FES 2025

Economics Annex

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NESO
National Energy
System Operator

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Summary

Energy and the services it enables are vital to modern life and to the economy. Expenditure on energy services is an important budgetary item for households and businesses. Our *Future Energy Scenarios*: *Pathways to Net Zero* (FES 2025), published in July 2025, explores how energy demand and supply may develop in Great Britain (GB) to 2050 on the path to net zero greenhouse gas emissions. This technical annex explores the economics of the three FES 2025 net zero pathways and the Falling Behind scenario that reduces emissions more slowly.

Our cost estimates cover both upfront and ongoing costs both for infrastructure, such as power plants and networks, and for relevant consumer purchases, such as cars and boilers. How costs translate to energy bills is a function of government policy and is not covered in this analysis.

The key results from our analysis are:

- The energy-related costs covered by our analysis are projected to decline in all FES 2025 pathways, from around 10% of GDP in 2025 to approximately 5-6% by 2050. This is despite a projected rise in energy demand, driven by population growth, increasing GDP and growing consumption from data centres. Investment in coming years enables a reduction in fuel costs and other operational spending in later years.
- Exposure to fossil fuel price volatility is substantially reduced in the FES 2025 pathways. The gas (and to a lesser extent oil) price crisis of 2022 led to an extra 1.8% of GDP being spent on energy compared to pre-crisis years. An equivalent price shock in 2050 in the Holistic Transition pathway, which meets all the UK's carbon targets, would increase energy costs by equivalent of 0.3% of GDP. In the Falling Behind scenario, which does not meet legally binding carbon targets, costs would still increase by over 1.1% of GDP in 2050.
- The net zero pathways involve a shift from spending on imported fuels to GB investment in renewables, networks and heating systems. As well as unlocking reduced operating spending, this investment can bring local economic opportunities and support new jobs, alongside the opportunity for improved air quality and health outcomes. These non-financial benefits are not included in our estimates.
- Projections of future costs are inevitably uncertain. Through our sensitivity analysis, we have explored the uncertainty in technology and fuel costs over the long term. We find that the potential range of costs due to these uncertainties is greater than the differences in costs between the FES 2025 pathways under fixed assumptions. This implies that the efficient delivery of any given pathway may be as important for cost as the choice of pathway.
- When carbon costs are included (at the UK Government's Green Book values), the Holistic Transition pathway has the lowest cost over 2025-2050 and enduring savings beyond 2050. If carbon costs are ignored, the Falling Behind scenario is cheaper over 2025-2050, saving the equivalent of around 0.4% of GDP on average annually. It would have higher

costs beyond 2050, given higher ongoing fuel costs and the need for further investment if net zero is to be achieved later. Falling Behind would also forego many of the non-financial benefits and could see negative trade effects as trading partners target faster emissions reductions. The comparative costs should be seen only as indicative given the uncertainties and differences between pathway assumptions detailed later in this report. The numbers cannot be compared directly to those published earlier in the year by the Climate Change Committee (CCC) and used by the Office for Budget Responsibility, as their costs represent the cost of reaching net zero compared to a no-action baseline, which our numbers do not.

While costs are an important consideration in their design, the FES 2025 pathways are illustrative ways of meeting net zero by 2050 that are not fully optimised to minimise cost. They are likely to differ from the path actually taken to net zero, with scope to deliver any given pathway in a similar way but with lower costs than modelled.

Part of the value of estimating costs of the pathways is in identifying ways in which costs can be minimised. These require strategic planning, alongside efficient markets and effective policy making. Our analysis points to the following ways to keep costs as low as possible, which we will consider in our strategic energy plans and policy advice:

- Take low-cost opportunities for energy saving and flexibility on the demand side.
- Electrify the transport fleet at pace.
- Focus deployment on the lowest cost, low emission options where possible.
- Coordinate build-out of infrastructure, aligning growth of electricity generating capacity with decarbonisation needs, network growth, flexibility and demand growth.
- Design policy to minimise costs of capital while promoting competition and innovation.

1. Introduction and approach

Costing the FES pathways

We published our *Future Energy Scenarios: Pathways to Net Zero* (FES 2025) in July 2025. The 'Holistic Transition', 'Electric Engagement' and 'Hydrogen Evolution' pathways explore a range of routes to net zero in 2050 for energy demand and supply by considering the choices that can be made and the uncertainties. Our 'Falling Behind' scenario does not reach net zero by 2050 but does include some progress towards decarbonisation goals.

The *Future Energy Pathways Guidance*[1] requires that, where possible, we must include indicative costs. Although it was not possible to include these with our FES 2025 publication in July, we are publishing costs now and in line with our licence obligation to publish easily accessible information to generate value for consumers and stakeholders. Our analysis is based on information available at the time of publication of FES 2025 on 14 July 2025. Any changes or new information released after 14 July 2025 are not reflected in this analysis.

