INEVITABLE POLICY RESPONSE

The Inevitable Policy Response: Forecast Policy Scenario

Summary

Preparing financial markets for climate-related policy and regulatory risks

Consortium partners

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PRI Principles for Responsible Investment

:vivideconomics putting economics to good use

Energy Transition Advisors ETA

2° Investing Initiative

Carbon Tracker Initiative

Grantham Research Institute on Climate Change and the Environment

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THE FINANCE HUB

GORDON AND BETTY MOORE FOUNDATION

KR foundation

ClimateWorks FOUNDATION

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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
- 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

Contents page

- Executive summary
- The Forecast Policy Scenario (2020-2050)
- Land-use results
- Trend-constrained pathway
- Aspirational policies and technologies to bridge overshoot to reach 1.5°C
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Executive Summary - Overview

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Financial markets are underprepared for climate-related policy risks

A forceful policy response to climate change is not priced into today's markets.

Yet it is inevitable that governments will be forced to act more decisively than they have so far, leaving investor portfolios **exposed to significant risk.**

The longer the delay, the more disorderly, disruptive and abrupt the policy will inevitably be.

In anticipation, PRI, Vivid Economics and ETA are building a landmark forecast of the financial impact of this Inevitable Policy Response (IPR), including a Forecast Policy Scenario:

- How will it affect the economy?
- Which sectors are most at risk?
- Which asset classes will be impacted?

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Value-add of the IPR: **Forecast Policy Scenario (FPS)**

- **A high conviction policy-based forecast**, not a hypothetical scenario that optimises policy to meet a temperature constraint
- **Designed to be an alternative** to, for example, the IEA STEPS for business planning by corporations, investors and governments
- **Covers all regions of the world**, with specific policy forecasts for key countries and regions
- **Sets out the gap to 1.5°C** scenarios and how this might be filled by greater policy aspiration
- **Transparent**: on expectations for policy and deployment of key technologies, such as Negative Emission Technologies
- **Complete**: includes macroeconomic, energy system, and land use models linking crucial aspects of climate across the entire economy
- **Fully integrating land-use** to ensure the full system impacts of policies, and highlight the critical role of land use
- **Applicable to TCFD**: aligned forward-looking analyses

Later this year, the IPR will extend from macro and sector level results to portfolio and company level financial impacts to show investors the cost and impacts of this delayed, forceful and disruptive policy response forecast, and to make the case to ACT NOW and aspire to a more orderly transition to 1.5°C

We believe that any forecast will need to contain these elements. We welcome feedback on the forecasted policies and the results to enhance value-add and relevance on an ongoing basis.

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Growing awareness and momentum on climate issues makes a near-term, forceful policy response more likely

Extreme weather events

Impacts on security

The effects of a changing climate are **a national security issue.**

- US Dept. of Defense

Cheaper renewable energy

FINANCIAL TIMES

Europe 'watershed' as green energy set to overpower coal

JUNE 3, 2019

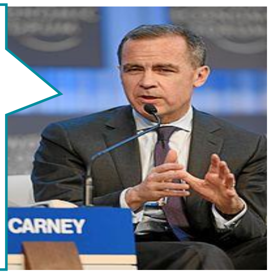
New climate research

Global warming report, an 'ear-splitting wake-up call' warns UN chief

Civil society action

Regulators warning on stability

The catastrophic effects of climate change are already visible around the world. We need collective leadership and action across countries, and we need to be ambitious.



Uninsurable World

Munich RE

"Climate change could make insurance too expensive for most people"

MOODY'S INVESTORS SERVICE

"Climate change risks outweigh opportunities for P&C (re)insurers"

Influence Shifting

FINANCIAL TIMES

GRAPHICS OPINION WORK & CAREERS LIFE & ARTS HOW TO SPEND IT

BHP UK investors urge halt to fossil fuel lobbying

The Sydney Morning Herald

Activist shareholders make history in anti-lobby resolution at Origin AGM

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Timing: Paris Ratchet process triggers a cumulating policy response into 2025

2020

Countries communicate their updated or 2nd round of climate pledges

2023

Global stocktake on climate, mitigation and finance

2025

Countries submit their 3rd round of climate pledges (NDCs)

2028

Second global stocktake

Policy announcements are expected to accelerate in 2023-2025

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Key policies we forecast are detailed in the IPR Policy Forecasts:

Coal phase-outs

- Early coal phase-out for first mover countries by 2030
- Steady retirement of coal-fired power generation after 2030 in lagging countries

ICE sales ban

- Early sales ban for first mover countries by 2035
- Other countries follow suit as automotive industry reaches tipping point

Carbon pricing

- US$40-80/t$CO_2$ prices by 2030 for first movers
- Global convergence accelerated by BCAs to ≥$100/t$CO_2$ by 2050

CCS and industry decarbonisation

- Limited CCS support in power
- Policy incentives primarily for industrial and bioenergy CCS
- Public support for demonstration, and then deployment of hydrogen clusters

Zero carbon power

- Significant ramp-up of renewable energy globally
- Policy support for nuclear capacity increase in a small set of countries, nuclear managed out elsewhere

Energy efficiency

- Increase in coverage and stringency of performance standards
- Utility obligation programs,
- Financial and behavioral incentives

Land use-based GHG removal

- Strong policy support for re/afforestation
- Stronger enforcement of zero deforestation
- Controlled expansion of bioenergy crops

Agriculture

- Technical support to increase agricultural productivity
- Increasing public investment in irrigation and AgTech
- Incremental behavioural incentives away from beef

Enabling a green economy

'Just Transition' lens to ensure social and political feasibility

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A fully-integrated modelling framework from policy to financial markets

Why?

Key Messages driving the IPR specification and its communication

What and When?

Forecast specification defining and justifying the critical characteristics of the IPR and of comparator alternative scenarios

How?

Macro-economic modelling of IPR impacts on overall economic system

Energy system modelling tracing detailed system effects for all emitting sectors

Land use system modelling tracing detailed system effects for land-use sectors

Asset-level value stream modelling estimating implications bottom-up using asset-level data across major asset classes

Investor strategies

Implications for investor strategic asset allocation *and* for regulatory requirements

from December

Please see annex for further detail

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The Inevitable Policy Response (IPR) has three parts

2023-2050

The **Forecast Policy Scenario (FPS)** which lays out the policies and their impact expected from 2025 to 2050 based on IPR policy announcements 2023-2025

2050-2100

A **trend-constrained pathway** from 2050 to 2100 that reflects continued linear trends in energy, transport, industry and land-use, including the introduction of greenhouse gas removal options (such as nature-based solutions and BECCS) as known today

A **1.5°C Aspirational discussion** which looks at how this could accelerate further, particularly if there were a stronger policy push after 2035, and deeper deployment of greenhouse gas removal technologies past 2050

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Setting the context

The Forecast Policy Scenario (FPS) lays out the implemented policies for sectors and the economy from 2025 to 2050 based on the Inevitable Policy Response forecasts for the Paris ratchet process (2023-25).

Many well-established scenarios exist which we use to compare in our detailed analysis below.

Key 'reference' for comparison are those published by the IEA and the IPCC.

The International Energy Agency (IEA) produces three scenarios using the World Energy Model: **Stated Policies Scenario (STEPS), the Sustainable Development Scenario (SDS) and the Current Policies Scenario (CPS).**

- The STEPS includes policies which have already been stated and policies which are outlined under the Nationally Determined Contributions (NDC) made for the Paris Agreement. Many corporations reference this in discussions of their business planning and we believe markets are in effect priced on this.
- The SDS is a more ambitious scenario which is aligned to climate target of 'well below 2°C' according to the IEA.
- Our comparisons are based on World Energy Outlook 2019.

The IEA undertake energy modelling but do not consider the implication on land-use and the economy in an integrated way.

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Setting the context

The IPCC have collated many different modelling exercises which consider the integrated impacts of climate policy on the macroeconomics, energy-system, and land-use.

These modelling exercises are often based on scenarios which are constrained to a specific temperature target and therefore may include policies modelled which do not account for institutional and political readiness, technology readiness, or behavioural and societal momentum.

We investigate two representative 1.5° pathways:

- P1 is a scenario in which social and technological innovations reduce energy demand dramatically up to 2050. There is a rapid decarbonisation of the energy system and neither fossil fuels with CCS or BECCS are used.
- P2 is a scenario with a focus on sustainable consumption patterns and low-carbon technological innovations. There is limited societal acceptability for BECCS but with well-manage land systems.
- Both P3 and P4 scenarios deploy significant amounts of Negative Emissions Technologies (see page 95).

The IPR FPS provides a complete integrated scenario built upon realistic policy implementation to challenge investors to evaluate their own forecasts and to help strengthen the discussion on forecasts of policy action towards a Paris-aligned 'well below 2°C' outcome and prepare financial markets for climate-related policy risk.

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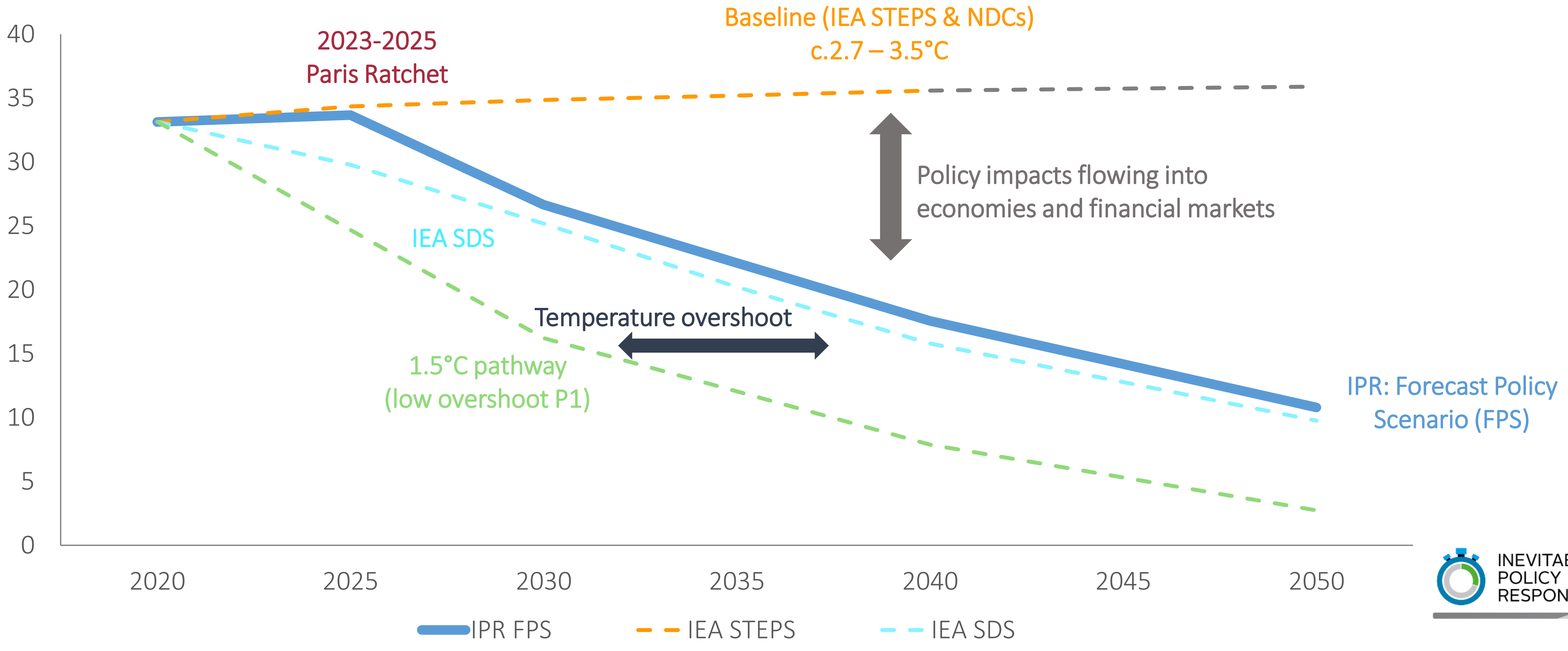
The IPR: Forecast Policy Scenario (FPS) facilitates discussion around a business planning case to fully value climate-related policy risk

Global energy-related CO_2 emissions, $GtCO_2$



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Headline takeaways for investors

Deep and rapid changes in the energy system

- Oil to peak in 2026-28
- Thermal coal virtually non-existent by 2040
- Renewables generating approximately half of all electricity in 2030

Transport electrified inside 20 years

- ICE sales bans, supported by falling cost of EVs, drive rapid deployment of ultra-low emissions vehicles
- Making up almost 70% of passenger vehicles by 2040

Major changes in land use

- Deforestation virtually eliminated by 2030, with pressures on supply chains
- Large opportunities to invest in nature-based solutions

Rapid reductions in carbon emissions, but not enough to hit 1.5°C

- > 60% fall in global CO_2 emissions by 2050
- New innovative policy and industrial solutions, not yet proven or achieved at scale, are needed to achieve 1.5°C

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IPR FPS results in rapid emissions reductions towards reaching 2°C, but even greater action is required to meet a well below 2°C target*

Global GHG emissions in IPR FPS decline by 3.0% on average per year from 2025 to 2050 thanks to:

- Transformative decarbonisation of the power and transport systems
- Elimination of deforestation, and steady incorporation of nature-based solutions
- Maintaining and propagating the recent acceleration in energy efficiency
- Continued strong improvements in agricultural productivity

Nevertheless, IPR FPS expects slower progress than implied by existing 1.5°C and well-below 2°C 'constrained scenarios':

