



Carbon Pricing Options to Deliver Clean Growth

12 October 2018

Contents

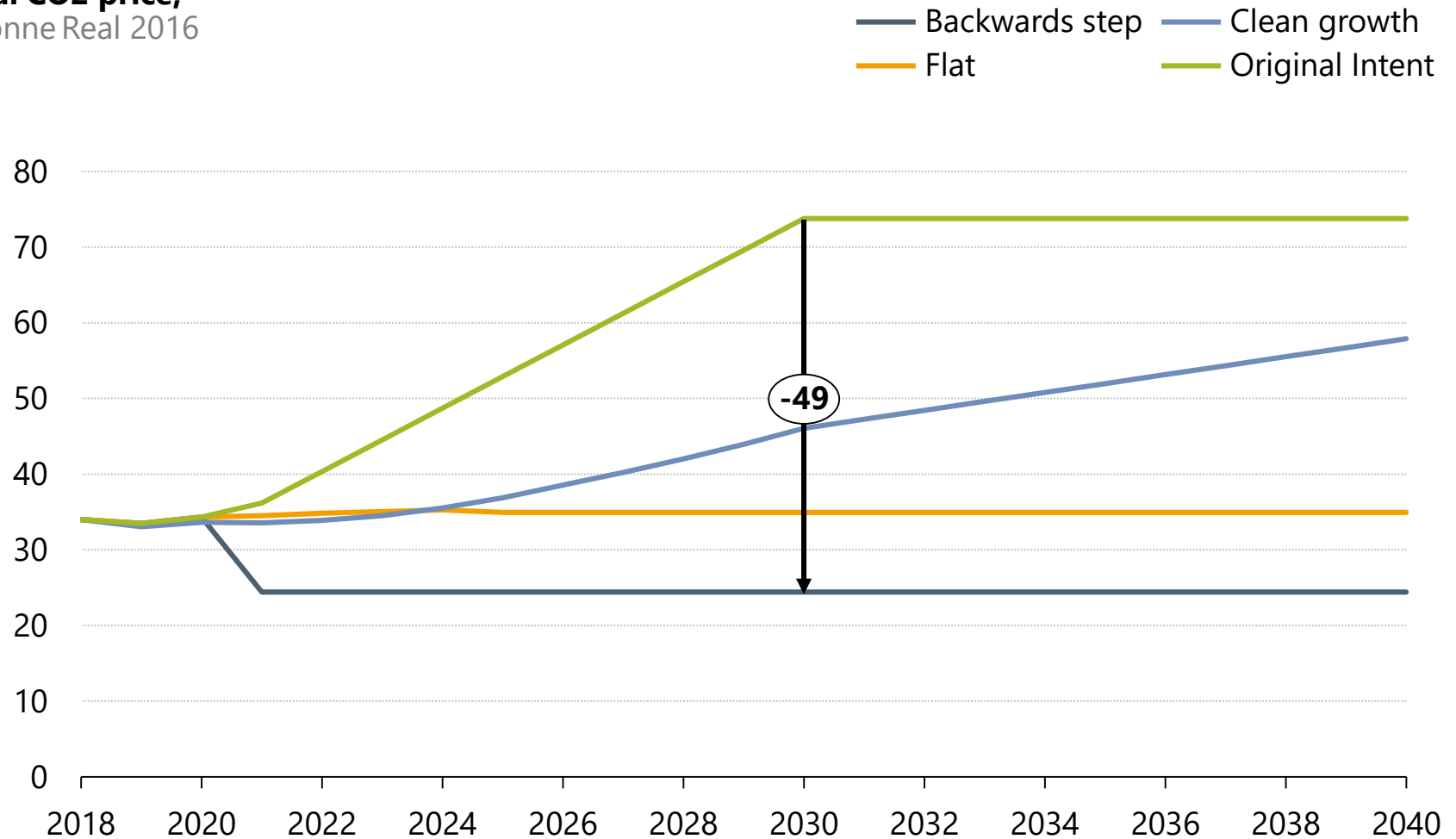
1. Overview of scenarios
2. Impact on GB Market
3. System impact: affordability, tax spending & carbon emission

Aurora has modelled the following 4 scenarios with different CO₂ price trajectories

Scenario	Total CO ₂ price, £/tonne 2016	Description
1 Backwards Step		<ul style="list-style-type: none"> Total CO₂ price stays flat post-2025 at £25/tonne, with CPS decreasing to c. £7/tonne
2 Flat		<ul style="list-style-type: none"> Total UK carbon price remains flat with both EU-ETS and CPS staying relatively flat
3 Clean Growth		<ul style="list-style-type: none"> Total CO₂ price to increase due to higher EU-ETS and a fixed CPS rate of £18/tonne
4 Original Intent		<ul style="list-style-type: none"> Total CO₂ price to hit the original CPF trajectory to £70/tonne (Real 2009) in 2030

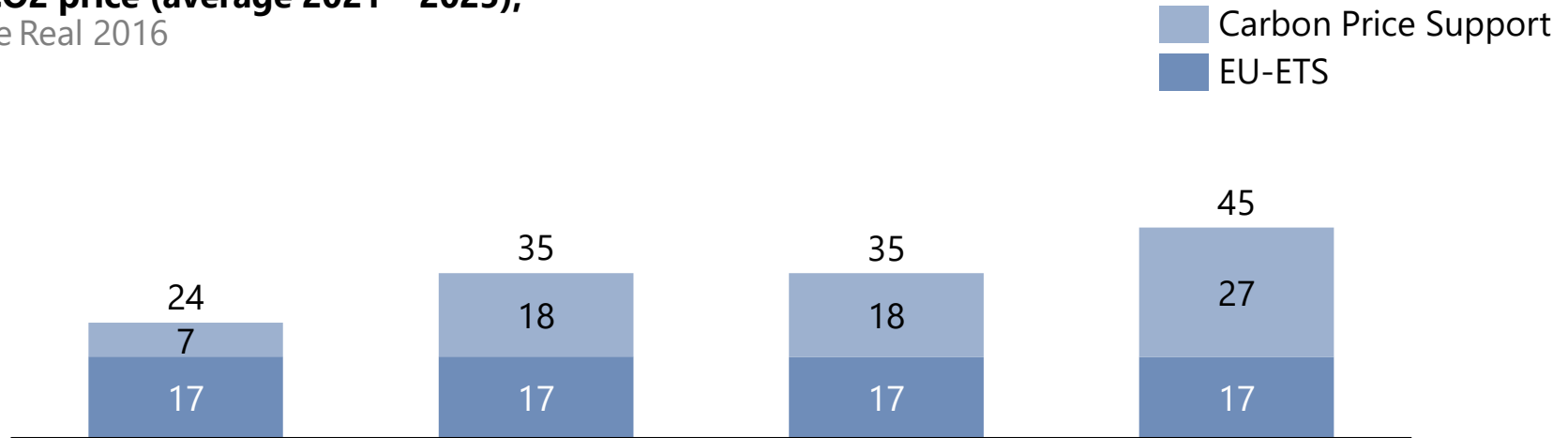
Total CO₂ price vary significantly across the 4 scenarios, driven by different CPS and EU-ETS trajectories