Estimating the costs involved in the pathways allows us to develop better options, understand the trade-offs between pathways and technologies, and provide a deeper evidence base for future analysis and for our stakeholders. Given the importance of keeping energy bills as low as possible for households and businesses across the country, costs are a vital lens for strategic planning and policy development.

FES 2025 does not aim to optimise future pathways around costs; it presents a broad view of possible pathways and looks at a range of outcomes across supply and demand, which are likely to differ from the path actually taken to achieve net zero by 2050. Therefore, the costings we present do not represent the cheapest way of achieving net zero, rather they explore the potential cost implications of the options and the choices available to decarbonise GB's energy system. Achieving net zero requires the adoption of both cost-saving options, such as electric vehicles (EVs), and options that add cost, for example the application of carbon capture and storage (CCS).

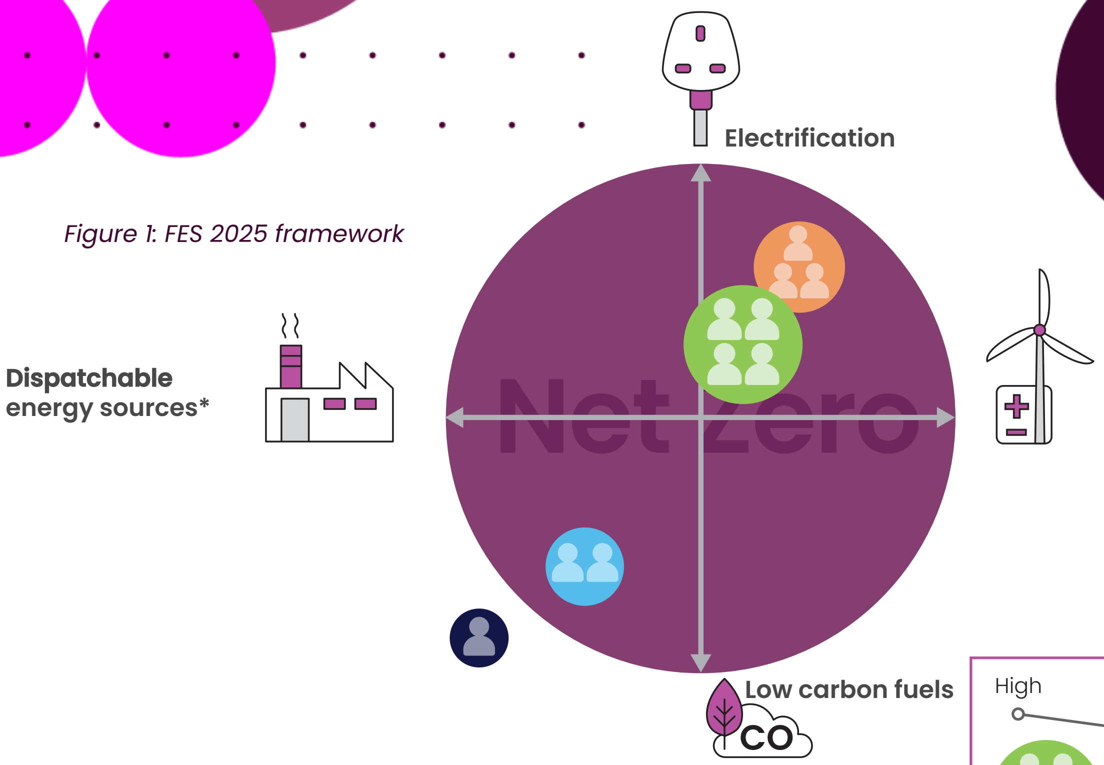
Our analysis focuses on the economic resources needed. We do not include transfer payments between groups, such as taxes or subsidies, as these do not represent an additional cost to the economy. This is distinct to other analyses that consider the impact or cost of decarbonisation activities to GB's consumers and businesses. The costs outlined in our report could be distributed across consumers or recovered over time in different ways depending on policy choices.

Throughout this report, we highlight the uncertainties associated with the pathways, which influence their comparative costs. The different FES 2025 pathways capture uncertainties over

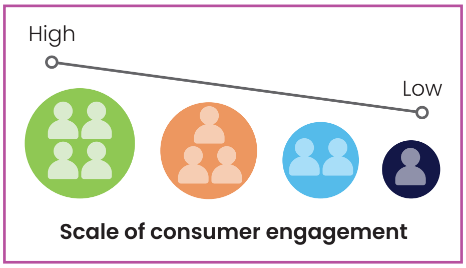
[1] Future Energy Pathways Guidance

pathway and policy choices, such as the relative deployment of different energy technologies, and over consumer choices, for example the effect of autonomous vehicles and growth of data centres. In calculating costs, we also explore sensitivities on fuel costs and the capital cost of technologies. There are of course wider uncertainties beyond this and potential for options not widely deployed in the FES 2025 pathways to play a greater role and reduce costs.

