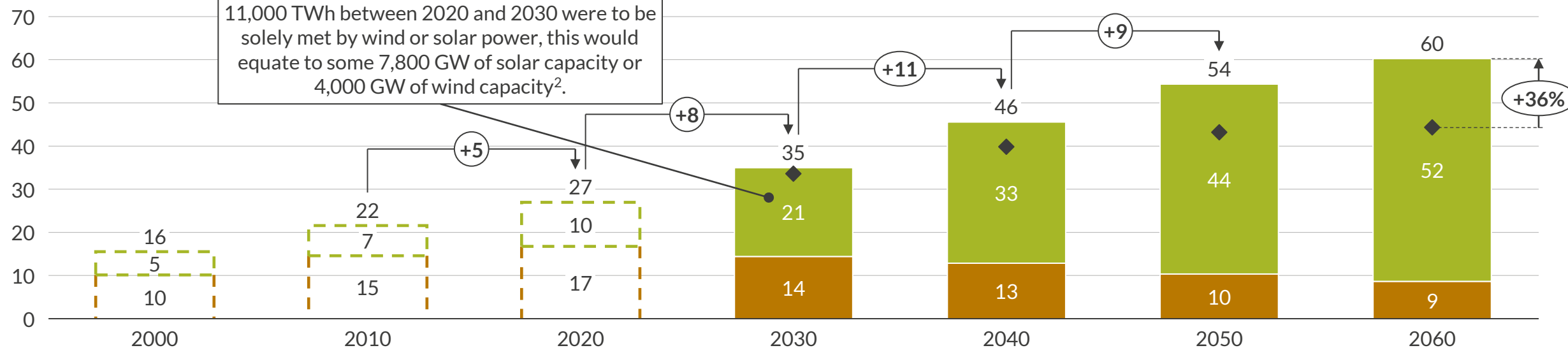


Coal Oil Natural Gas Electricity Extra electricity relative to Central

Global Two Degrees requires an unprecedented process of electrification as well as switch to low carbon power generation

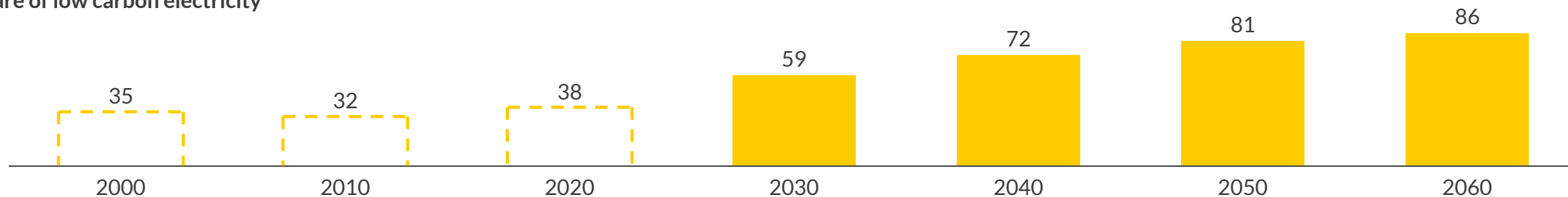
Global electricity generation in Global Two Degrees

'000s TWh



Share of low carbon electricity

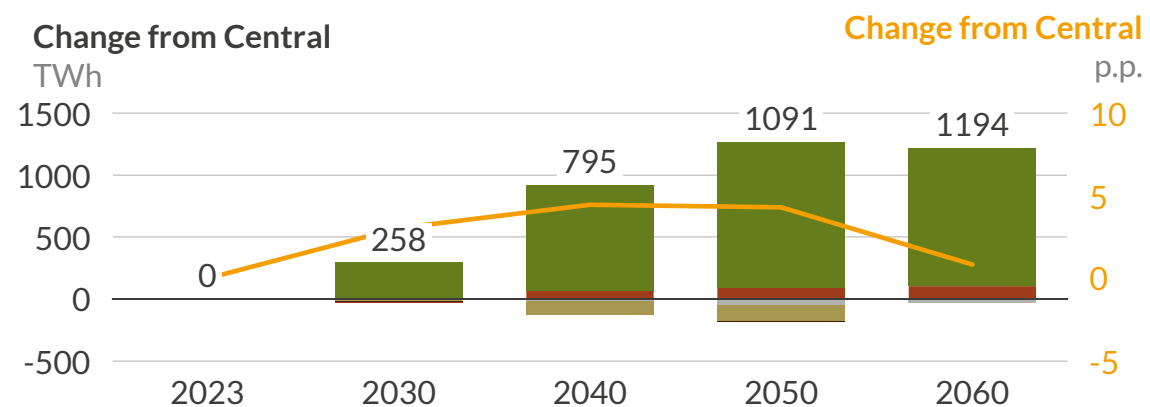
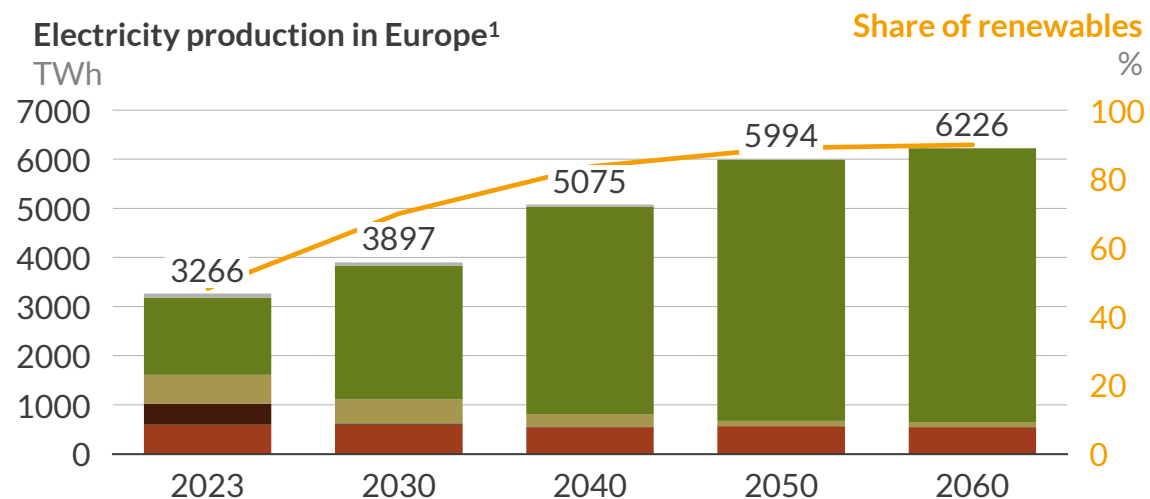
%