- There is a delay to policy action
- Industrial sector reductions less rapid due to less aggressive expectations for industrial demand reductions.
- Land-use sector reductions less rapid due to less aggressive expectations for radical dietary change, less disruptive changes in land-use, and resulting persistence of land-use emissions

The IPR FPS is significantly closer to the IEA SDS than the IEA STEPS by 2050, with combustion CO_2 emissions in 2050 25.1 $GtCO_2$ below STEPS and 1.0 $GtCO_2$ above SDS; however the pathway to decarbonisation differs significantly:

- IPR FPS expects rapid decarbonisation in power and transport, but does not expect as steep a contraction in energy demand, a rapid transformation of industry and the quick deployment of CCS underlying SDS
- IPR FPS sees negligible CCS in fossil fuel power
- IPR FPS more explicitly incorporates persistence of land-use emissions, which are not modelled in detail in SDS

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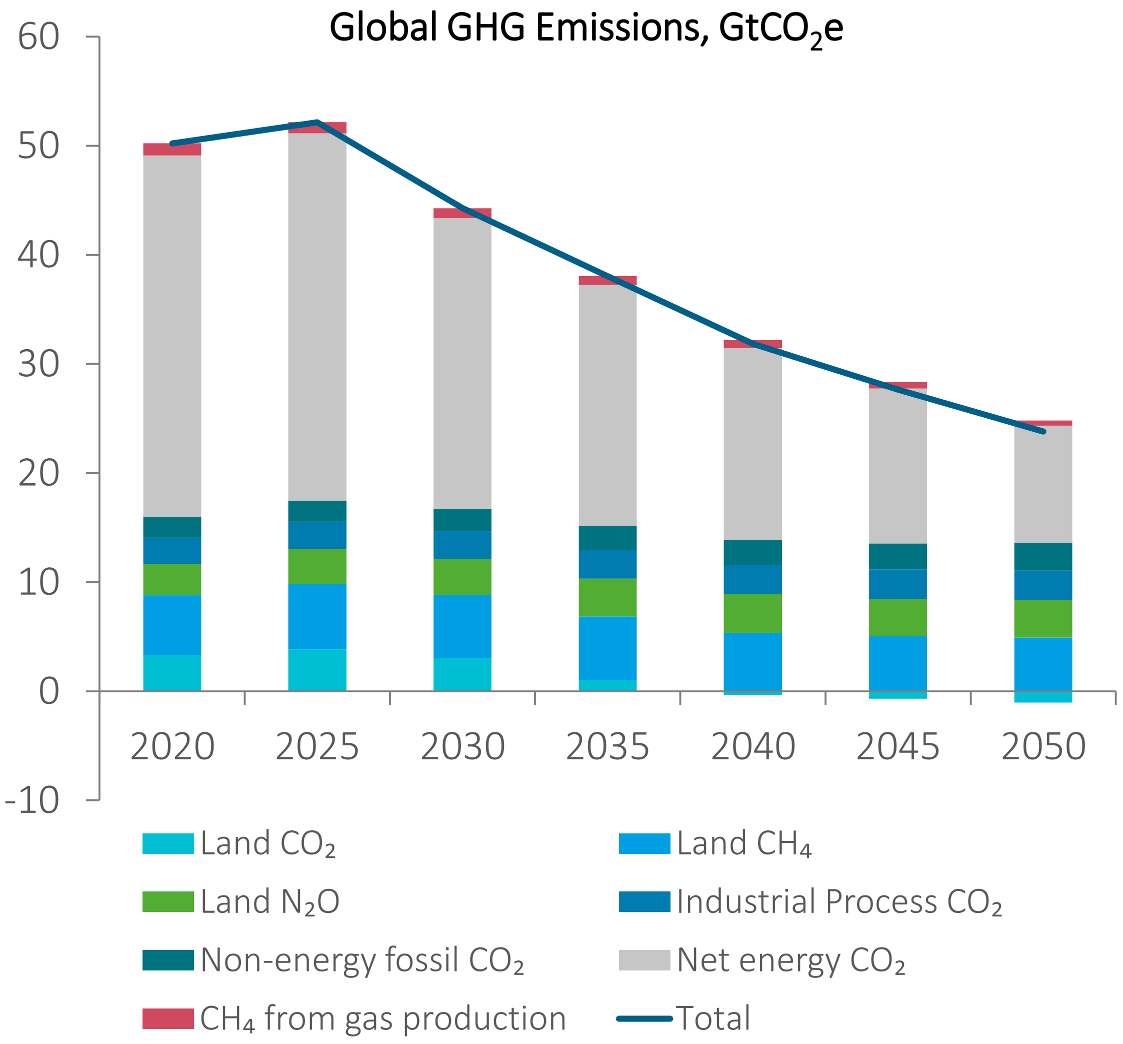
Note: The FPS was designed from the policy forecast, and not constructed to meet a specific temperature target. However, the accumulated GHG emissions of FPS to 2050 are consistent with and comparable to scenarios that label themselves as aligned to **2°C. Therefore, FPS can be used alongside (or in place of) 2°C scenarios for investors or corporates seeking to test the impact of a 2°C transition on their portfolios**

Global emissions fall rapidly



In the IPR FPS global emissions fall rapidly to 2050 following the IPR in 2023-2025

- Global CO_2 emissions fall by over 60%, while global GHG emissions fall by over 50%
- GHG emissions fall by around 3.0% annually from 2025 to 2050
- Energy-related CO_2 emissions decrease rapidly by around 4.4% annually from 2025 to 2050 which is comparable with 2°C aligned scenarios
- CO_2 emissions from land are negative from 2040 as moderate dietary shifts take effect, and policies gradually drive investment in agricultural productivity and incentivising a/reforestation
- N_2O and CH_4 emissions in land use will be harder to reduce, and are expected to persist to 2050

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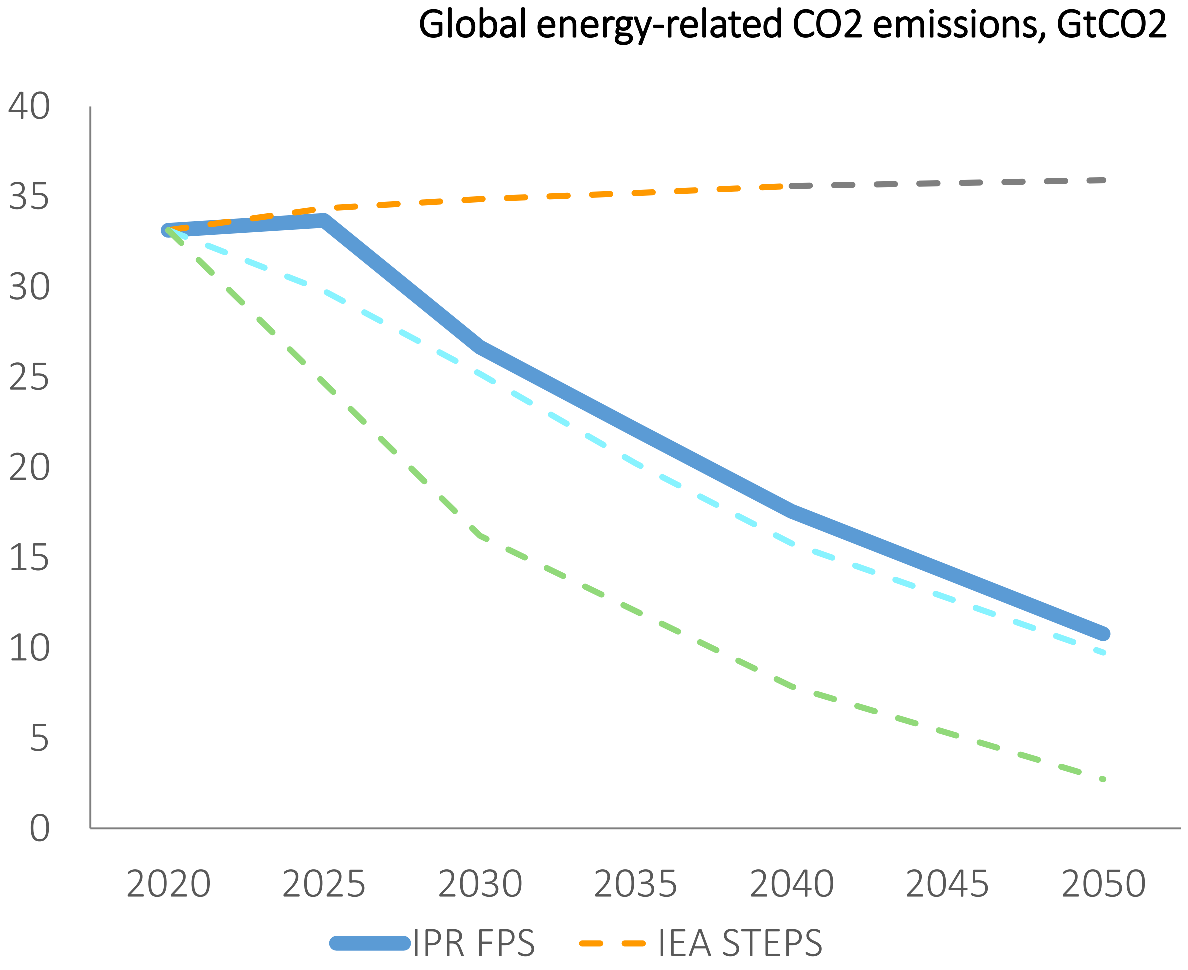
The IPR FPS reduces emissions compared with STEPS – but is still cumulatively above SDS



IPR FPS emissions peak in the 2020s due to the IPR in 2025. The emissions continue to decrease as the policy announcements come into effect and policy strengthens further

- The IPR FPS is significantly closer to the IEA SDS than the than IEA STEPS by 2050, with energy emissions 25.1 $GtCO_2$ below STEPS, but only 1.0 $GtCO_2$ above IEA SDS
- Energy-related CO_2 emissions decrease by around 60% 2025-2050 in the IPR FPS scenario. From 2025 to 2050 the SDS and IPR FPS scenarios decarbonise at the around same annual rate with SDS at 4.4% a year and IPR FPS at 4.5%
- The IPR FPS and IEA SDS decarbonise on similar pathways but meet these decarbonisation goals in different ways

Note: as IEA does not project 2020 CO_2 emissions, IEA scenarios pathways aligned to IPR FPS scenario in 2020

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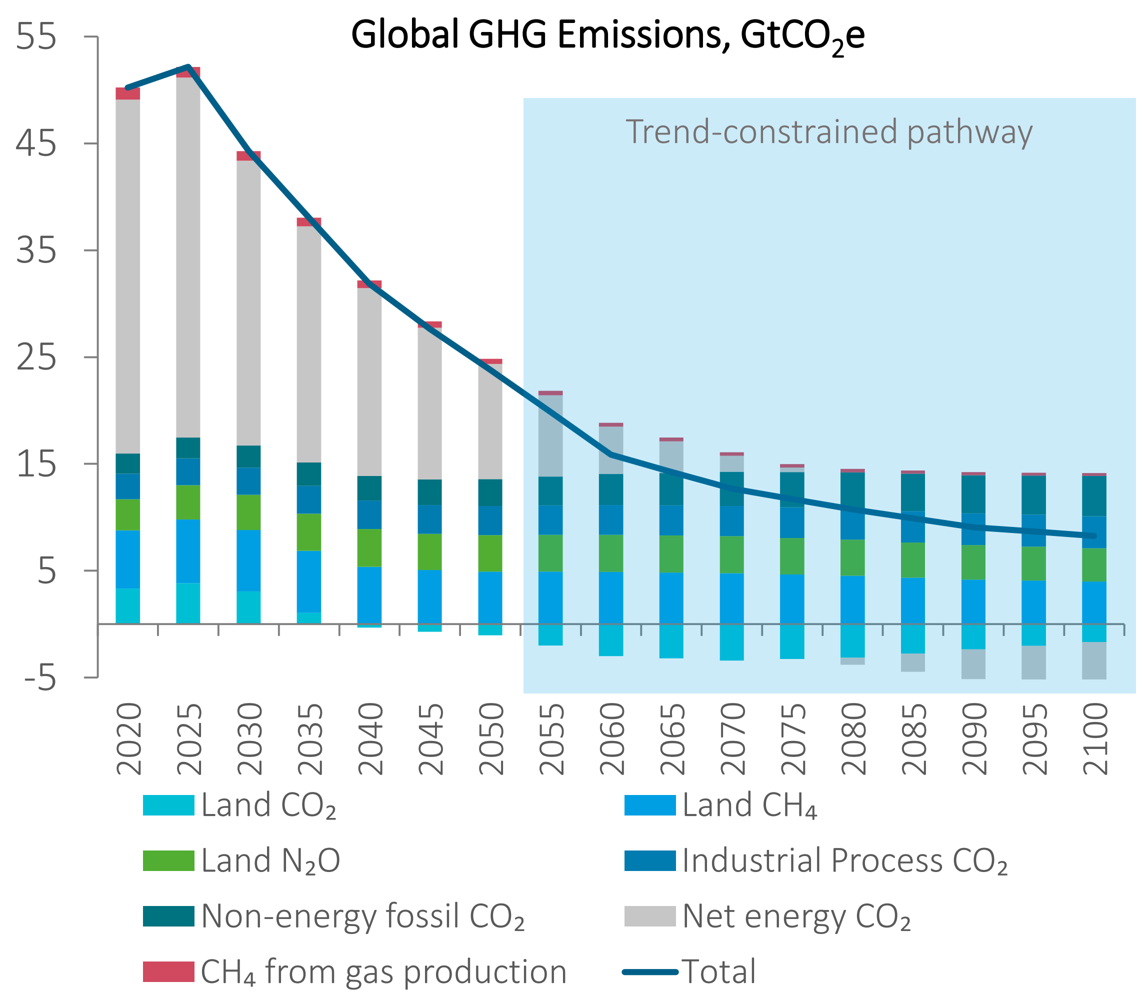
The IPR FPS is forceful and, combined with the 'trend-constrained pathway' after 2050, leads towards 2°C, but does not lead to 1.5°C*