Figure 1: FES 2025 framework



Includes electricity and hydrogen production



Future Energy Scenarios outputs

Holistic Transition

Net zero is met in Holistic Transition through a mix of electrification and hydrogen, with hydrogen mainly used around industrial clusters. Hydrogen is not used for heat except as a secondary fuel for heat networks in small quantities. Consumer engagement is very strong through the adoption of energy efficiency improvements and demand shifting, with smart homes and electric vehicles providing flexibility to the grid.

Holistic Transition is a high-renewable capacity pathway, with unabated gas dropping sharply. This pathway sees moderate levels of nuclear capacity and the lowest levels of hydrogen dispatchable power. Supply side flexibility is high, delivered through electricity storage and interconnectors. No unabated gas remains on the network in 2050.

Electric Engagement

Net zero is achieved in Electric Engagement mainly through electrified demand. Consumers are highly engaged in the transition through smart technologies that reduce energy demand, such as electric heat pumps and electric vehicles.

Electric Engagement has the highest peak electricity demand, requiring high nuclear and renewable capacities. It also has the highest level of bioenergy with carbon capture and storage across all the net zero pathways. Supply side flexibility is high, delivered through electricity storage, interconnectors and low carbon dispatchable power.

Hydrogen Evolution

Net zero is met in Hydrogen Evolution through fast progress for hydrogen in industry and heat. Widespread access to a national hydrogen network is assumed. Some consumers will have hydrogen boilers, although most heat is electrified. There are low levels of consumer engagement within this pathway.

Hydrogen is used for some heavy goods vehicles, but electric vehicle uptake is strong.

Hydrogen Evolution sees high levels of hydrogen dispatchable power plants, leading to reduced need for renewable and nuclear capacities. Hydrogen storage provides the most flexibility in this pathway.

Falling Behind

Falling Behind considers a world where some decarbonisation progress is made against today, but at a pace not sufficient to meet net zero.

Falling Behind is used in downstream gas and electricity security of supply processes - it is important that we use Falling Behind alongside the net zero pathways to consider the full range of potential demand levels for possible remaining reliance on unabated fossil fuels.

With the current level of low carbon projects in the pipeline and increased policy ambition, we consider some level of progress in Falling Behind in areas where there is increased certainty or progress. It is not a 'status quo' scenario.

Methodology and approach

We worked with energy consultants AFRY to assess the economics of the FES 2025 pathways. A full view of our methodology, including sectoral approaches and data sources, can be found in the accompanying **Methodology document** (for a comprehensive explanation of our approach), **Assumptions log** and **Data workbooks**. Key elements of our approach are outlined below:

- We have sought to capture as many relevant costs as possible without double counting. Costs that affect more than one sector are only included once. For example, the cost of the electricity used for EVs is included in the electricity sector, where electricity has been produced, and is excluded from the road transport sector.
- We focus on the 'resource costs' of the pathways in GB. These include the costs of investment in energy technologies, the costs of operating/maintaining them and the costs of the fuels they use. In line with *Green Book* guidance[2], we do not include transfer payments between groups, such as taxes, subsidies and economic rents. This is because such payments represent moves of resources between groups rather than an overall cost to the economy.
- The costings presented are derived from outputs of unconstrained network analysis, as modelled in FES 2025.
- As is the case with FES 2025, this is a forward-looking analysis. We do not attempt to estimate costs or savings of historical choices which have already happened and are consistent across the FES 2025 pathways.
- All costs are in real terms, in 2025 prices, including cost values referenced from other sources. The 2025 GDP deflator has been obtained from Oxford Economics, based on their independently developed forecast.
- The cost estimates we present are based on assumptions made for the purpose of this specific analysis and may be updated or changed for other areas of NESO work. We draw on a range of sources, including our own independent assumptions drawn from wide research, assumptions provided by AFRY based on their expertise and research, cost estimates from the Department for Energy Security and Net Zero (DESNZ) and from CCC.
- Our oil and gas wholesale price forecasts are independently sourced from Oxford Economics and Aurora[3]. We use the same fuel prices across the pathways for clear comparisons and explore sensitivities using the DESNZ High and Low values. As shown in Figure 2, the High case is considerably lower than the price spike seen for gas in 2022.