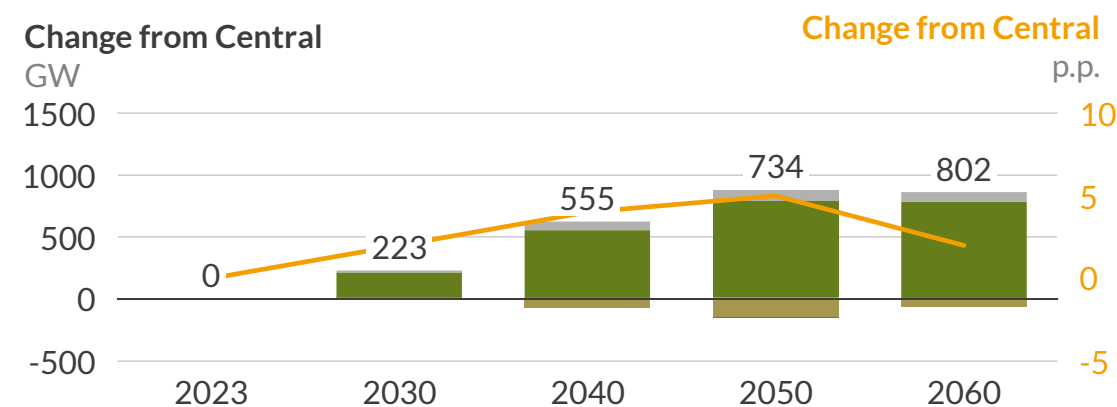
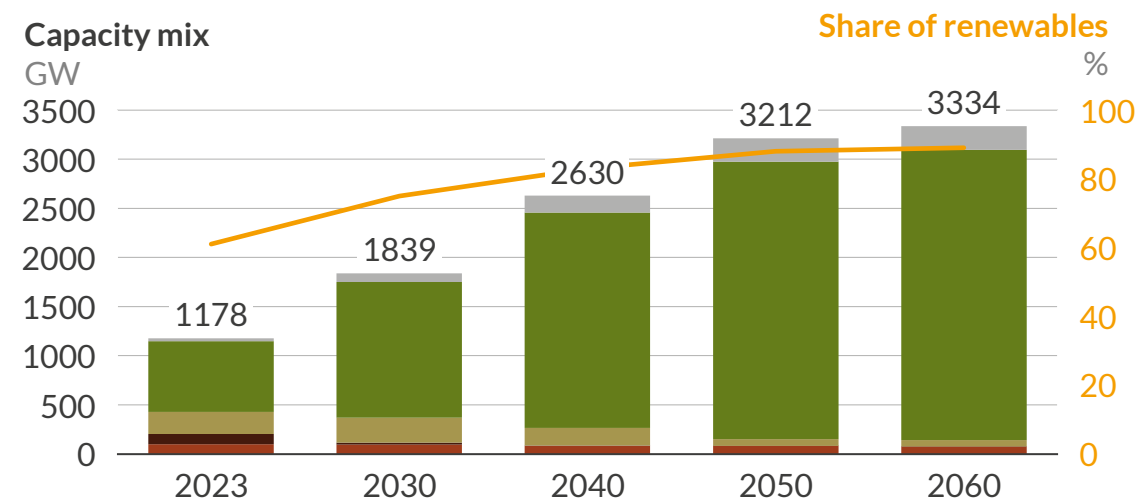
1) Low carbon electricity includes hydro, nuclear, wind, solar, other renewables and abated fossil fuel power plants. 2) Assumes average load factors in the period of 16% for solar and 30% for wind.

Europe quadruples its installed renewables capacity to deliver 89% of total power generation by 2060

Electricity production



Capacity mix



Other² Renewables³ Gas⁴ Coal Nuclear Share of renewables

1) Europe includes EU-27, the UK, Norway, and Switzerland. 2) Other includes demand side response (DSR) and battery storage. 3) Renewables include hydro, onshore wind, offshore wind, solar, pumped hydro and other renewables. 4) Gas includes unabated gas and gas CCS.

Source: Aurora Energy Research

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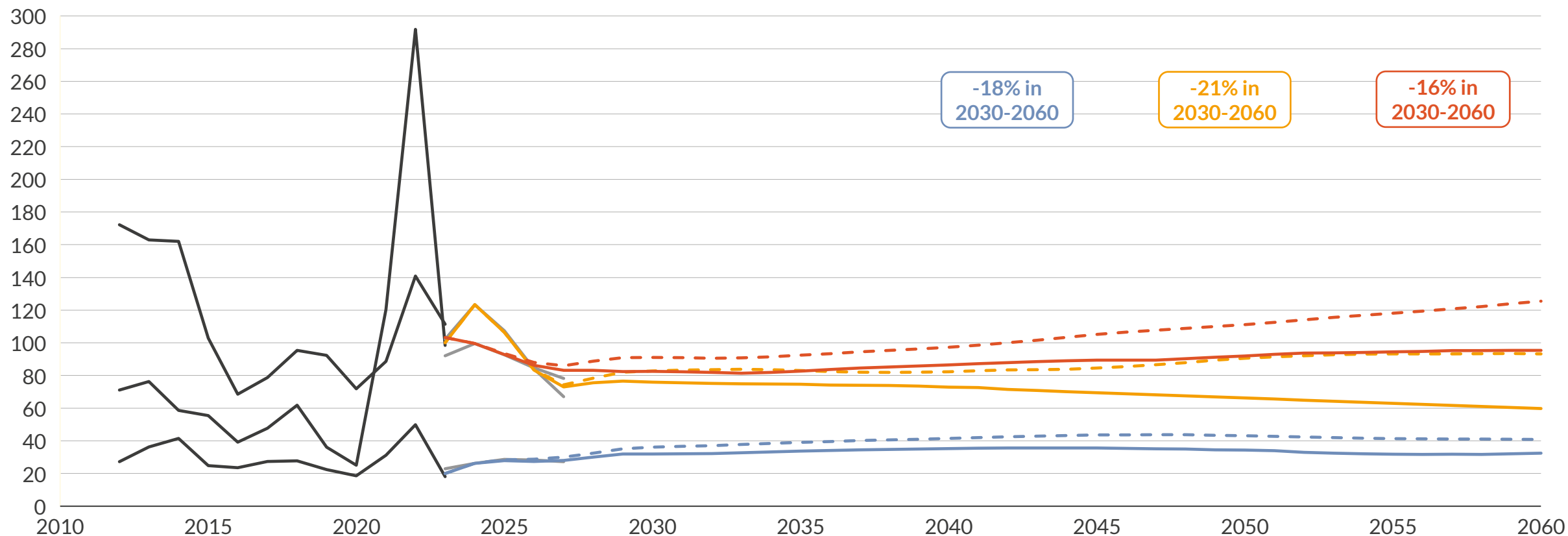


