INEVITABLE POLICY RESPONSE

- The Inevitable Policy Response 1.5°C Required Policy Scenario (RPS) 2021:
- Detailed energy system results

Preparing financial markets for climate-related policy and regulatory risks

December 2021

IPR is commissioned by the Principles for Responsible Investment (PRI), supported by world class research partners and joined by leading financial institutions

PRI Principles for Responsible Investment

PRI commissioned the Inevitable Policy Response in 2018 to advance the industry's knowledge of climate transition risk, and to support investors' efforts to incorporate climate risk into their portfolio assessments

:vivideconomics putting economics to good use

Energy Transition Advisors ETA

A research partnership led by Energy Transition Advisors and Vivid Economics conducts the initiative's policy research and scenario modelling and includes 2Dii, Carbon Tracker Initiative, Climate Bonds Initiative, Quinbrook Infrastructure Partners and Planet Tracker

The consortium was given the mandate to bring leading analytic tools and an independent perspective to assess the drivers of likely policy action and their implications on the market

Planet Tracker

quinbrook infrastructure PARTNERS

2° Investing Initiative

Carbon Tracker Initiative

Climate Bonds Initiative

Who supports the Inevitable Policy Response ?

Leading financial institutions joined the IPR as Strategic Partners in 2021 to provide more in-depth industry input, and to further strengthen its relevance to the financial industry

BLACKROCK · FitchRatings · nuveen A TIAA Company · ROBECO The Investment Engineers · BNP PARIBAS ASSET MANAGEMENT · Goldman Sachs Asset Management · NewForests

Core philanthropic support since IPR began in 2018. The IPR is funded in part by the Gordon and Betty Moore Foundation through The Finance Hub, which was created to advance sustainable finance and the ClimateWorks Foundation striving to innovate and accelerate climate solutions at scale

GORDON AND BETTY MOORE FOUNDATION · THE FINANCE HUB · climateworks FOUNDATION

The IPR helps the financial sector navigate the climate transition

Markets inconsistently price transition risk

- Policies will continue interacting with new technologies to deeply disrupt established industries and economies
- Financial institutions need to deepen their understanding of this unfolding environment to manage their assets effectively
- Yet the scenarios currently available provide limited intelligence about the realistic risks and opportunities most critical to the financial sector, and omit the land sector

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The IPR offers a range of applications

IPR Policy Forecast

A **high-conviction policy-based forecast** of forceful policy response to climate change and implications for energy, agriculture and land use

IPR Forecast Policy Scenario (FPS)

A **fully integrated climate scenario** modelling the impact of the forecasted policies on the real economy up to 2050, tracing detailed effects on all emitting sectors

IPR 1.5°C RPS Scenario

A **'1.5°C Required Policy Scenario'**(1.5°C RPS) building on the IEA NZE by deepening analysis on policy, land use, emerging economies, NETs and value drivers. This can be used by those looking to align to 1.5°C

IPR value drivers

A set of publicly available **outputs from the FPS and 1.5°C RPS** that offer significant granularity at the sector and country level allowing investors to assess their own climate risk

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IPR 2021 reports

A series of new IPR reports have been released in 2021. Please visit the PRI website here for more information

Glossary

- AgTech - Agriculture technology
- BECCS - Bioenergy with carbon capture and storage
- BNEF - Bloomberg New Energy Finance
- CAGR - Compound average growth rate
- CCS - Carbon capture and storage
- CDR - Carbon dioxide removal
- CH_4 - Methane
- CO_2 - Carbon dioxide
- CPS - Current Policies Scenario
- DAC - Direct air capture
- LT-DAC - Low temperature solid sorbent
- EV - Electric vehicle
- FPI - Food Price Index
- FPS - Forecast Policy Scenario
- GHG - Greenhouse gas
- ICE - Internal Combustion Engine
- IEA - International Energy Agency
- IPR - Inevitable Policy Response
- N_2O - Nitrous oxide
- NDC - Nationally determined contributions
- NEO - New Energy Outlook
- NETs - Negative emission technologies
- NPS - New Policies Scenario
- P1 - An IPCC 1.5°C scenario
- P2 - An IPCC 1.5°C scenario
- 1.5°C RPS - 1.5°C Required Policy Scenario
- SDS - Sustainable Development Scenario
- STEPS - Stated Policies Scenario
- TCFD - Task Force on Climate-related Financial Disclosures
- ULEV - Ultra low emission vehicles
- WEO - World Energy Outlook

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Executive summary overview

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Policy methodology for the IPR 1.5°C RPS

Our analysis allows us to pinpoint what key sectors require to achieve an outcome consistent with 1.5°C

- We assume carbon prices to be similar to IPR FPS 2021 levels, as the extremely rapid transition required to achieve 1.5°C RPS will be challenging to achieve through carbon pricing mechanisms beyond what is already expected in the IPR FPS 2021
- What drives the additional impact of the RPS is performance standards (bans) or more direct subsidies driven by policymakers rather than higher carbon pricing or more rapid development of carbon markets
- These further policies would need to be announced as quickly as possible and certainly by the 2023 stocktake
- Implementation is required immediately upon announcement

Key findings of the IPR 1.5°C Required Policy Scenario

1. Global energy-related and industrial process **CO_2 emissions** fall around 25% between 2020 and 2030 and to just above zero in 2050

2. Total **fossil fuel demand peaks** in the mid-2020s before declining rapidly, with coal seeing the fastest fall. **Coal** demand declines by 90% to 2050, **oil** by 80% and **natural gas** by 60%

3. Electricity is **fully decarbonised** from 2045, with **renewables** accounting for almost 80% of generation

4. **Hydrogen** emerges as an important fuel in power, transport and industry, with around 20% of primary energy used for hydrogen production by 2050

5. **Electric vehicles** quickly dominate in light duty vehicles, making up the majority of the vehicle fleet before 2035. **Zero emissions trucks** emerge slightly later than light duty vehicles, though grow to dominate the fleet by 2040

6. In industry, **fossil fuel use falls** by over 80% and over 70% of fossil fuels are **with Carbon Capture and Storage (CCS)**

7. In buildings, **electric heat pumps** displace fossil heating systems to become the dominant heating technology by the mid-2040s

8. **CCS** reduces emissions by around 7.5 $GtCO_2$ across energy sectors

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Key Policy Assumptions

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Global coal phase out by 2045 requires immediate policy action

Phase out of existing unabated coal

	Timeline									annual reduction*	
	2020	2025	2030	2035	2040	2045	2050	2055	2060	RPS	FPS
AU			RPS		FPS					10%	5%
BRA				RPS		FPS				7%	4%
CAN		RPS	FPS							20%	10%
CHI				RPS		FPS				7%	4%
CSA				RPS		FPS				7%	4%
EEU			RPS		FPS					10%	5%
EURA						RPS			FPS	4%	3%
GCC						RPS			FPS	4%	3%
IND						RPS			FPS	4%	3%
INDO						RPS			FPS	4%	3%
JAP				RPS		FPS				7%	4%
MENA						RPS			FPS	4%	3%
RU						RPS			FPS	4%	3%
SA						RPS			FPS	4%	3%
SAF				RPS	FPS					7%	5%
SEAO						RPS			FPS	4%	3%
SK				RPS		FPS				7%	4%
SSA						RPS			FPS	4%	3%
UK		Both								20%	20%
USA			RPS	FPS						10%	7%
WEU			RPS		FPS					10%	5%

** reduction in coal generation as a share of 2020 levels*

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100% clean power can be achieved with immediate policy action if taken now

100% clean power

	Timeline									annual reduction*	
	2020	2025	2030	2035	2040	2045	2050	2055	2060	RPS	FPS
AU					RPS		FPS			5%	3%
BRA					RPS		FPS			5%	3%
CAN			RPS	FPS						10%	7%
CHI					RPS		FPS			5%	3%
CSA					RPS		FPS			5%	3%
EEU				RPS		FPS				7%	4%
EURA						RPS			FPS	4%	3%
GCC						RPS			FPS	4%	3%
IND						RPS			FPS	4%	3%
INDO						RPS			FPS	4%	3%
JAP				RPS		FPS				7%	4%
MENA						RPS			FPS	4%	3%
RU						RPS			FPS	4%	3%
SA						RPS			FPS	4%	3%
SAF				RPS	FPS					7%	5%
SEAO						RPS			FPS	4%	3%
SK				RPS		FPS				7%	4%
SSA						RPS			FPS	4%	3%
UK				RPS	FPS					7%	5%
USA				RPS	FPS					7%	5%
WEU				RPS		FPS				7%	4%

** reduction in power CO2 emissions as a share of 2020 levels*

INEVITABLE POLICY RESPONSE

Light duty vehicles: new fossil vehicles must be phased out between 2030 and 2045, five years earlier than under IPR FPS 2021 policies

Fossil vehicle phase out (light duty)

	Timeline									annual reduction*	
	2020	2025	2030	2035	2040	2045	2050	2055	2060	RPS	FPS
AU				RPS	FPS					7%	5%
BRA					RPS	FPS				5%	4%
CAN			RPS	FPS						10%	7%
CHI			RPS	FPS						10%	7%
CSA				RPS	FPS					7%	5%
EEU			RPS	FPS						10%	7%
EURA					RPS	FPS				5%	4%
GCC					RPS	FPS				5%	4%
IND				RPS	FPS					7%	5%
INDO				RPS	FPS					7%	5%
JAP				RPS	FPS					7%	5%
MENA				RPS	FPS					7%	5%
RU					RPS	FPS				5%	4%
SA						RPS	FPS			4%	3%
SAF				RPS	FPS					7%	5%
SEAO				RPS	FPS					7%	5%
SK			RPS	FPS						10%	7%
SSA						RPS	FPS			4%	3%
UK			Both							10%	10%
USA				RPS	FPS					7%	5%
WEU			RPS	FPS						10%	7%

** reduction in fossil vehicle sales as a share of 2020 levels*

INEVITABLE POLICY RESPONSE

Heavy duty vehicles: new fossil vehicles must be phased out between 2035 and 2050, five years earlier than under IPR FPS 2021 policies

Fossil vehicle phase out (heavy duty)

	Timeline									annual reduction*	
	2020	2025	2030	2035	2040	2045	2050	2055	2060	RPS	FPS
AU					RPS	FPS				5%	4%
BRA					RPS	FPS				5%	4%
CAN					RPS	FPS				5%	4%
CHI				RPS	FPS					7%	5%
CSA					RPS	FPS				5%	4%
EEU				RPS	FPS					7%	5%
EURA						RPS	FPS			4%	3%
GCC						RPS	FPS			4%	3%
IND					RPS	FPS				5%	4%
INDO					RPS	FPS				5%	4%
JAP				RPS	FPS					7%	5%
MENA					RPS	FPS				5%	4%
RU						RPS	FPS			4%	3%
SA							RPS	FPS		3%	3%
SAF					RPS	FPS				5%	4%
SEAO					RPS	FPS				5%	4%
SK				RPS	FPS					7%	5%
SSA							RPS	FPS		3%	3%
UK				Both						7%	7%
USA					RPS	FPS				5%	4%
WEU				RPS	FPS					7%	5%

** reduction in fossil vehicle sales as a share of 2020 levels*

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Industry: the sector has a 30-year transition opportunity to net zero

100% clean industry

	Timeline									annual reduction*	
	2020	2025	2030	2035	2040	2045	2050	2055	>2060	RPS	FPS
AU							RPS		FPS	3%	2%
BRA								RPS	FPS	3%	2%
CAN							RPS		FPS	3%	2%
CHI								RPS	FPS	3%	2%
CSA								RPS	FPS	3%	2%
EEU							RPS		FPS	3%	2%
EURA								RPS	FPS	3%	2%
GCC								RPS	FPS	3%	2%
IND								RPS	FPS	3%	2%
INDO								RPS	FPS	3%	2%
JAP							RPS		FPS	3%	2%
MENA								RPS	FPS	3%	2%
RU								RPS	FPS	3%	2%
SA								RPS	FPS	3%	2%
SAF							RPS		FPS	3%	2%
SEAO								RPS	FPS	3%	2%
SK							RPS		FPS	3%	2%
SSA								RPS	FPS	3%	2%
UK							RPS		FPS	3%	2%
USA							RPS		FPS	3%	2%
WEU							RPS		FPS	3%	2%

** reduction in industry CO2 emissions as a share of 2020 levels*

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Buildings: new fossil heating systems must be phased out globally by 2040, and by 2030 in regions with large heating needs

New fossil heating system phase out

	Timeline									annual reduction*	
	2020	2025	2030	2035	2040	2045	2050	2055	2060	RPS	FPS
AU			RPS	FPS						10%	7%
BRA					RPS		FPS			5%	3%
CAN			RPS	FPS						10%	7%
CHI					RPS	FPS				5%	4%
CSA				RPS	FPS					7%	5%
EEU			RPS	FPS						10%	7%
EURA					RPS		FPS			5%	3%
GCC					RPS		FPS			5%	3%
IND					RPS		FPS			5%	3%
INDO					RPS		FPS			5%	3%
JAP				RPS	FPS					7%	5%
MENA					RPS		FPS			5%	3%
RU					RPS		FPS			5%	3%
SA					RPS		FPS			5%	3%
SAF			RPS	FPS						10%	7%
SEAO					RPS		FPS			5%	3%
SK				RPS	FPS					7%	5%
SSA					RPS		FPS			5%	3%
UK			RPS	FPS						10%	7%
USA				RPS	FPS					7%	5%
WEU			RPS	FPS						10%	7%

** reduction in fossil heating system sales as a share of 2020 levels*

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CO_2 emissions

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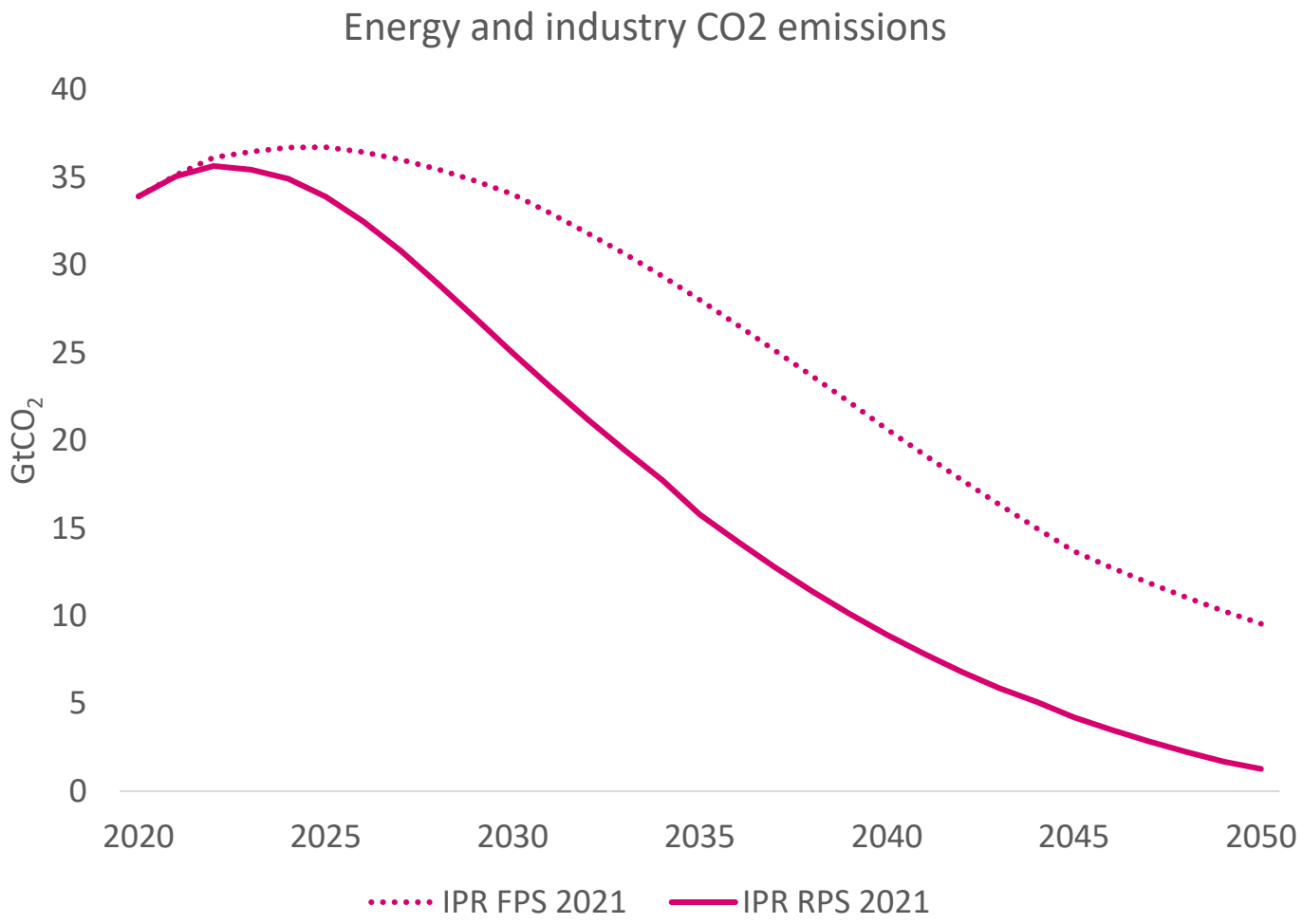
Relative to the IPR FPS 2021, energy-related CO_2 emissions in the IPR 1.5°C RPS decline rapidly, and are just above zero by 2050



- CO_2 emissions rise slightly in the early 2020s, driven by recovery from the COVID-19 pandemic and further economic growth
- Emissions peak in 2022, as immediate policy action begins to take effect
- By 2030, CO_2 emissions are around 25% below 2020 levels, and 9 Gt below FPS levels
- Emissions fall steadily to around 1 $GtCO_2$ to 2050, and are around 8 $GtCO_2$ below FPS levels in that year

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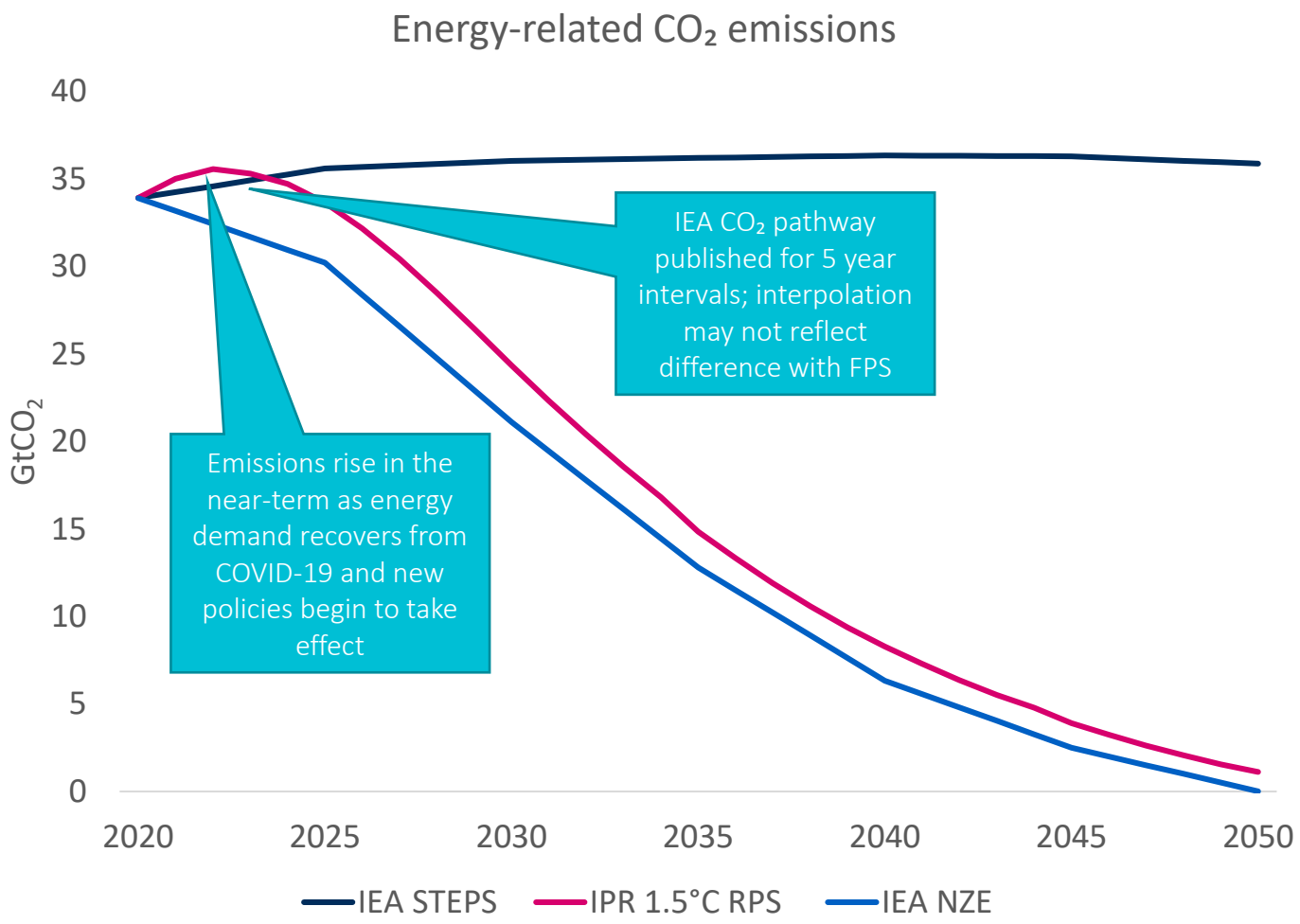
Energy-related CO_2 emissions follow a comparable path to IEA's NZE scenario