Total CO₂ price,
£/tonne Real 2016

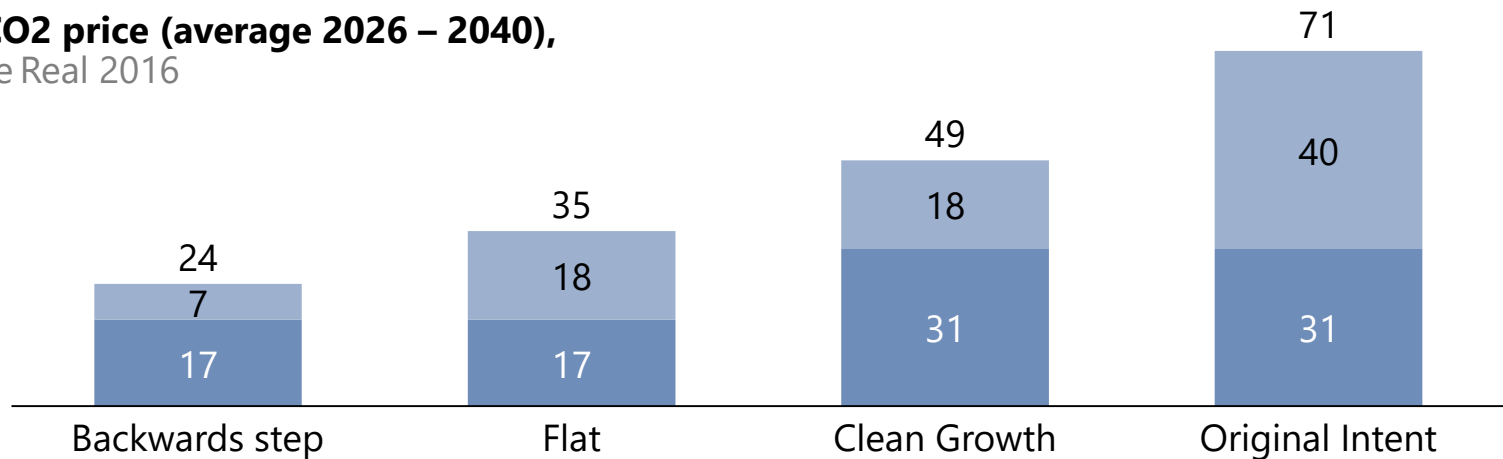


In Backwards Step, the CPS is reduced and kept low at £7/tonne/year to offset the increase in EU-ETS

Total CO2 price (average 2021 – 2025),
£/tonne Real 2016



Total CO2 price (average 2026 – 2040),
£/tonne Real 2016



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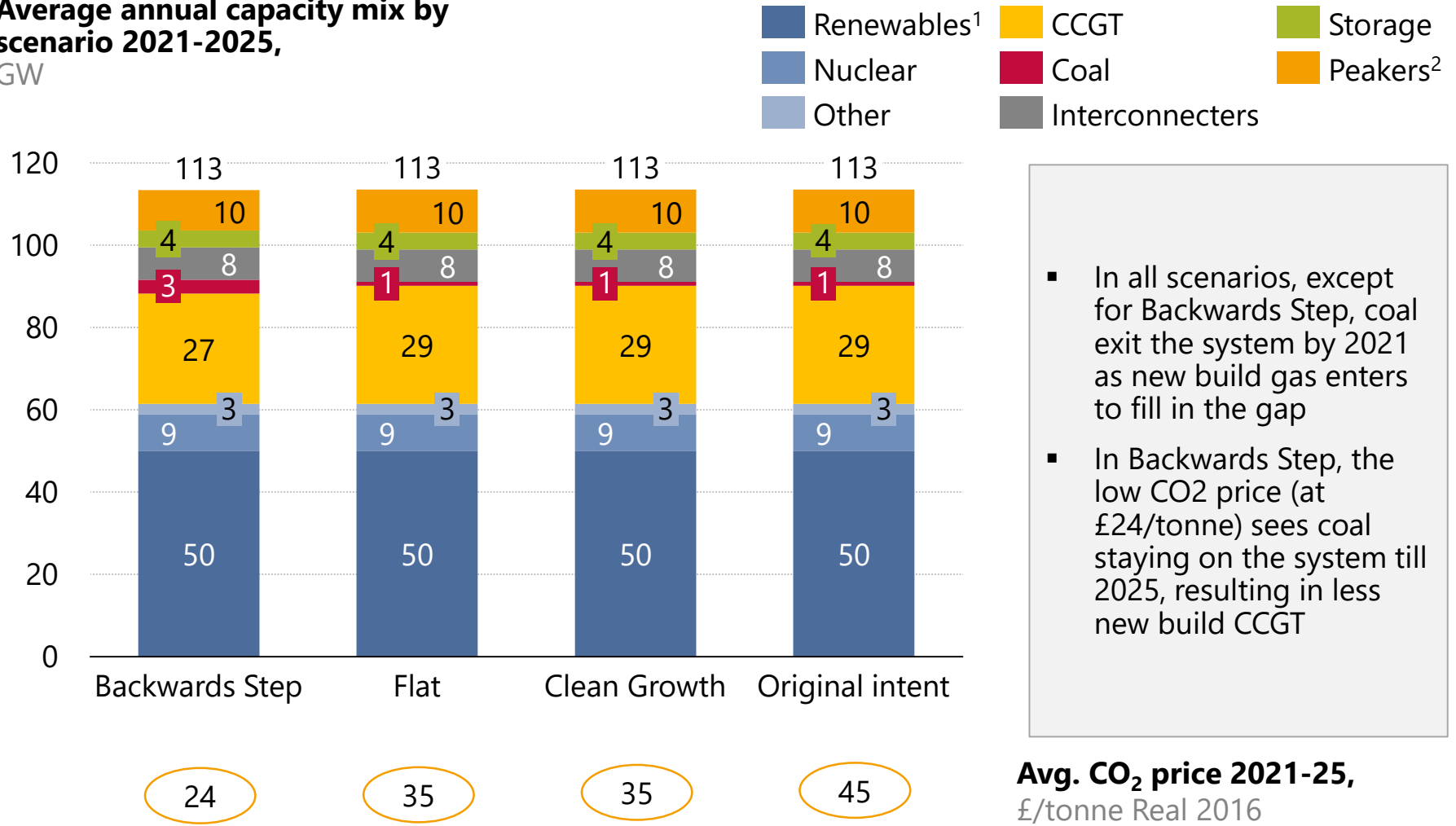
– Pre-2025

– Post-2025

3. System impact: affordability, tax spending & carbon emission

In all scenarios, except for Backwards Step, the high CO₂ price results in coal to exit the system by 2021

Average annual capacity mix by scenario 2021-2025, GW



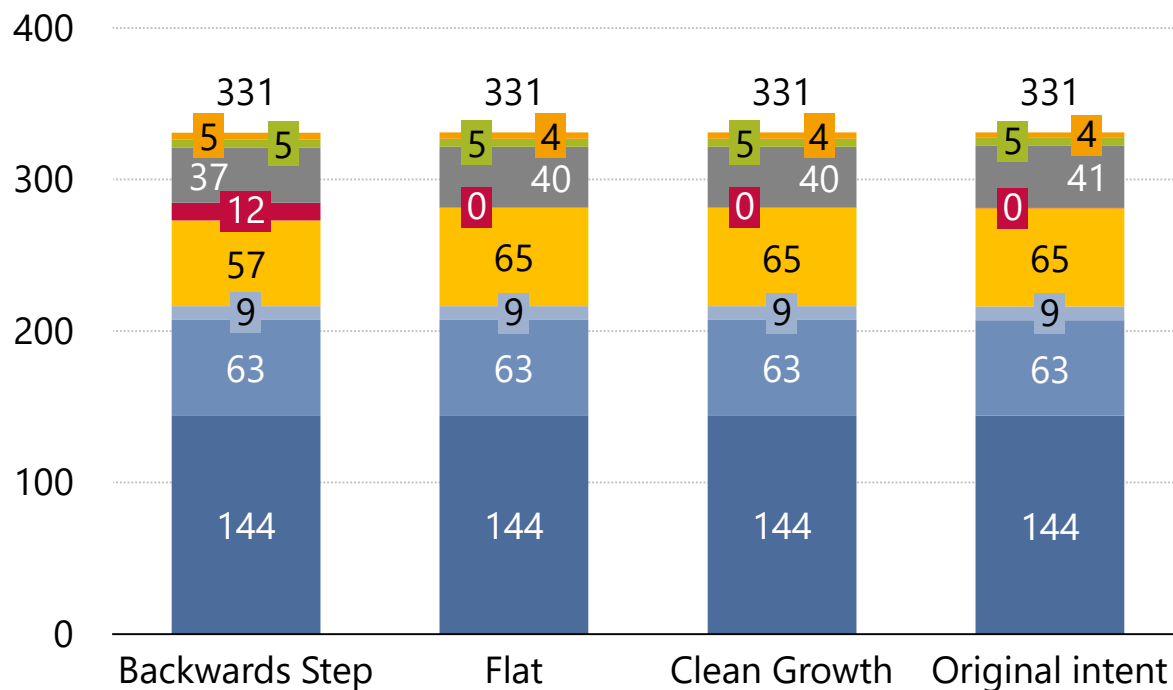
- In all scenarios, except for Backwards Step, coal exit the system by 2021 as new build gas enters to fill in the gap
- In Backwards Step, the low CO₂ price (at £24/tonne) sees coal staying on the system till 2025, resulting in less new build CCGT