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Gas prices do not crash in a Global Two Degrees scenario, but are substantially below Central and the gap widens over time

Global natural gas prices¹

2023 TTF forecast price = 100

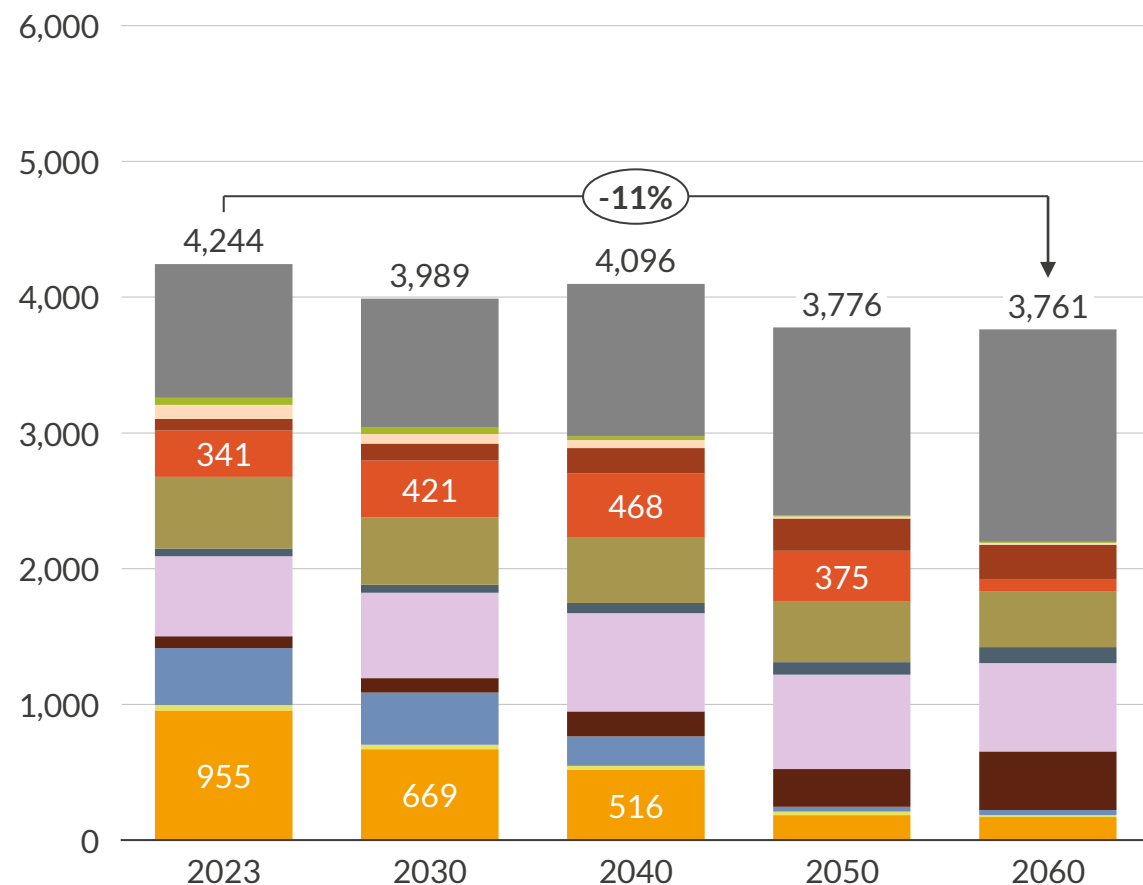


— Historical — US Henry Hub - Global Two Degrees — TTF - Global Two Degrees — Japan - Global Two Degrees
 — Futures² - - US Henry Hub - Central - - TTF - Central - - Japan - Central