- Emissions reductions are comparable to those in the IEA NZE scenario
- Emissions are within around 1 $GtCO_2$ of IEA NZE over the period to 2050
- Energy sector emissions are just above zero in 2050, and are offset by reductions in the land sector

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Fuel demand

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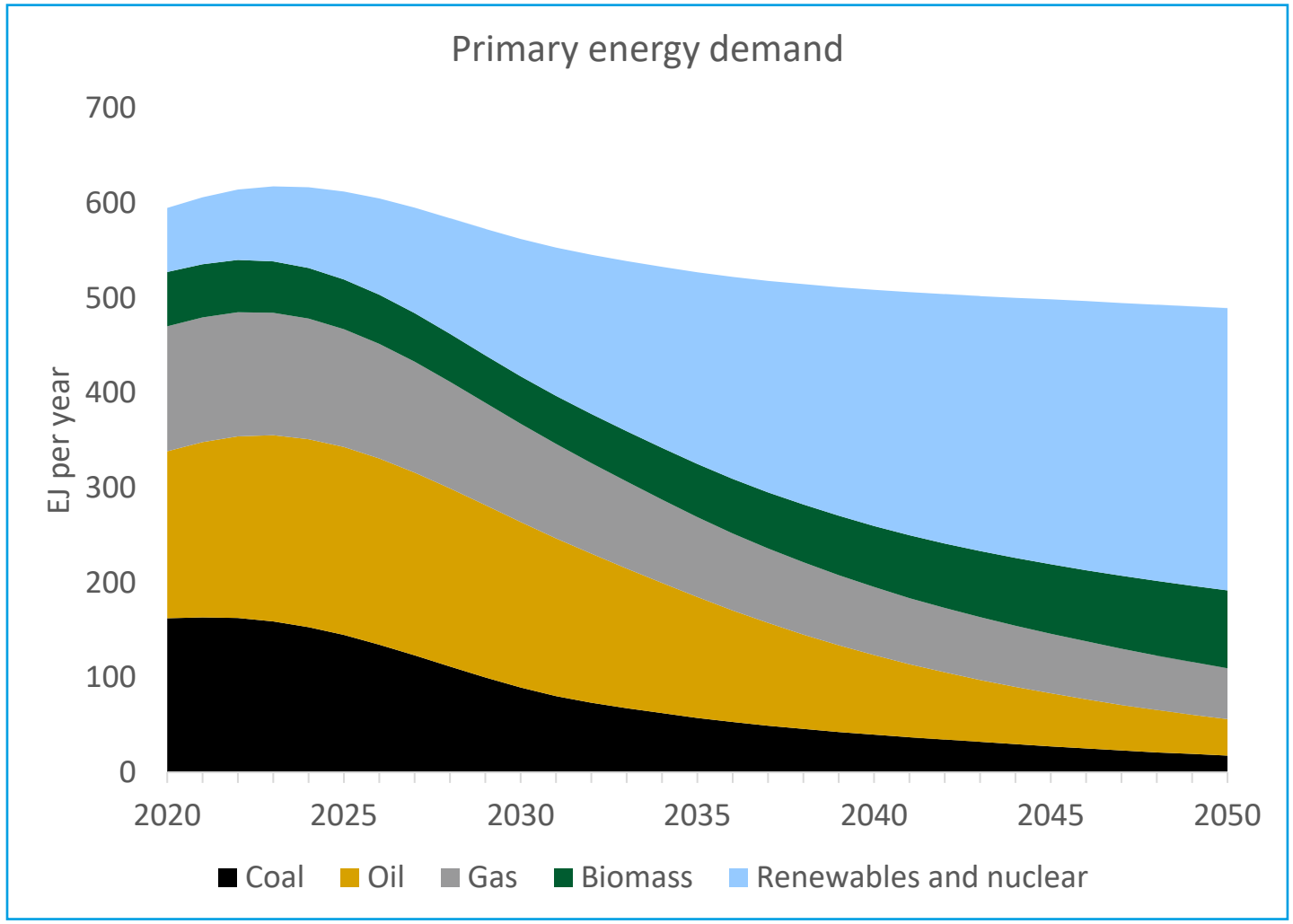
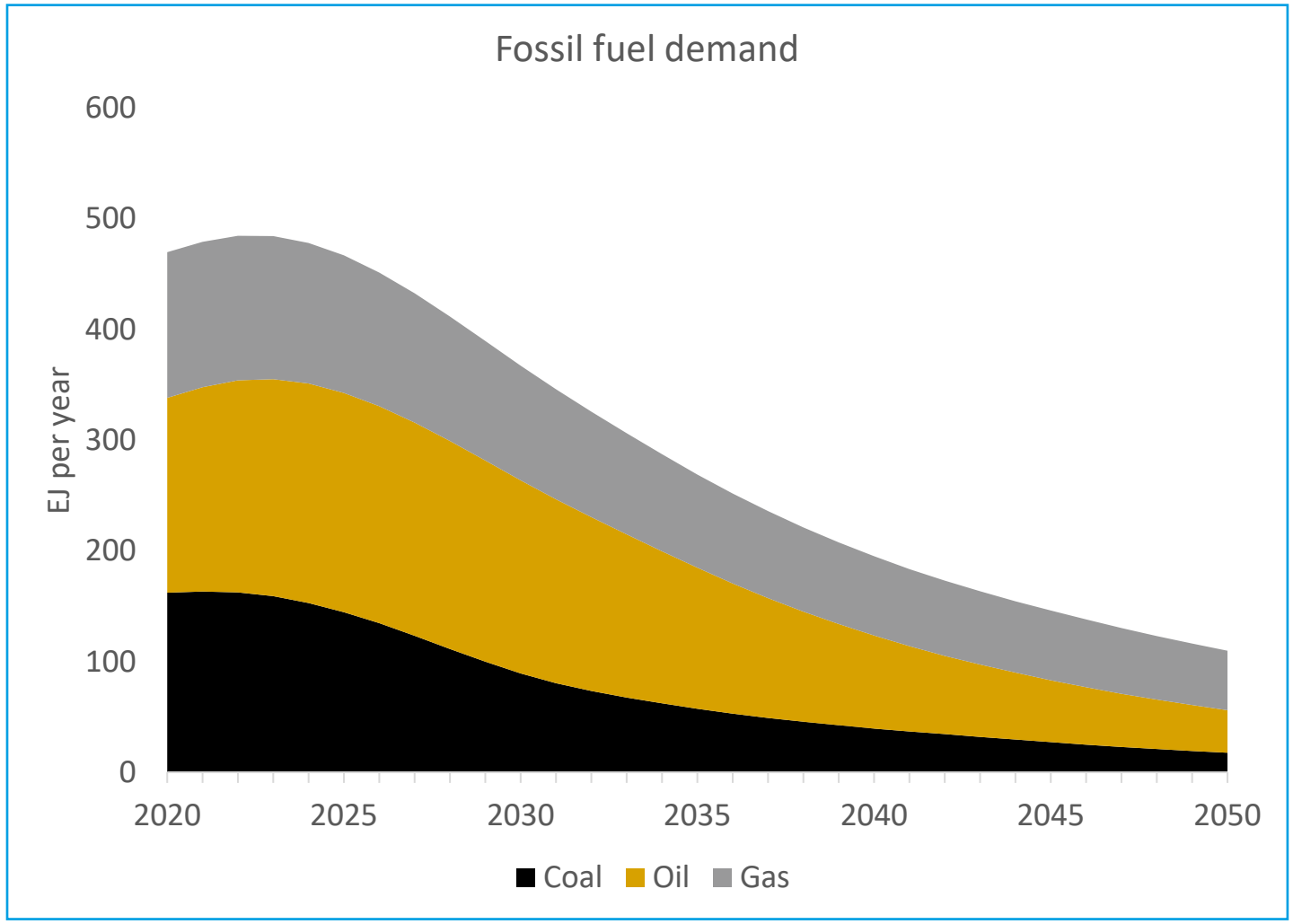
Biomass, renewables and nuclear grow from around 20% of primary energy in 2020 to almost 80% in 2050



- The share of fossil fuels in primary energy falls from around 80% in 2020 to around 20% in 2050. Around 85% of remaining coal and gas are fitted with CCS
- In contrast, the share of biomass, renewables and nuclear rises substantially
- These low-carbon fuels account for the majority of primary energy by the mid-2030s and for almost 80% by 2050
- Overall, around 20% of primary energy is used to produce hydrogen

INEVITABLE POLICY RESPONSE

Total fossil fuel demand peaks in the mid-2020s before declining rapidly, with coal seeing the fastest fall



- Total coal, oil and gas demand peak in the mid-2020s before declining substantially to 2050
- Coal demand decreases around 45% between 2020 and 2030, driven by widespread aggressive phase outs in some regions; between 2020 and 2050 coal demand falls by around 90%
- Oil demand rises in the early 2020s before falling to 2030; between 2020 and 2050 oil demand falls by around 80%
- Gas demand falls around 20% between 2020 and 2030, and then falls further: between 2020 and 2050 gas demand falls by around 60%

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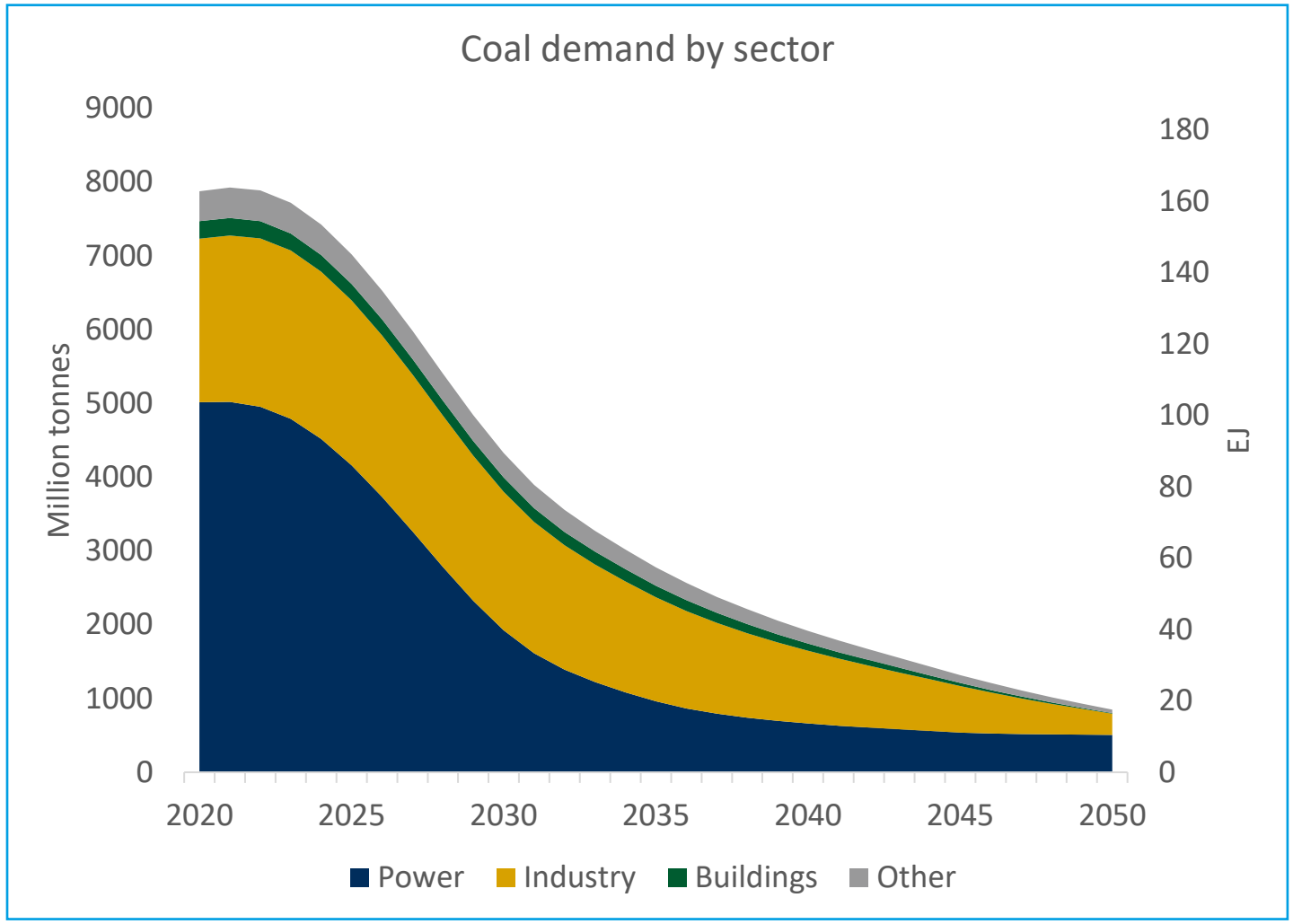
Coal demand falls 90%, driven primarily by a reduction in demand in the power sector; by 2050 industry accounts for the largest share of coal demand



- Coal demand falls around 90% between 2020 and 2050. Around 80% of remaining coal is fitted with CCS
- Demand from power falls rapidly in the next decade, with around a 60% reduction 2020-30
- As a result, the share of power in total coal demand falls from over 60% in 2020 to around 45% in 2030
- Demand from industry falls less rapidly initially, with around a 15% reduction 2020-30
- By 2030 industry accounts for almost half of total coal demand, up from around 30% in 2050
- By 2050, demand in both power and industry fall to around 10% of 2020 levels

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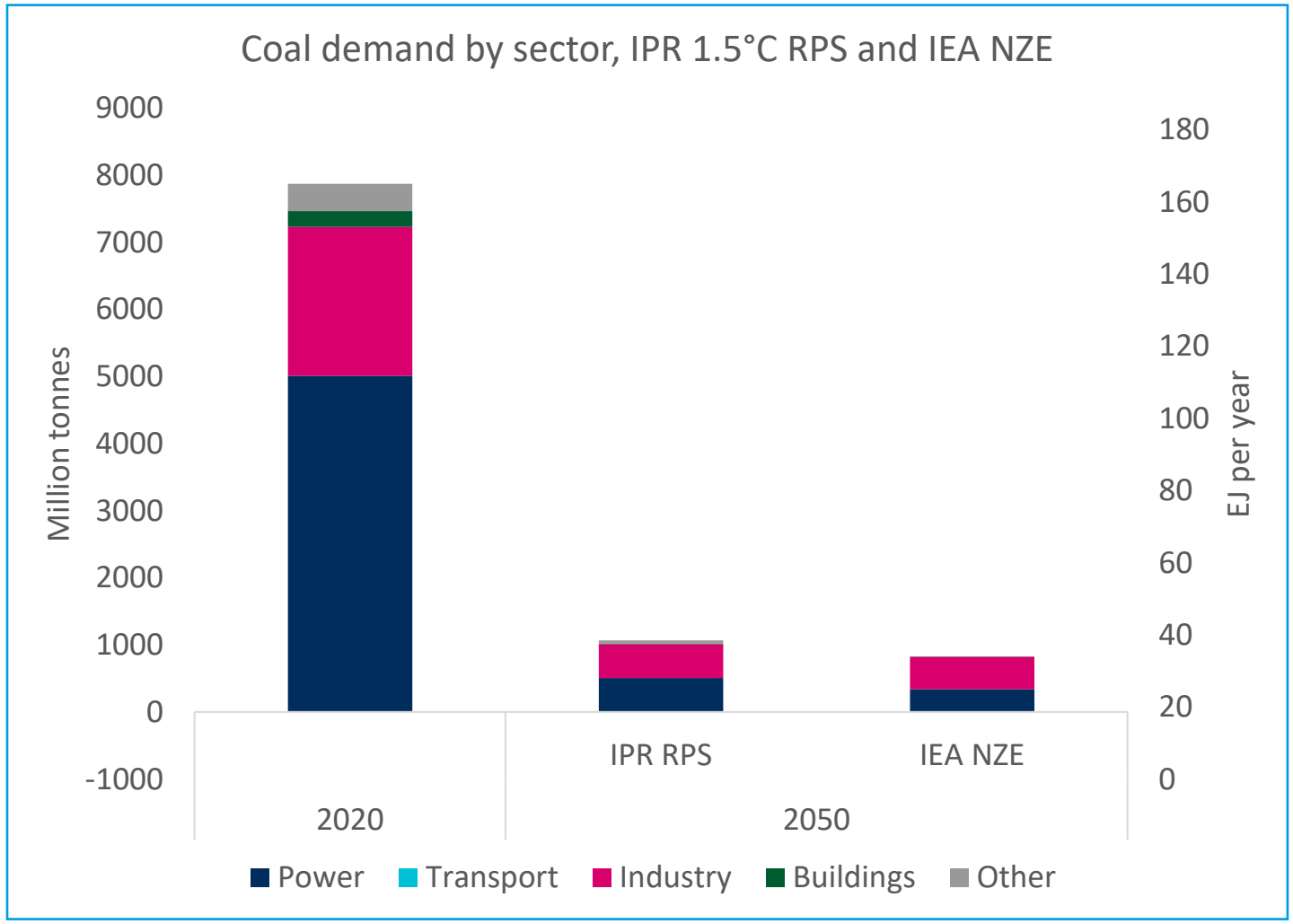
The fall in coal demand is comparable to that seen in IEA's Net Zero Emissions scenario



- Coal demand falls at a comparable rate to IEA NZE, with coal demand in IPR 1.5°C RPS just above IEA NZE levels by 2050
- Coal is slightly higher in power than under IEA NZE, driven by higher use of coal CCUS in China
- Coal is also slightly higher in industry than under IEA NZE. In 1.5°C RPS, 60% of coal in industry is fitted with CCUS, and remaining unabated coal is phased out shortly after 2050

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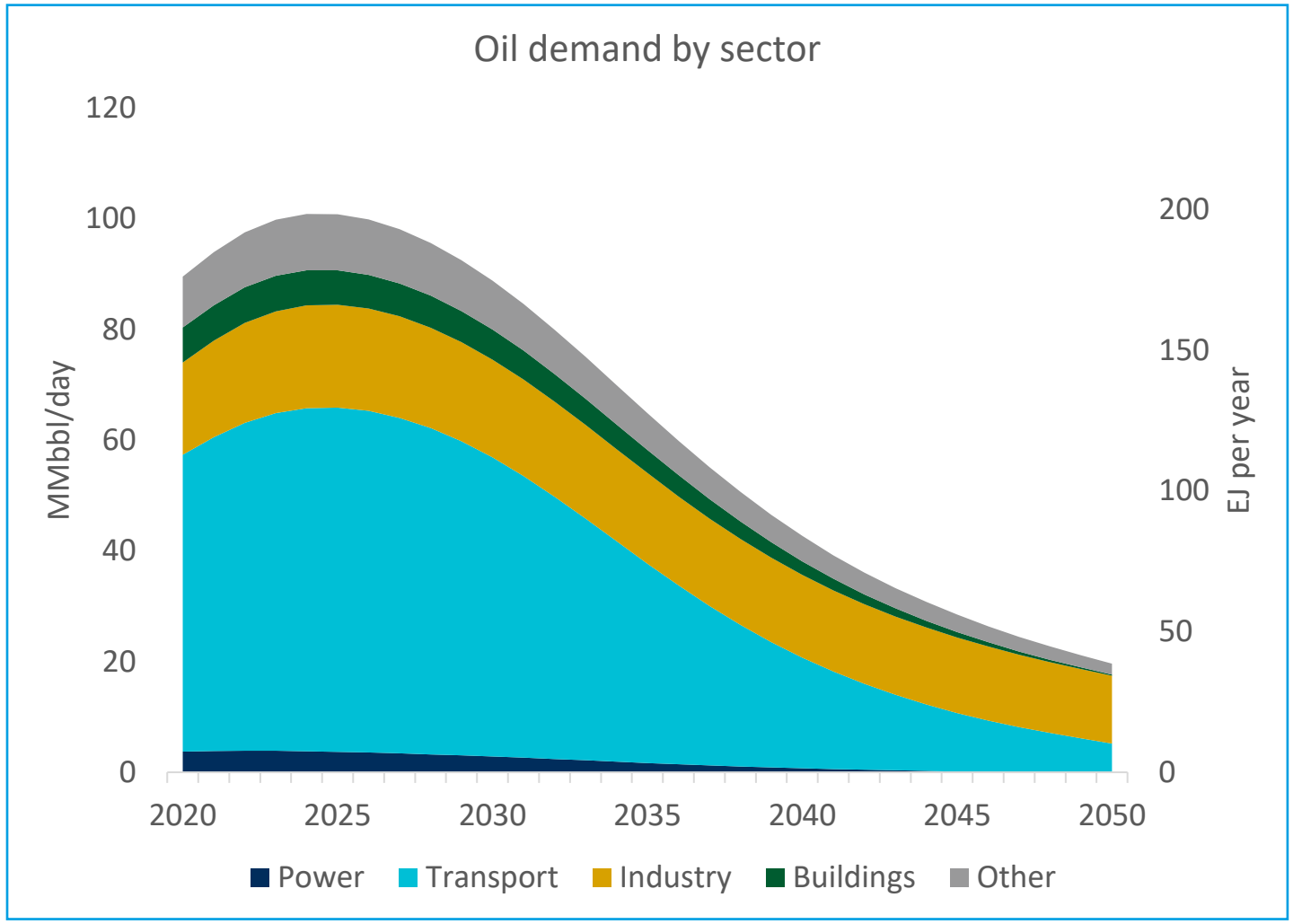
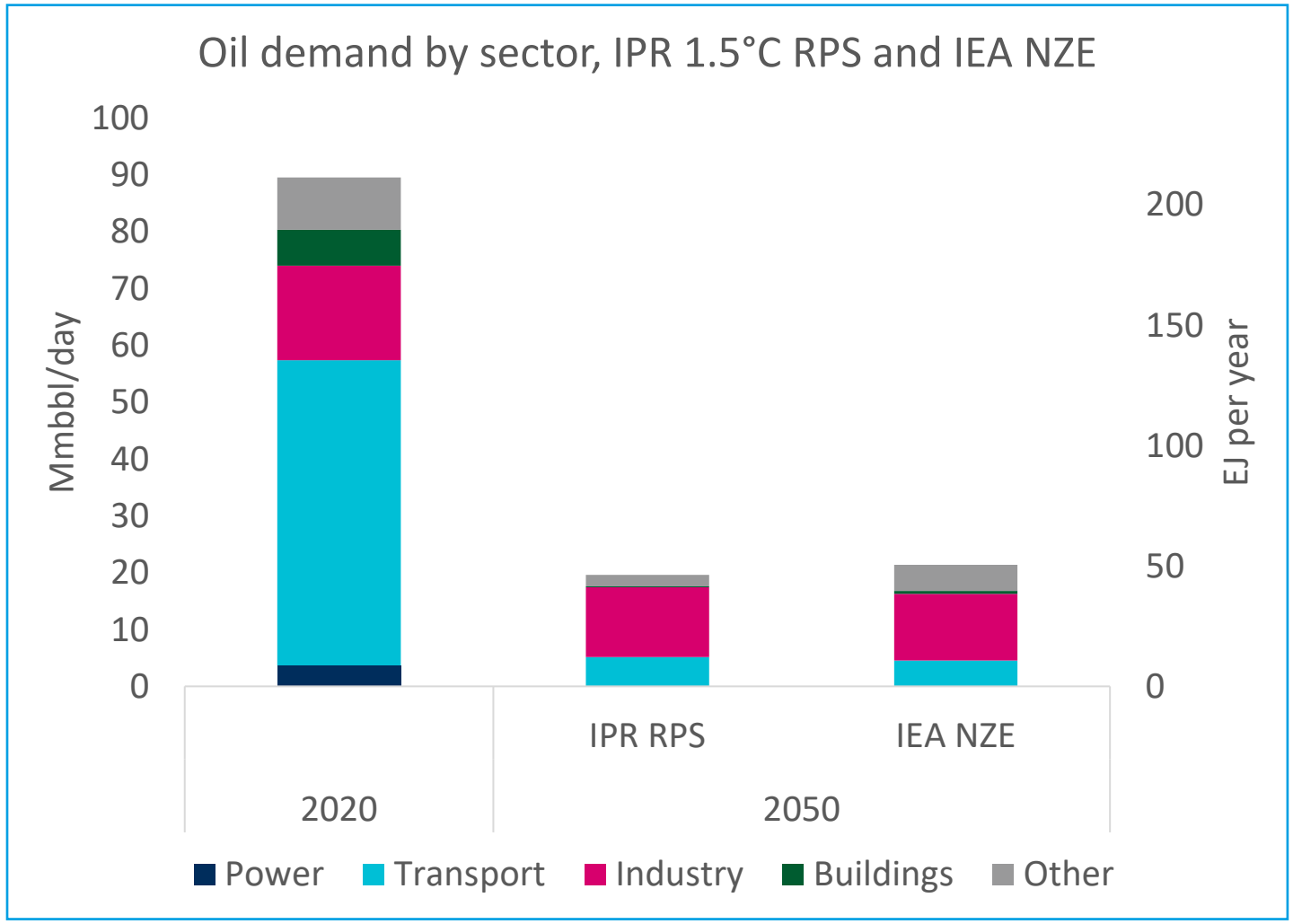
Oil demand peaks in 2025, and falls around 80% between 2020 and 2050