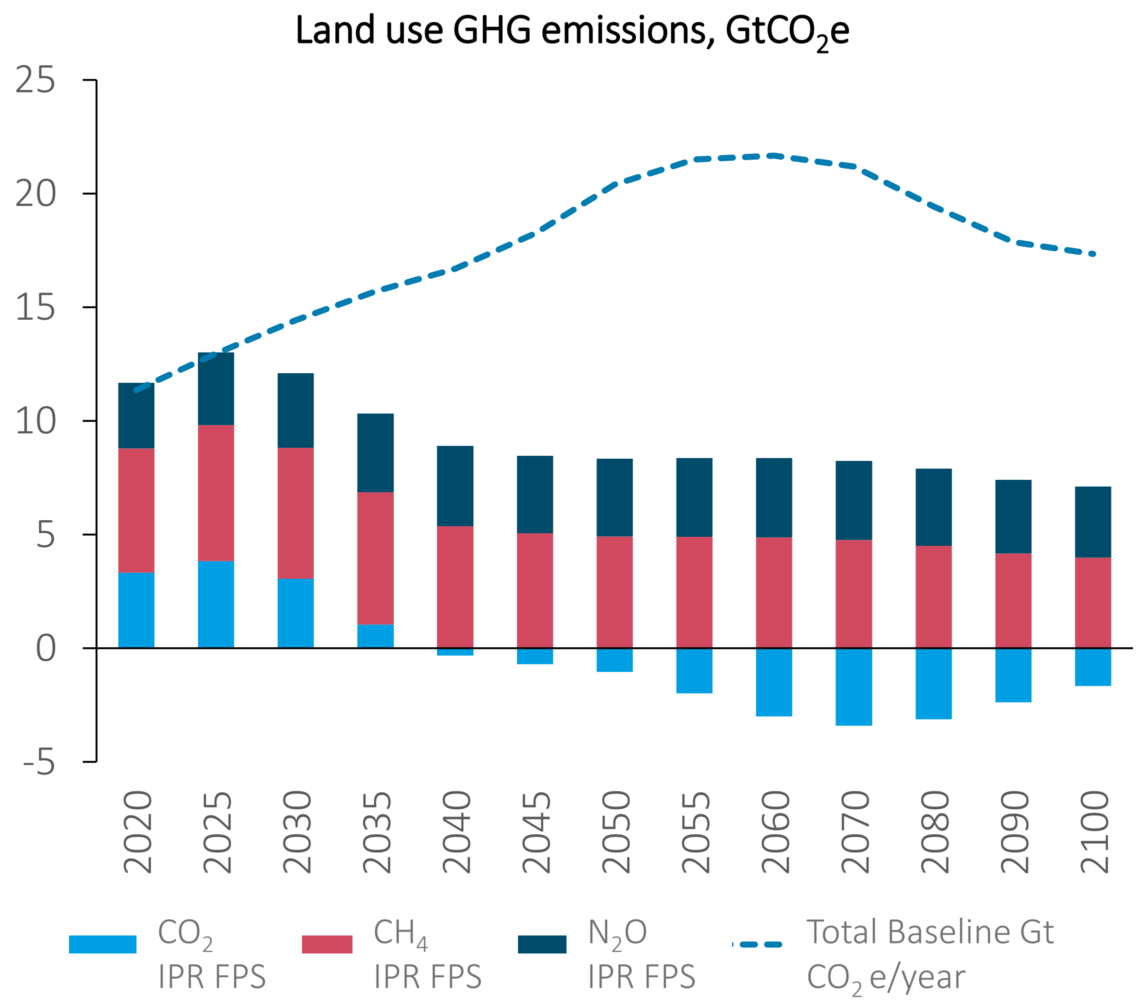


Trend-constrained pathway

- The trend constrained pathway assumes that from 2050 onwards there are no new breakthroughs in technology and that land use constraints are important in limiting Negative Emission technologies such as BECCS
- Energy-related CO_2 emissions are negative from 2090 onward driven by reductions in emissions and CCS in industry and some BECCS in power
- Hard to abate land emissions for N_2O and CH_4 persist through the end of the century
- This contrasts with IPCC P3 and P4 pathways that assume the deployment of large amounts of BECCS in order to reach their optimised temperature goal

Note: The FPS was designed from the policy forecast, and not constructed to meet a specific temperature target. However, the accumulated GHG emissions of FPS to 2050 are consistent with and comparable to scenarios that label themselves as aligned to 2°C. Therefore, FPS can be used alongside (or in place of) 2°C scenarios for investors or corporates seeking to test the impact of a 2°C transition on their portfolios

IPR FPS expects cumulative GHG emissions in land-use sectors to be 631 $GtCO_2e$ lower than the current baseline

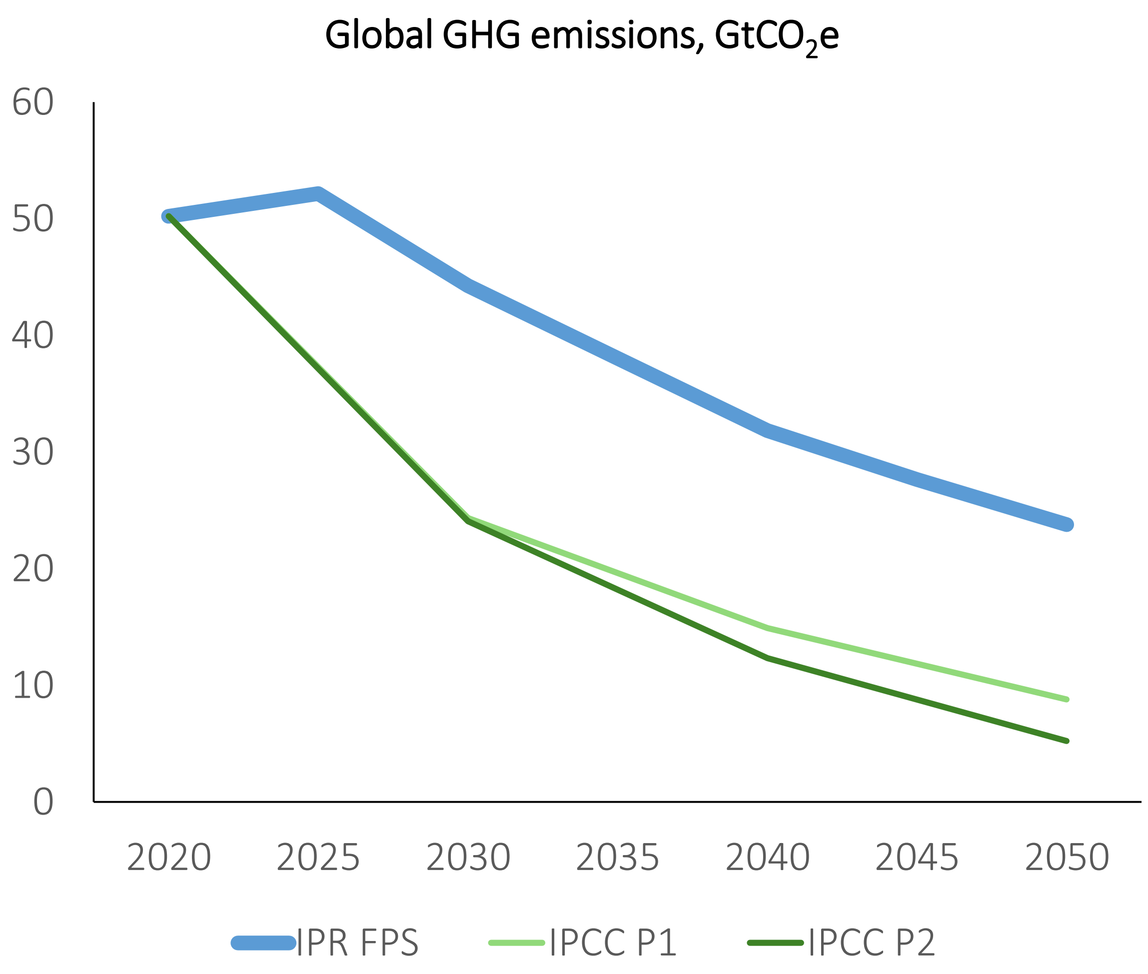


CO_2 emissions become net negative starting in 2040, driven by net increases in forest cover

CH_4 and N_2O emissions, primarily from livestock and fertiliser use, persist as a dominant part of land sector GHGs through the end of the century

- Increases in baseline are due primarily to increasing population and shifts toward meat in diets associated with development
- IPR FPS expects lower emission growth with technical mitigation in agriculture and some diet shift away from ruminant meat (especially beef) starting in 2020
- Non-CO_2 GHGs persist since difficult and expensive to reduce without a radical shift in diets and steep increases in food prices

The IPCC 1.5°C P1 scenario decarbonises faster than IPR FPS as it does not utilise CCS technologies and has dramatic demand reductions



The IPCC 1.5°C scenarios decarbonise faster than IPR FPS

- The IPCC 1.5°C scenarios show a variety of pathways, with particularly important differences in assumptions around the levels of CCS and negative emissions, especially after 2050
- The IPCC P1 1.5°C scenario decarbonises rapidly as it is highly ambitious in its assumptions around demand reductions and does not use CCS
- The IPCC P2 1.5°C scenario also decarbonises rapidly, driven by higher levels of afforestation and CCS
- The rate of decarbonisation needed to meet a 1.5°C target is much higher than IPR in the short term even under a moderate CCS scenario.
- IPPC P3 and P4 are shown on page 94 and include large amounts of Negative Emission Technologies that have yet to be deployed at scale

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Achieving the 1.5°C target will require accelerated and substantial effort across multiple emerging solutions

Today	2030 –2050	Post 2050

Faster investor and policy action today

ACT NOW
to move more smoothly and cost-effectively to 1.5°C

- Second Ratchet by 2035
- Circular economy
- The agricultural revolution
- Bioeconomy
- Hydrogen economy
- Consumer preferences, such as dietary shifts
- Negative emissions technologies
- AI revolution / future tech
- Last resort measures

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Executive Summary - Sector results

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Energy – key findings: the phase out of fossil fuels

Thermal coal phases out rapidly in electricity and with a decline in industry. Coal demand peaks by 2020-2022 at the latest.

- In 2040, thermal coal is virtually out of the energy system, with small amounts remaining but declining in selected regions and industry

Oil demand peaks between 2026-28

- Road transport oil demand peaks in 2025; industry and other uses such as petrochemicals continue to grow but at a rate that is slower than the decline caused by ICE phase-outs

Natural gas continues as a transition fuel and to replace a share of coal in industry – gas demand plateaus over the 2030s and begins to decline in the 2040s.

- Natural gas in electricity begins to decline from 2030; renewables replace thermal coal and satisfy new demand
- Natural gas replaces thermal coal in industry and helps reduce emissions from heating, but then is gradually replaced by zero-carbon electricity and hydrogen from 2040 onwards

Renewables grow quickly and supersede fossil fuels in electricity by 2030, and virtually replace all fossil fuels by 2050

- Renewables generate approximately half of all electricity in 2030; Solar and wind alone generate approximately 2/3 of all electricity in 2050
- Nuclear does not grow to replace fossil fuels and stays broadly constant, with regional variation

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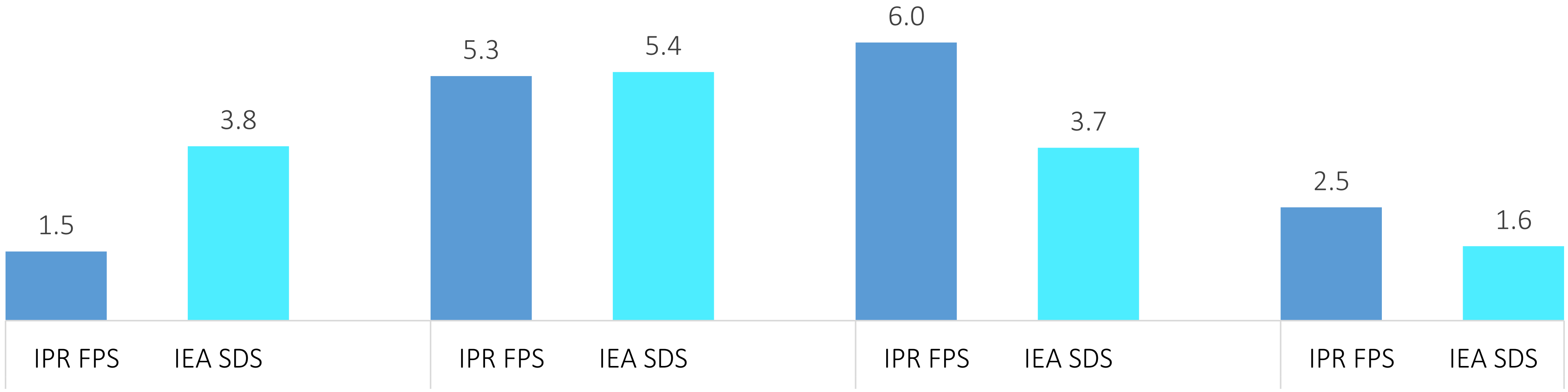
Where IPR FPS is different from IEA SDS in 2040