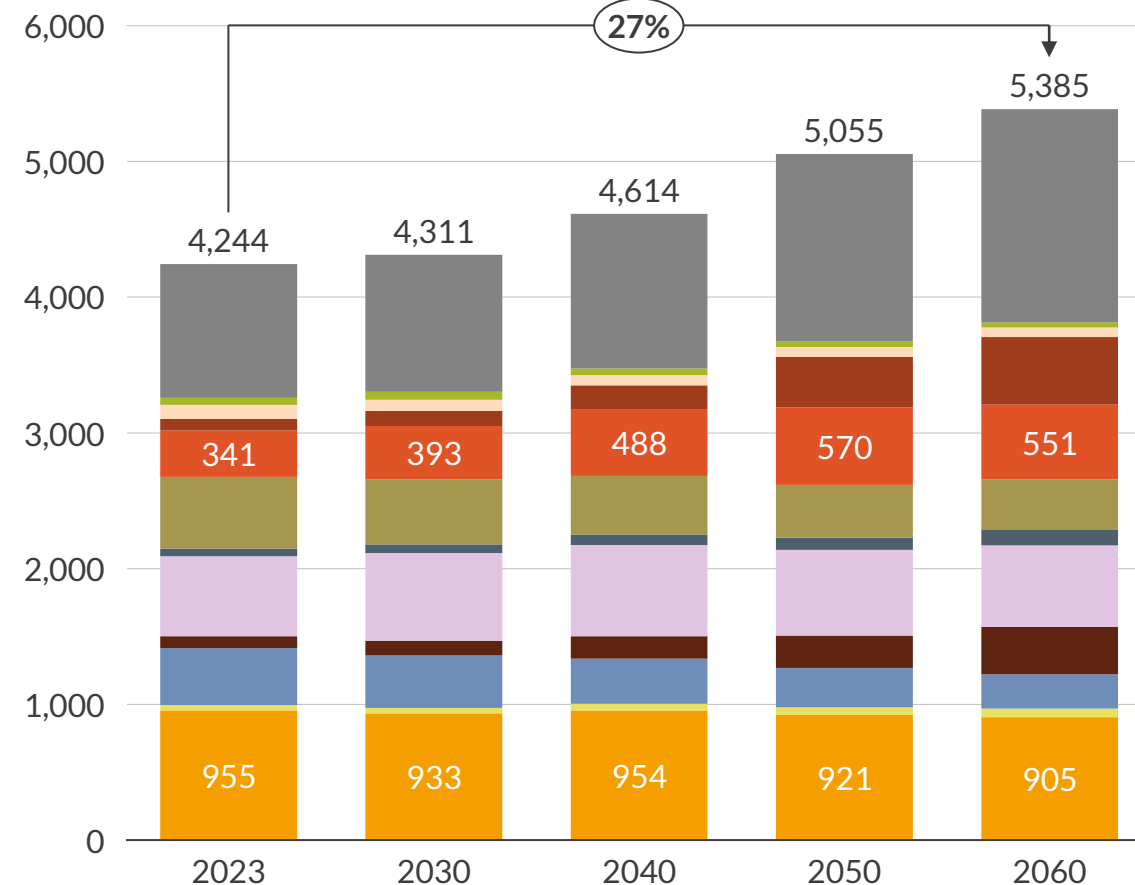
1) For years 2023-2028, the prices shown take into account futures prices as of 20/08/2023 for the years in question, with declining weights. In 2023, forecast prices include historical prices up to Jul-23. 2) A rolling 14-day average as of 20/08/2023.

Even in a Global Two Degrees scenario global gas demand remains robust across the forecast horizon, but well below Central

Natural gas consumption in Global Two Degrees
bcm



Natural gas consumption in Apr-23 Central
bcm

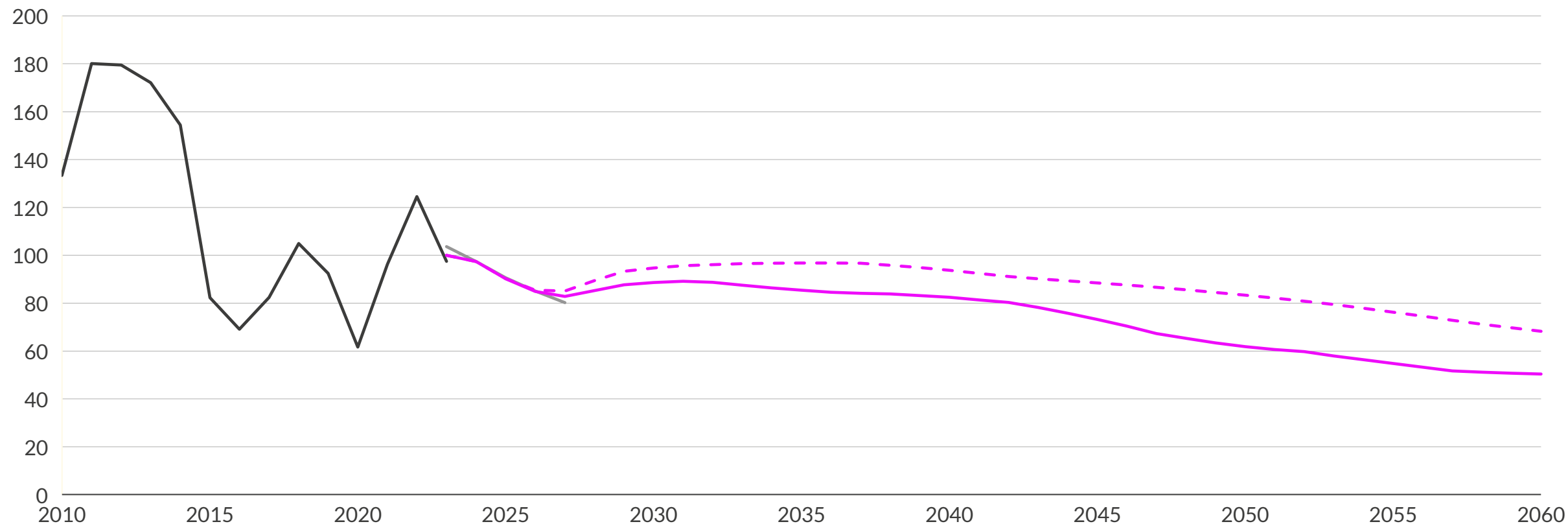


■ US
 ■ Brazil
 ■ Europe¹
■ Non-OPEC Africa
 ■ OPEC
 ■ Qatar
 ■ Russia
 ■ China
 ■ India
 ■ Japan
 ■ Australia
 ■ Rest of the world

1) EU-27, the UK, Switzerland, and Norway.

In Global Two Degrees, Brent oil prices peak in the early 2030s as EV penetration eats into demand and OPEC increases its market share

Brent crude oil prices¹
2023 forecast price = 100



— Historical — Futures² — Global Two Degrees - - Central

1) For years 2023-2028, the prices shown take into account futures prices as of 20/08/2023 for the years in question, with declining weights. In 2023, forecast prices include historical prices up to Jul-23. 2) A rolling 14-day average as of 20/08/2023.