- Oil demand grows until the mid-2020s, driven by recovery from the COVID-19 pandemic and further economic growth
- Oil demand peaks around 2025, as transport and other sectors reduce use of fossil fuels. Overall oil demand falls around 80% between 2020 and 2050 as fossil vehicles exit the fleet
- Transport accounts for the majority of the demand reduction; oil demand in transport falls around 90% between 2020 and 2050. By 2050, transport accounts for around 25% of oil demand
- Demand in industry falls around 25% over the period to 2050, due to continued use of oil as a petrochemical feedstock, where the carbon content is largely embedded in the products. By 2050, industry accounts for over 60% of oil demand

INEVITABLE POLICY RESPONSE

Oil demand declines to levels comparable with the IEA's Net Zero Emissions scenario



- Oil demand falls to very similar levels to 2050, in IPR RPS and IEA NZE
- Oil demand in transport is almost identical in both scenarios in 2050
- Oil demand in industry is also very similar in both scenarios
- Oil demand in RPS is slightly lower than in NZE in other sectors, which could include agriculture, forestry and non-energy uses

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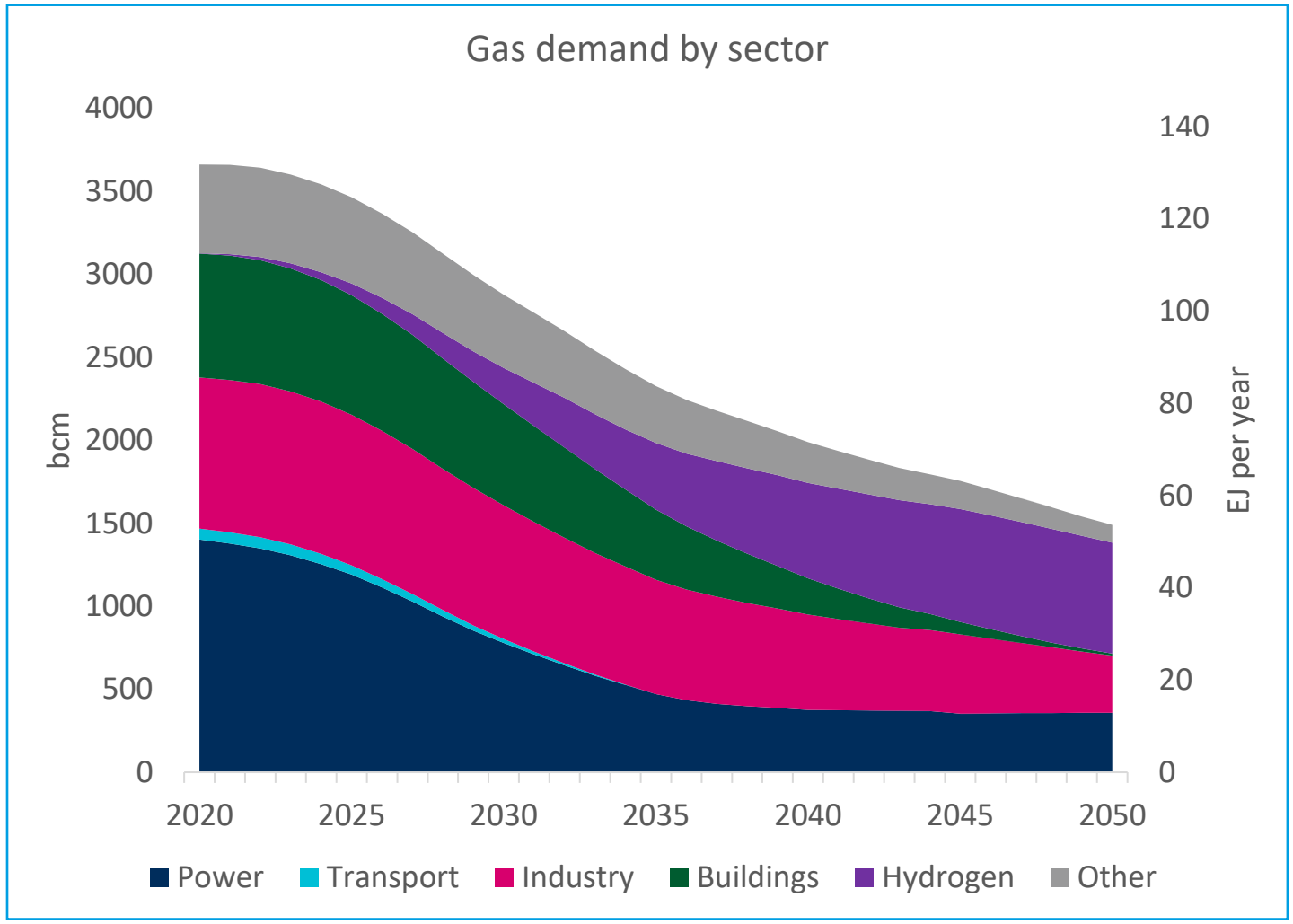
Gas demand falls by around 60%, driven primarily by a reduction in demand in the power and buildings sectors



- Gas demand falls around 60% between 2020 and 2050
- The power sector accounts for the majority of the demand reduction; gas demand in power falls around 75% between 2020 and 2050
- Buildings also account for over one third of the demand reduction; gas demand in buildings falls to almost zero to 2050 as heating and cooking are electrified in many countries
- Demand falls more slowly in industry, with around a 60% reduction between 2020 and 2050
- Blue hydrogen production emerges as an important source of gas demand, accounting for over 40% of total demand by 2050

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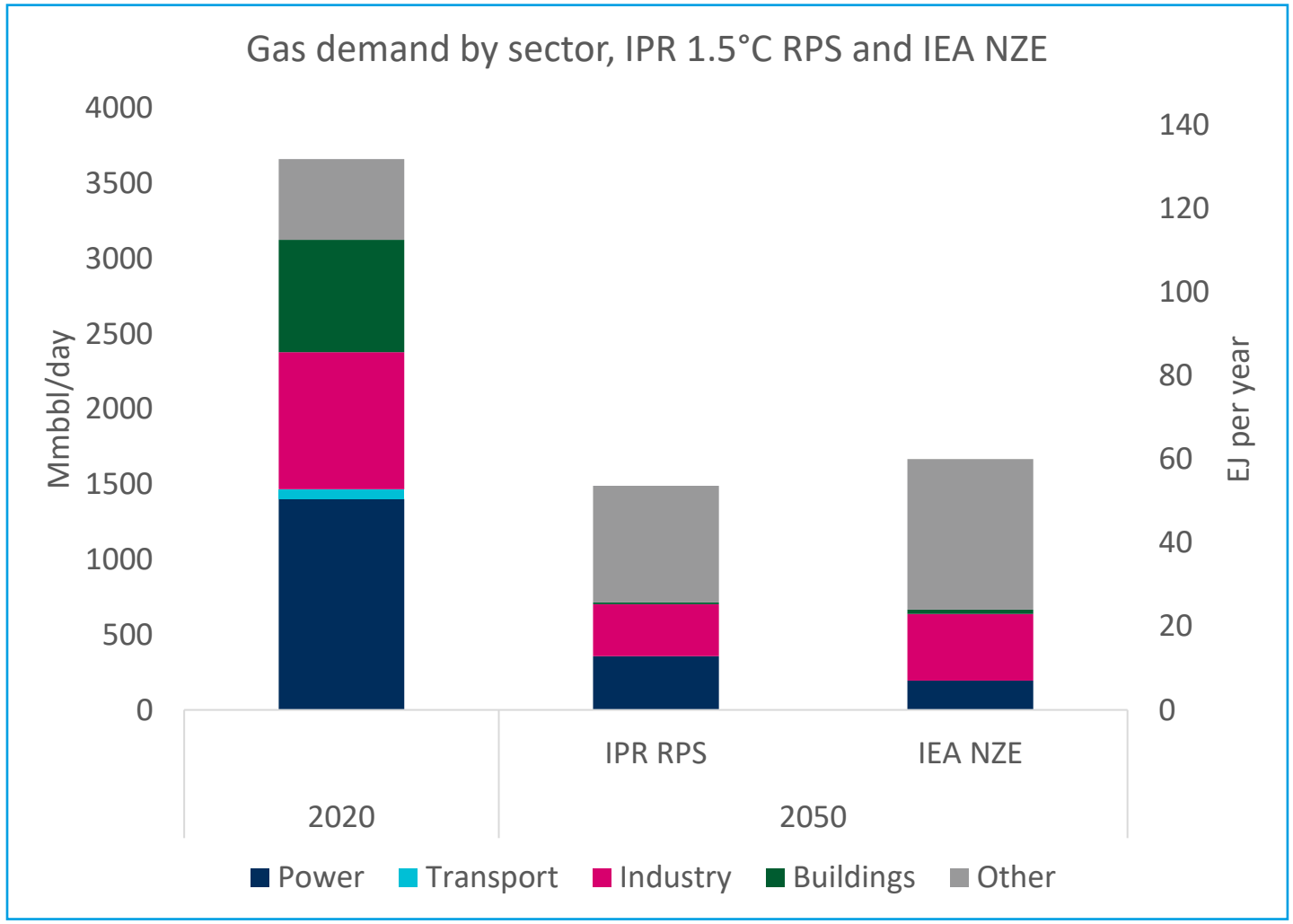
Gas demand falls more rapidly than in IEA's Sustainable Development Scenario, due to more rapid transport decarbonisation



- Gas demand falls around 60% to 2050, compared to only around 55% in IEA NZE
- Gas demand in power remains above NZE levels, driven by a stronger role for gas CCUS in the RPS
- Conversely, gas demand in industry falls slightly below NZE levels, potentially due to a larger shift towards electrification and hydrogen

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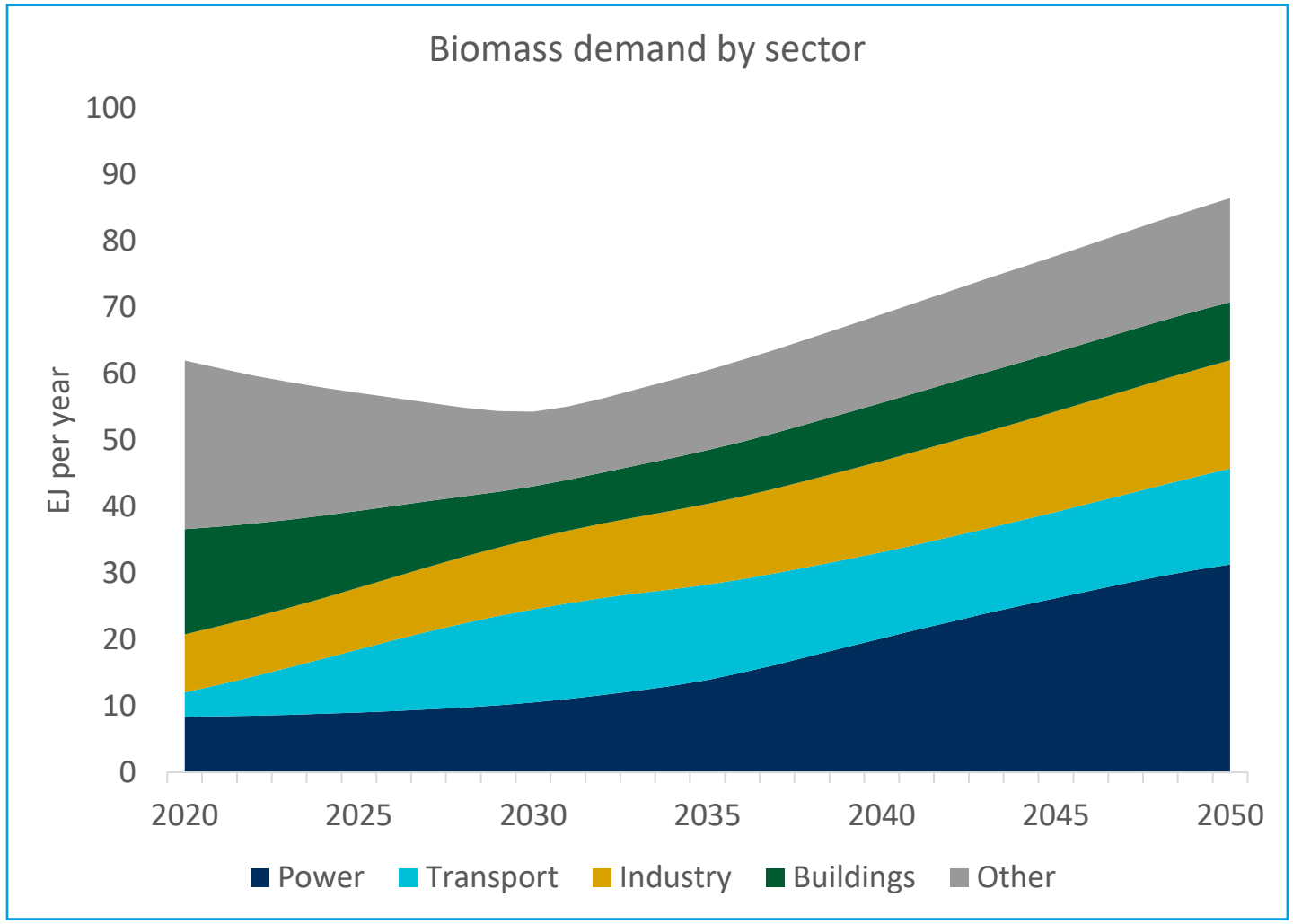
Biomass plays an important role in reducing fossil fuel use across the power, transport and industry sectors



- Biomass is currently used in most sectors. Around half of all biomass use is as traditional biomass for cooking and heating in developing and emerging economies
- Traditional biomass is phased out between 2020 and 2030 as income growth and public health policy drives adoption of modern methods of cooking and water heating
- Between 2030 and 2050, biomass demand rises to over 85 EJ, reducing fossil fuel use in the power, transport and industry sectors
- The largest growth is in the power sector, where biomass provides baseload generation as well as some opportunities for bioenergy with carbon capture and storage (BECCS)

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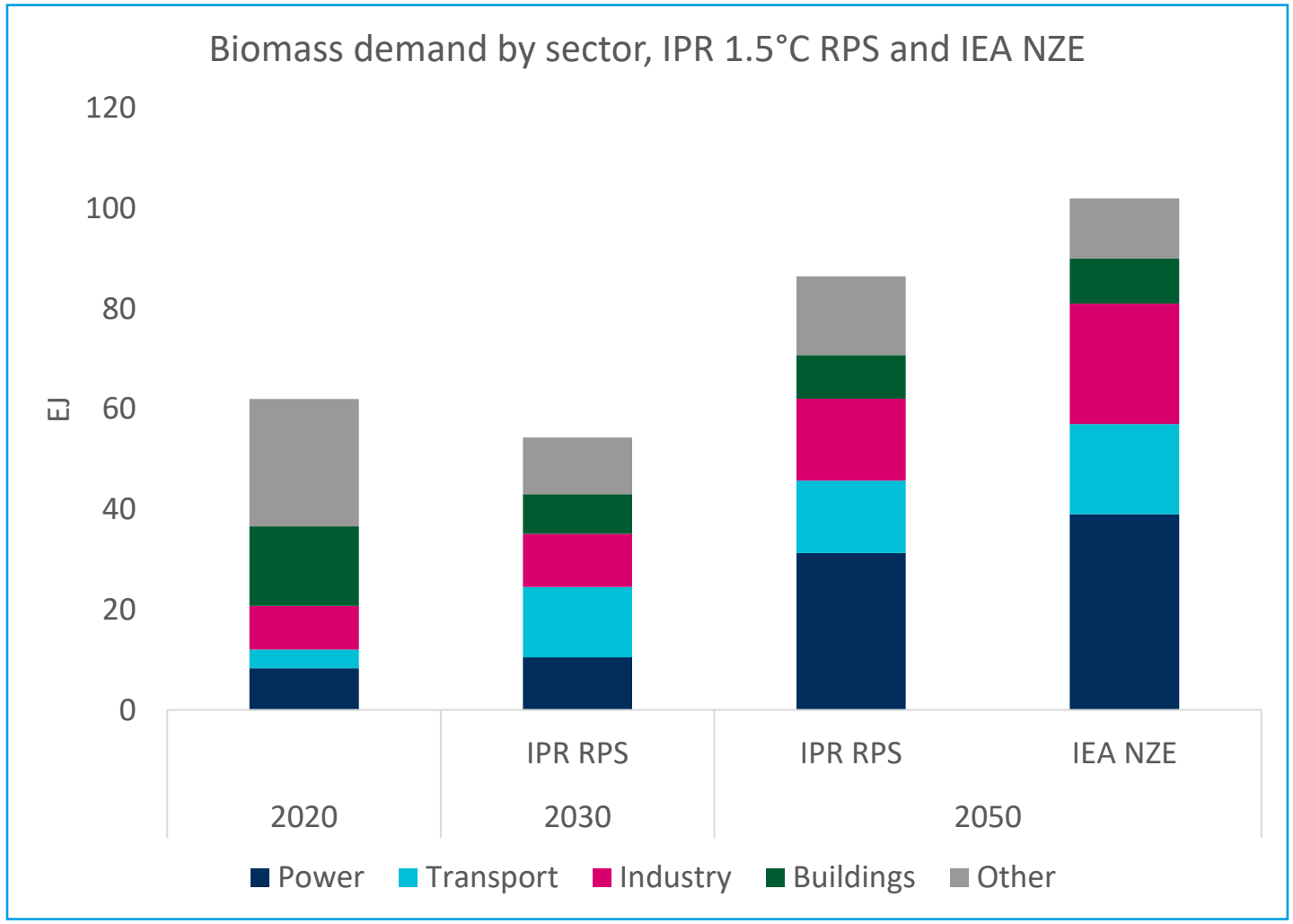
Biomass demand grows substantially, though remains below levels seen in the IEA's Net Zero Emissions Scenario