Power		Transport		Industry		Buildings	
IPR FPS	IEA SDS	IPR FPS	IEA SDS	IPR FPS	IEA SDS	IPR FPS	IEA SDS
Low carbon generation		Low carbon fuel share		Low carbon fuel share		Low carbon fuel share	
81%	79%	26%	27%	46%	43%	74%	70%
total electricity demand		total fuel demand		total fuel demand		total fuel demand	
40,000 TWh	39,000 TWh	88 EJ	111 EJ	156 EJ	134 EJ	149 EJ	120 EJ

IPR FPS has higher share for EVs vs. biofuels than SDS

CO2 emissions by sector in 2040, GtCO2



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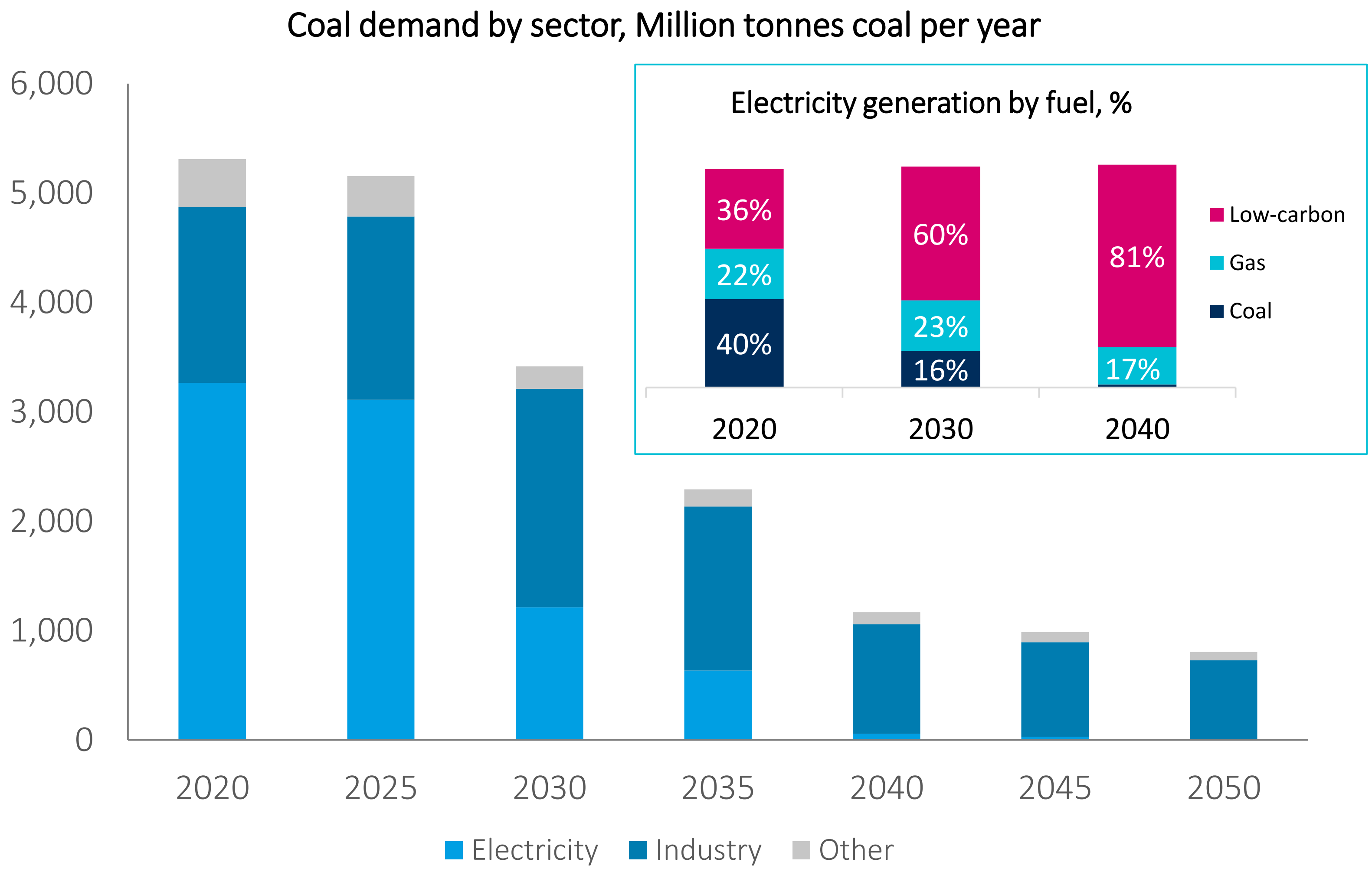
Coal demand is at its peak and will decline rapidly by 2025

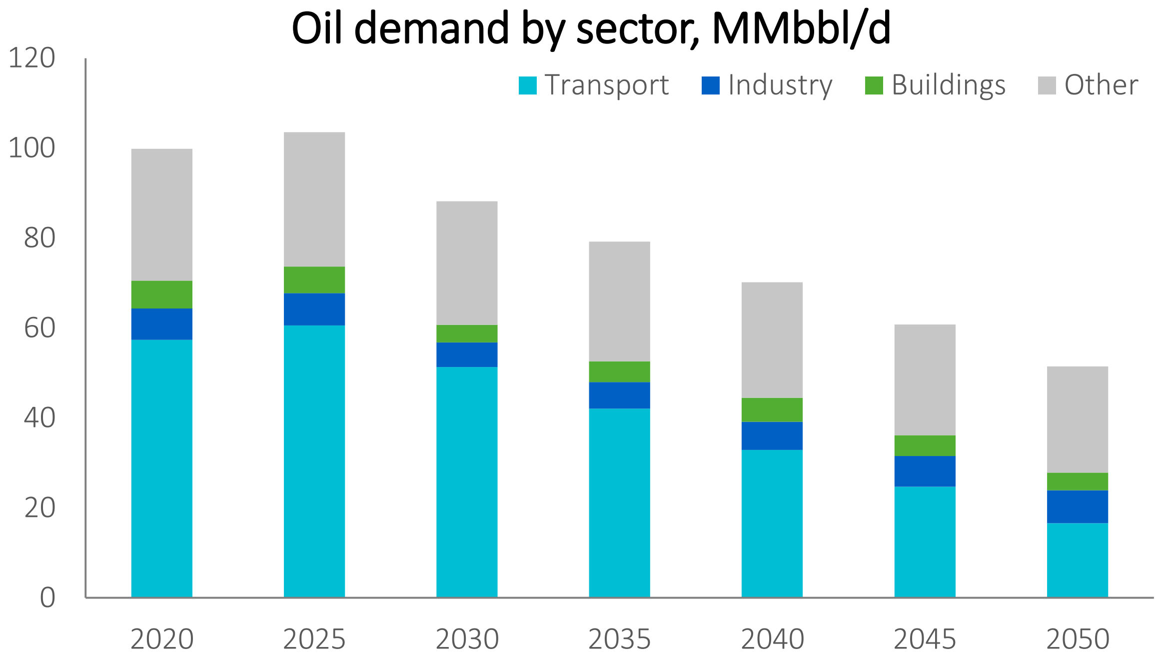


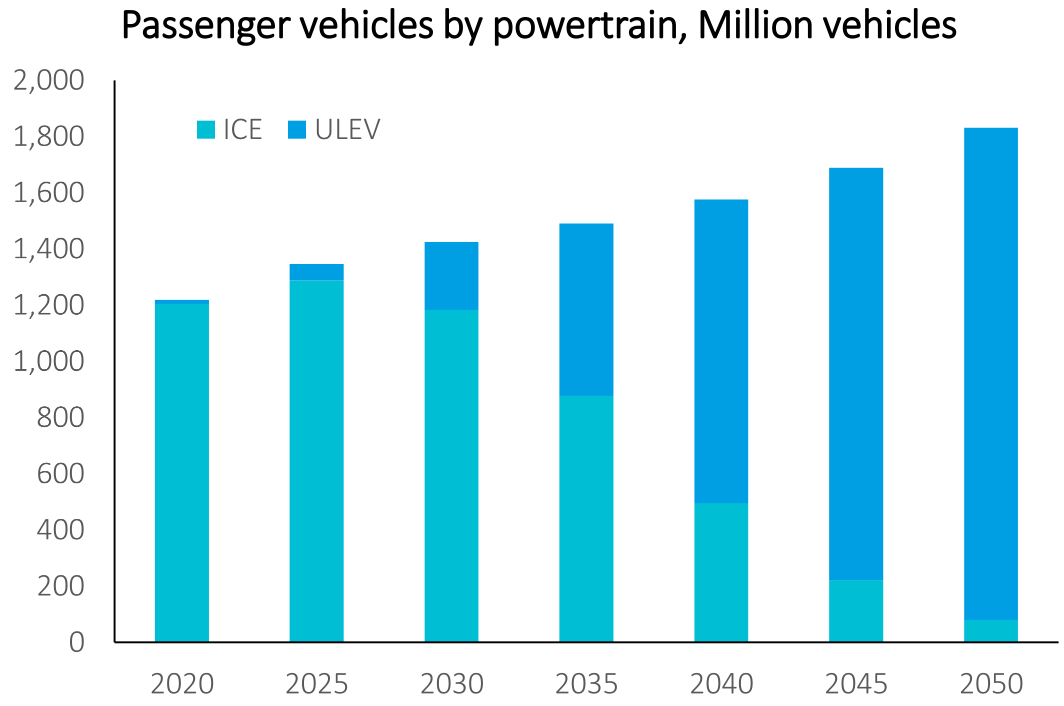
Driven by relative costs and policy, demand for coal for electricity generation declines by 23% per year from 2025 to 2040

- Coal is almost completely phased out of the electricity sector by 2040
- In the 2030s demand for coal in industry decreases significantly
- Electricity, gas and hydrogen replace coal across industry sectors

Note: 'Other' coal use includes energy used in the energy industry, use in agriculture and losses

Oil demand peaks 2026-28 and falls rapidly as transport uses alternative fuels





Oil demand peaks between 2026-28 driven by improving ICE efficiency and early uptake of electric vehicles

- Oil demand from transport decreases by around 70%, while total oil demand decreases around 50% 2025-2050
- Road transport oil demand peaks in 2025
- However, oil demand in aviation and shipping and as a feedstock for petrochemicals remains significant through to 2050

INEVITABLE POLICY RESPONSE

Note: 'Other' oil use includes energy used during oil extraction and refining, feedstock for petrochemicals, and use in agriculture

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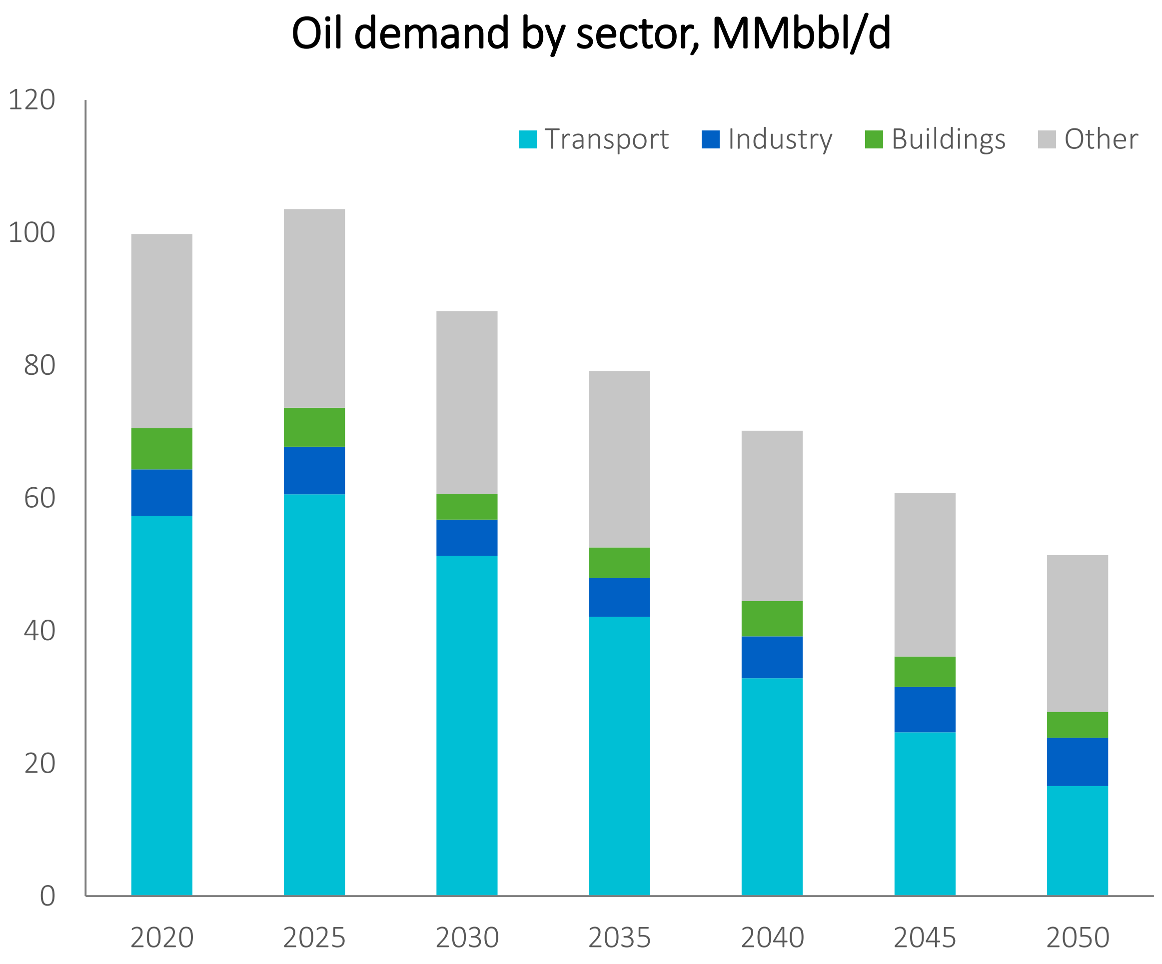