Avg. CO₂ price 2021-25,
£/tonne Real 2016

1 Includes onshore wind, offshore wind, solar, hydro and biomass 2. Includes reciprocating engines, DSR and OCGTs

In all scenarios, except for Backwards Step, the high CO₂ price results in a coal to gas switching

Average annual generation mix by scenario 2021-2025, TWh



- In the short-term, carbon prices primarily influence fuel switching between coal and gas
- In all scenarios, except for Backwards Step, coal generation is negligible due to the high CO₂ price, as gas and interconnector fill in the gap
- Conversely, in Backwards Step, the low carbon price leads to a revival of coal as well as lower I/C inflows and lower CCGT generation

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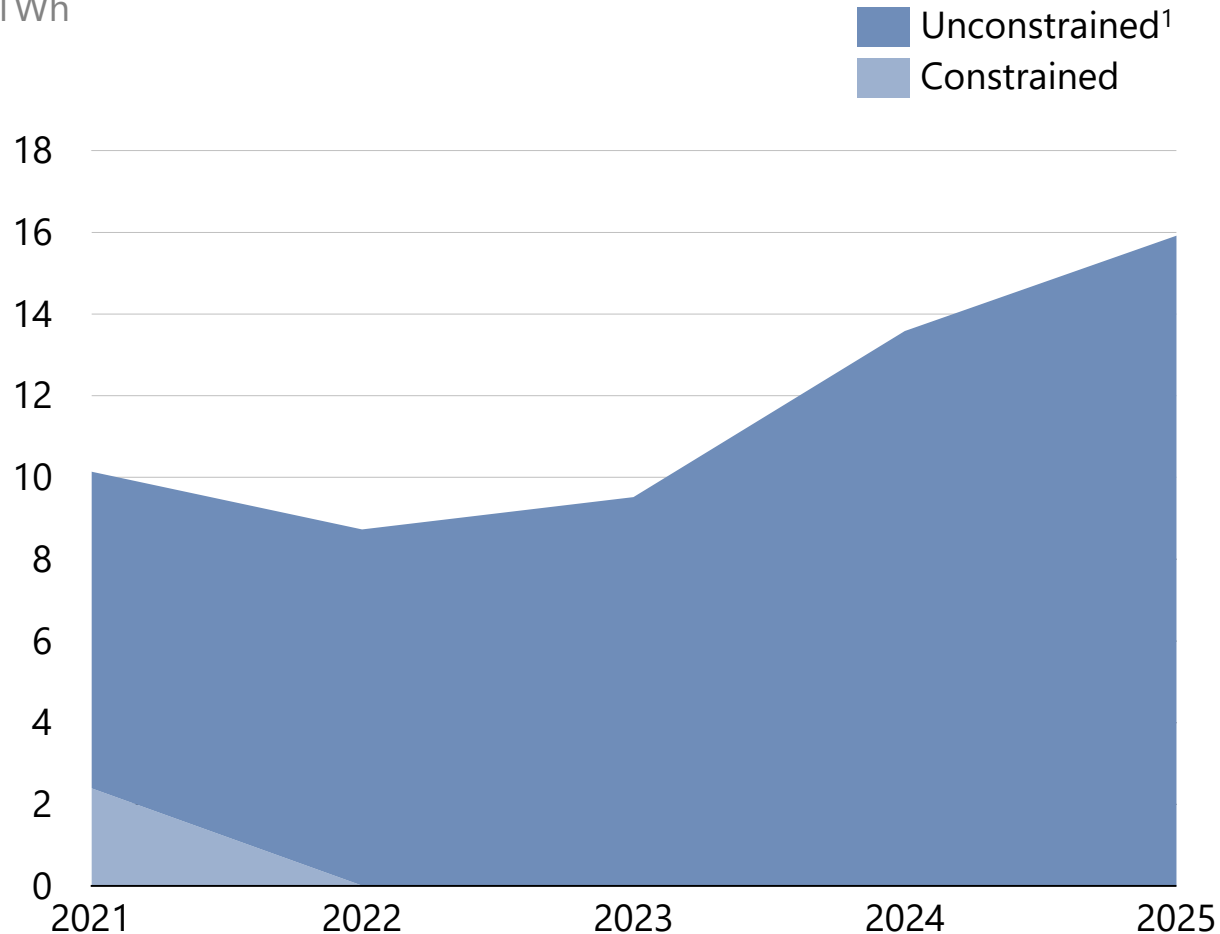
Avg. CO₂ price 2021-25,
£/tonne Real 2016

1 Includes onshore wind, offshore wind, solar, hydro and biomass 2. Includes pumped storage and batteries; shown as gross production 3. Includes reciprocating engines, DSR and OCGTs

In Backwards Step, coal generation comes predominantly from IED compliant coal plants

Total coal generation

TWh



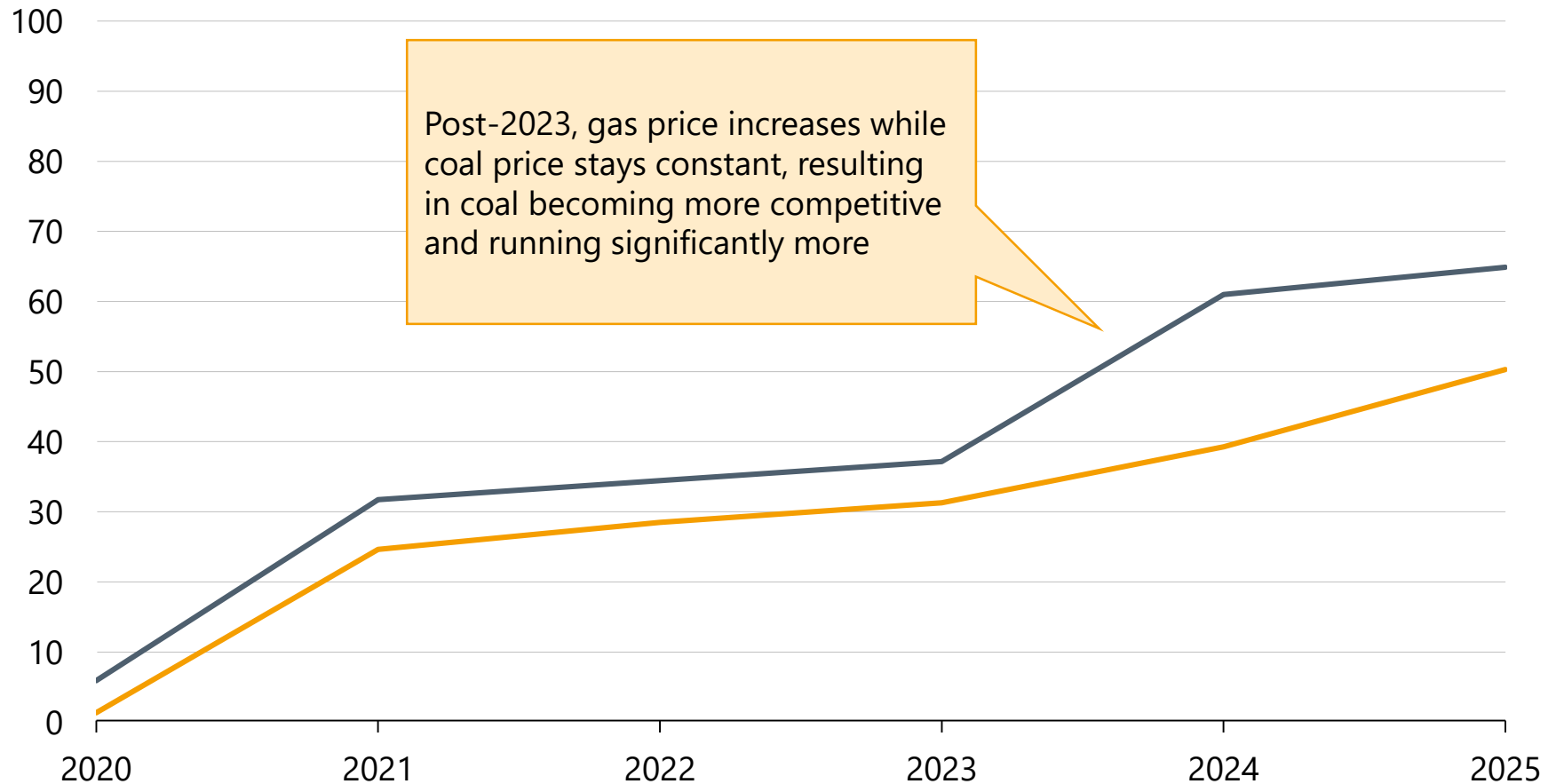
- In Backwards Step, the low carbon price results in both Ratcliffe and Drax staying online until 2025, when they are mandated to close
- The non-IED compliant coal exit by 2022 as the entry of new build CCGT Keadby and other gas reciprocals pushes them out of the market
- Post-2023, the increase in gas price and low carbon price result in a gas to coal switching as coal output increase significantly