[2] *The Green Book*, HM Treasury, 2022
[3] Oxford Economics & Aurora Energy We use these fuel prices to calculate long-run variable costs to value changes in energy consumption, in line with Green Book guidance.

Our sector coverage is focused on the GB energy sector and sectors that are modelled by NESO with the necessary granularity.

- We have not included costs associated with agriculture (except where it relates to energy use), land, aviation, shipping and engineered removals. Agriculture and land are not part of the energy sector while aviation and shipping are primarily international. These sectors are not directly modelled in FES 2025, which focuses on GB energy. The majority of engineered removals are required to displace remaining emissions from aviation and shipping (see FES 2025, Figure 32), so these costs are also excluded.
- For GB energy sectors where NESO does not explicitly model activity as part of FES 2025 (such as rail or construction) or where we lack the needed granularity for costing (industrial), we have used data from CCC's *Seventh Carbon Budget* report[4], incorporating fuel switching from FES 2025 pathways where possible. The CCC figures are specifically the costs of action relative to their baseline with no further decarbonisation action.[5]

We do not include carbon costs in our resource cost estimates as they are not included in standard GDP accounting; they generally represent a transfer from businesses to the Exchequer, rather than an additional cost to the economy. However, reducing carbon is an important goal for the pathways and there is a recognised social cost attached to carbon emissions and the resulting climate change. We therefore illustrate this value of emissions by calculating carbon costs in the pathways, based on the UK Government's *Green Book* values for appraisal[6]. These are shown separately in our charts and do not form part of our calculations when considering overall cost.

We are presenting costs mainly as total energy cost (TotEx) which includes total investment and operating costs both as an absolute number and as a percentage of GDP. The latter is intended to give a sense of scale; it does not imply an estimated effect on GDP or economic growth, which will depend on various dynamics within the economy that we have not modelled in this work. For example, the shift in spending away from imported fossil fuels towards GB investment could be advantageous for economic growth.

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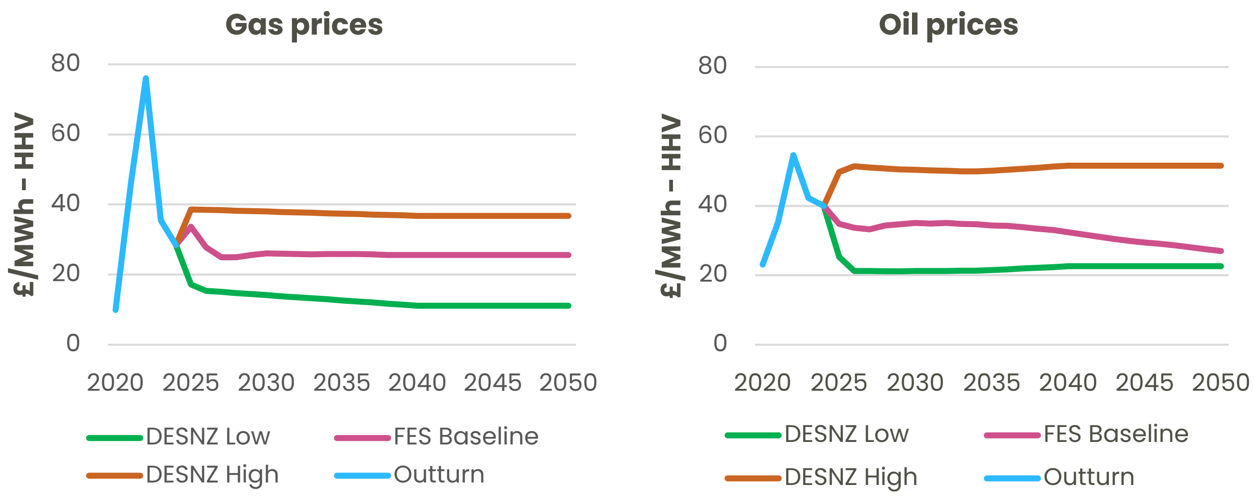
[4] CCC's remit covers the UK, and while FES focuses on Great Britain, this is not expected to materially impact the costing analysis.

[5] CCC figures are for costs relative to a no-action path, so we include them in the total cost estimates for our net zero pathways but not the Falling Behind scenario.

[6] DESNZ (2023) – Carbon values and sensitivities for appraisal - we use the Central values for appraisal, which start at £307/tCO_2 in 2025 and rise to £448/tCO_2 in 2050 (2025 prices). These are higher than prevailing market carbon prices but are recommended for use in appraisal.