Note: 'Other' oil use includes energy used during oil extraction and refining, feedstock for petrochemicals, and use in agriculture

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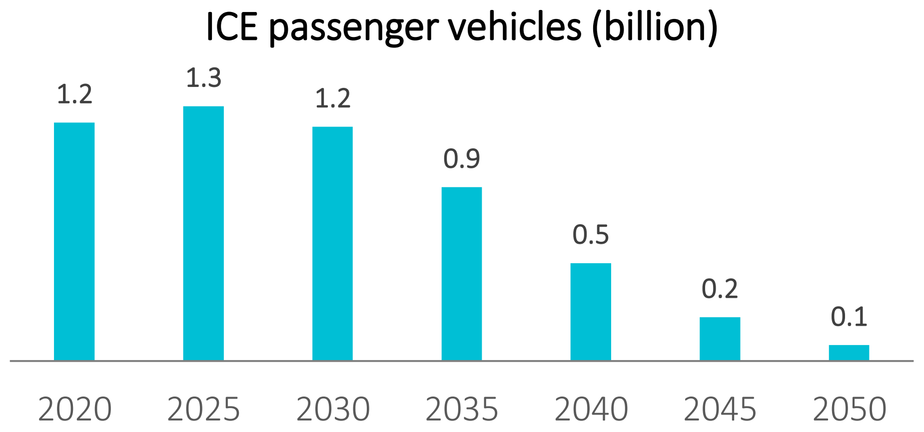

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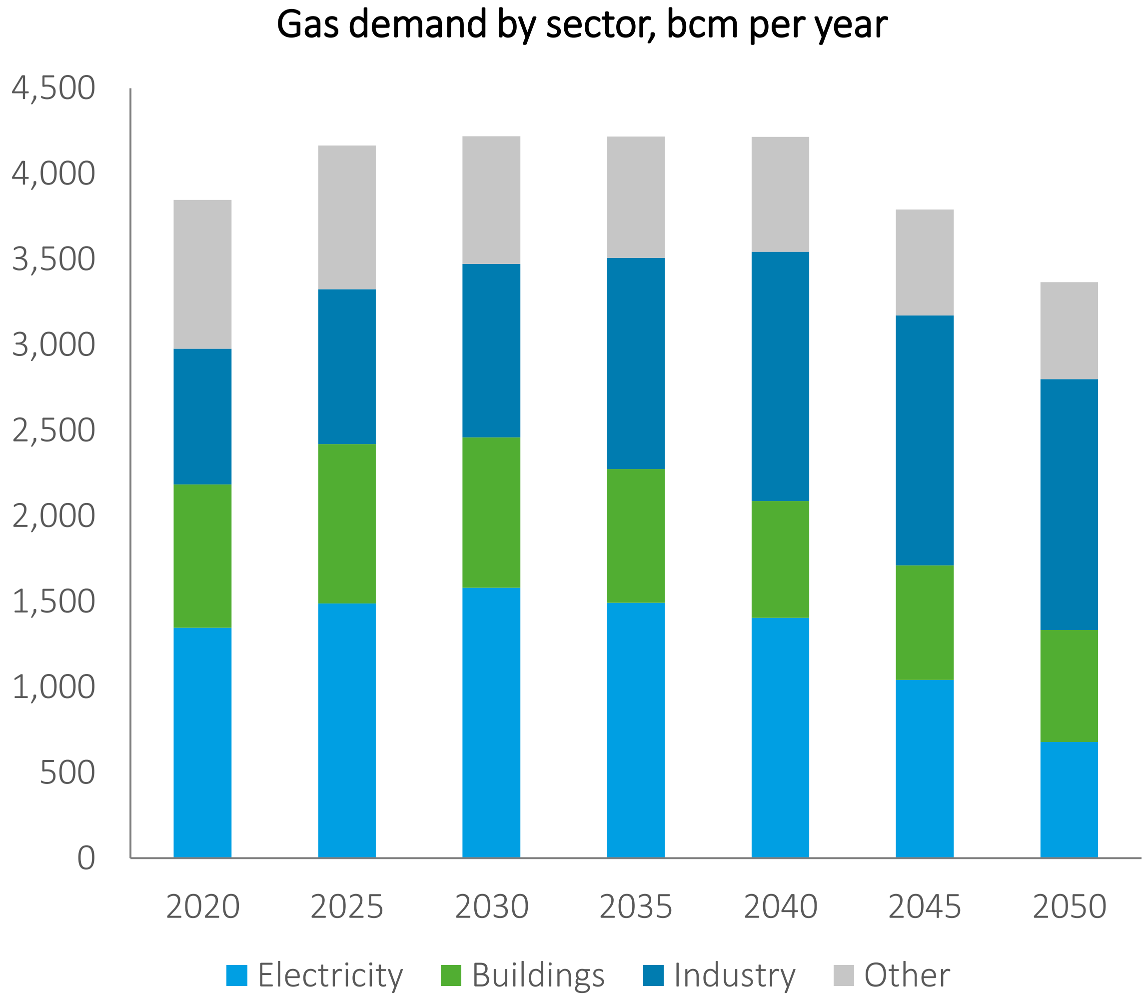
Gas replaces a part of coal in industry and plateaus during the 2030s



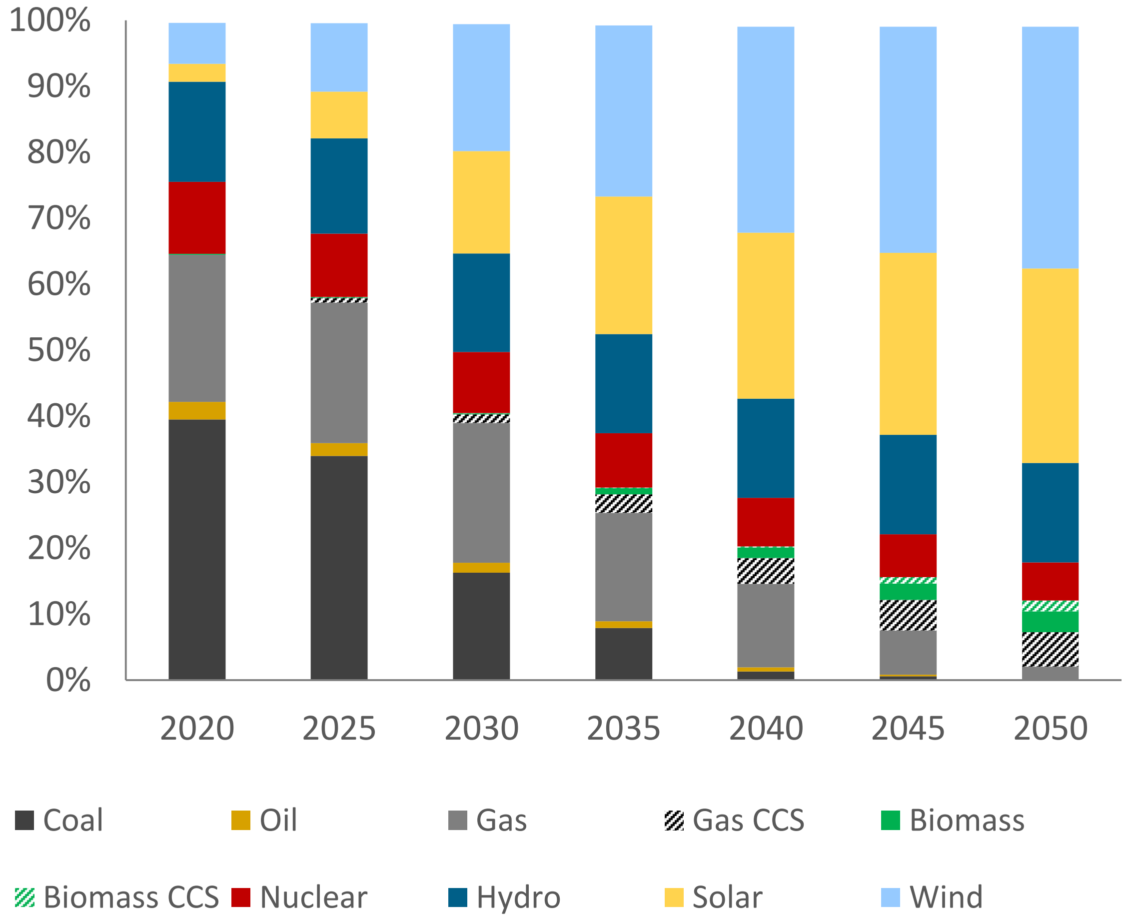
Gas demand in electricity increases to 2030, but begins to decline steadily thereafter

- Natural gas in electricity declines from 2030 onwards; renewables replace thermal coal and satisfy new demand
- Electricity is the largest source of gas demand to 2040, when industry emerges as the largest source, including demand for both fuel and feedstock
- Natural gas replaces thermal coal in industry and helps reduce emissions from heating, but then is replaced by zero-carbon energy from 2040 onwards
- The hydrogen economy emerges gradually as an alternative to gas in industry

Note: 'Other' gas use includes energy used during natural gas extraction and processing, and as feedstock for petrochemicals

Renewable generation grows quickly and supersedes fossil fuels by 2030

Electricity generation mix, %



Renewables generate approximately half of all electricity in 2030, and virtually replace all fossil fuels by 2050

- Solar and wind alone will generate approximately 2/3 of all electricity in 2050
- IPR FPS has 72% renewable generation in 2040, more than in the IEA SDS, IEA STEPS, and BNEF NEO
- Coal is phased out by 2050 while gas retains a minor role. By 2050, CCS is applied to around 72% of gas generation but this is only 5% of the total generation mix
- Biomass with CCS grows to 2% of the generation mix by 2050, slow development of CCS is a barrier to use of biomass as a negative emissions technology as are land use constraints
- Overall, nuclear does not grow to replace fossil fuels or renewables given cost and societal issues

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Transport, Industry and Carbon Capture and Storage – key findings

ICE sales bans, supported by technology cost reductions, drive rapid deployment of ultra-low emissions vehicles

- As a result of its policy assumptions, IPR FPS expects twice as many electric passenger and light-duty vehicles as Bloomberg New Energy Finance (BNEF) by 2040 with near total decarbonisation by 2050
- Heavy-duty vehicles are expected to follow a similarly rapid shift to zero-emissions vehicles, with a greater role for hydrogen, and near total decarbonisation by 2060

Industry decarbonises quickly, but at pace commensurate with technology readiness and long plant lifecycles

- Coal-to-gas switching plays a major role in next two decades, as technically ready, cost effective and non-disruptive to production
- Electricity and hydrogen begin pushing out coal and gas as market price of carbon rises, technology costs fall, and the cycle of plant replacement enables greater and greater industrial transformation

Carbon Capture and Storage (CCS) plays a small role in power and industry (to cover hard-to-abate sources)

- Fossil fuel electricity declines rapidly
- Industrial CCS plays a role in the pace of industrial transformation
- Some bioenergy with CCS can play a role as a long-term solution for generating negative emissions

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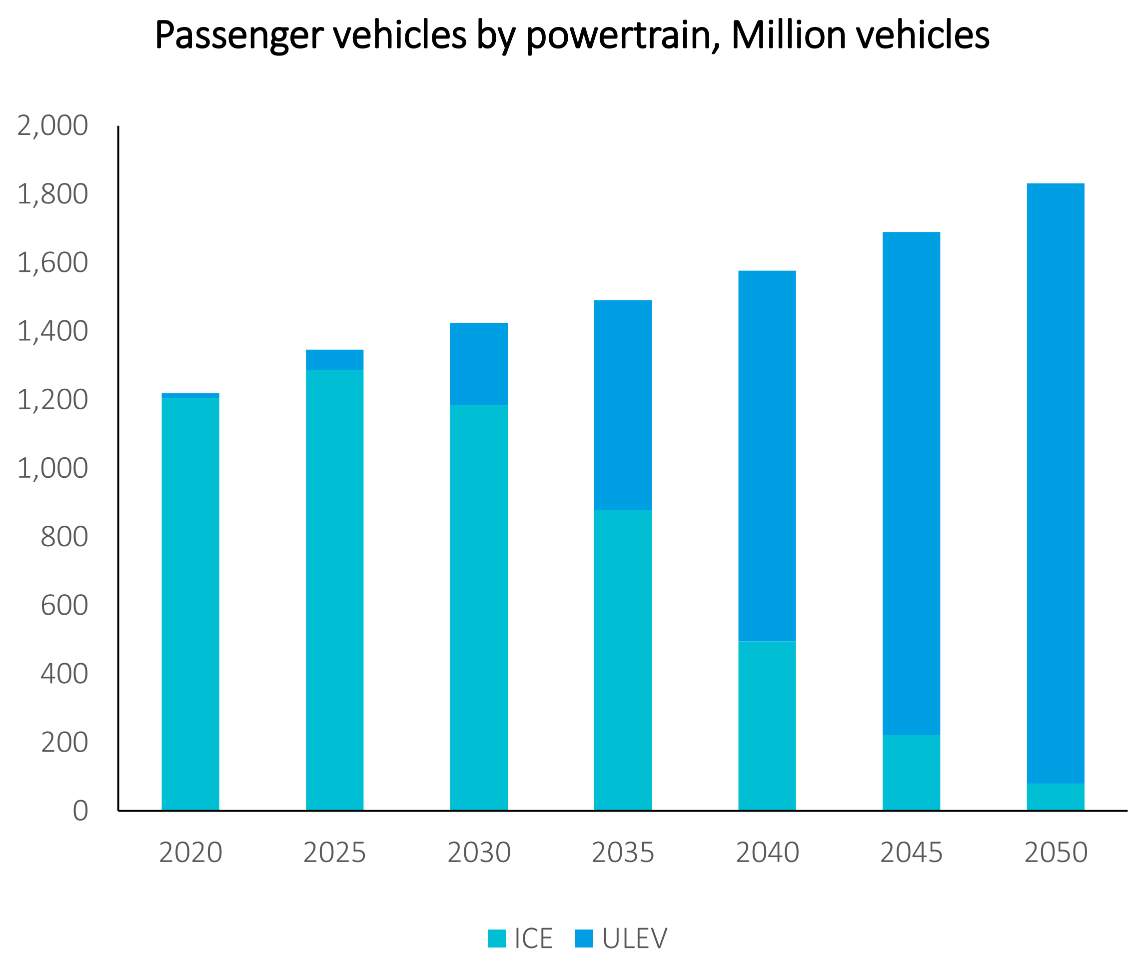
ICE vehicles peak in 2025 – by 2040, ultra-low emissions vehicles are the majority