- Biomass demand falls to 2030 as traditional biomass is phased out, before growing over 60% to around 85 EJ between 2030 and 2050
- In contrast, biomass demand in IEA SDS rises to just over 100 EJ
- Biomass demand plays a comparable role to that in IEA SDS in power, transport, industry and buildings, albeit at somewhat lower overall volumes

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Power and hydrogen

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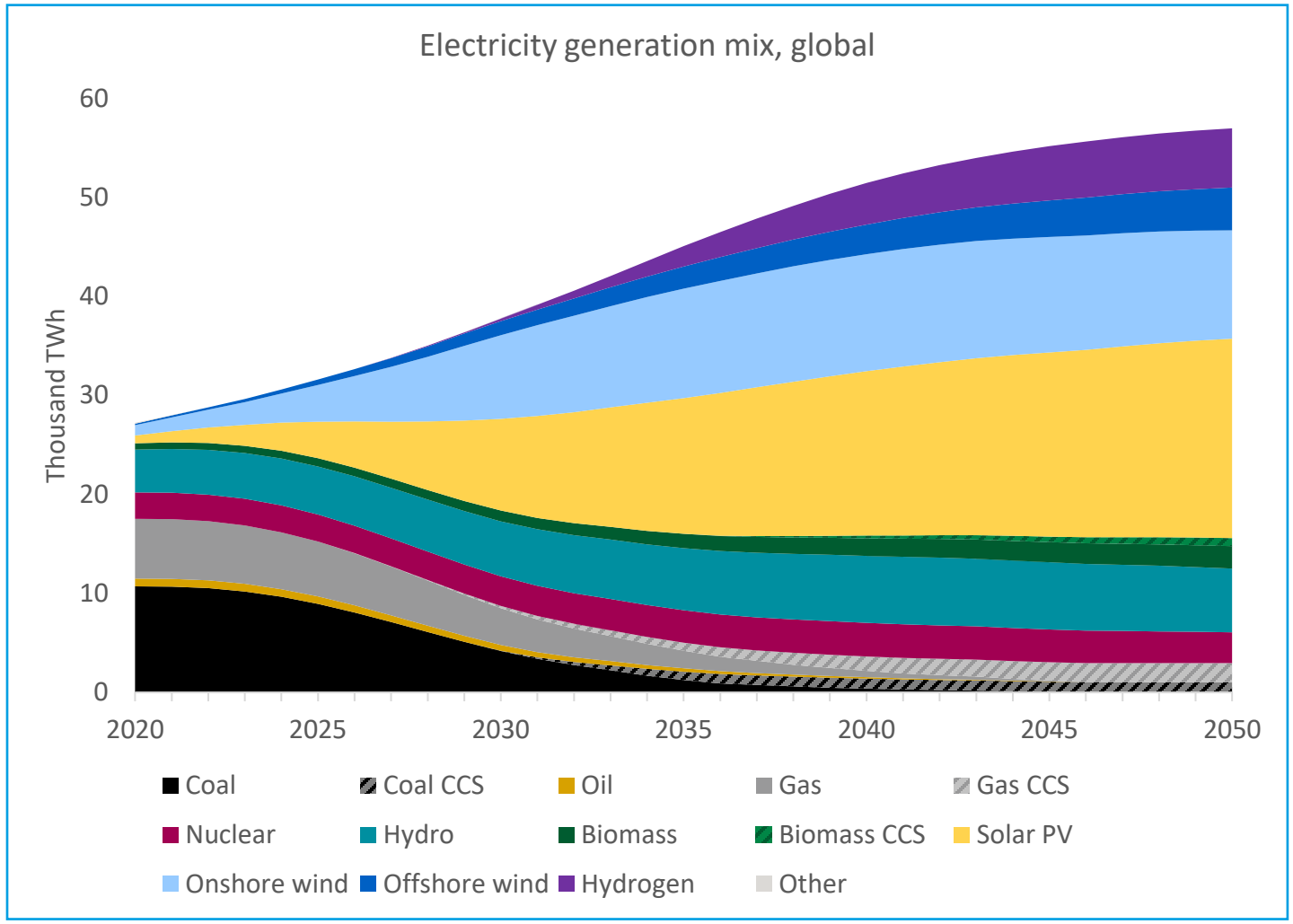
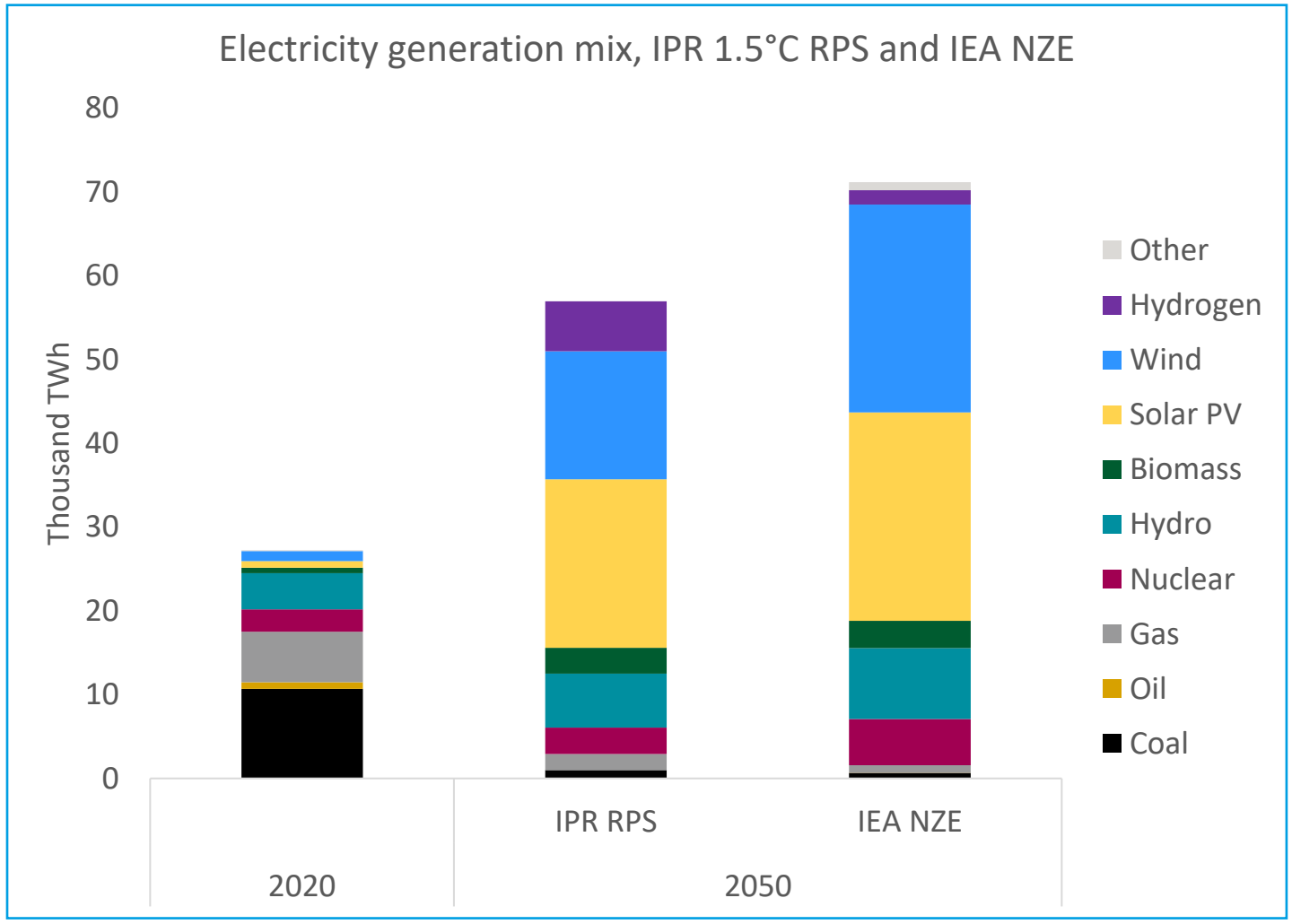
Electricity is fully decarbonised from 2045, with renewables accounting for almost 80% of generation



- Fossil generation falls from around 65% of the mix in 2020 to 25% in 2030 and under 5% by 2050. By 2050, CCS accounts for all remaining fossil fuel use
- Wind and solar grow from under 10% of the mix in 2020 to over 50% in 2030 and over 60% in 2050
- Including biomass and hydro, renewables account for almost 80% of generation by 2050
- From 2030, hydrogen emerges as an important balancing technology
- From 2045, all generation is low-carbon

INEVITABLE POLICY RESPONSE

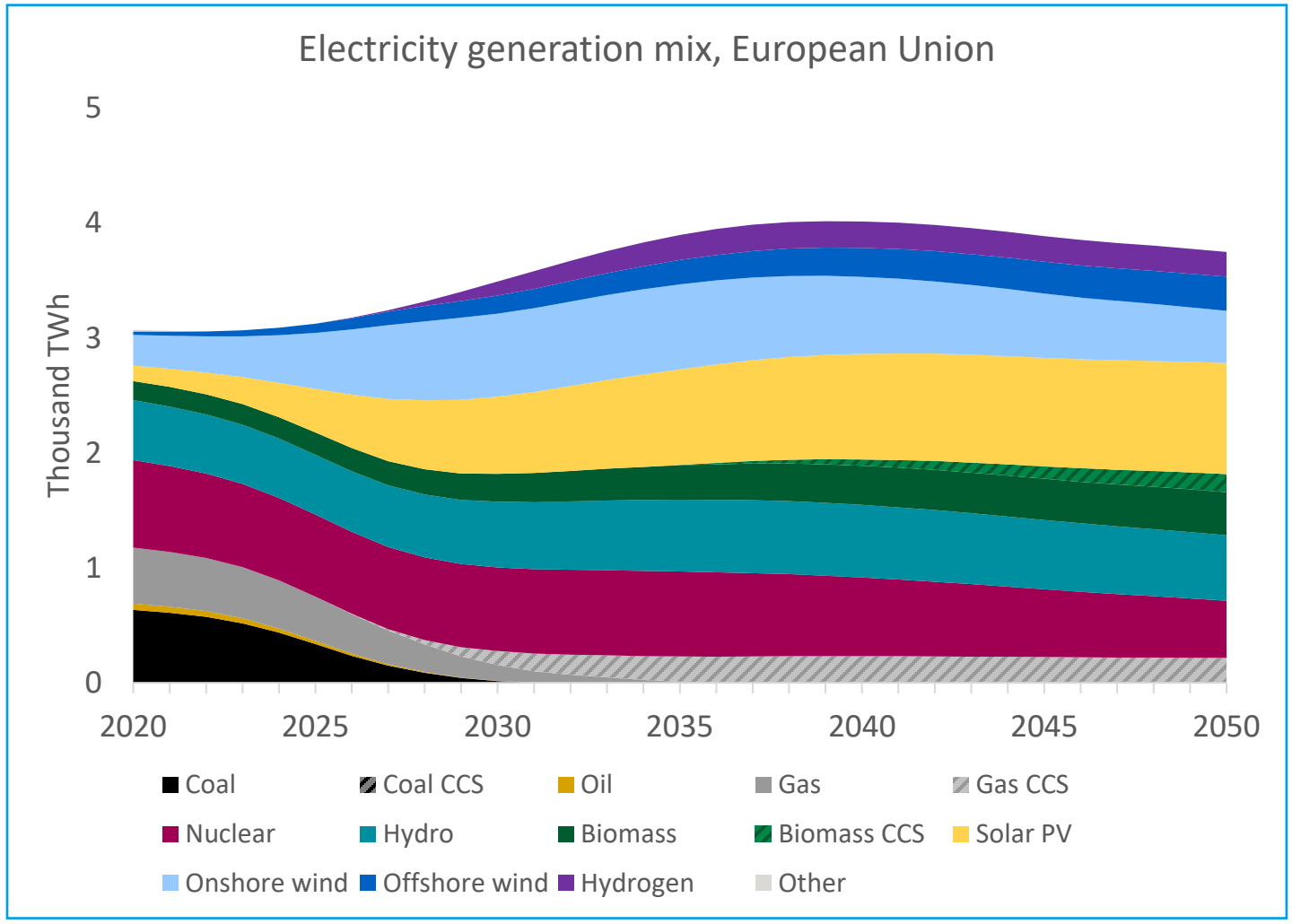
IPR RPS has a similar generation mix to IEA NZE, though with higher levels of hydrogen



- Electricity generation grows substantially in both IPR RPS and IEA NZE, as economic growth and electrification of heat and transport drive greater electricity demand
- The generation mix in both scenarios is comparable, with a large reduction in coal, oil and gas; and a large increase in low-carbon generation
- Wind and solar account for the majority of generation by 2050 in both scenarios
- Hydrogen plays a bigger role in IPR RPS, accounting for 10% of generation

Note: electricity generation in IPR RPS represents grid electricity only; in IEA NZE it may include electricity for hydrogen production

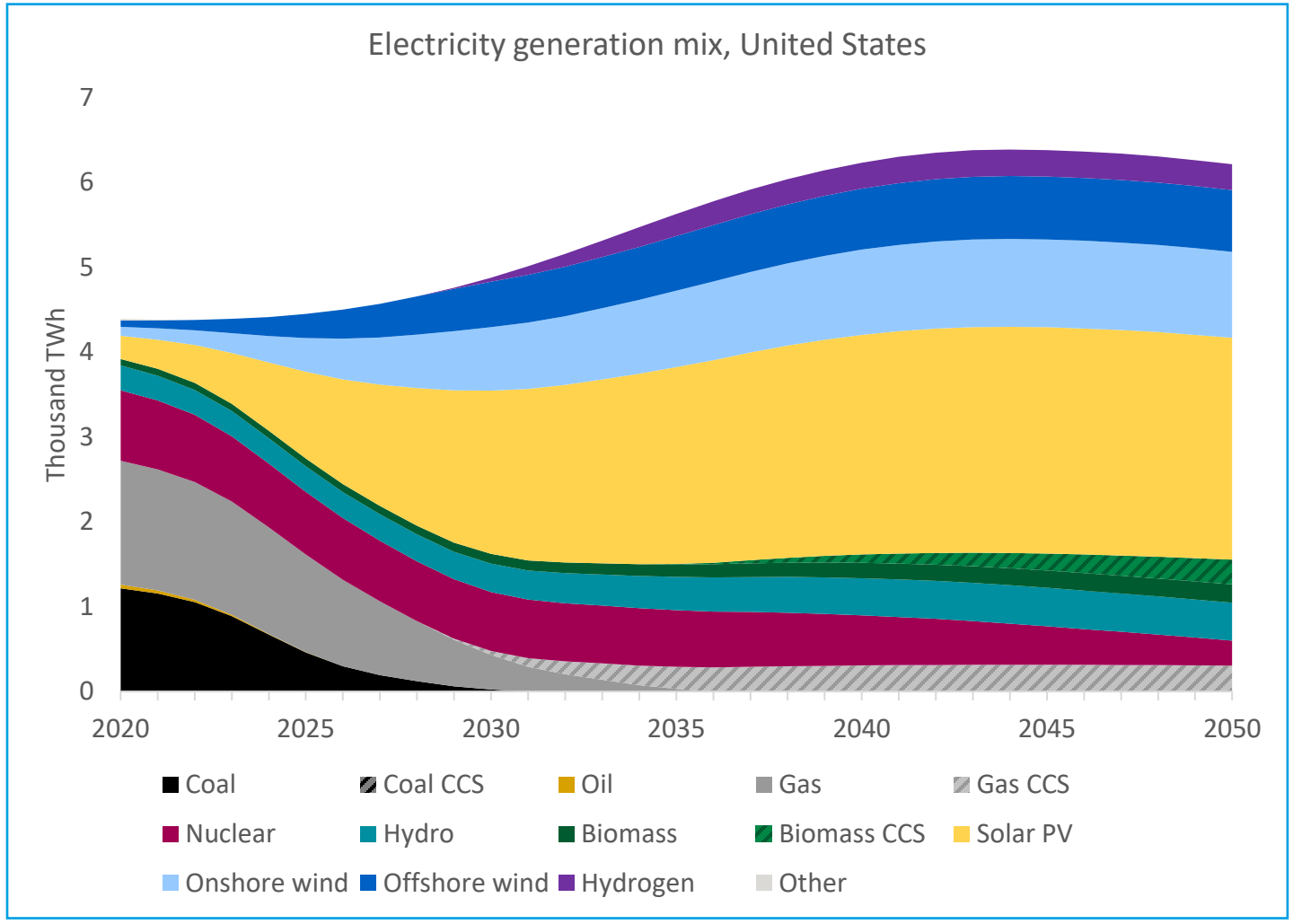
The European Union achieves 100% clean power by 2035 through a portfolio of low-carbon generation technologies



- The EU achieves its RPS policy objective of a coal phase out by 2030 and 100% clean power by 2035
- Fossil generation falls from around 40% of the mix in 2020 to under 10% in 2030 and around 5% by 2050; by 2035, gas CCS accounts for all remaining fossil generation
- Wind and solar grow from around 15% of the mix in 2020 to around 45% in 2030 beyond
- The share of hydro and nuclear declines from around 40% of the mix in 2020 to 30% in 2050, though these technologies continue to play an important role

INEVITABLE POLICY RESPONSE

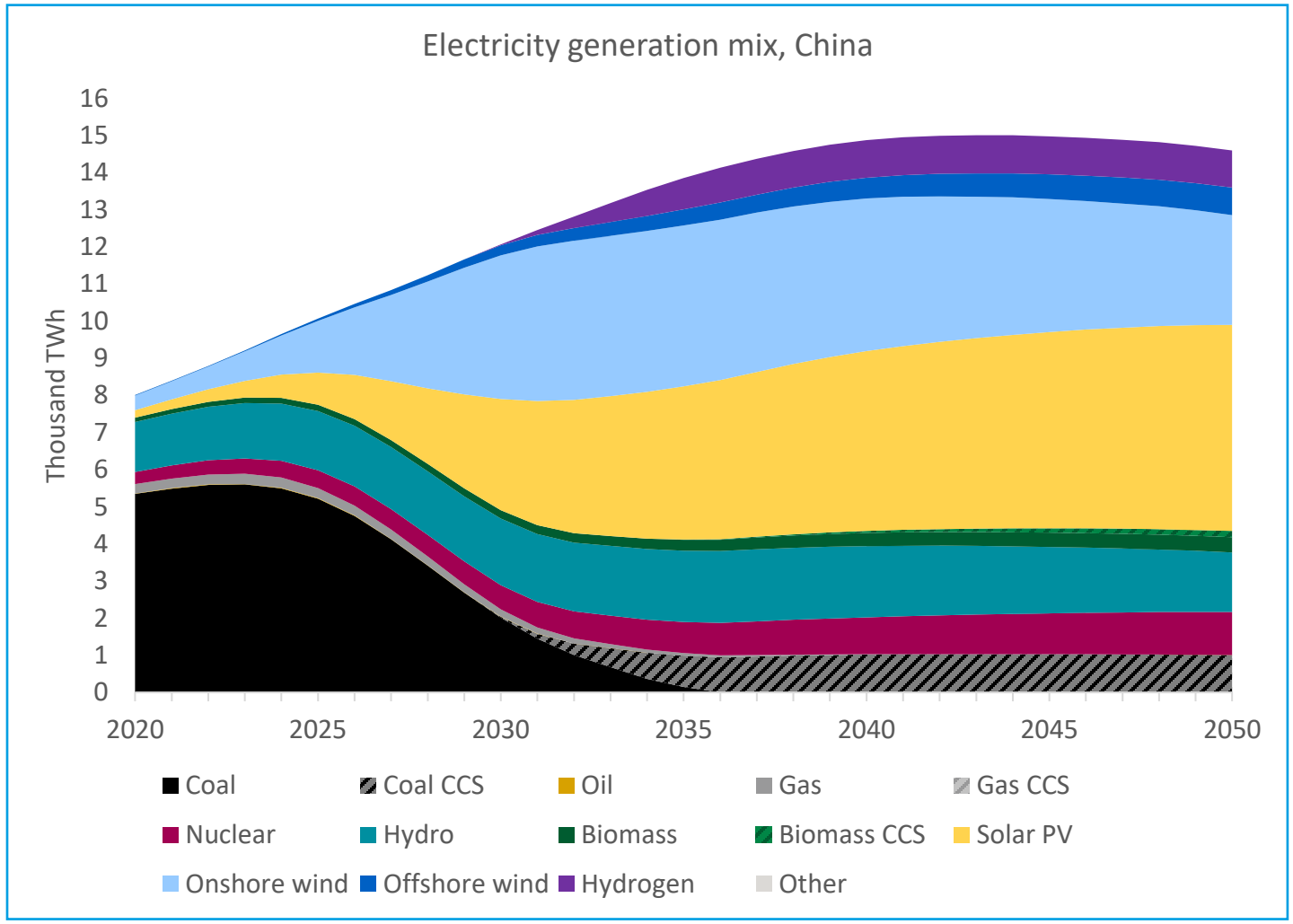
The United States achieves 100% clean power by 2035, with wind and solar providing the majority of power generation from 2030



- The USA phases out coal generation by 2030 and achieves 100% clean power by 2035
- Fossil generation falls from around 60% of the mix in 2020 to 10% in 2030 and around 5% by 2050; by 2035, gas CCS accounts for all remaining fossil generation
- Wind and solar grow from around 10% of the mix in 2020 to over 60% in 2030 and over 70% in 2050