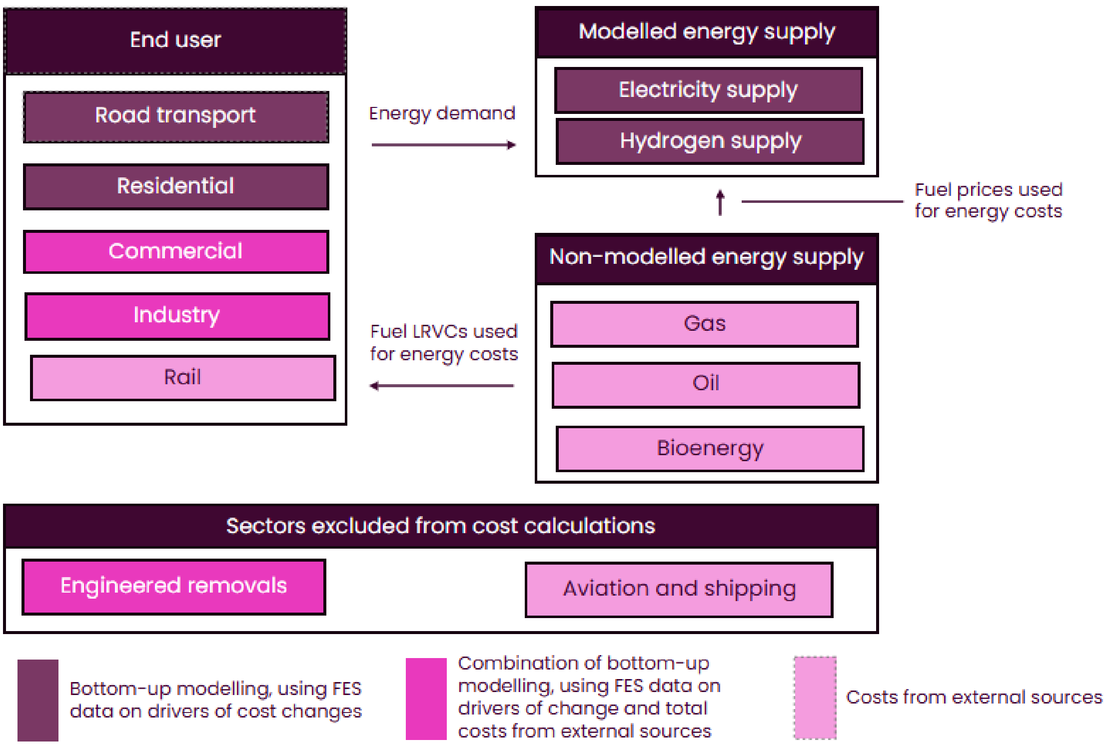
Figure 2: Gas and oil wholesale price assumptions (2020-2050)



Note: Outturn values are the average of the daily spot prices for each given year.

A summary of the approach for each sector is shown in Figure 3.

Figure 3: Summary of approach



Note: Costs from external sources are generally only available as incremental values in comparison to a no-action scenario. LRVC: Long-run variable cost.

2. GB spending on energy

Energy costs covered in our analysis

Energy bills are a major item in household budgets and in the cost base of many businesses. This report does not cover energy bills, which include taxes and transfers and are dependent on government policy. Instead, it focuses on underlying energy costs, many of which are ultimately recovered through energy bills.

Energy costs result from two main categories: investment in assets that produce and use energy and the operational costs of fuelling, running and maintaining those assets. We cover both in our analysis. We include all costs of producing and using energy, for example the costs of building power plants and buying fuels. We include the costs of assets that use energy where these are expected to be materially affected in the transition to net zero. This means we include the purchase and maintenance costs of vehicles and heating systems, but not of lights and appliances which already use electricity (and while they may see changes in efficiency or flexibility, we do not assume these will involve material changes in cost).

Fuel and other operating costs

Ongoing operating costs for energy include fuel costs and other operating costs such as maintenance and insurance. This could include, for example, the cost of maintaining generating plants or keeping the electricity transmission network in safe working order.

A large part of the ongoing operational spending for energy is the cost of buying the fossil fuels that are burnt in our vehicles, buildings, power stations and industry. Together, this totalled over £50 billion in 2024, equivalent to almost 2% of total spending across the economy:

- Petrol and diesel for road transport represents one of the largest costs. In 2024, a total of 40 billion litres was purchased in the UK, at an average price before tax of 69 pence/litre. This implies an annual fuel spend for road transport of around £27 billion, or around 1% of current UK GDP. There is a significant additional spend on insurance and maintenance.
- Heating needs in the UK are predominantly met through burning gas. Along with oil, heating fuels cost around £12 billion in 2024 (before tax, levies and network costs).
- Gas is also used in the electricity sector and alongside other fossil fuels in industry. These fuels and net imports of electricity cost the UK around £12 billion in 2024.[7]

[7] All figures in this list are calculated based on UK energy consumption levels published in DUKES and estimated resource cost for the respective fuels adjusted to 2025 prices. Other fossil fuels used in industry include coal and various petroleum products, mainly diesel.