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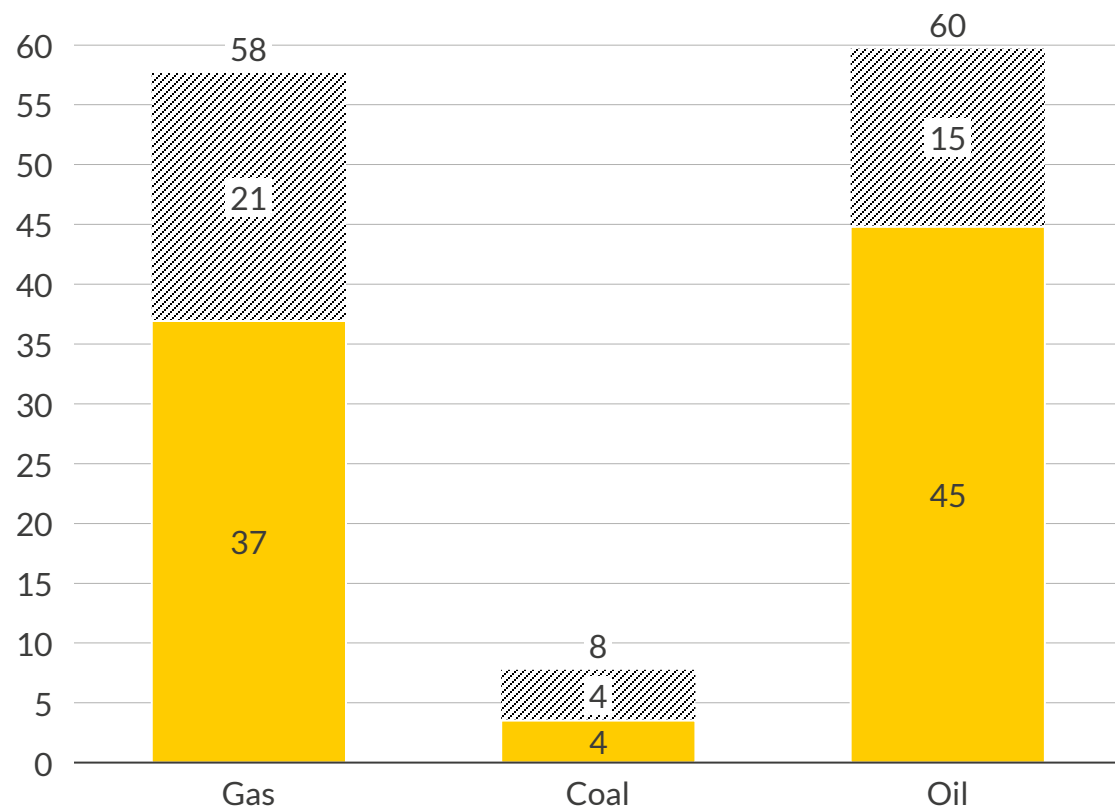
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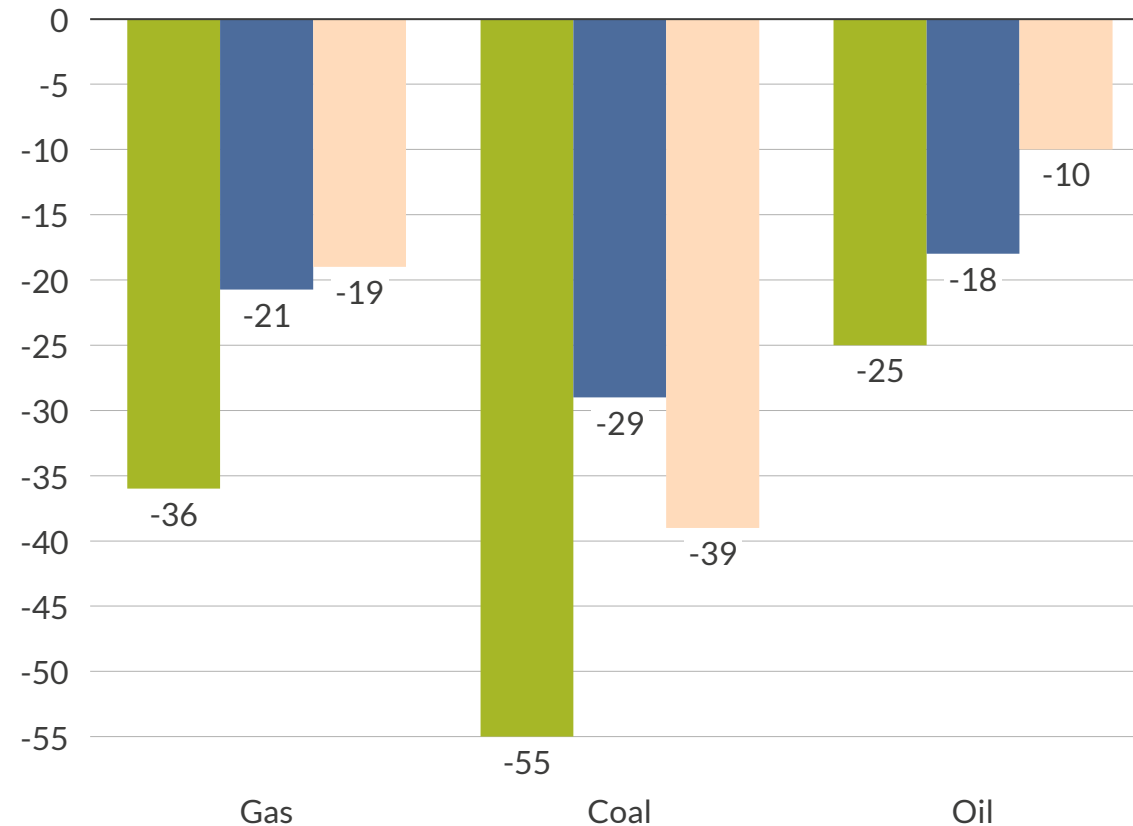
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Global fossil fuel revenues could shrink by some \$40 trillion between 2030 and 2060 in Global Two Degrees relative to Central

Cumulative global fossil fuel revenues¹ in 2030-2060
Trillion \$ (real 2022)