INEVITABLE POLICY RESPONSE

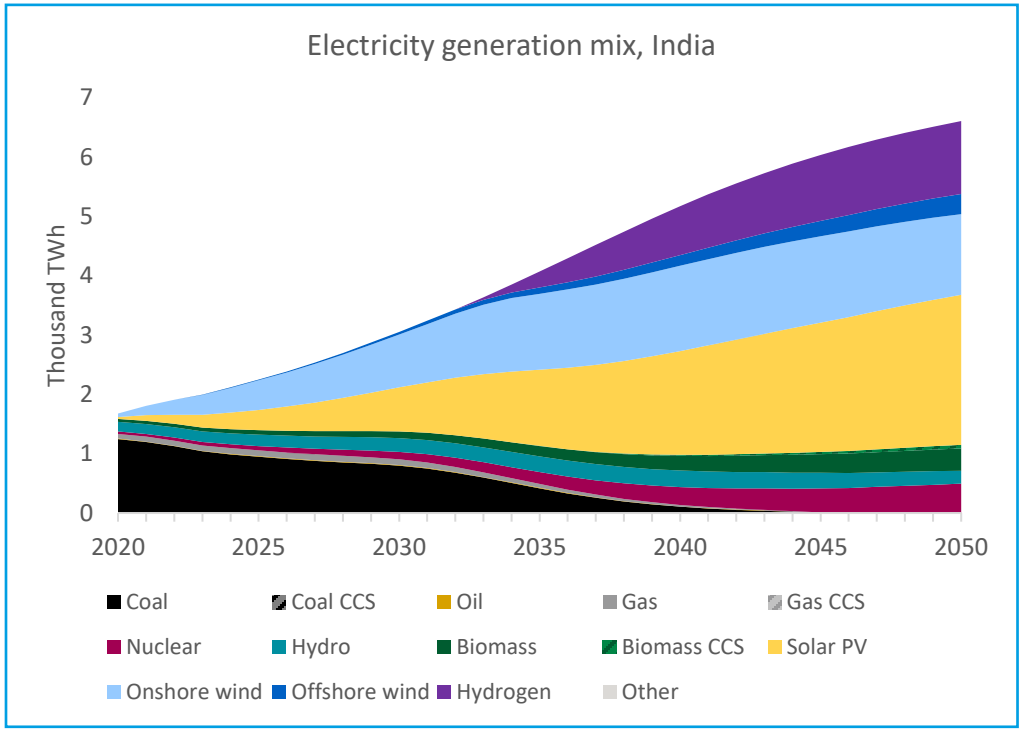
China achieves 100% clean power by 2040, with CCS retrofit used to decarbonise remaining coal generation

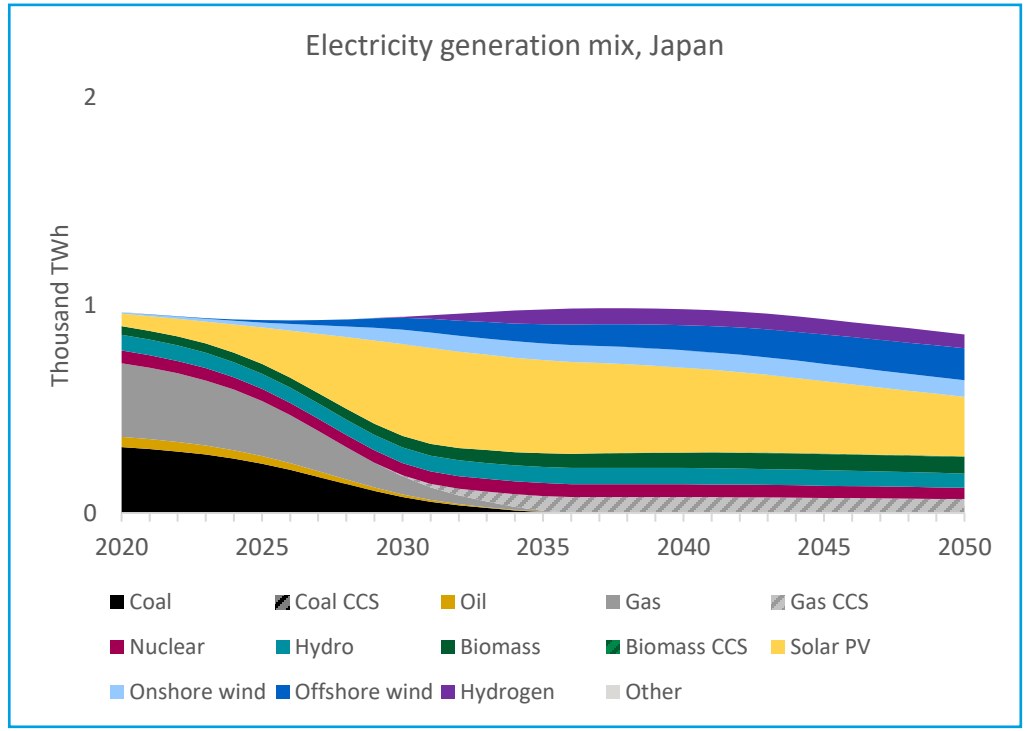


- China phases out unabated coal generation by 2035 and achieves 100% clean power by 2040
- Coal generation falls rapidly to 2030 and beyond; coal generation falls from around 70% of the mix in 2020 to around 15% in 2030 and less than 10% by 2050
- From 2035, all remaining coal generation is retrofitted with CCS
- Wind and solar grow from under 10% of the mix in 2020 to around 60% and beyond
- Hydro and nuclear continue to play an important role, accounting for around 20% of the mix between 2020 and 2050

INEVITABLE POLICY RESPONSE

Generation mix, India and Japan



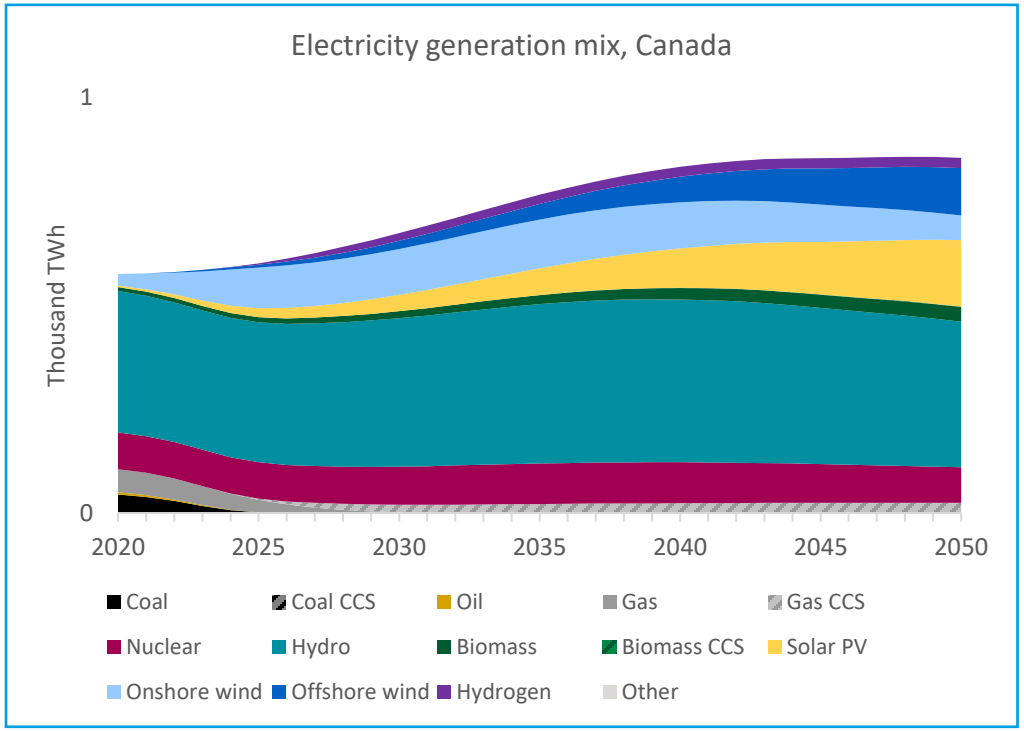


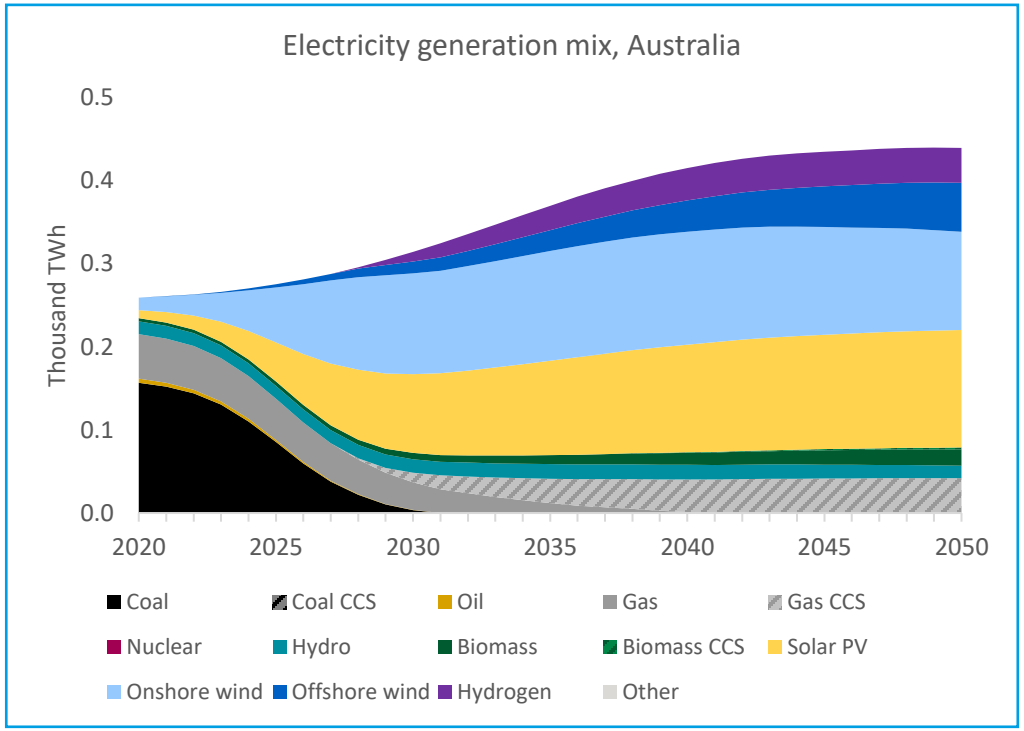
- India phases out unabated coal generation and achieves 100% clean power by 2045
- Wind and solar grow from around 5% of the mix in 2020 to around 55% in 2030 and 65% in 2050

- Japan phases out unabated coal generation and achieves 100% clean power by 2035
- Wind and solar grow from under 10% of the mix in 2020 to around 60% in 2030 and beyond; offshore wind plays an important role due to land constraints

INEVITABLE POLICY RESPONSE

Generation mix, Canada and Australia



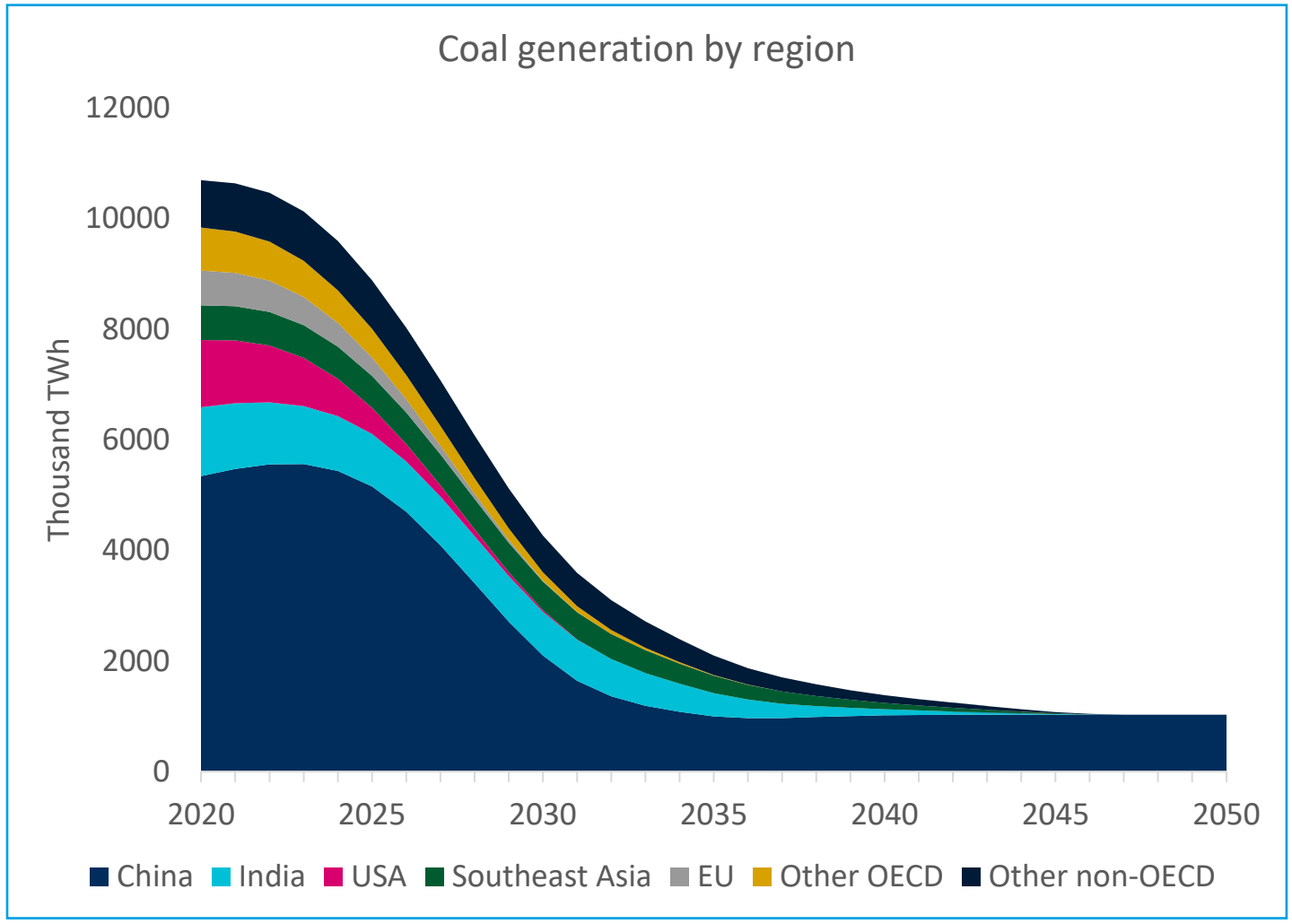


- Canada phases out unabated coal generation by 2025 and achieves 100% clean power by 2030
- Hydro continues to play a major role in the mix, though its share falls from around 60% in 2020 to 40% in 2050
- Wind and solar provide the majority of demand growth, and account for 40% of the mix in 2050

- Australia phases out unabated coal generation by 2030 and achieves 100% clean power by 2040
- Wind and solar grow from around 10% of the mix in 2020 to 75% in 2030 and beyond

INEVITABLE POLICY RESPONSE

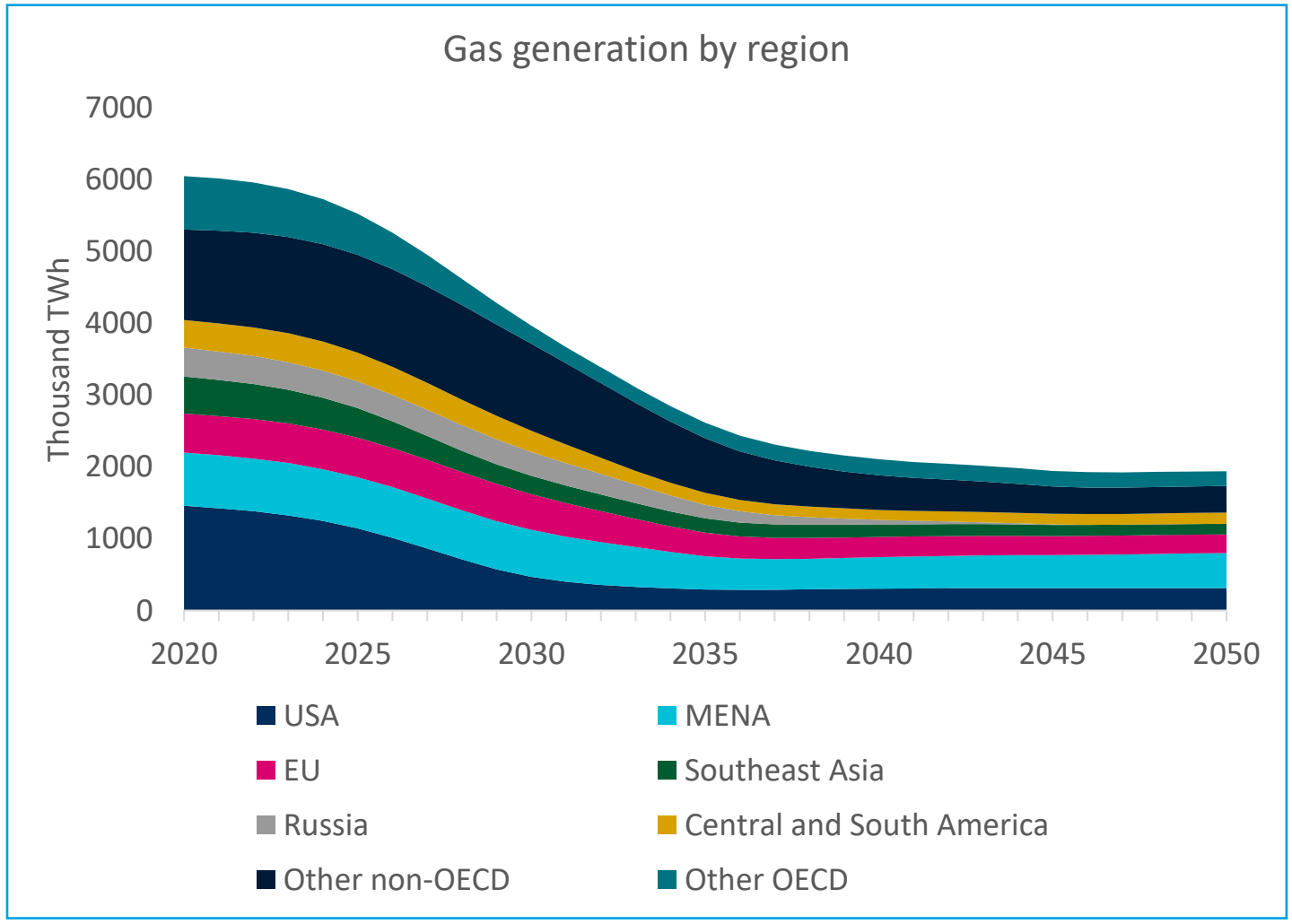
Coal-fired power generation declines around 80% to 2050, with non-OECD countries accounting for all coal generation post-2035



- Coal-fired power generation declines around 90% between 2020 and 2050
- Coal generation in the USA, EU and other OECD countries falls to zero by 2030-5 as they phase out unabated coal and rely on gas CCS and hydrogen for dispatchable low-carbon power. From 2035, all coal generation is located in non-OECD countries
- Coal generation in China falls over 80% between 2020 and 2050, driven by the phase out of unabated coal. From 2035, all residual coal generation in China is retrofitted with CCS and all unabated coal generation ends by 2045

Note: chart shows total coal, both with and without CCS

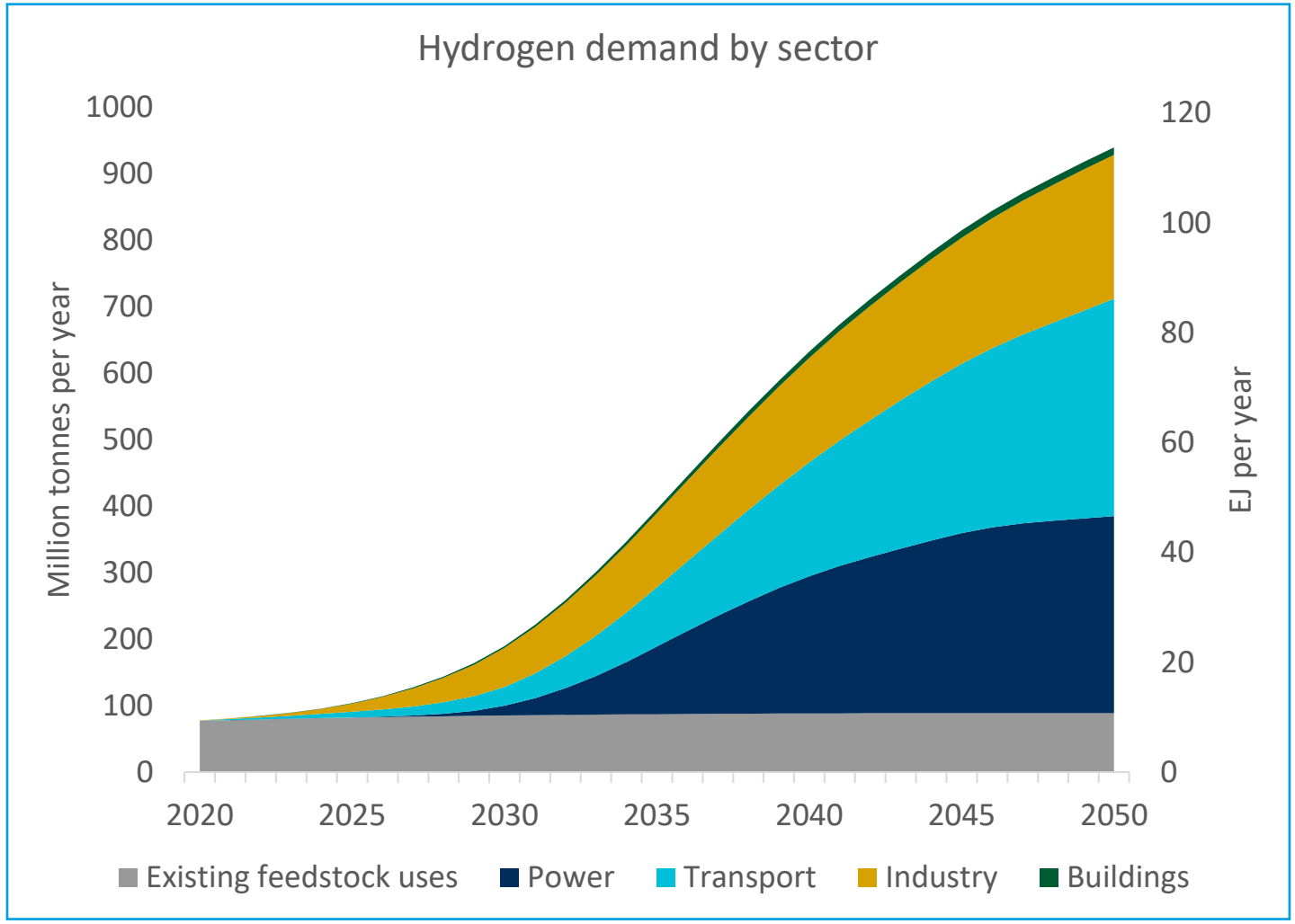
Gas-fired power generation declines around 50% to 2050, with non-OECD countries accounting for a growing majority of overall gas generation