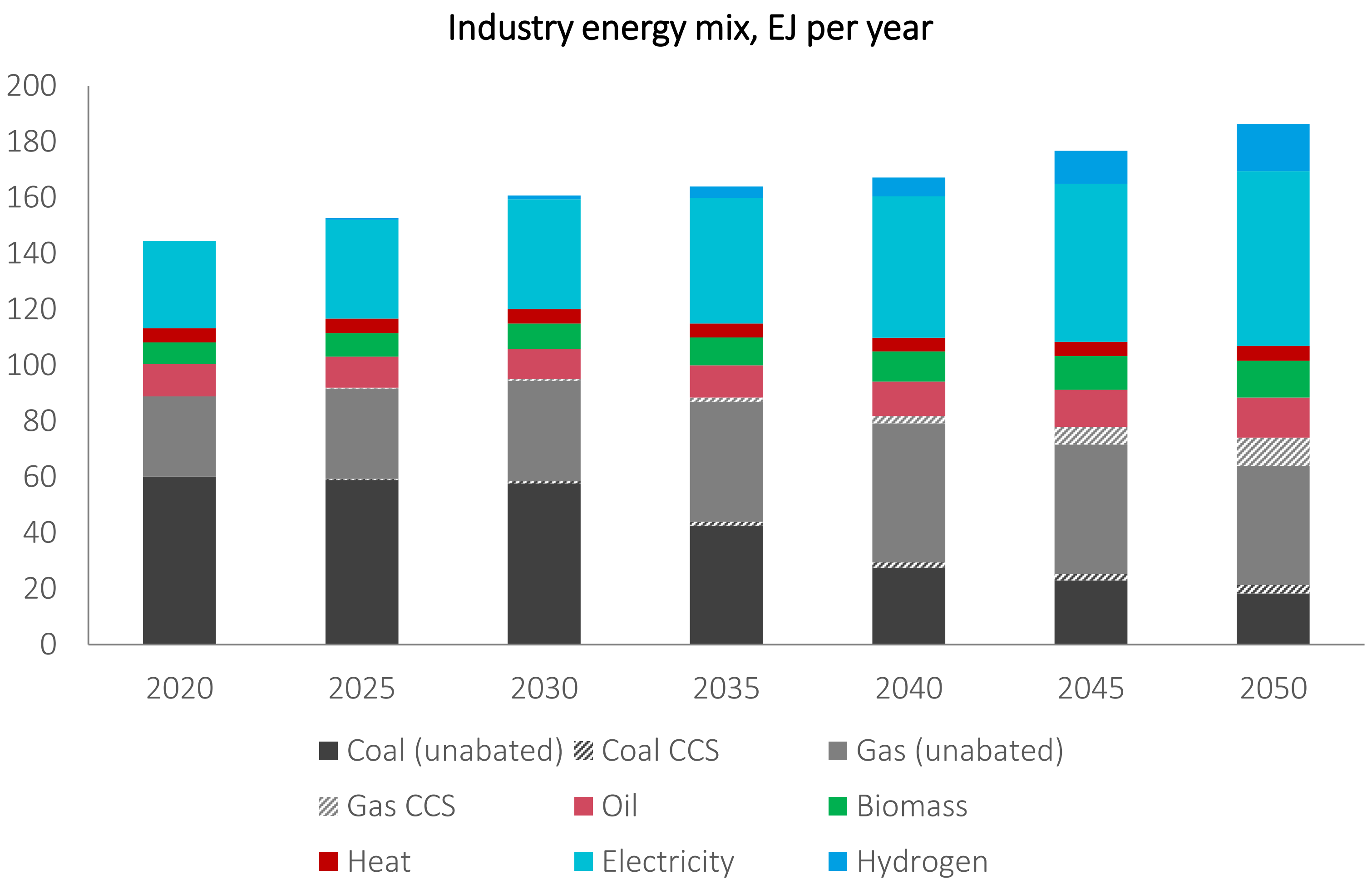


Number of ICE vehicles peaks in 2025 driven by EV cost reductions and ICE sales bans, with significant implications for demand along the automotive supply chain

- Acceleration of ULEVs driven by 2035 ICE bans in Western Europe and China; 2040 bans USA, Japan and other regions
- By 2050 relatively few ICE vehicles remain, primarily in less developed countries that transition more gradually
- In the BNEF New Energy Outlook, sales of ICE passenger vehicles have already peaked and number of ICE passenger vehicles peaks around 2030. In 2040 around a third of the fleet are EVs

INEVITABLE POLICY RESPONSE

Electrification, hydrogen and CCS contribute to the progressive decarbonisation of industry

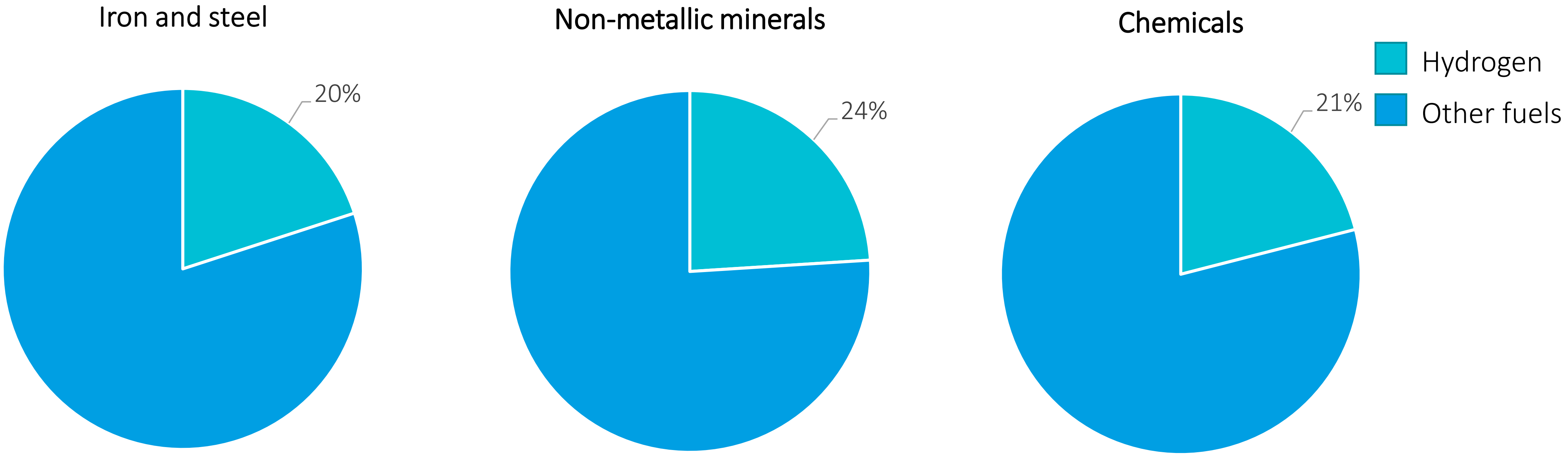


Coal-to-gas switching – proven, economical and non-disruptive – accelerates as a near-term solution to reducing industrial emissions

- Electrification, hydrogen, and CCS contribute to decarbonising energy intensive industry sectors in medium to long term with the carbon price forecasts playing an important role
- Fuel mix changes proceed at a pace consistent with economics of emerging technologies, and long plant lifecycles

INEVITABLE POLICY RESPONSE

By 2050, hydrogen contributes at least 20% of energy demand in hard-to abate sectors



Hydrogen can become a significant energy source in industry. Advantages of hydrogen include:

- Hydrogen is an alternative to electrification technologies. Like natural gas, hydrogen can be burned as a fuel, and less innovation is needed to develop hydrogen burning technologies than many electrification technologies
- Hydrogen is an alternative to carbon capture and storage. Hydrogen allows decarbonisation of industry without fitting capture technologies to individual plant, and without developing new CO2 transport and storage infrastructure
- Hydrogen can also be used as a reduction agent in steelmaking, potentially eliminating the use of coke as a reduction agent and its resulting process emissions

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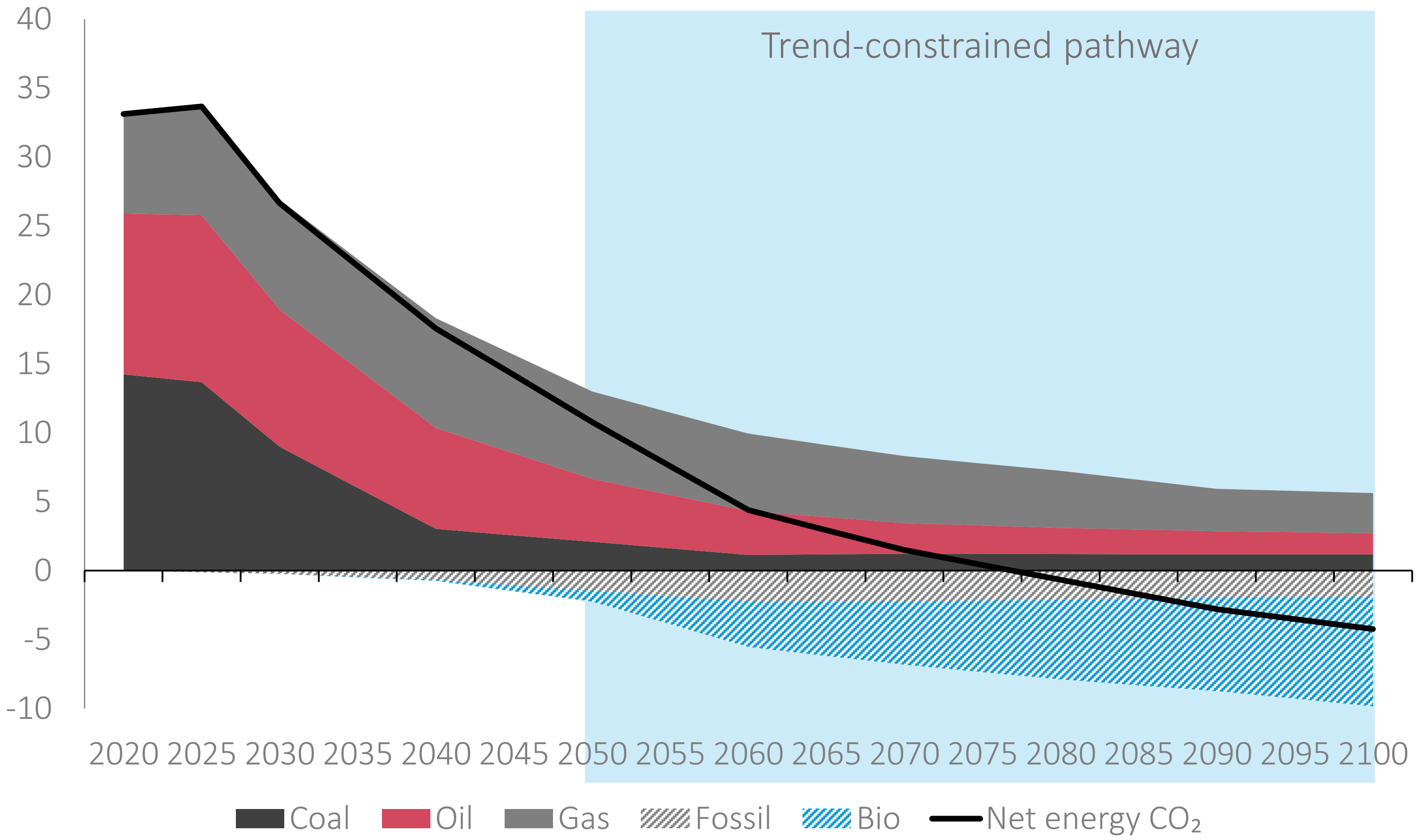
Bioenergy with CCS is crucial to reduce energy CO_2 emissions below zero by 2100, with CCS in industry mitigating the impacts of remaining fossil fuel use

Energy CO_2 emissions by fuel, $GtCO_2$ emissions



Coal emissions decline rapidly – remain for coking coal and other uses

- CCS on fossil fuels in industry and power and Bioenergy and CCS (BECCS) are needed to reduce emissions rapidly but face constraints
- Oil and natural gas have several uses beyond power and transport – aspirational policies are needed to tackle these remaining emissions
- For ambitious scenarios such as 1.5°C, many assume much more CCS will need deploying than shown here