Change between Global Two Degrees and Central
%



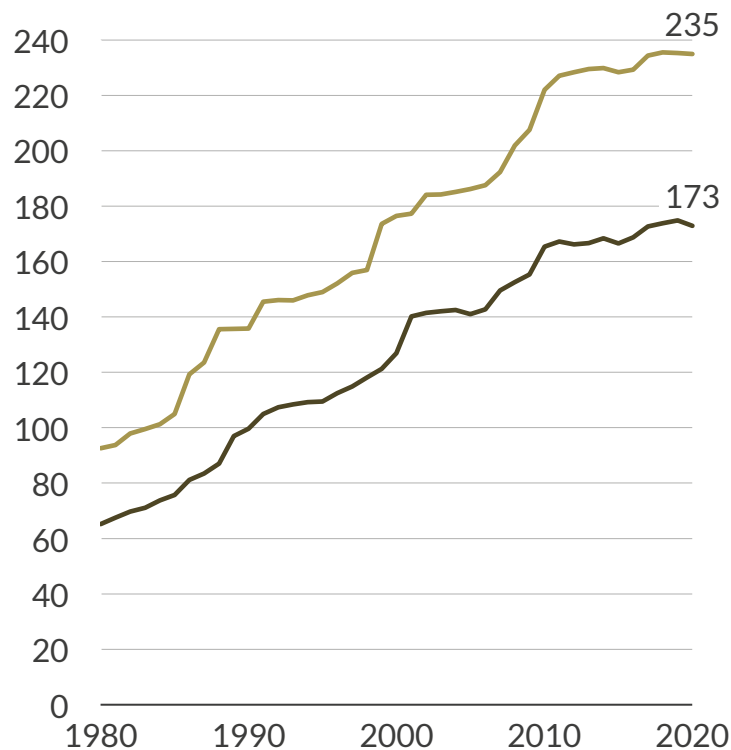
■ Global Two Degrees ■ Extra revenues in Central

■ Global revenues 2030-2060 ■ Global cumulative consumption 2030-2060
■ Average price 2030-2060

1) Our estimation is based off of the change in our forecast for TTF gas, ARA coal and Brent oil prices and forecast total cumulative fossil fuel consumption between Global Two Degrees and Central scenarios.

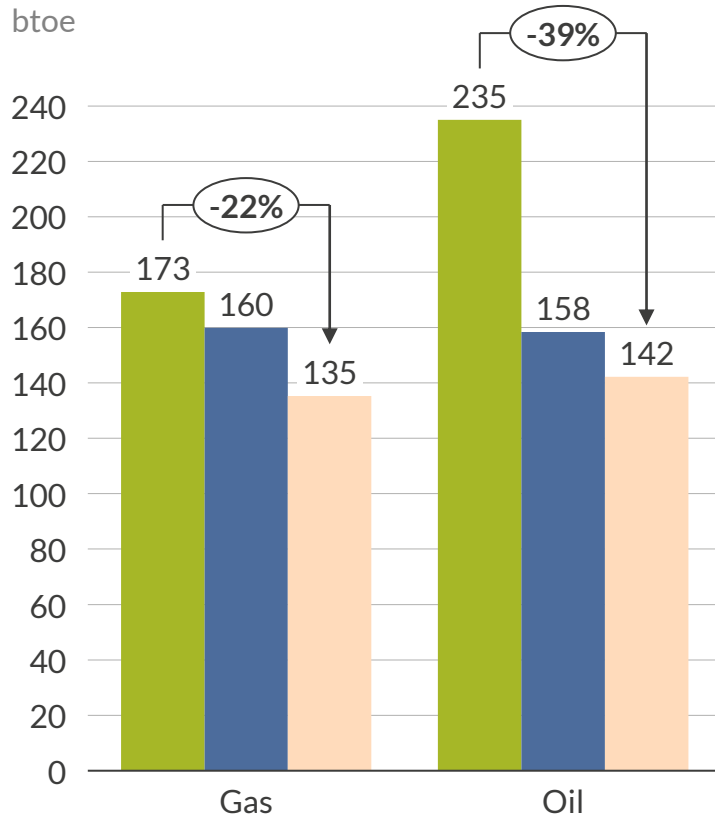
No new exploration for fossil fuels is needed in a Global Two Degrees world, unless to improve a region's security of supply

Historical evolution of global oil and gas reserves¹
btoe



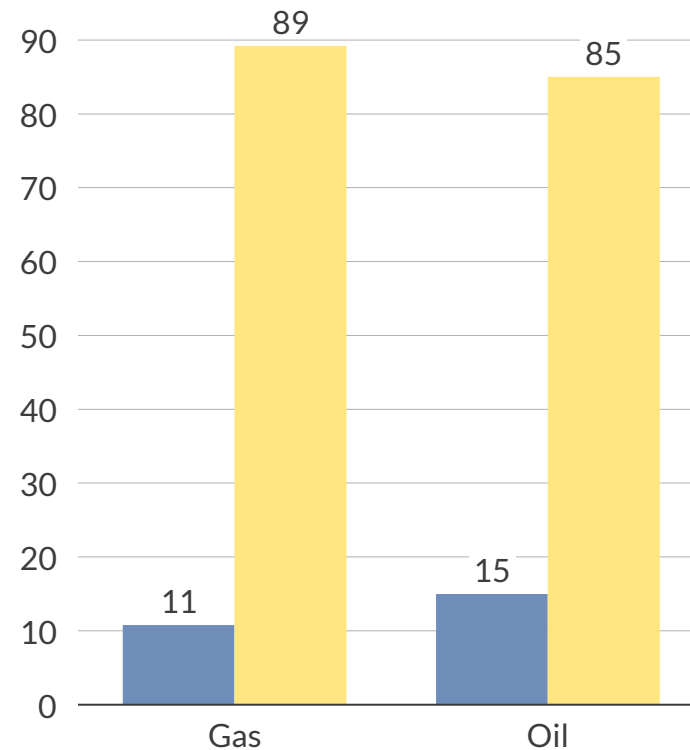
— Gas — Oil

Global reserves of fossil fuels as of 2020¹
btoe



■ Proven Reserves
■ Central cumulative consumption by 2060
■ Global Two Degrees cumulative consumption by 2060