- Gas-fired power generation declines around 70% between 2020 and 2050. By 2050 all gas generation is fitted with CCS
- Gas generation in the USA, EU and other OECD countries falls around 70% between 2020 and 2050 as they decarbonise their electricity systems
- Gas generation in MENA, Southeast Asia and other non-OECD regions falls around 65% over the same period, due to rising electricity demand and slightly longer to achieve power sector decarbonisation

INEVITABLE POLICY RESPONSE

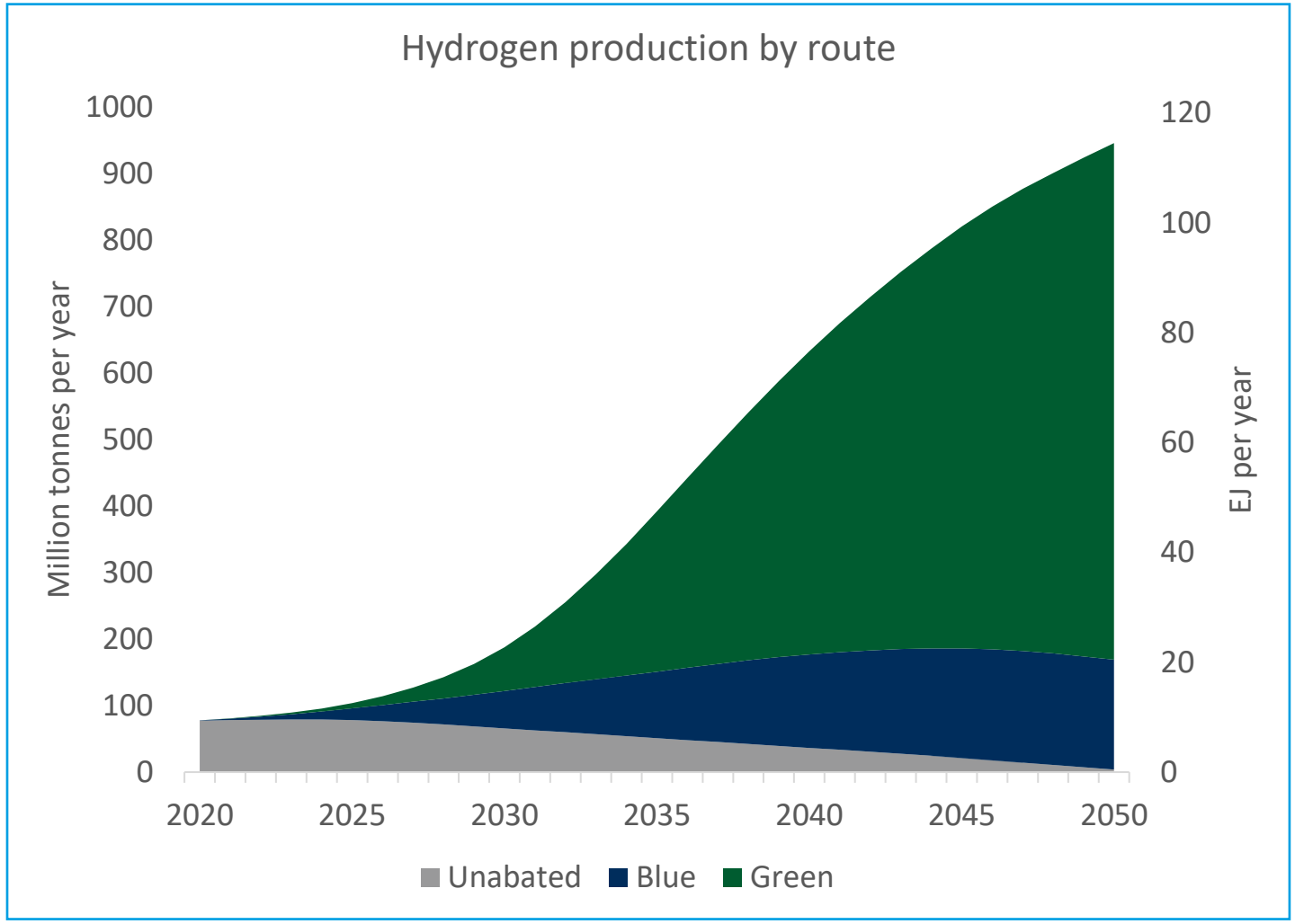
Hydrogen emerges as an important fuel in power, transport and industry, with around 20% of primary energy used for hydrogen production by 2050



- Hydrogen emerges as an important fuel across multiple sectors
- By 2050, transport accounts for the largest share of demand, with hydrogen used as a fuel in the road freight, aviation and shipping sectors
- In power, hydrogen plays an important role in balancing supply and demand
- In industry, hydrogen is used as a reducing agent in iron and steel production, and as an alternative to fossil fuels in generating high temperature heat in a range of industries
- In buildings, hydrogen plays a small role as a low-carbon heating fuel
- Overall, around 20% of primary energy demand is used to produce hydrogen

INEVITABLE POLICY RESPONSE

Green hydrogen dominates the hydrogen mix, though blue hydrogen plays an important early role in meeting overall low-carbon hydrogen demand



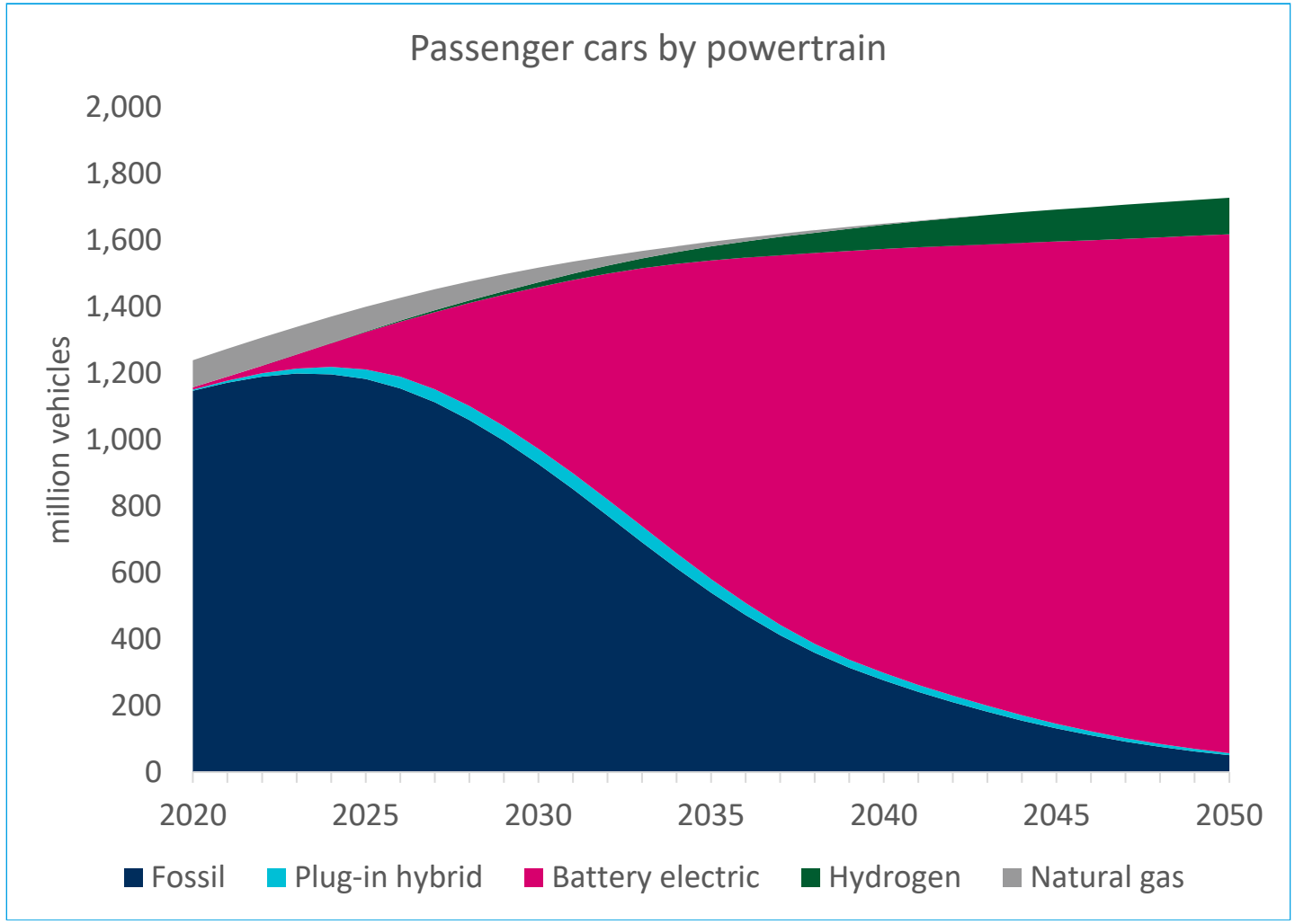
- As hydrogen demand grows to meet climate targets, the composition of hydrogen production shifts substantially
- Unabated hydrogen, the dominant form of hydrogen production today, is replaced by low-carbon (blue and green) hydrogen
- Low-carbon hydrogen accounts for around 25% of total in 2030, and 95% by 2050
- Blue hydrogen plays a small but important role in meeting demand for low-carbon hydrogen as green hydrogen scales up
- Green hydrogen meets almost 60% of low-carbon hydrogen demand by 2030 and 85% by 2050

INEVITABLE POLICY RESPONSE

Transport, industry and buildings

INEVITABLE POLICY RESPONSE

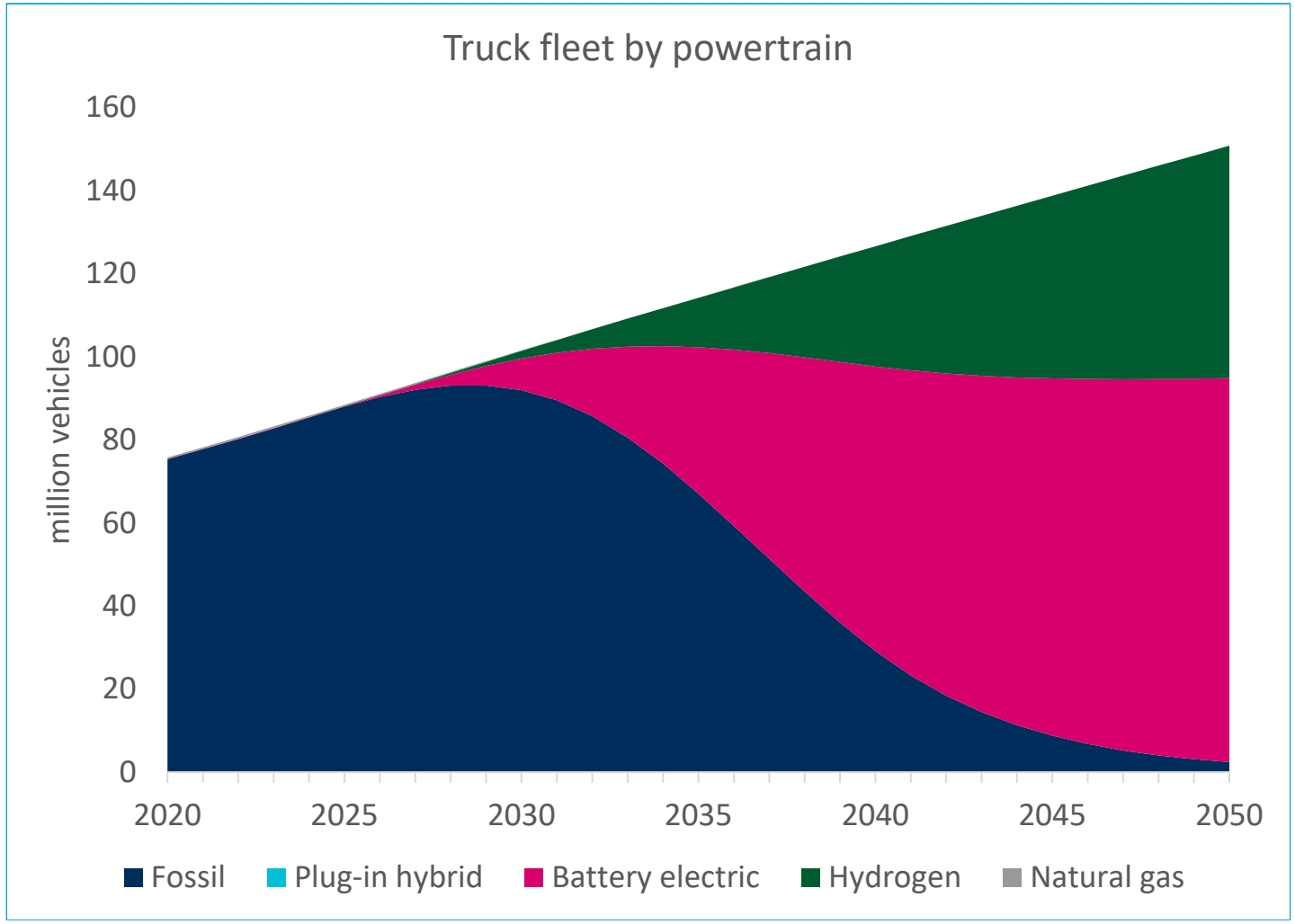
Electric vehicles quickly dominate in light duty vehicles, making up the majority of the vehicle fleet before 2035



- The share of fossil cars and vans in the fleet falls from almost 100% today to less than 65% in 2030, and near-zero by 2050
- In contrast, electrified cars and vans grow rapidly, to over 35% of the fleet by 2030 and almost 100% by 2050
- The majority of electrified vehicles are pure battery electric; however plug-in hybrid vehicles and later, hydrogen fuel cell vehicles gain some market share for market segments with large travel distances

INEVITABLE POLICY RESPONSE

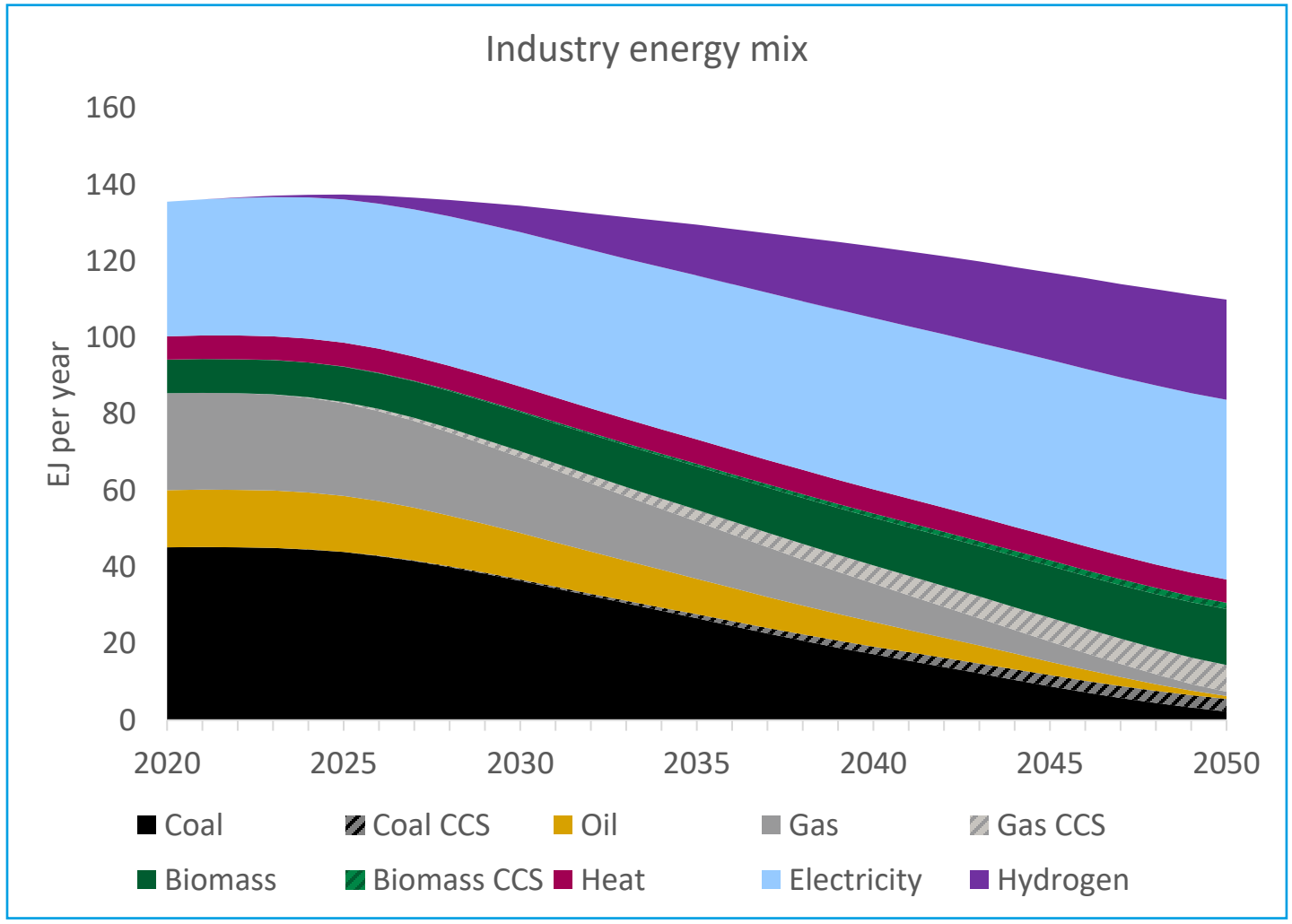
Zero emissions trucks emerge slightly later than light duty vehicles, though grow to dominate the fleet by 2040



- Development of low-carbon trucks and associated policies slightly lag passenger vehicles
- As a result, zero emissions trucks account for only 10% of the fleet by 2030, compared to over 35% for light duty vehicles
- However, due to rapid fleet turnover, the share of zero emission trucks grows substantially beyond 2030; these vehicles account for over 75% of the fleet by 2040 and almost 100% by 2050
- Hydrogen fuel cell vehicles play an important role, offering long distances required for the long-distance freight

INEVITABLE POLICY RESPONSE

In industry, fossil fuel use falls by over 80% and over 70% of fossil fuels are with CCS