INEVITABLE POLICY RESPONSE

Land-use – key findings

Deforestation virtually eliminated by 2030, but continues in short term

- Forecasted policies will take time to be fully implemented as land-use change involves significant legal, institutional and social change
- Economy-wide carbon price pressures will increase political incentive through Paris process
- International payments begin playing a bigger role by 2030 as rules gradually negotiated

Bioenergy meets around 10% of global energy demand by 2050, with the bulk coming from 2nd generation crops

- Food competition and political challenges of land-use change dampen economic incentives for bioenergy
- Wider land use shifts include growth in bioenergy crops which meet around 10% of global energy demand by 2050

Land competition induces substantial investment in yield-enhancing technologies – crop yields estimates imply a 1.5% compound average growth rate (CAGR) between 2015 and 2050

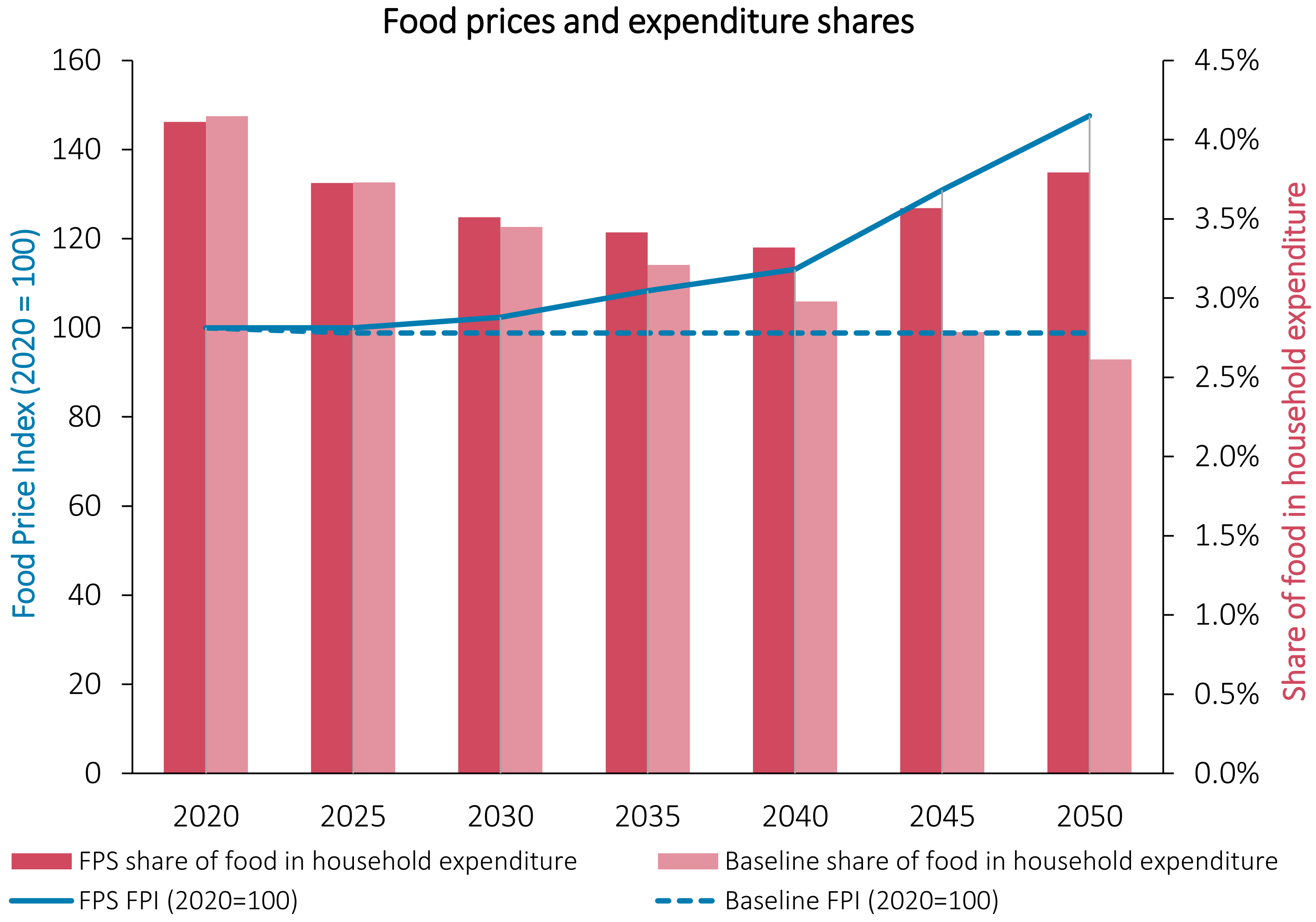
Dietary shift away from ruminant meat (especially beef) is significant against trend thanks to both price and social pressures, but behavioural barriers persist to a rapid and complete transformation of dietary habits

Globally, the IPR FPS keeps food expenditure's share in household income near stable

- The share decreases from roughly 4.1% in 2020 to 3.8% in 2050 as GDP per capita grows
- Regions with stronger land competition experience more significant food price increases; particularly bioenergy-rich regions such as Central and South America, Mexico, and Brazil

INEVITABLE POLICY RESPONSE

IPR FPS keeps food expenditure's share in household income near stable



Between 2020 and 2050, the share of food in household expenditures decreases from 4.1% to 3.8%

Wholesale prices from producers (farm gate) increase by 45% globally by 2050, with regions experiencing strong land competition observing the highest impact

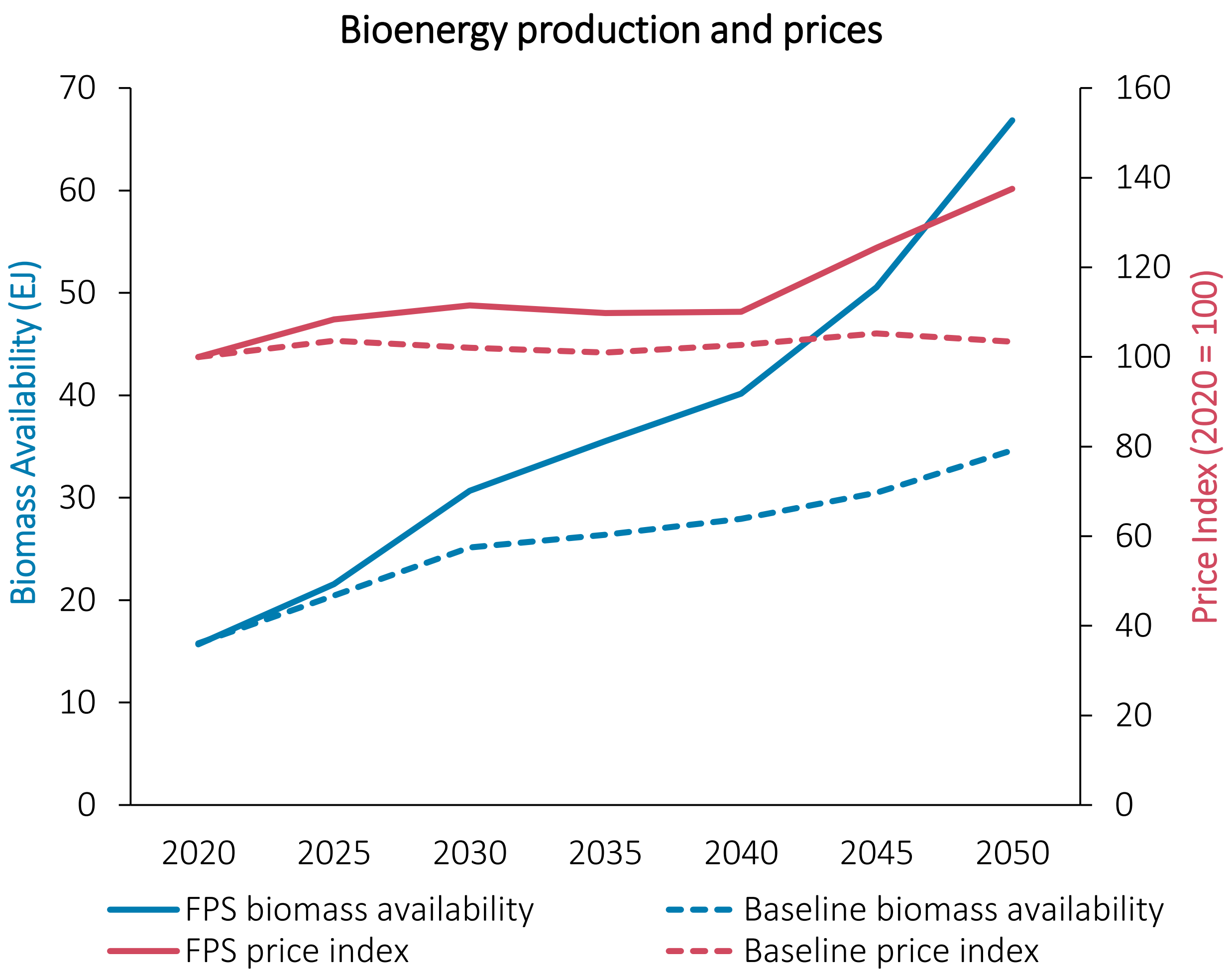
- These include Central and South America, Mexico, and Brazil
- Food prices in some countries are sensitive to trade pattern changes resulting from shifts

Food price increases are within historical bounds, for example:

- Global CAGR in food price index was 7% between 2005 and 2010
- Maximum IPR FPS CAGR is 3.0%

INEVITABLE POLICY RESPONSE

Bioenergy crops represent 65 EJ annually by 2050, with the bulk coming from 2nd generation crops



Bioenergy crops supply nearly 65 EJ annually by 2050

- First generation bioenergy crops continue to dominate in the coming decade
- Second generation crops, such as miscanthus, phase in beginning in 2025, and account for more than two thirds of bioenergy production in 2050

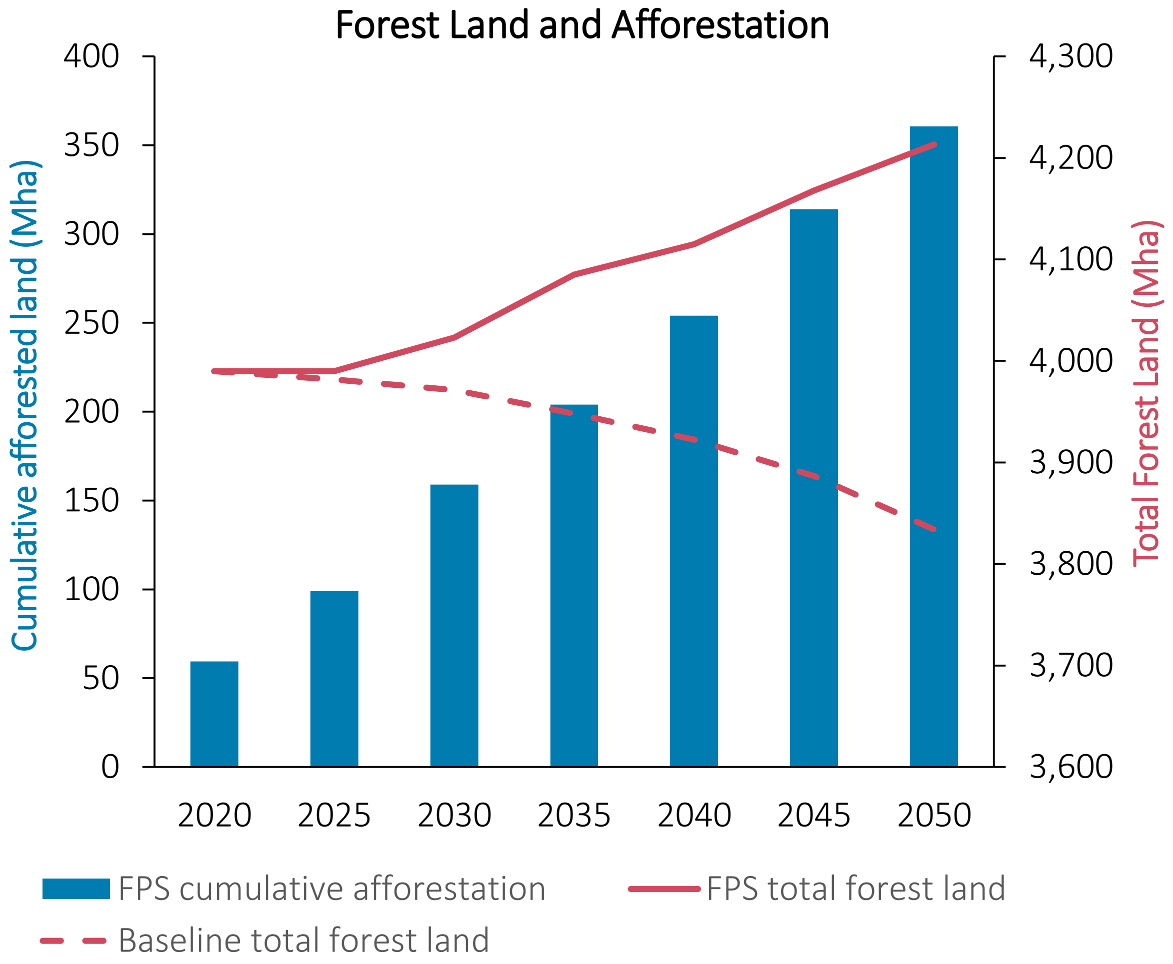
Environmental sustainability and land competition constrain bioenergy production

- Consistent with literature estimates of 100-125 EJ in 2100 of bioenergy as the sustainable limit

Bioenergy production increases across the globe, although relatively sooner in China, North America and Europe, which have better conditions for sustainable, industrial-scale production. The former Soviet Union emerges later as major producer.