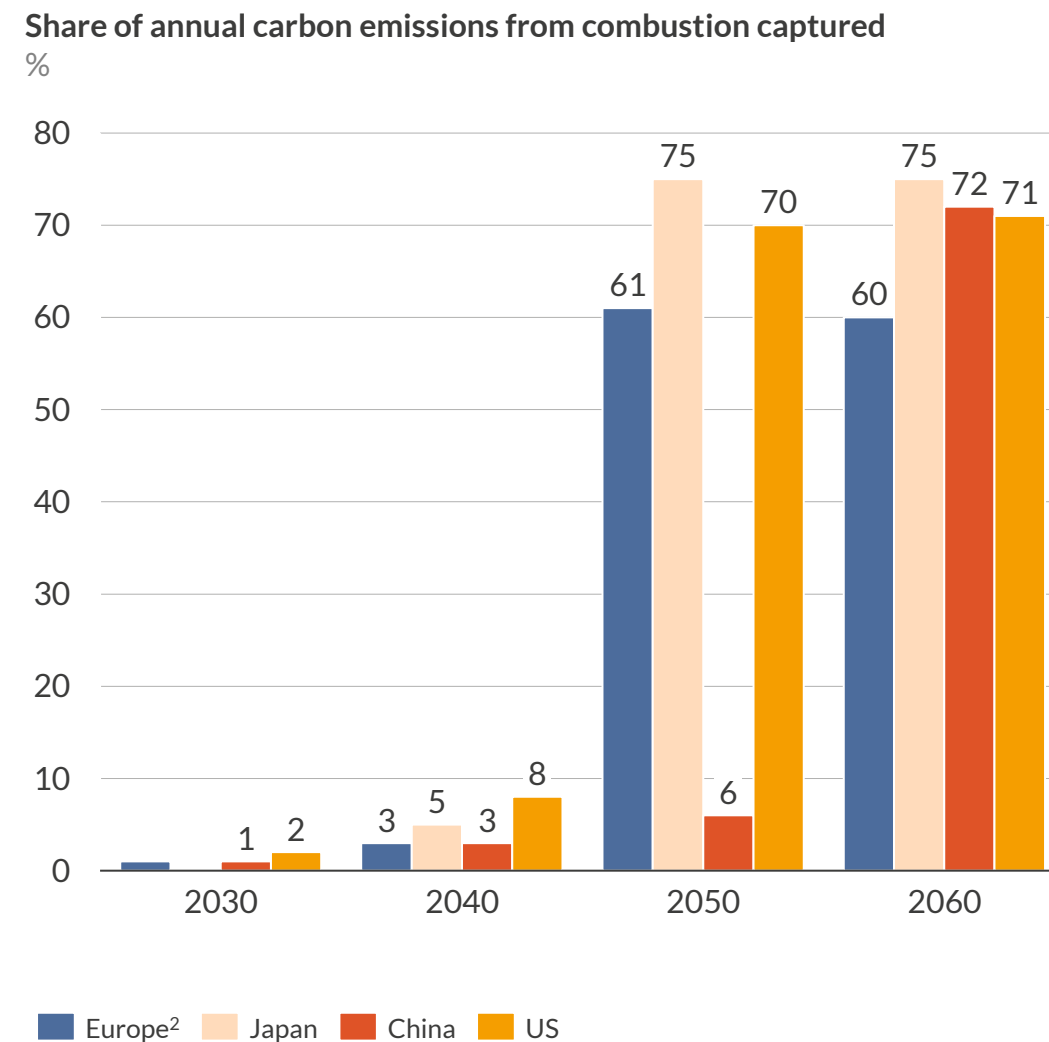
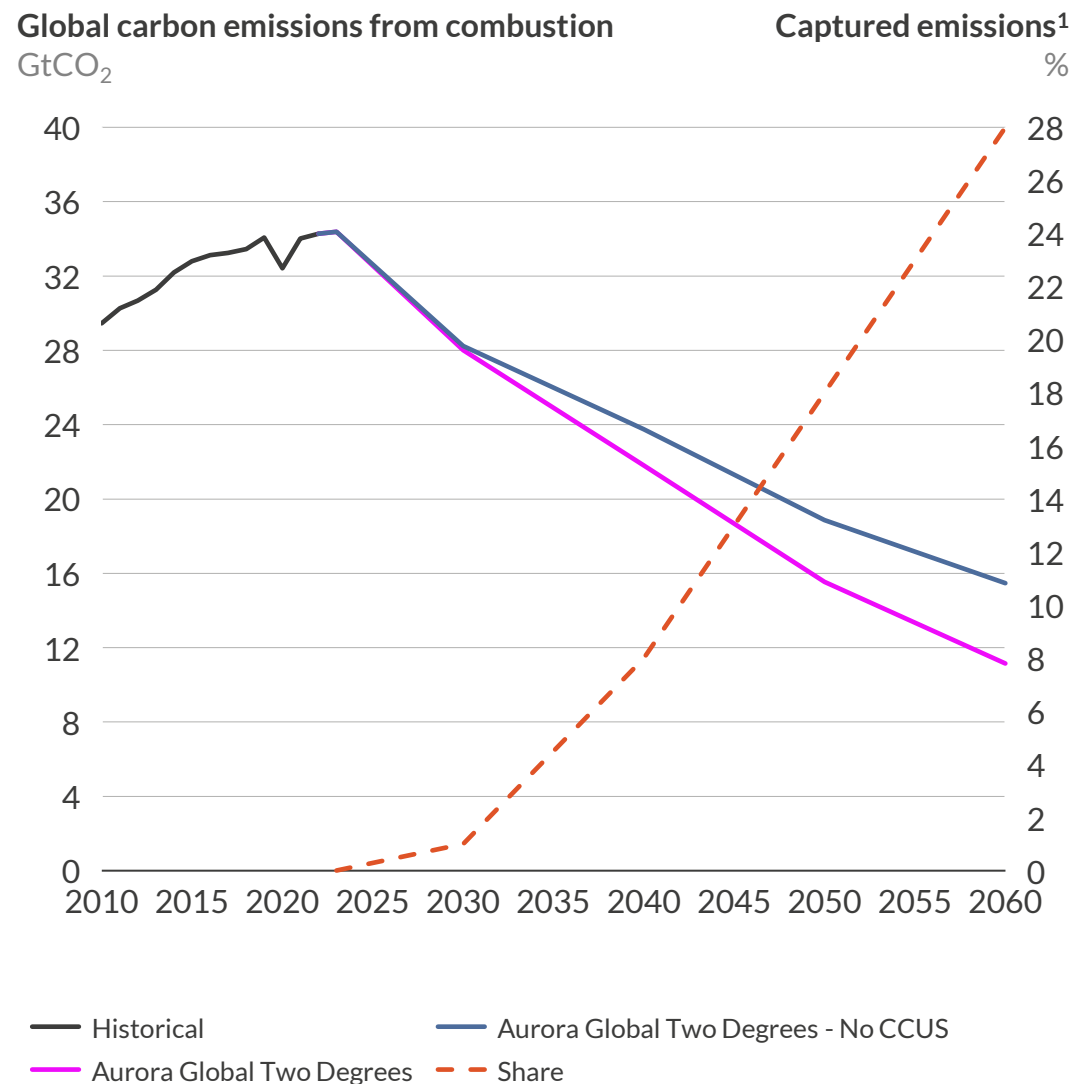
Regional concentration of reserves as of 2020
%