This reliance on fossil fuels, for which GB is a net importer and which are priced internationally, exposes energy spending to volatility in the prices of these fuels. This volatility in turn has material economic effects:

- Increased fossil fuel prices in 2022 and 2023 following the Russian invasion of Ukraine led to subsequent increases in energy prices and rises in the cost of living for the UK population. When prices peaked in 2022, estimated energy spending (oil and gas fuel cost) had increased by £36 billion compared to 2021, reaching £100 billion (equivalent to 3.5% of GDP).[8] This was a significant jump from the pre-crisis average of 1.7% of GDP; an increase of 1.8%. By early 2023, the UK Government had spent over £65 billion (2.3% of annual GDP) on energy and cost of living support schemes as a result of the energy crisis.[9]
- Crude oil supply shortages were a key contributor to the sharp drop in economic output in the early 1980s (a 3.4% reduction in GDP in 1981) and the consequent rise in unemployment[10].

We also include spend on insurance and maintenance of vehicles and servicing of heating systems, as these are expected to change as the vehicle fleet electrifies and low-carbon heating systems are taken up.

Capital expenditure on energy production and use

Investment in energy assets[11] also draws on the economy's resources during the development and construction of power stations and network infrastructure, and the manufacture and installation of energy-using products such as boilers and vehicles. The costs of these are often recovered over time rather than consumers paying the full cost immediately. For example, renewables are rewarded over multi-year contracts and cars are often paid for through finance deals.

We have not calculated these costs historically given data challenges. However, as an indication of their scale we present modelled investment and operating costs for 2025. Together, these total around 10% of 2025 GDP.

We use the four categories from Figure 4 in our results throughout this report and show results with greater sectoral granularity in the Appendix.

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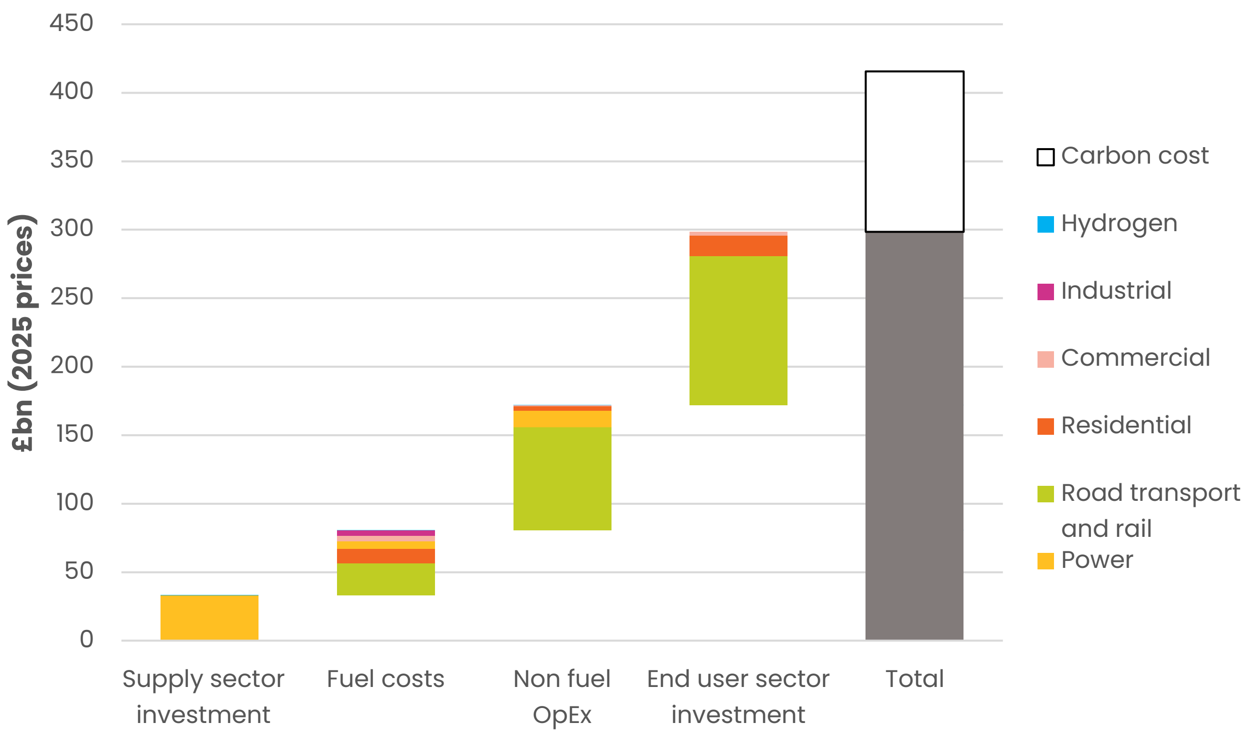
[8] Estimates in this paragraph are based on spot prices: they do not include additional rent creation or hedging, in line with our wider approach. Accordingly, extra costs faced by consumers are liable to have been higher.