INEVITABLE POLICY RESPONSE

Deforestation continues until mitigation policies phase into the land sector, and afforestation and reforestation efforts ramp up substantially



Note: 'Total Forest Land' is includes dense, high-carbon stock forest land only

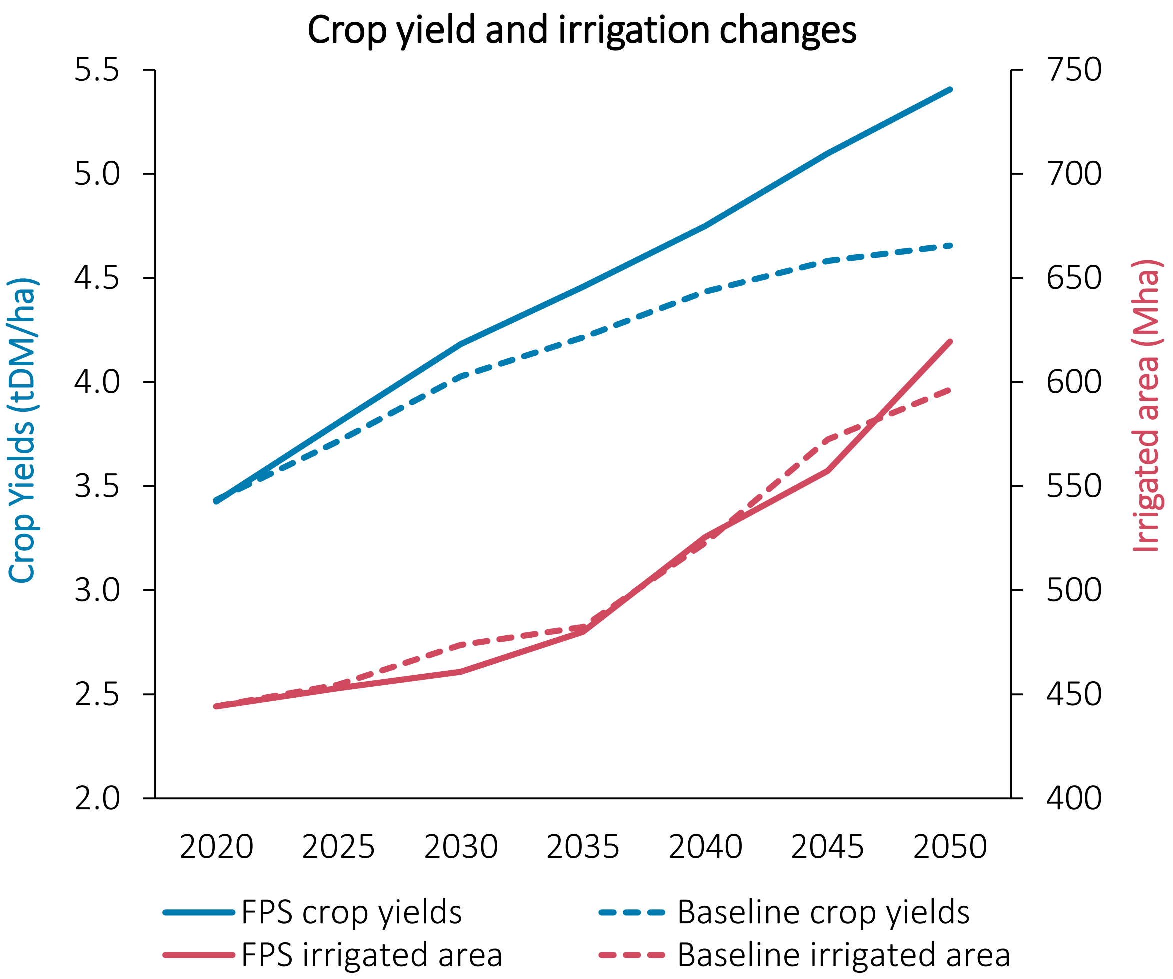
Deforestation practically eliminated by 2030, as domestic climate policies fully implemented, and international payments increasingly introduced

- IPR FPS expects rapid re/afforestation to meet feasible NDC land use targets in coming decade
- Total forest area recovers to 1995 levels between 2030 and 2035, although not all native forest
- Re/afforestation is driven by emerging payment systems – national and international – and impact of increasing prices in carbon markets
- World meets the Bonn Challenge of 350 Mha of land restoration, but well after 2030 target
- Re/afforestation occurs largely in tropical regions: Brazil, Latin America, China and Southeast Asia

Re/afforestation to 2050 draws estimated $780 billion in offsets financing

INEVITABLE POLICY RESPONSE

Land competition induces substantial investment in yield-enhancing technologies



Aggregate global productivity increases by 58% between 2020 and 2050

- This represents a roughly linear rate of increase in line with historical gains

Much of this is driven by baseline catch-up improvements in developing country agricultural systems

- Irrigated area expands globally, with the fastest coverage increases in Africa

Further productivity gains are achieved thanks to policy and price incentives

- Increasing public and private support for R&D and agricultural extension
- Global estimates for yield enhancing investments total $23,000 billion from 2015 to 2050

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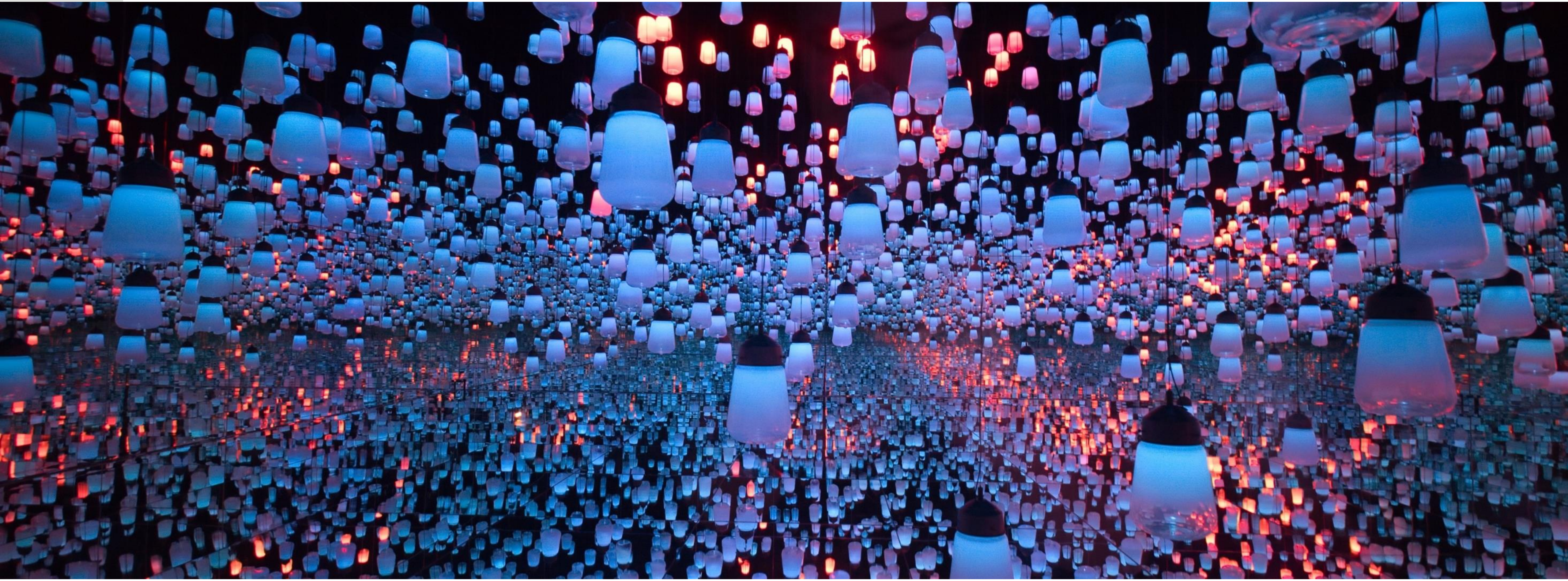
Annex



INEVITABLE POLICY RESPONSE

Summary of results

Sectors	Statkraft Low Emissions Scenario (2018)	IRENA Remap (2018)	IEA Stated Policies Scenario (STEPS) (2019)	IEA Sustainable Development Scenario (SDS) (2019)	Shell Sky Scenario (2018)	BP ET (2018)	IPR FPS (2019)
CO_2 emissions							
Global energy-related CO_2 emissions ($GtCO_2$) in 2040	23.4	15	35.6	15.8	28.7	35.9	**18**
Primary energy							
Average annual primary energy demand growth 2015-2040	0.5%	-0.1% (to 2050)	1.0% (2018-2040)	-0.3% (2018-2040)	1.1%	1.3% (2010 -2040)	**-0.3%** (2017-2040)
Oil consumption: annual average growth 2015-40	-0.80%	n/a	0.4% (2018-2040)	-1.8% (2018-2040)	-0.1%	0.5% (2010 -2040)	**-1.4%** (2017-2040)
Gas consumption: annual average growth 2015-40	6%	n/a	1.4% (2018-2040)	-0.2% (2018-2040)	0.8%	1.8% (2010 -2040)	**0.7%** (2017-2040)
Coal consumption: annual average growth 2015-40	-2.60%	n/a	-0.10% (2018-2040)	-4.3% (2018-2040)	-0.9%	0.0% (2010 -2040)	**-6.4%** (2017-2040)
Transport sector							
Oil share (final, 2040)	70%	33% (2050)	82%	60%	91%	86%	**73%**
% Electric vehicle (EV+PHEV) share of new vehicle sales	77% by 2040	n/a	13% by 2030	14.5% by 2030	n/a	n/a	**90% by 2040**
Power sector							
Demand (annual average growth, 2015-2040)	2.4%	2.0%	2.0% (2018-2040)	1.7% (2018-2040)	3.5%	n/a	**2.2%** (2017-2040)
Wind power (annual average growth, 2015-2040)	8.0%	9.0%	6.7% (2018-2040)	8.9% (2018-2040)	10.2%	n/a	**11.2%** (2017-2040)
Solar power (annual average growth, 2015-2040)	15.0%	11.3%	9.9% (2018-2040)	12.0% (2018-2040)	17.5%	n/a	**14.7%** (2017-2040)
Hydropower (annual average growth, 2015-2040)	2.1%	1.1%	1.7% (2018-2040)	2.3% (2018-2040)	1%	n/a	**1.7%** (2017-2040)
Fossil fuel share in power (% of total 2040)	21%	18%	48%	21%	29%	n/a	**18%** (2017-2040)

INEVITABLE POLICY RESPONSE

How we translate the Policy Forecast into a modelling framework

We translate the IPR FPS into a modelling scenario using an integrated modelling framework which draw on models which have been extensively used to study global decarbonisation.

Model	Description	Key features
G-Cubed	• A **macroeconomic** intertemporal general equilibrium model of the global economy. The version used for the IPR project has been G-cubed has been developed at Australian National University.	• It includes the monetary side of the economy allowing simulations of exchange rates, nominal interest rates and financial flows over time across regions • The model also incorporates features of neo-Keynesian models allowing for short run wage rigidities
TIAM-Grantham	• A version of the ETSAP-TIAM model, a global **energy system** model developed by the Energy Technology Systems Analysis Programme (ETSAP). The version used for the IPR project is run by Imperial College in London.	• The TIAM-Grantham model covers the full energy chain from extraction of energy resources (e.g. coal mining) through conversion (e.g. electricity generation or oil refining) and to final use to provide an ‘energy service’ to the end-user (e.g. heating or lighting in a building; mobility etc.)
MAgPIE	• The Model of Agricultural Production and its Impact on the Environment (MAgPIE) is a global **land use** allocation model. It has been developed by the Potsdam Institute For Climate Impact Research (PIK).	• MAgPIE is connected to the grid-based dynamic vegetation model. The model takes into account regional economic conditions such as demand for agricultural commodities, technological development and production costs as well as spatially explicit data on potential crop yields, land and water constraints.

INEVITABLE POLICY RESPONSE

How we translate the Policy Forecast into a modelling framework

Economic system models

Macroeconomic (G-cubed)

- Production activity, emissions, and abatement costs – in general equilibrium
- Monetary, fiscal and financial adjustments

Land use (MAgPIE)

Production activity, emissions, and abatement costs

Carbon prices

Bioenergy prices and demand

Energy (TIAM)

Production activity, emissions, and abatement costs

Carbon prices

Changes to service demand

Outputs

Economic activity (by sector, country)

Price changes (by product)

Energy use (by fuel and carrier)

Cleantech deployment (by type)

- **Forecast of macroeconomic impacts** of transition across major regions
- **Forecasts of price and quantity metrics** for key commodities/products

Value stream models (asset level)

Predict revenues and profits

Cost & competition model
- Carbon cost competitiveness
- Market power and cost pass-through
- Market share

Demand destruction model
- Change in market size in high-emissions sectors (e.g. O&G)
- Price impacts
- Market share

Cleantech market model
- Change in market size in clean sectors (e.g. electric vehicles, renewable energy)
- Product competitiveness and market share

- **Decomposition of downside and upside exposure** to macro and sector forecasts by asset

Financial implications (asset level)

Financial impacts

Asset class	Metric
Listed equity	Δ market capitalization
Private equity	asset value
Corporate debt	Δ bond yields, credit ratings
Sovereign debt	Δ bond yields, credit ratings
Infrastructure	asset value
Real estate	asset value
Commodities	Δ price

- **Disclosable metrics** at asset or portfolio level
- **Uniform metrics** across business

Financial release December 2019 onwards

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