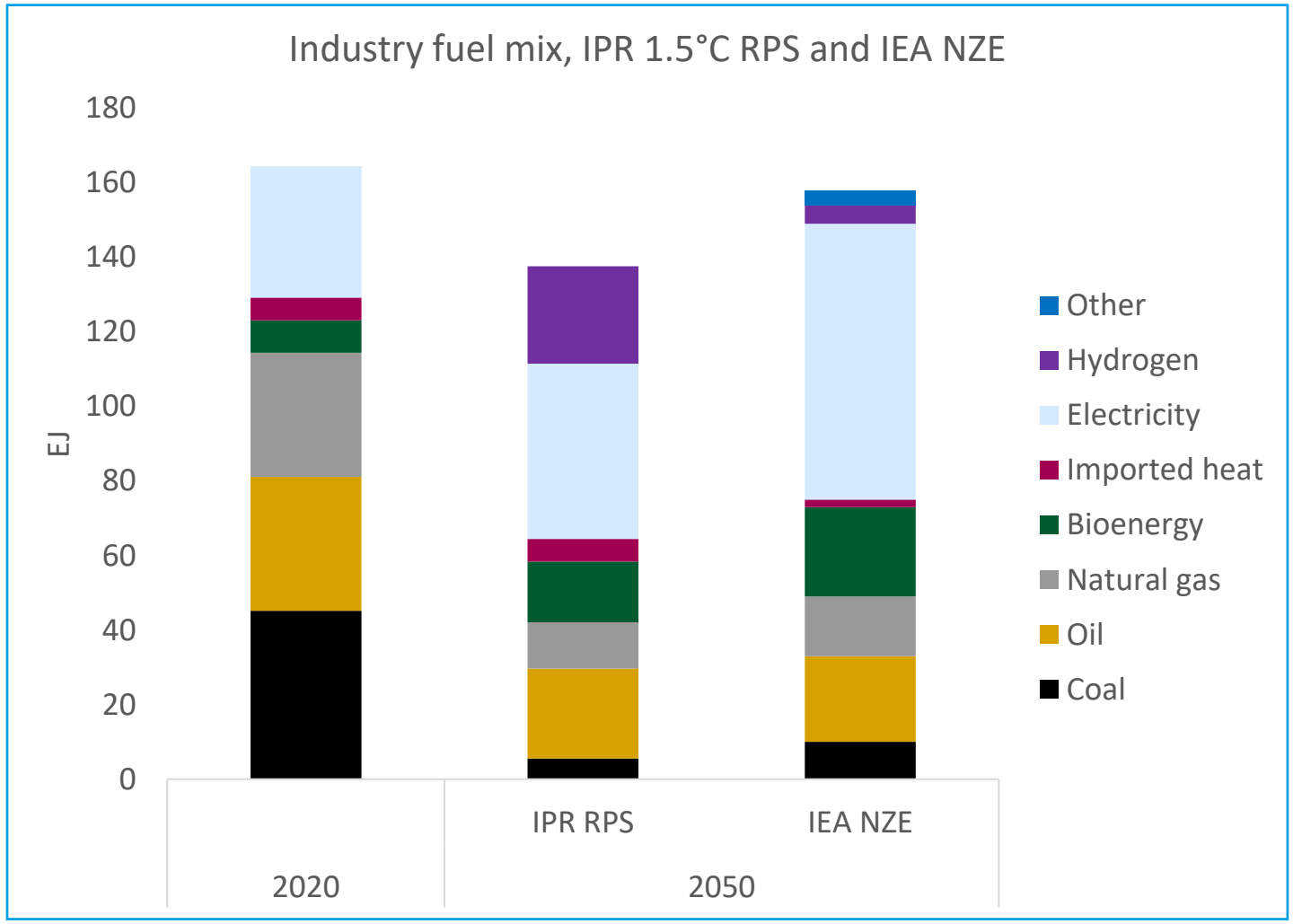


- Coal demand falls almost 90% by 2050. By 2050, around 60% of remaining coal is used with CCS, contributing to the decarbonisation of steel and cement production
- Oil use declines around 95%
- Gas demand falls around 70% over the same period, with around 85% of remaining gas used with CCS
- Electricity demand increases substantially as light industry electrifies
- Hydrogen emerges as the dominant steel production technology, and provides high temperature heat in the chemicals and other sectors

INEVITABLE POLICY RESPONSE

* Energy mix does not include coal, oil and gas used as chemicals feedstocks

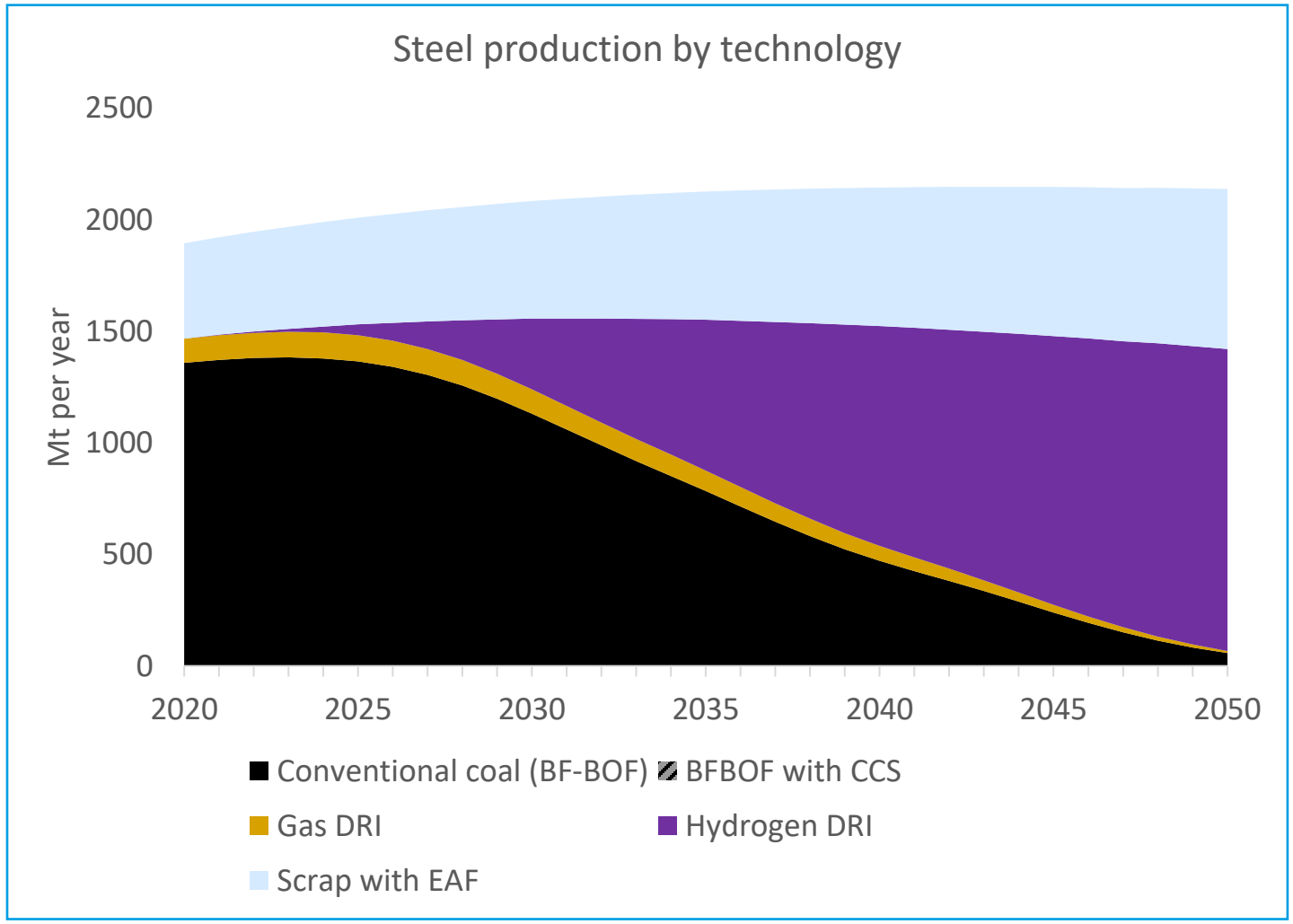
The industry energy mix is broadly similar in scale and composition between IPR RPS and IEA NZE



- Energy demand in industry falls around 15% between 2020 and 2050, compared with broadly similar energy demand in IEA NZE
- IEA NZE exhibits comparable energy demand to IPR FPS and IEA SDS. Energy demand in IPR RPS is lower than in FPS as a substantial share of the reduction in fossil fuels is driven by uptake of energy efficient heat pumps
- Demand for coal is around half levels of IEA NZE, due to more rapid displacement by hydrogen and electrification
- Demand for oil is broadly comparable, remaining substantial in both scenarios due to its use as a petrochemical feedstock
- Gas demand is broadly similar in both scenarios

* for comparability with IEA SDS, energy mix includes coal, oil and gas used as chemicals feedstocks

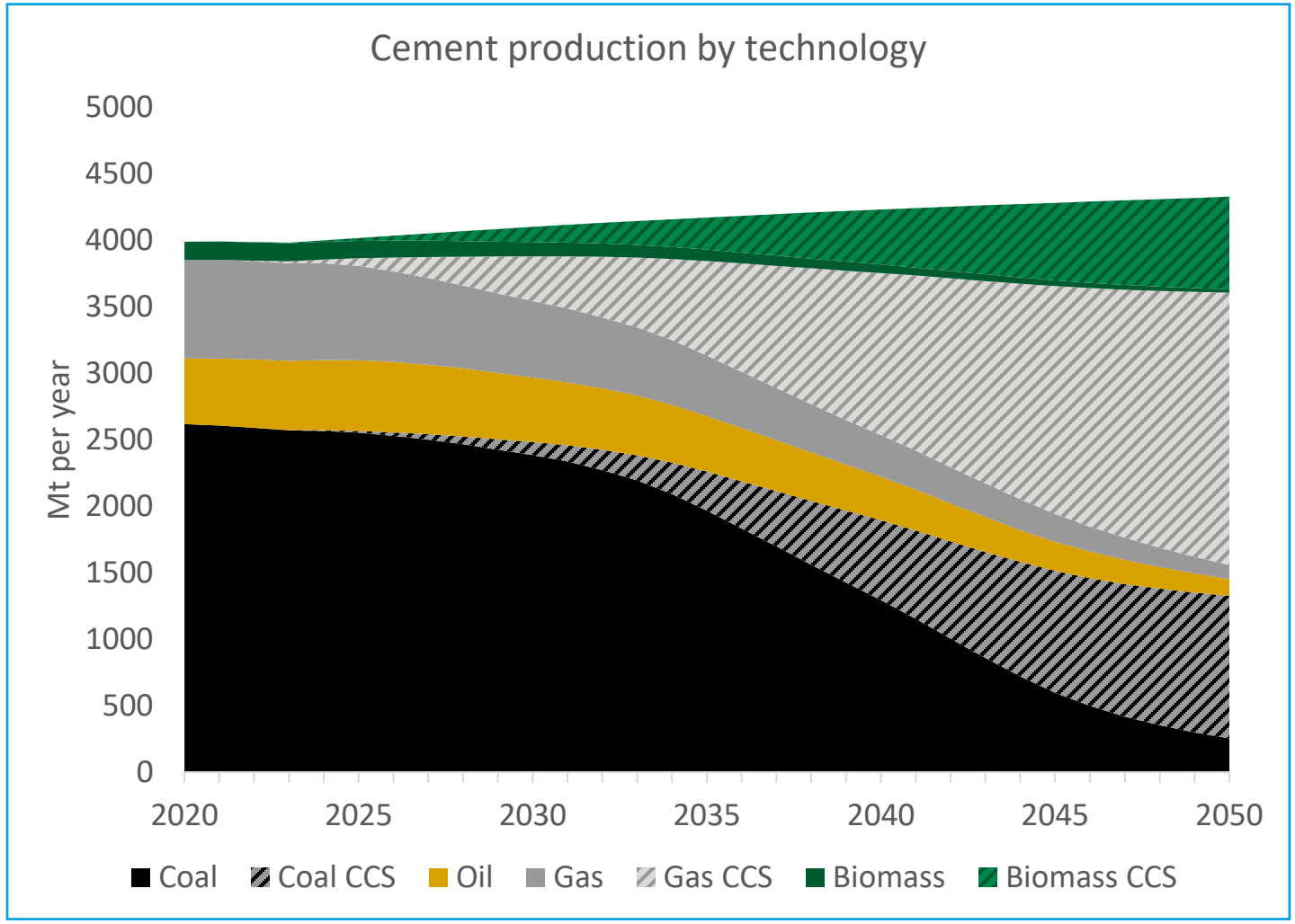
Hydrogen direct reduced iron (DRI) emerges as the dominant clean steel production technology, accounting for almost all virgin steel by 2050



- Conventional coal-based steel production falls by over 95% between 2020 and 2050
- Clean steel production using hydrogen direct reduced iron (DRI) rises rapidly after 2025, accounting for almost 45% of virgin steel production by 2035 and 95% by 2050

INEVITABLE POLICY RESPONSE

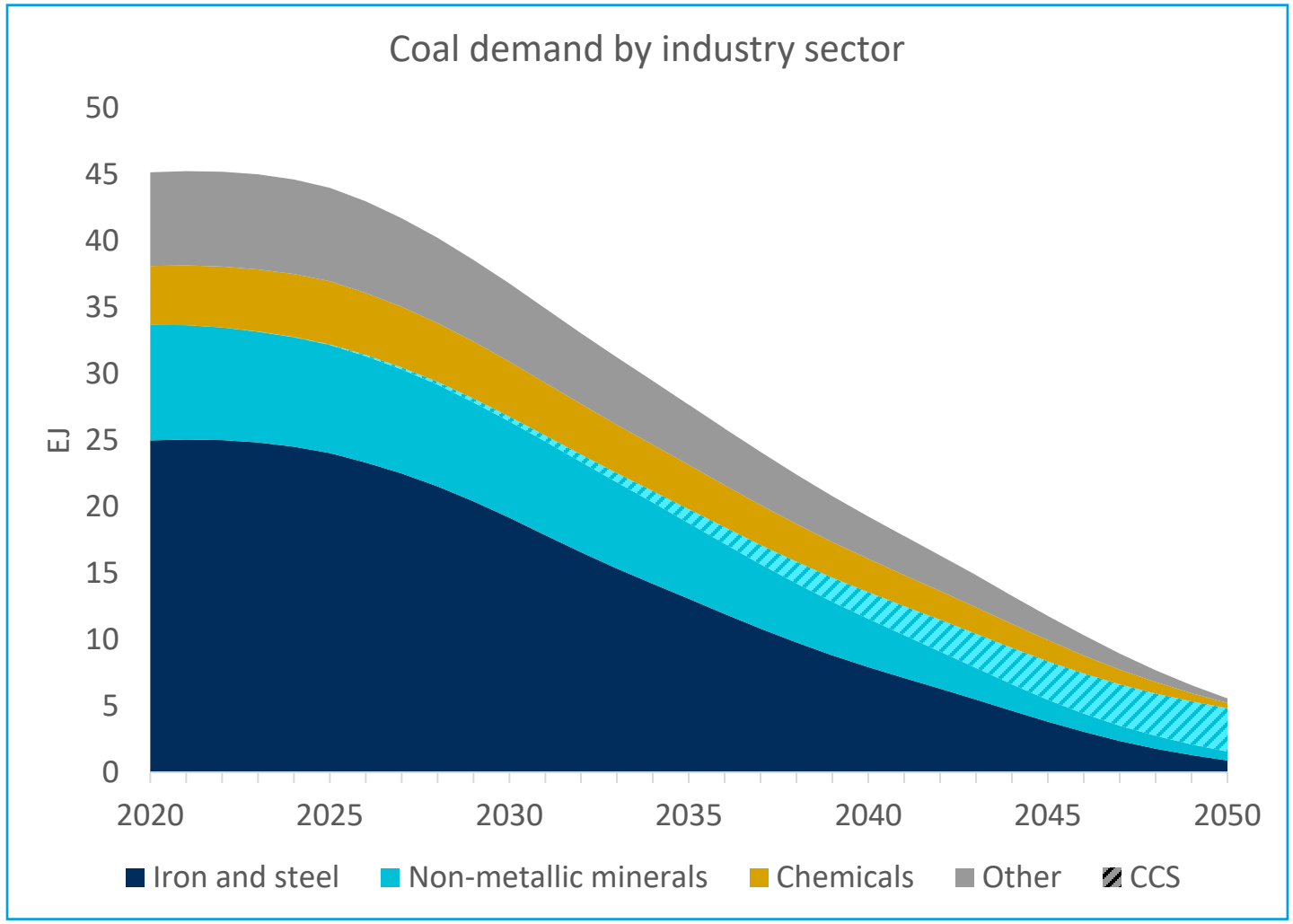
Carbon capture and storage is the primary solution to decarbonize the cement sector, capturing both combustion and process emissions



- Unabated fossil fuel based cement production falls by over 85% between 2020 and 2050; by 2050, unabated fossil fuels accounts for only around 10% of the production mix
- Over 70% of the mix is accounted for by fossil fuels with CCS. As industrial processes account for more than half of total emissions from cement, CCS is a vital technological solution in production of low-carbon cement
- Biomass with CCS accounts for around 15% of cement production, delivering negative emissions in addition to capturing process emissions

INEVITABLE POLICY RESPONSE

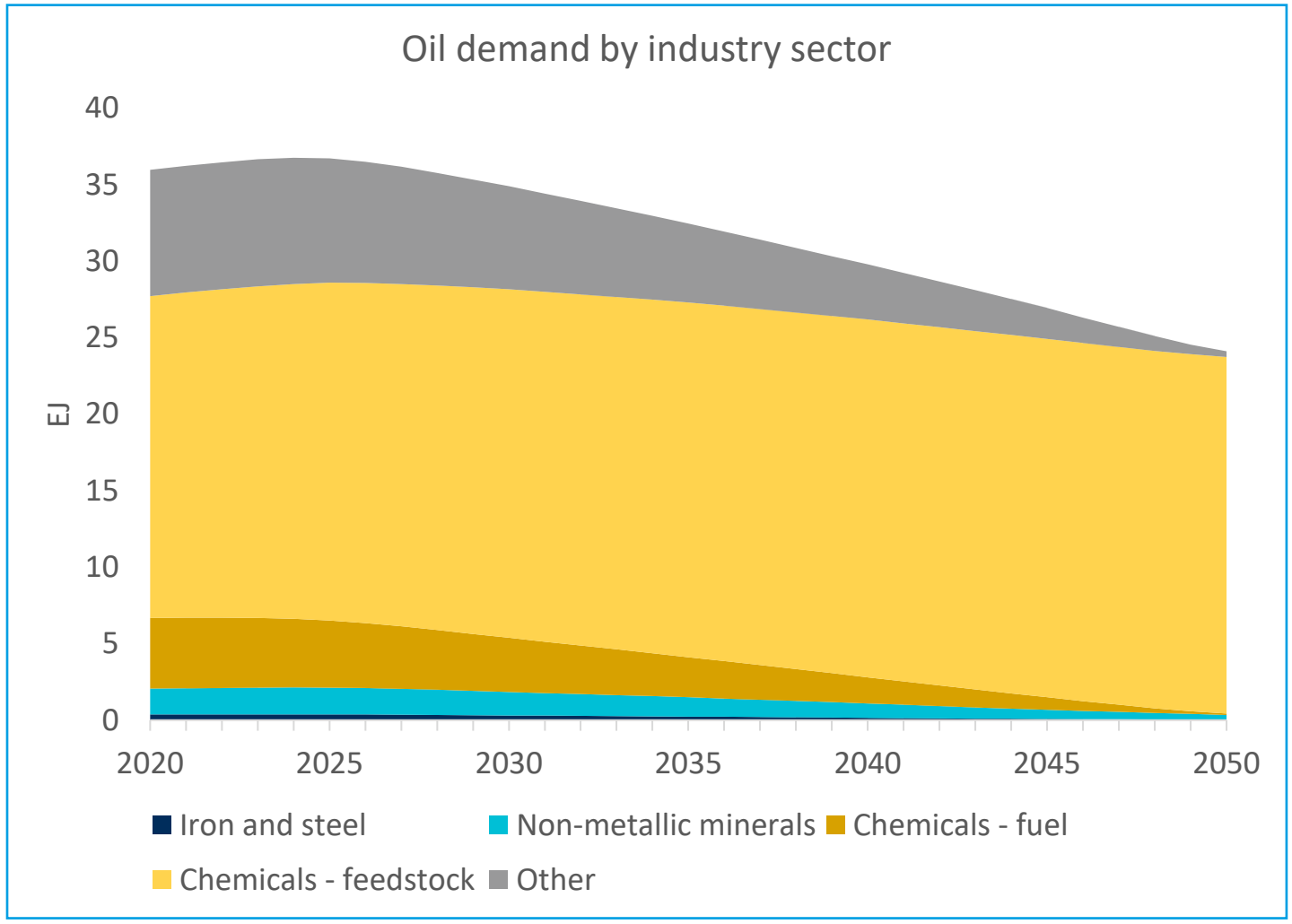
Coal demand falls very substantially in all industry sectors, with decarbonization of iron and steel driving the majority of the reduction



- Overall, coal demand falls around 90% 2020-50 as low-carbon production technologies displace it in most industry sectors
- Coal demand falls most rapidly in iron and steel, decreasing by over 95% between 2020 and 2050 as production shifts to hydrogen over the period
- Demand falls more slowly in the non-metallic minerals sector, dominated by cement. Coal remains an important fuel in cement production, and coal CCS provides a solution to decarbonise both fuel and process emissions
- In chemicals and light industry, coal use declines by over 95% as electrification and hydrogen reduce the need for coal in these sectors