[9] Total spend on energy support, cost of living payments and other measures in 2022–23 (£58 bn), adjusted to 2025 prices.

[10] Office for Budget Responsibility Fiscal risks and sustainability, July 2023 – CP 870

[11] Throughout this analysis, references to "investment" pertain to capital expenditure related to the FES pathways.

Figure 4: Modelled total in-year costs (total CapEx and OpEx spend) in the Holistic Transition pathway (2025)



Note: Supply side investment includes capital expenditure in the electricity and hydrogen sectors. End user sector investment captures capital expenditure in road transport and rail, residential, commercial and industrial sectors. Fuel and non-fuel OpEx refers to expenditure in both supply and end user sectors. In total energy costs, the cost in a few subsectors represent incremental value in comparison to the Falling Behind scenario due to the nature of the available datasets.

3. Costs of technologies in the FES 2025 pathways

Each FES 2025 pathway involves a range of technological choices, each with its own set of cost drivers. Some of these choices are expected to add to costs and some to reduce costs. These choices typically also shift costs from operating (fuel) costs towards upfront investment, as in many cases they require new assets to be bought or built, but will require less or negligible fuel to run on an ongoing basis (see Figure 6). As noted above, long-term contracts and financing options provide routes to align the payback of investments with the ongoing cost savings.

- **Low-carbon power generation.** Renewable electricity can be produced on a cost competitive basis compared to burning gas in a combined cycle gas turbine (as shown in Figure 5). As well as the costs of building and operating renewable capacity, there are further costs for network build and managing the electricity system. These are also included in our analysis.

- **Electric vehicles.** Rapidly falling battery costs have led to a narrowing price premium for the purchase of electric cars compared to their petrol and diesel equivalents. We use CCC's *Seventh Carbon Budget* (CB7) investment cost data for cars, which expects price parity for average-sized passenger cars to be reached by 2027. From this point, electric cars will cost less than a petrol or diesel car, both to buy and to run. Lower running costs (on a resource cost basis, excluding taxes) reflect the greater efficiency of electric vehicles and lower relative cost of electricity compared to petrol/diesel. We also include the extra costs associated with building an EV charging network and the savings expected in car maintenance given the reduced number of parts in EVs.
- **Heat pumps.** We assume that the upfront purchase cost of heat pumps will be more expensive than gas boilers until 2050, although learning rates imply the premium for an average air source heat pump falls to around £2,000 by 2050. Our technology cost assumptions are based on the available information at the time; should technology costs decrease faster, this would lead to a reduction in overall costs. As in all our analysis, this is the economic resource cost; it does not imply that consumers will have to pay more, since that will depend on policy such as availability of grants. We also assume additional one-off 'retrofit' costs when a heat pump is installed in a building for the first time. As more heat pumps are installed, less is spent on gas in the heating sector.
- **Energy efficiency.** There are many opportunities to improve energy efficiency at low cost, for example for appliances and by thorough draught proofing. We also include a set of more expensive investments (such as solid wall insulation in fuel poor homes) in the FES 2025 pathways. This helps meet emissions targets and reduce energy bills but tends to add to overall costs.
- **Demand side changes.** Changes in demand in the pathways can feed through to significant changes in cost, as more energy use generally implies higher overall costs. For example, the pathways explore a range of demands from data centres, with this demand lowest in the Falling Behind scenario. In the 2040s, under the Holistic Transition and Electric Engagement pathways, we also see lower levels of car purchases and an emerging role for autonomous vehicles, alongside a higher uptake of public transport.