¹ Drax & Ratcliffe only

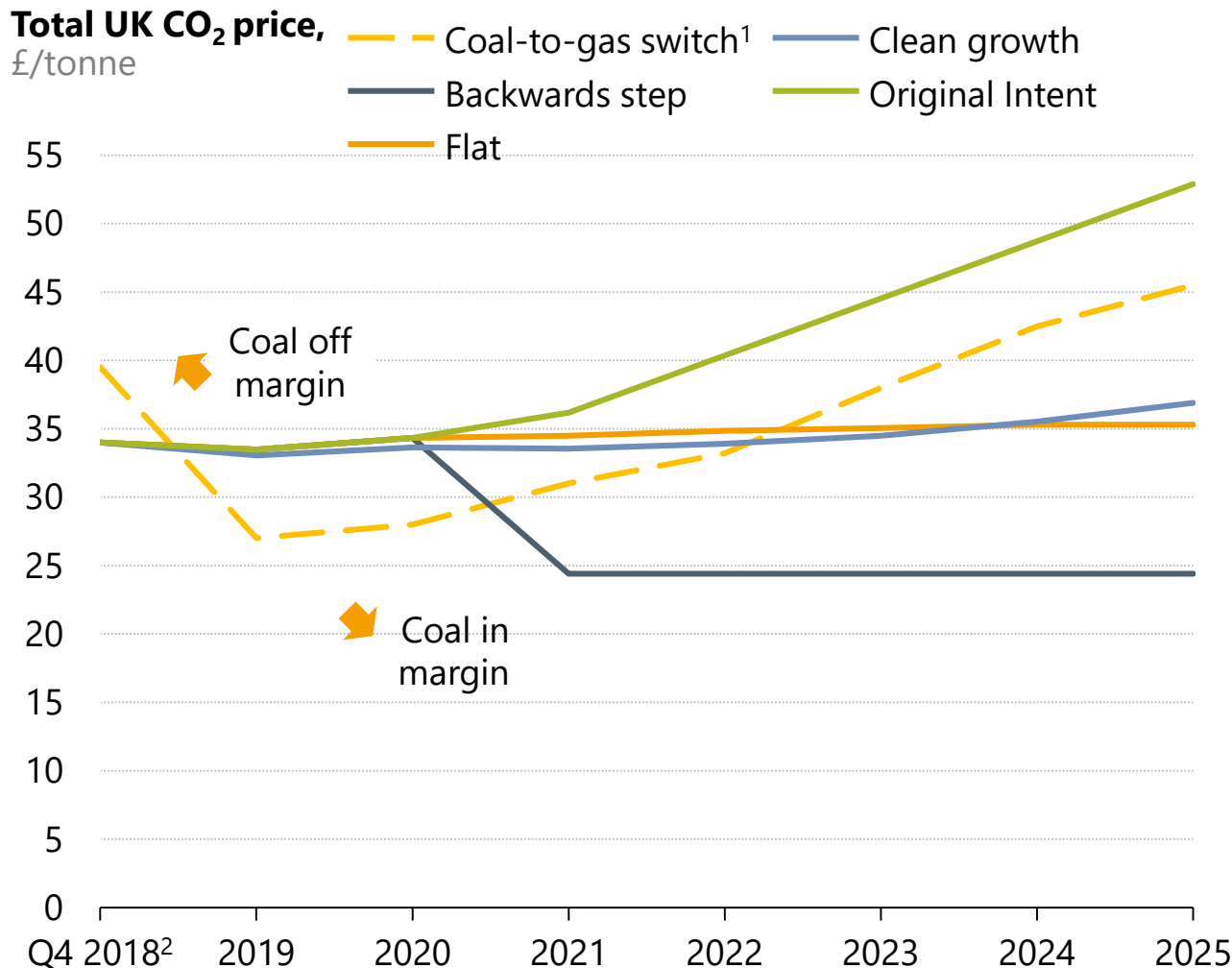
In Backwards Step, Drax's load factor increases to >60% as gas prices increase post-2023

Load factor in Backwards Step,
%

— Drax — Ratcliffe



Given central commodity forecasts, the economic phase-out of coal would require CO₂ prices to rise above £45/tCO₂ by 2025



- Given our central commodity price assumptions, we would expect a revival of coal in the Backwards Step scenario
- Phasing out coal using carbon prices alone would require CO₂ prices to double to increase to >£45/tonne by 2025
- In all scenarios, except Backwards Step, coal exit by 2021 due to the high CO₂ prices
- Clear and credible signalling of the future carbon price would critically influence decisions on whether to stay online or close

¹ Assumes CCGT plant with 49.13% HHV and coal plant with 37% HHV. ² Coal-to-gas switch calculated based on Q4 2018 gas and coal prices (Oct – Dec 2018)

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– Pre-2025

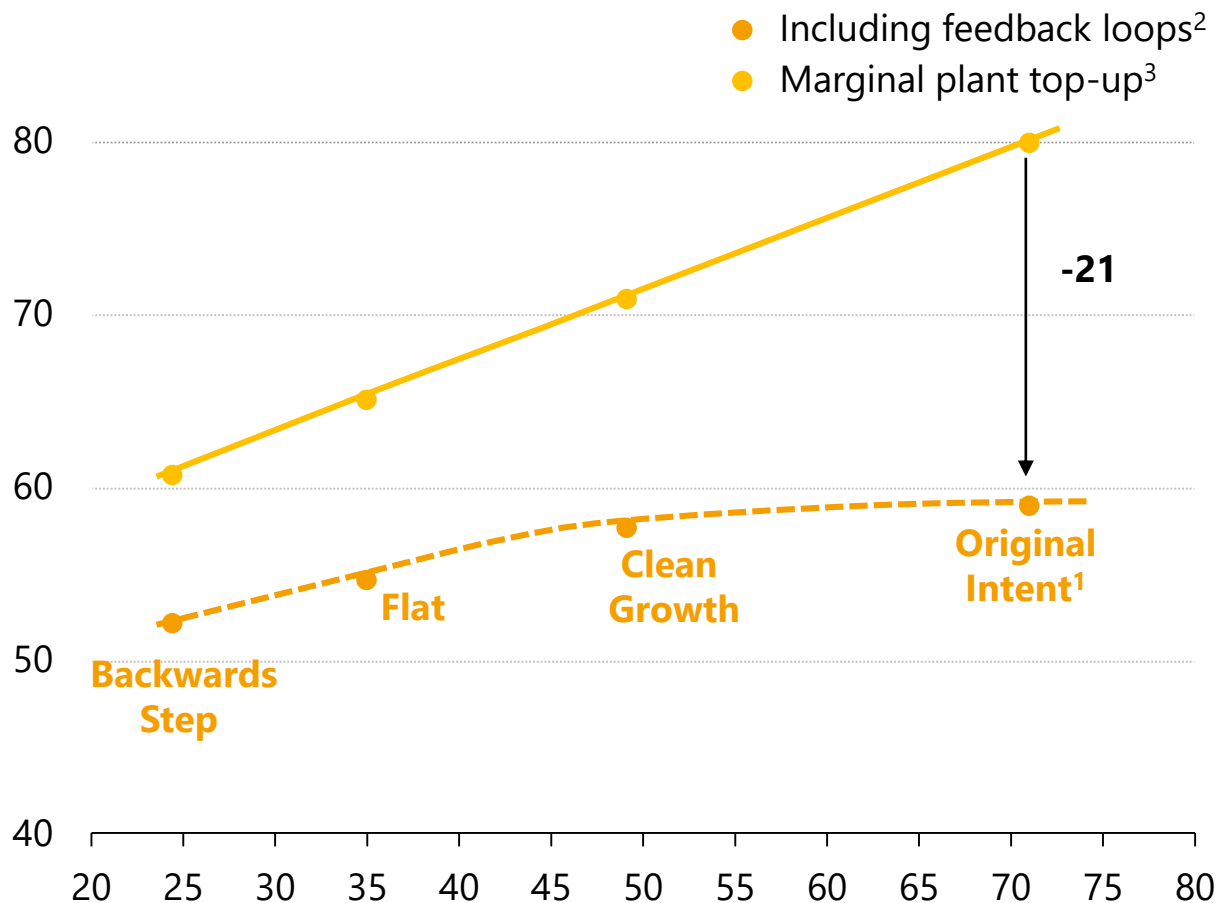
– Post-2025

3. System impact: affordability, tax spending & carbon emission

Increasing the CO₂ price could raise the average baseload price to around £59/MWh from 2026-40