■ OECD ■ Non-OECD

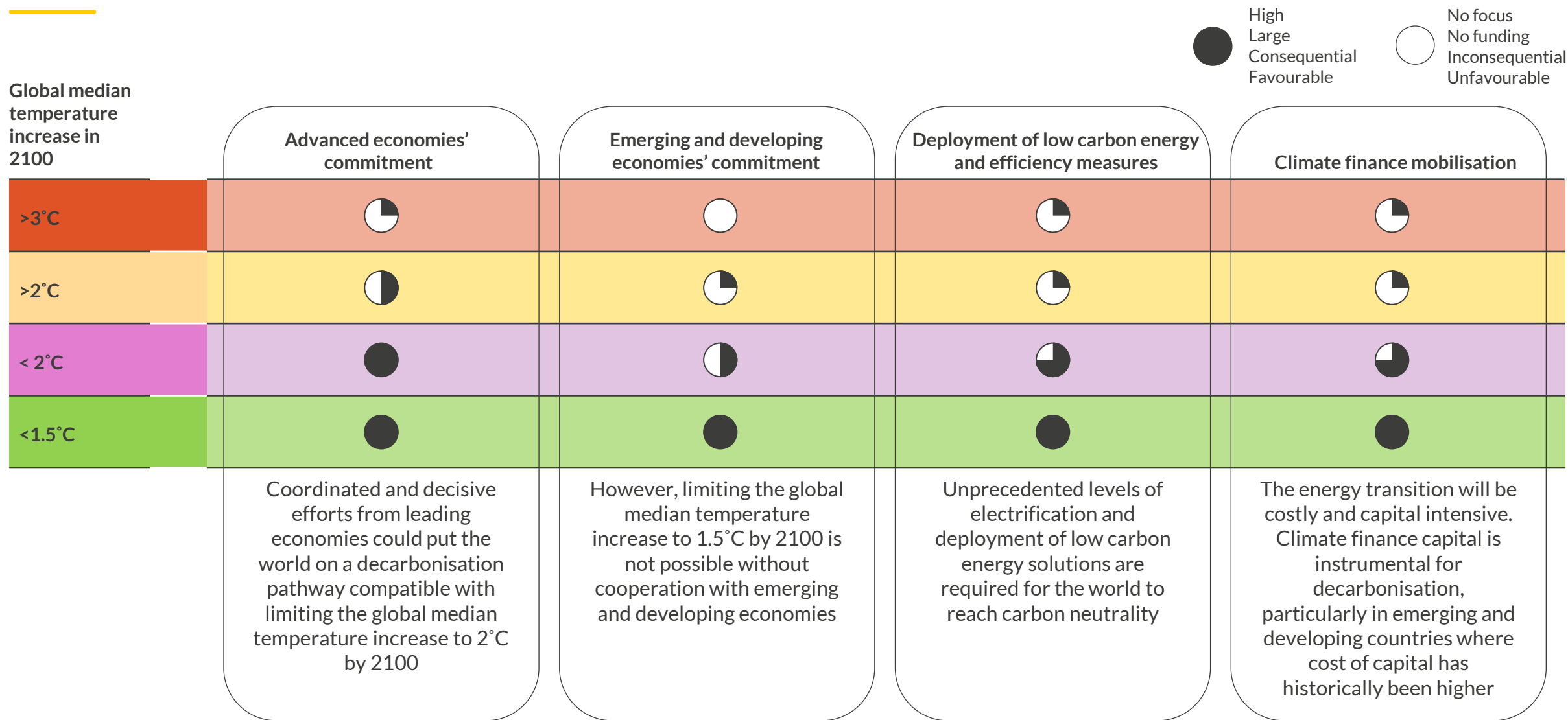
1) Only proven (1P) oil and gas reserves included.

CCUS¹ rollout is needed to keep emissions in line with Global Two Degrees, by abating 28% of global carbon emissions in 2060



.1) Only includes CCUS applications for abatement of emissions from the combustion of fossil fuels. 2) EU-27, the UK, Norway, and Switzerland.

Unprecedented collaboration and mobilisation of capital is needed to limit the global median temperature increase to 2°C by 2100



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Coordinated decarbonisation efforts from global leading economies could lead the world to limiting the global median temperature rise to 2°C by the end of the century in the Global Two Degrees scenario. For this to happen, average global carbon emissions per capita need to drop to 1.6 tCO₂/person by 2050, 2.5 tCO₂/person lower than current levels.



Unprecedented levels of electrification are required in Global Two Degrees. By 2060, world's electricity generation totals more than 60,000 TWh, twice the levels recorded in 2022, with low carbon electricity accounting for 86% of the total versus just 39% in 2022.



Fossil fuel demand would drop but not collapse if advanced economies were to take the actions needed to limit warming to 2°C: global gas consumption would fall by just 11% between 2023 and 2060, and would rise between 2030 and 2040 as China quickly phases down coal.



Global fossil fuel prices are substantially lower than in Central across the forecast horizon, but the drop is mitigated by higher costs to finance fossil fuel upstream projects and robust demand levels in emerging and developing markets. The overall loss in fossil fuel revenues between 2030 and 2060 amounts to \$40 trillion.

A U R  R A

E N E R G Y R E S E A R C H