INEVITABLE POLICY RESPONSE

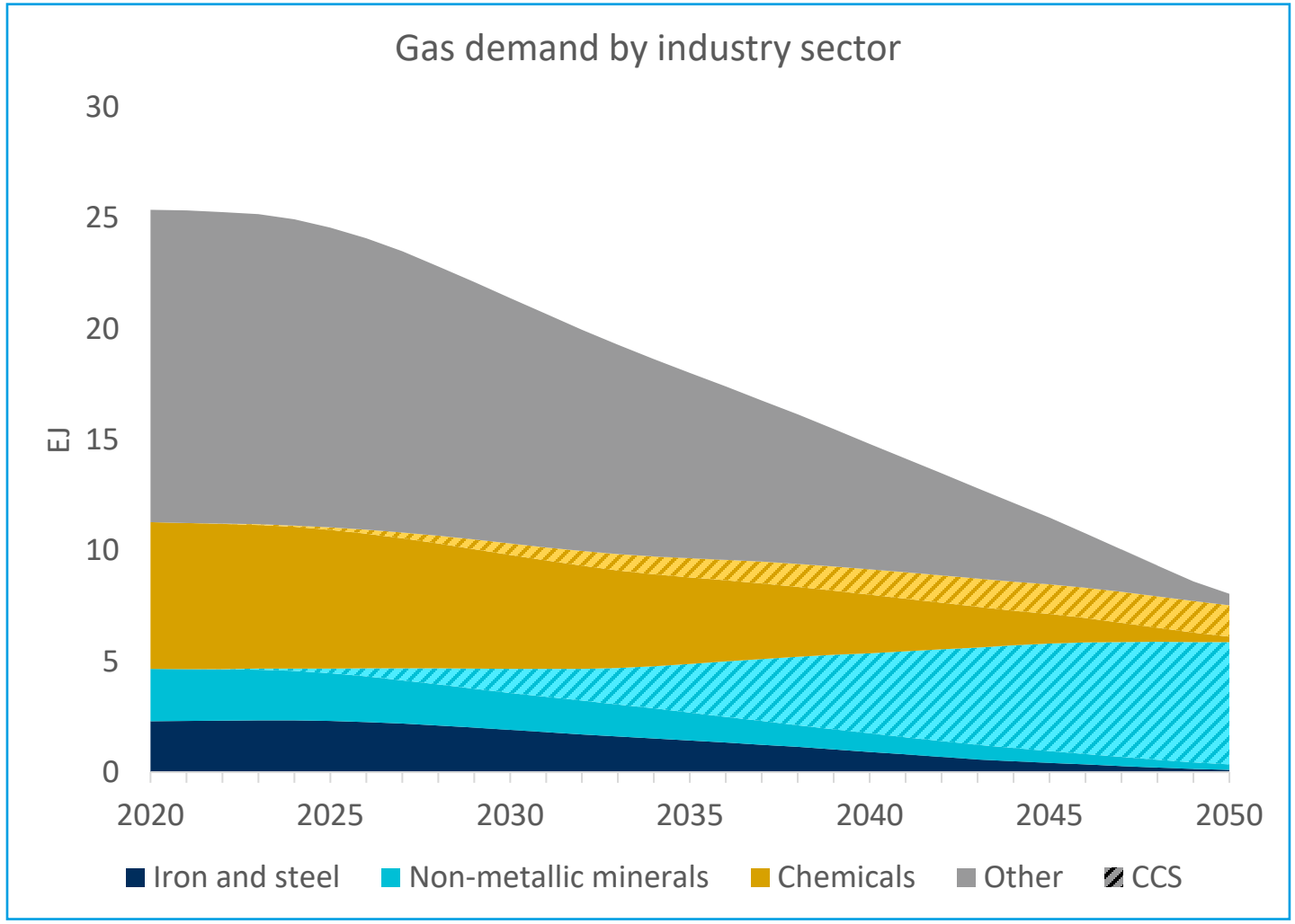
Oil demand in industry remains broadly flat, though it is used primarily as feedstock for chemicals where carbon is embedded



- Oil in industry is used primarily as a feedstock for chemicals, and as a fuel in light industry
- Use of oil as a fuel declines slightly to 2050 as electric and hydrogen heating replace it in many regions; but oil remains in use in countries without net zero targets
- Oil continues to be used as a feedstock for plastics and other high value chemicals, where the carbon is embedded
- Policy moderates but does not eliminate the growth in demand for plastics and other high value chemicals

INEVITABLE POLICY RESPONSE

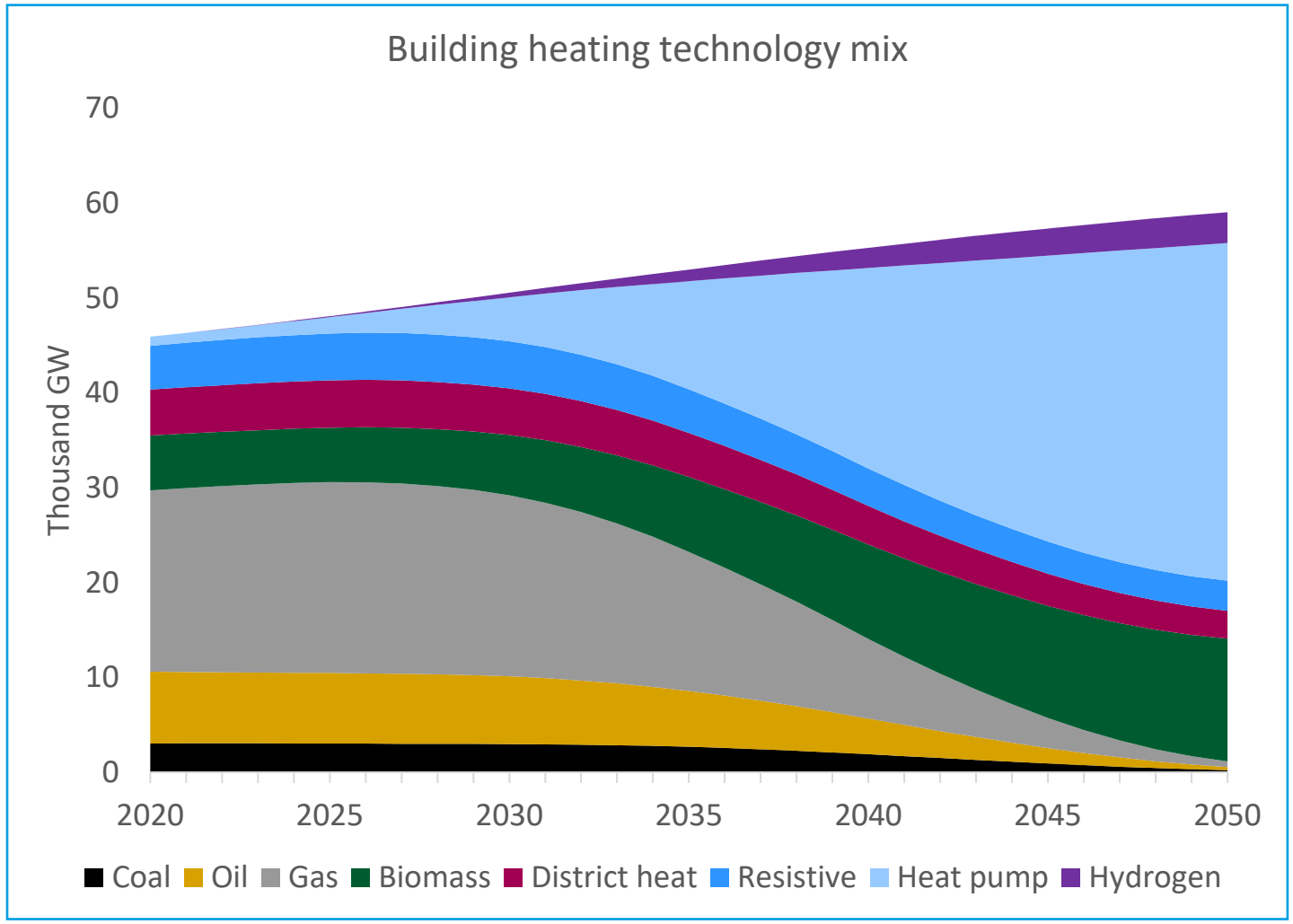
Gas demand in industry also falls substantially, though its use is sustained in the non-metallic minerals sector



- Gas demand falls around 80% 2020-50
- Gas is primarily used as a fuel in light industry and chemicals. Between 2020 and 2050 demand falls over 95% in light industry and 90% in chemicals as production shifts to electrification and hydrogen
- Gas demand grows in non-metallic minerals as some production shifts from coal to gas, and gas CCS provides a solution to decarbonise both fuel and process emissions

INEVITABLE POLICY RESPONSE

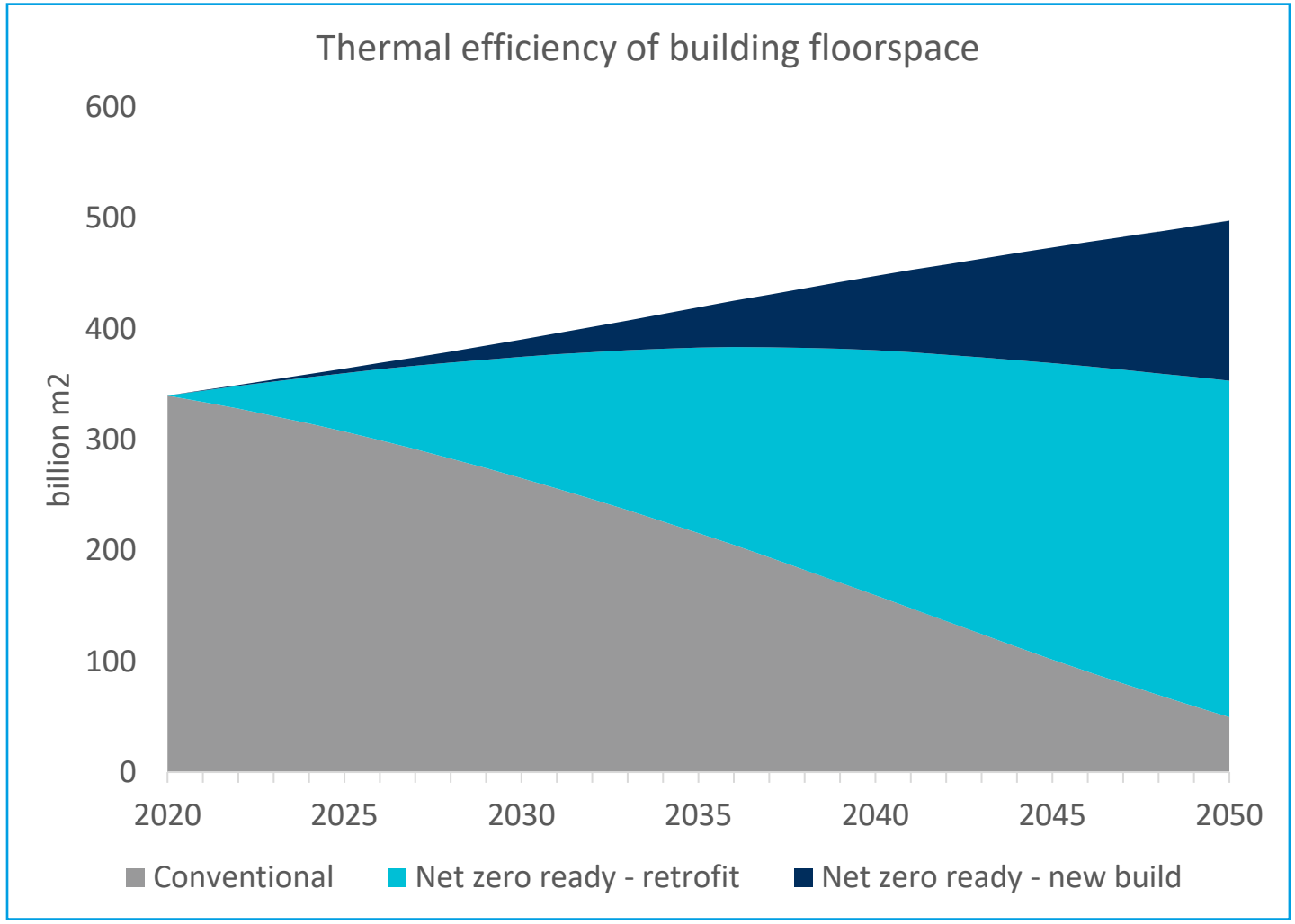
In buildings, electric heat pumps displace fossil heating systems to become the dominant heating technology by the mid-2040s



- Policy phases out new fossil heating systems between 2030 and 2040
- By 2050, almost all heating systems are low-carbon
- Driven by policy, heat pumps begin to dominate heating mix by the mid-2040s
- Hydrogen meets a share of heating demand in regions with an existing gas grid, and a less efficient building stock

INEVITABLE POLICY RESPONSE

Thermal efficiency of the building stock improves substantially between 2020 and 2050



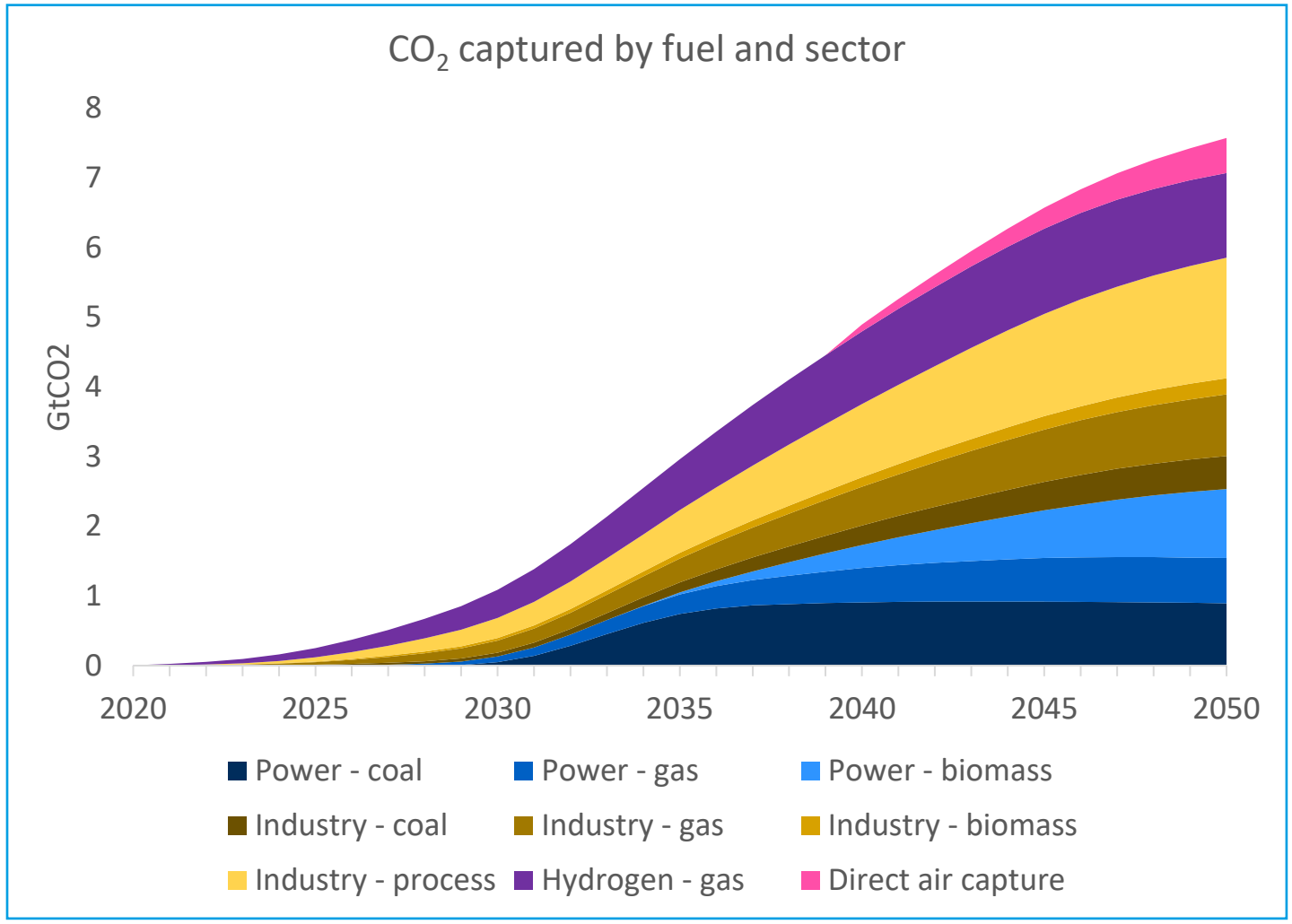
- Total building floorspace grows around 45% between 2020 and 2050
- A growing share of buildings are 'net zero ready', with high levels of thermal efficiency
- By 2050 around 30% of floorspace is in new buildings that are built net zero ready, while a further 60% is in buildings that are retrofit under energy efficiency policies

INEVITABLE POLICY RESPONSE

Carbon Capture and Storage (CCS)

INEVITABLE POLICY RESPONSE

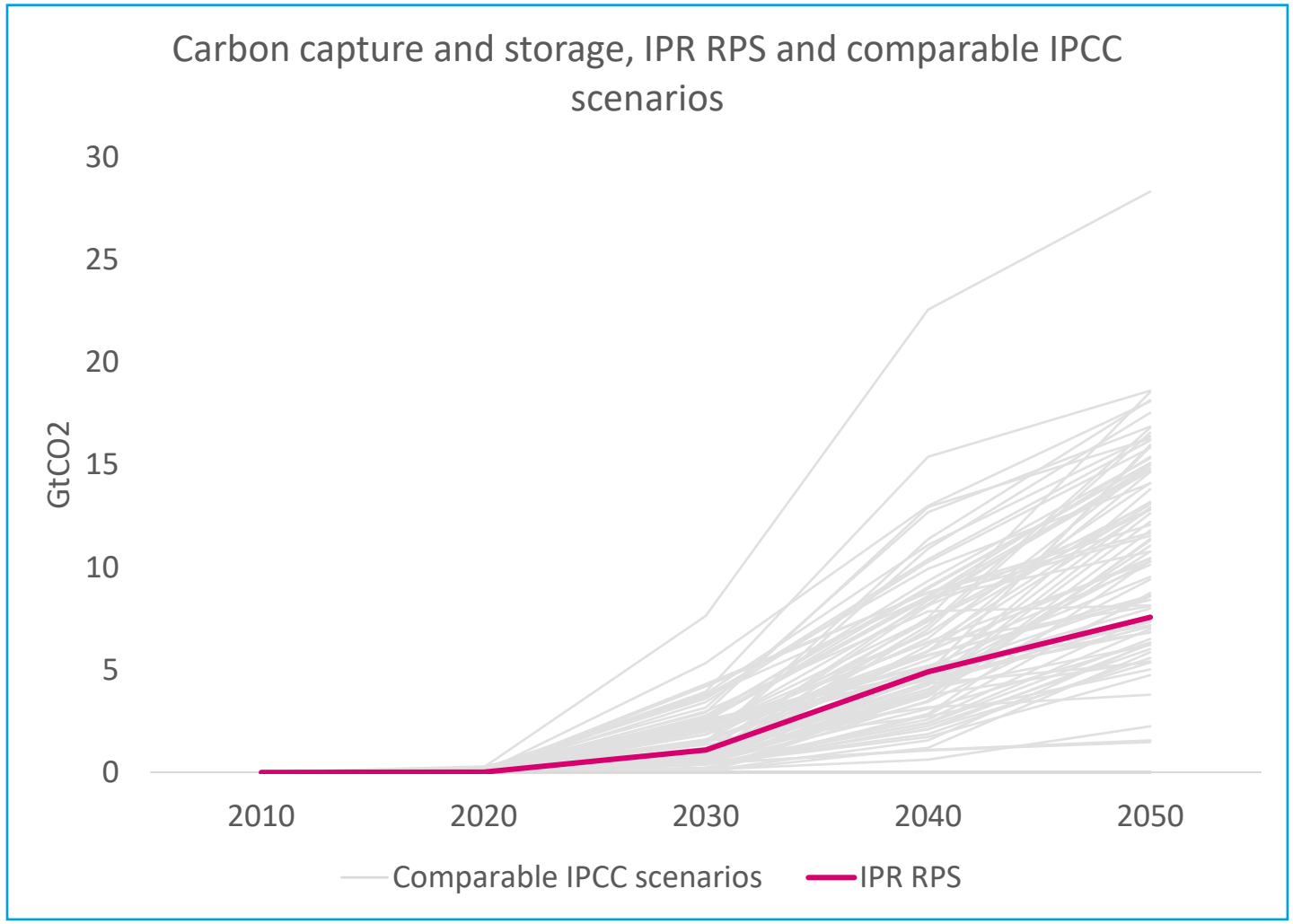
Carbon capture and storage (CCS) reduces emissions by around 7.5 $GtCO_2$ across energy sectors by 2050



- Overall around 7.5 $GtCO_2$ are captured and stored in 2050
- Of this, around 2.5 Gt is captured in the power sector, and 3.5 Gt in the industry sector, where process emissions are otherwise hard to reduce
- A further 1.2 Gt is captured in the production of blue hydrogen
- Finally, 0.5 Gt is captured through Direct Air Capture
- Of the total 7.5 Gt CCS, around 6 Gt of CO_2 is from fossil fuels or industrial processes, while around 1.5 Gt is from biomass or DAC, generating negative emissions

INEVITABLE POLICY RESPONSE

CCS Comparisons



- Almost all scenarios that achieve 1.5 degree climate outcome require CCS
- Across a range of 97 comparable IPCC scenarios (with temperature outcomes below 1.6 degrees), CCS captures between 1.5 and 28.5 $GtCO_2$ by 2050
- In IPR RPS, around 7.5 $GtCO_2$ are captured and stored in 2050, lower than levels in over 60% of comparable IPCC scenarios

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Thank you!

Please see PRI website for further details:

https://www.unpri.org/climate-change/what-is-the-inevitable-policy-response/4787.article

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INEVITABLE POLICY RESPONSE

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Appendix 1: Vivid Energy System Modelling (VESM) toolkit

The Vivid Energy Systems Model (VESM) toolkit covers the entire energy system allowing complex scenario analysis and development

Inputs

Energy demand

Housing/services:
- Lighting and appliances, heating, cooling

Commodity demand
- Iron/steel, cement, chemicals, light industry

Transport
- Passenger
- Freight

Technology

Energy production and transformation
- By sector
- By region
- By fuel
- Emissions profiles

Storage
- Batteries or hydrogen storage

Constraints

Physical constraints
- E.g. coal supply

Policy constraints
- E.g. ICE phase out

Technical constraints
- E.g. funding limits

Techno-economic analysis

Model type
- Global whole energy system model
- Calibrated to latest energy balances

Granularity
- 21 regions
- ~ 2,700 technologies

Time resolution
- 2015 to 2100 with annual resolution

Outputs

- Energy mix
- Discounted cost analysis
- Emissions accounting
- Investment portfolio

VESM is developed in OSeMOSYS - the Open Source Energy Modelling System (http://www.osemosys.org/)

INEVITABLE POLICY RESPONSE