Wholesale price (baseload), average 2026 - 2040

£/MWh Real 2016



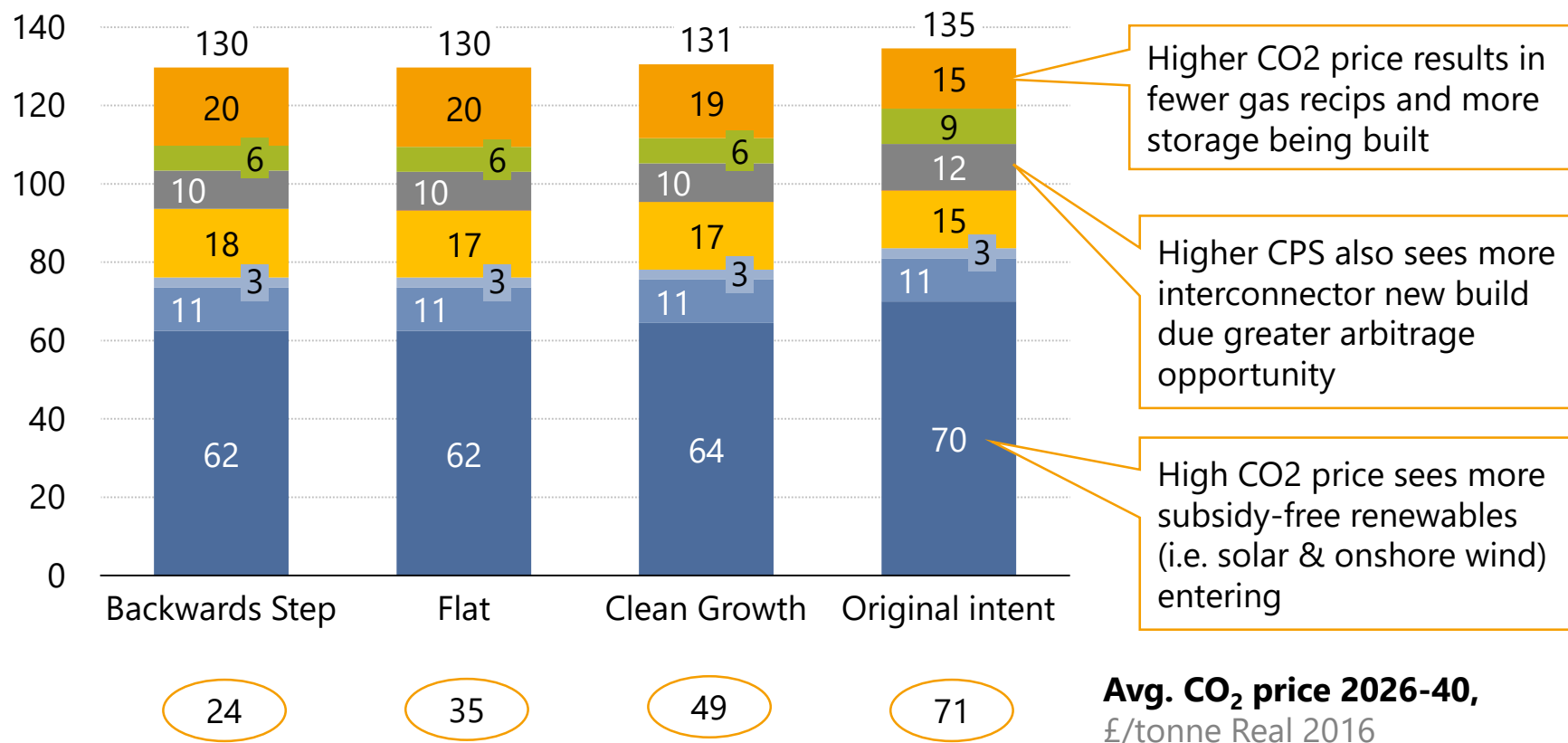
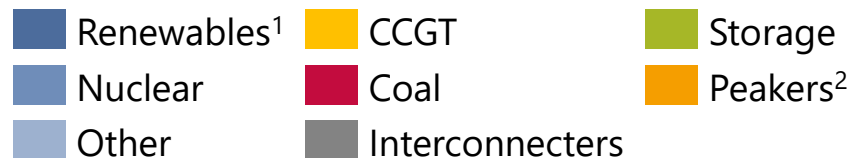
- Higher CO₂ price results in a £7/MWh higher average wholesale price from 2026 – 40 in Original Intent, compared to Backwards Step
- The impact of CO₂ price on wholesale price is dampened by feedback loops like renewables and interconnectors, and entry of more efficient CCGTs setting the price

Avg. CO₂ price 2026-40,
£/tCO₂

1. In Original Intent, additional 2GW of interconnectors are built due to the high CPS 2. Dotted line is extrapolated. 3. Simplified analysis, assumes that 49.13% HHV gas plant sets top up 100% of the time. In reality, in addition to renewables setting the price more often, the marginal gas plant is also likely replaced by more efficient ones, both effects decrease the wholesale price.

Higher CO₂ price results in greater renewables and storage deployment while increase in CPS incentivises interconnector entry

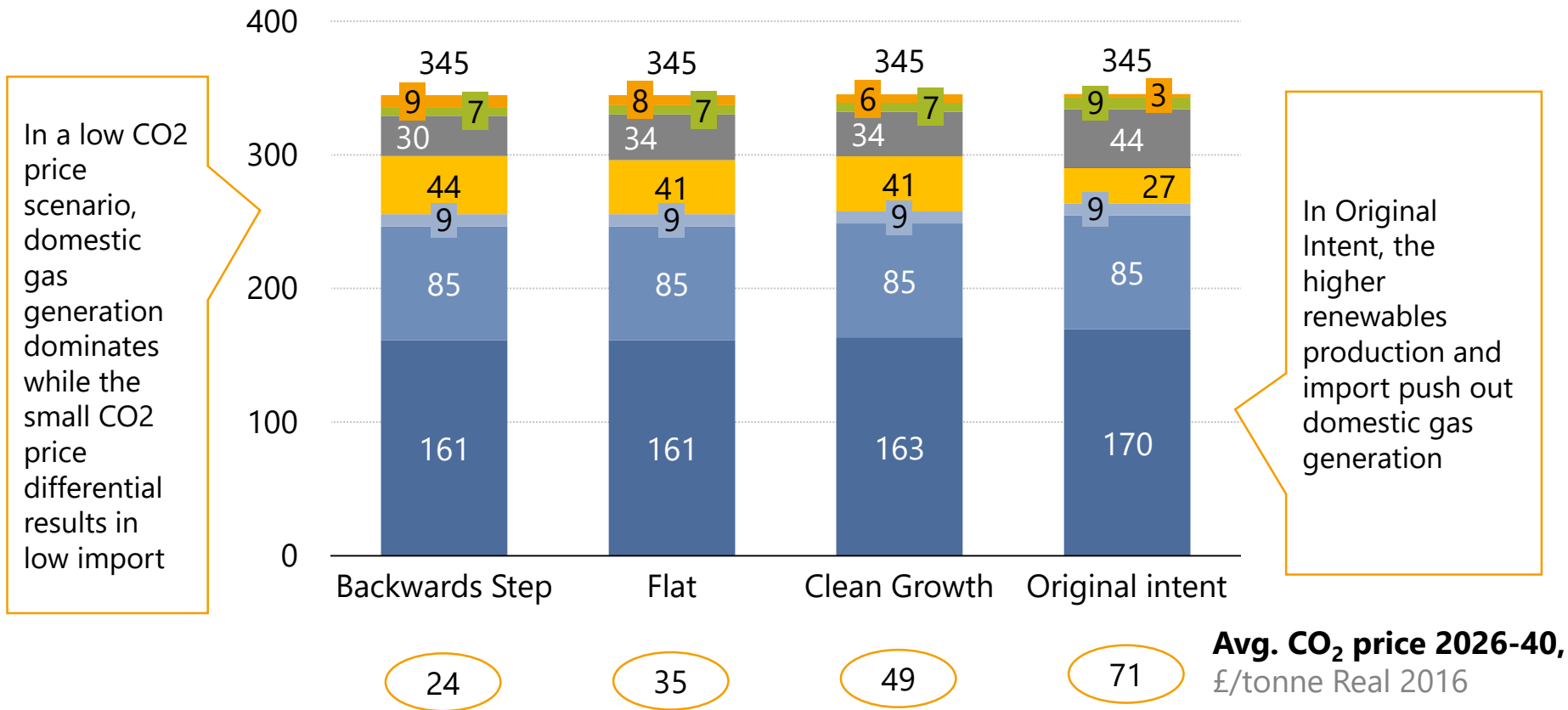
Average annual capacity mix by scenario 2026-2040, GW



1 Includes onshore wind, offshore wind, solar, hydro and biomass 2. Includes reciprocating engines, DSR and OCGTs

Post-2025, higher CPS results in higher import, crowding out domestic CCGT production

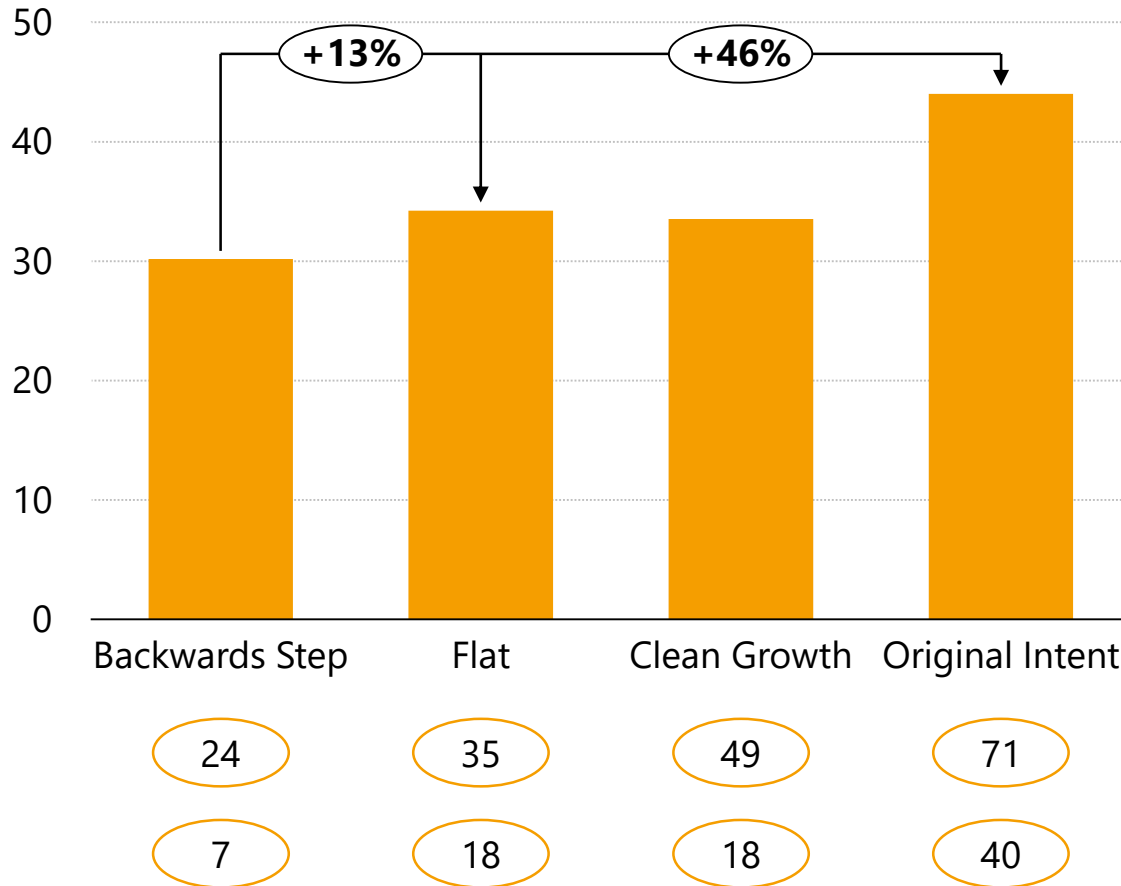
Average annual generation mix by scenario 2026-2040, TWh



¹ Includes onshore wind, offshore wind, solar, hydro and biomass ² Includes pumped storage and batteries; shown as gross production ³ Includes reciprocating engines, DSR and OCGTs

Higher CO₂ price differential results in greater interconnector inflow

Net electricity imports to GB from 2026-40,
TWh



- Higher CPS results in greater CO₂ price differential between GB and other EU countries, resulting in better interconnector economics and higher imports
- In the Original Intent scenario, net import increases by 46% from the Backwards Step, driven by higher interconnector capacity (additional 2GW) and greater inflow for each interconnector

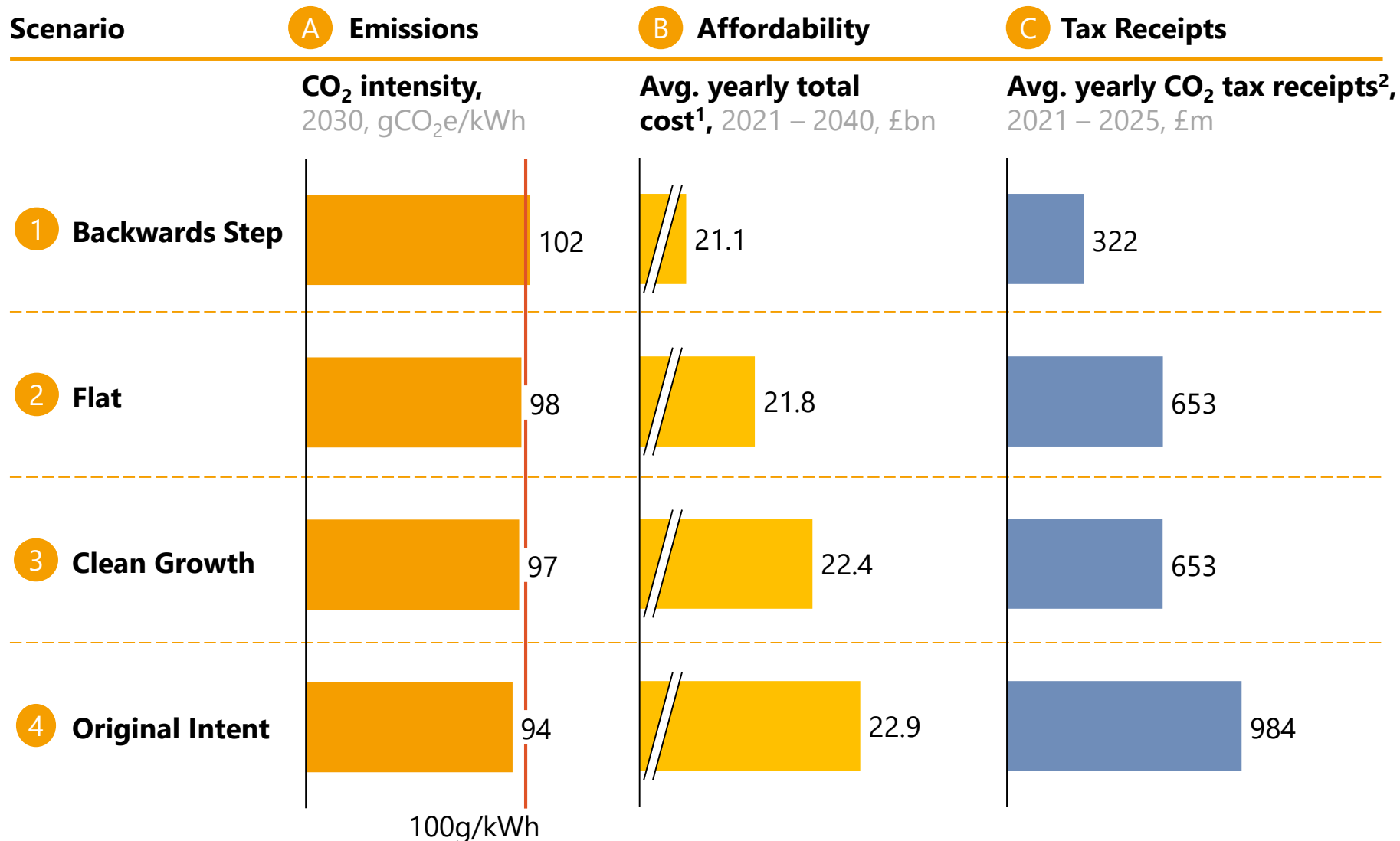
Total UK CO₂ price 2026-40,
£/tonne

CPS price 2026-40,
£/tonne

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Differences between scenarios expose the scale of trade-offs faced

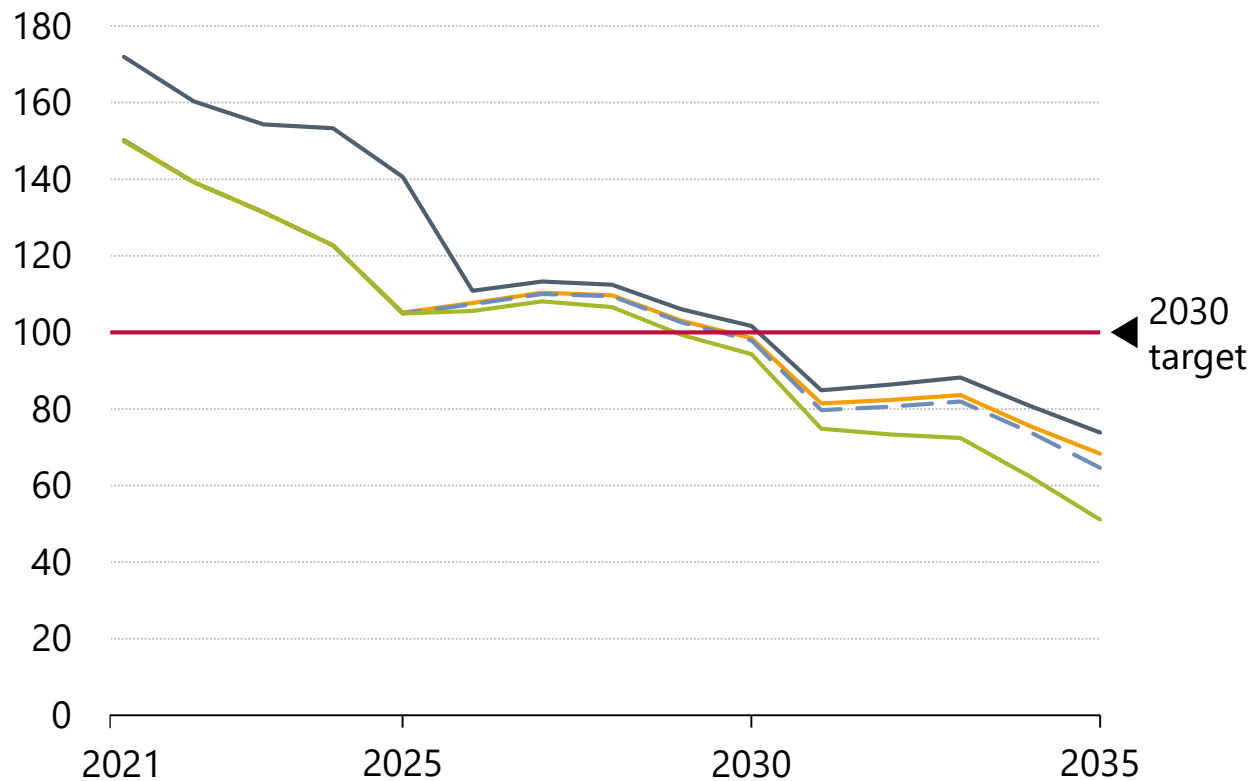


1. Considers wholesale, CfD and Capacity Market costs. 2. Includes only CPS income

In Backwards Step, the low CO₂ price results in GB not to meet its 2030 CO₂ target of 100g/kWh

GB carbon intensity,
gCO₂/kWh

— Backwards Step — Flat - - Clean Growth — Original intent



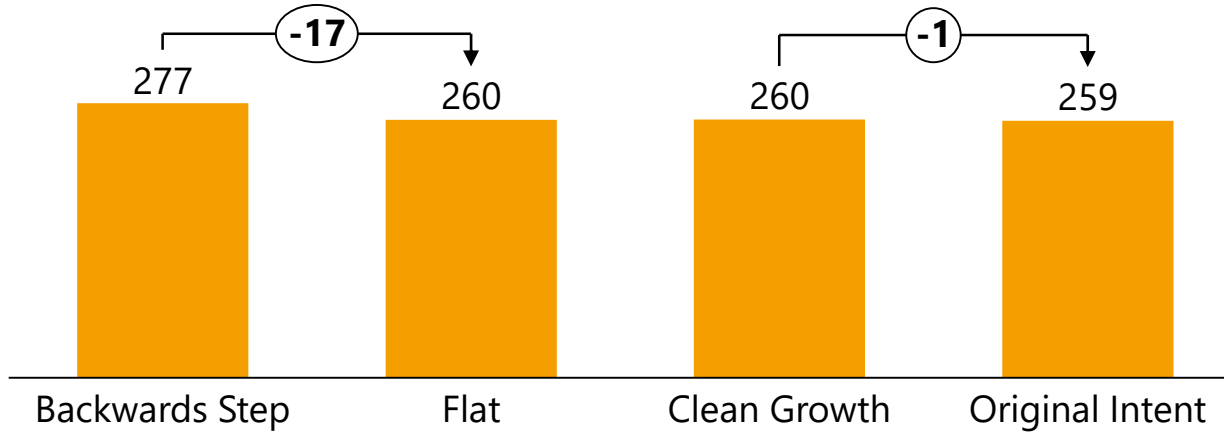
- The carbon price has significant bearing on whether UK is able to reach 2030 power sector carbon target
- In all but the Backwards Step scenario, the high CO₂ price sees emissions reaching below the 100g/kWh target in 2030

In line with the carbon accounting methodology by the CCC, interconnector carbon intensity is assumed to be 0 gCO₂e/kWh.

Backwards Step results in 46Mtonnes of extra CO₂ emission on the system in 2018 – 27 compared to Flat

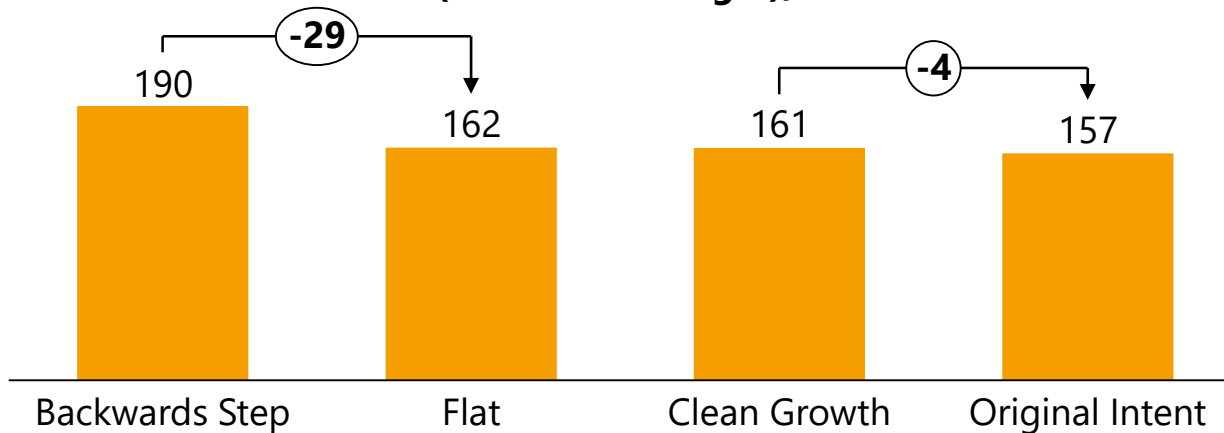
Total carbon emission from 2018 – 2022 (3rd Carbon Budget),

Mtonnes



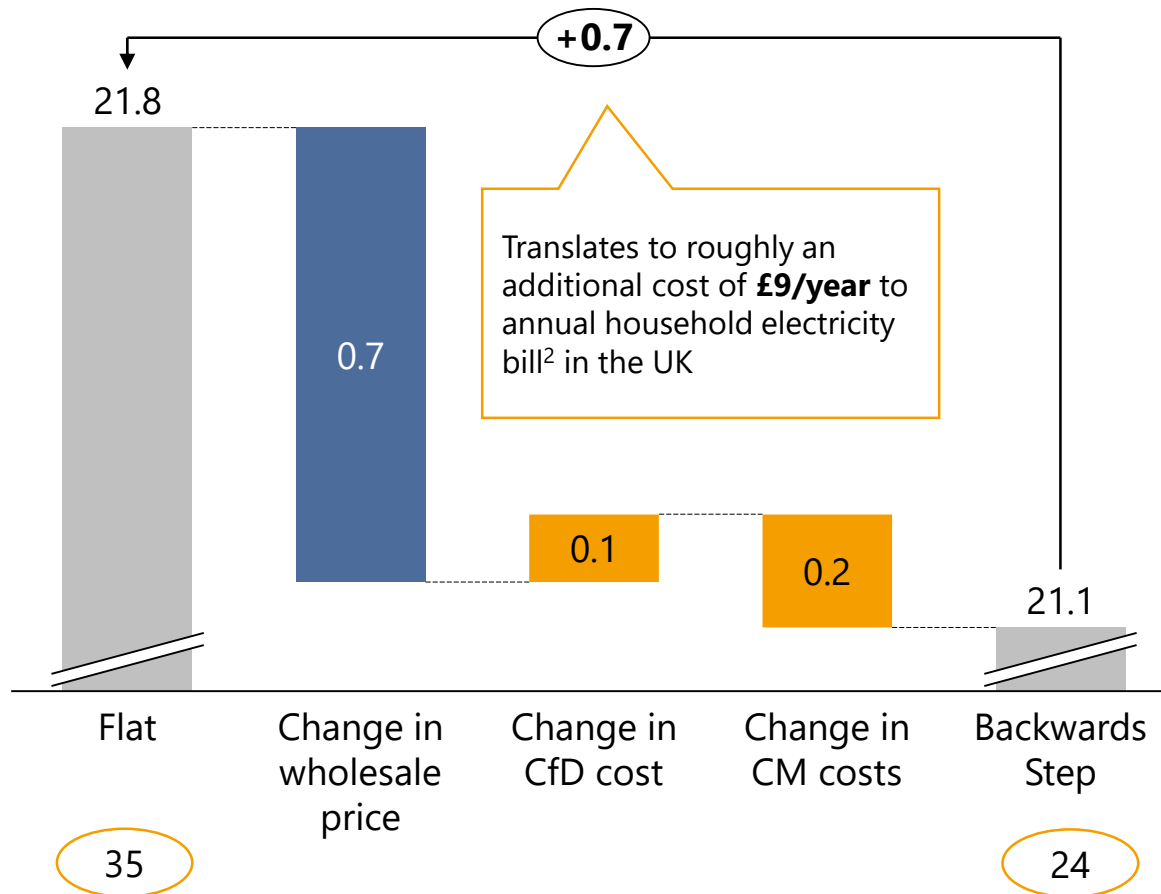
Total carbon emission from 2023 – 2027 (4th Carbon Budget),

Mtonnes



A £11/tonne higher CO₂ price could result in an additional £0.7bn/year in system cost on average from 2021-40

Average annual total cost 2021-40¹,
£bn



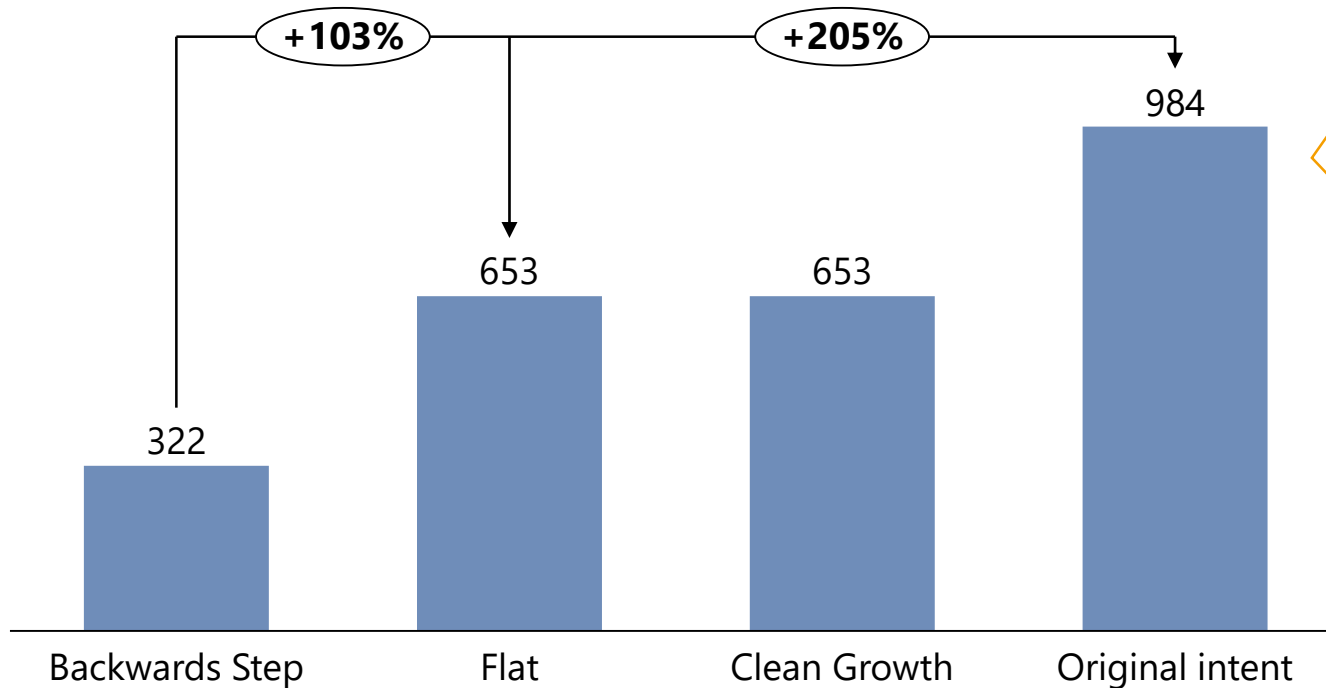
- Overall, system cost is on average £0.7bn/year higher in Flat, compared to Backwards Step
- The higher cost is mainly driven by higher CO₂ price, which results in
 - Significantly higher wholesale spending due to higher wholesale prices
 - Slight decrease in CfD spending as captured prices of renewables increase
 - Higher Capacity Market spending as gas plants capture lower profits in the merchant market and bid higher in CM

Avg. CO₂ price 2021-40,
£/tonne Real 2016

1. Simplified analysis, only includes electricity and capacity market costs as well as CfD subsidies, thus excluding i.e. network, intermittency and other system costs. 2 Calculated based on the following assumptions: domestic consumes 30% of total UK power generation and total number of households in UK projected to be 27million on average from 2021-40

Higher CPS price results in higher CO₂ tax income but also early coal closure and lower emission

Average yearly CO₂ tax income¹ 2021-25,
£m



The higher CO₂ price results in early exit of coal capacity and a higher CO₂ tax income, which almost triple from the Backwards Step scenario

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Avg. CPS price 2021-25,
£/tonne

¹ CPS only

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