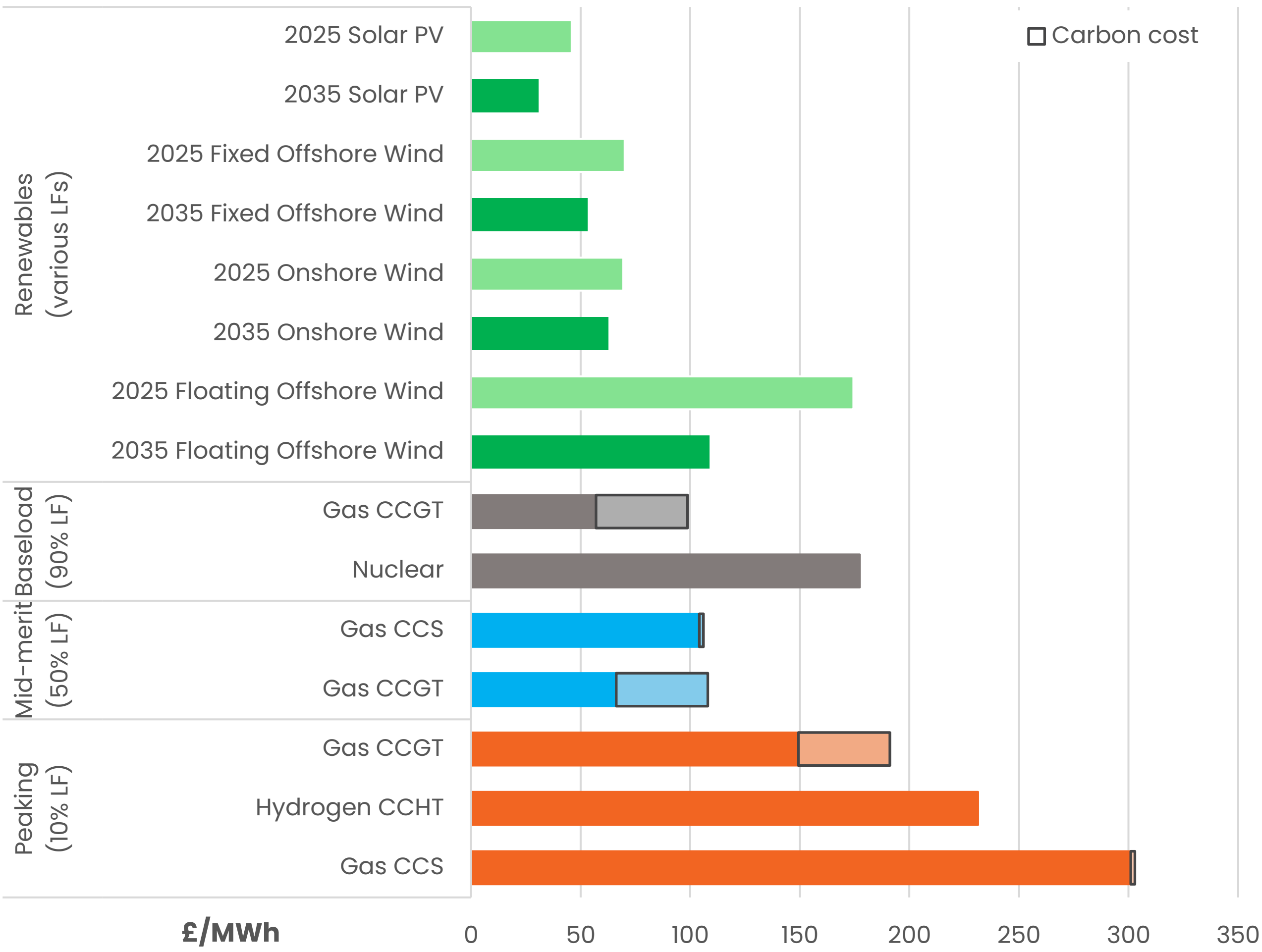
Many of these options involve low costs or cost savings over their lifetimes, as the cost of financing initial investments can be repaid for less than the operational saving they make. The availability of options at low cost, or with a saving, reflects progress made over the last two decades in improving technologies and reducing costs. Meeting net zero requires the uptake of both options that save costs (such as electric vehicles) and options that add costs (such as applying CCS).

The FES 2025 pathways are designed to meet carbon budgets and delivery constraints in various plausible ways. They consider cost, but do not fully minimise it. Furthermore, there may be scope to reduce technology costs faster or to make greater use of low-cost measures, including those not yet sufficiently established to build into the FES 2025 pathways. Therefore, there is scope for lower costs than in the FES 2025 pathways over the next 25 years.

There are also wider considerations, such as health and social policy, as well as environmental considerations, where decarbonisation can lead to significant benefits. We do not include any value for these areas as we have focused on direct economic resource costs.

There are uncertainties around all technologies and their future costs, especially for newer technologies or those that have not yet been rolled out at scale. We explore these in our sensitivities where we consider how costs would change if capital costs differ from what is expected.[12]

Figure 5: Levelised costs of energy for key electricity generation options in 2035



Note: These costs are provided for comparison and context. They do not include all components of system cost but do include financing costs that are not part of our economic resource cost estimates set out in the rest of this report. Carbon costs here represent forecasts of traded value over the lifetime of a unit, not social cost of emissions. These estimates assume that biomass has zero carbon emissions. For renewables, load

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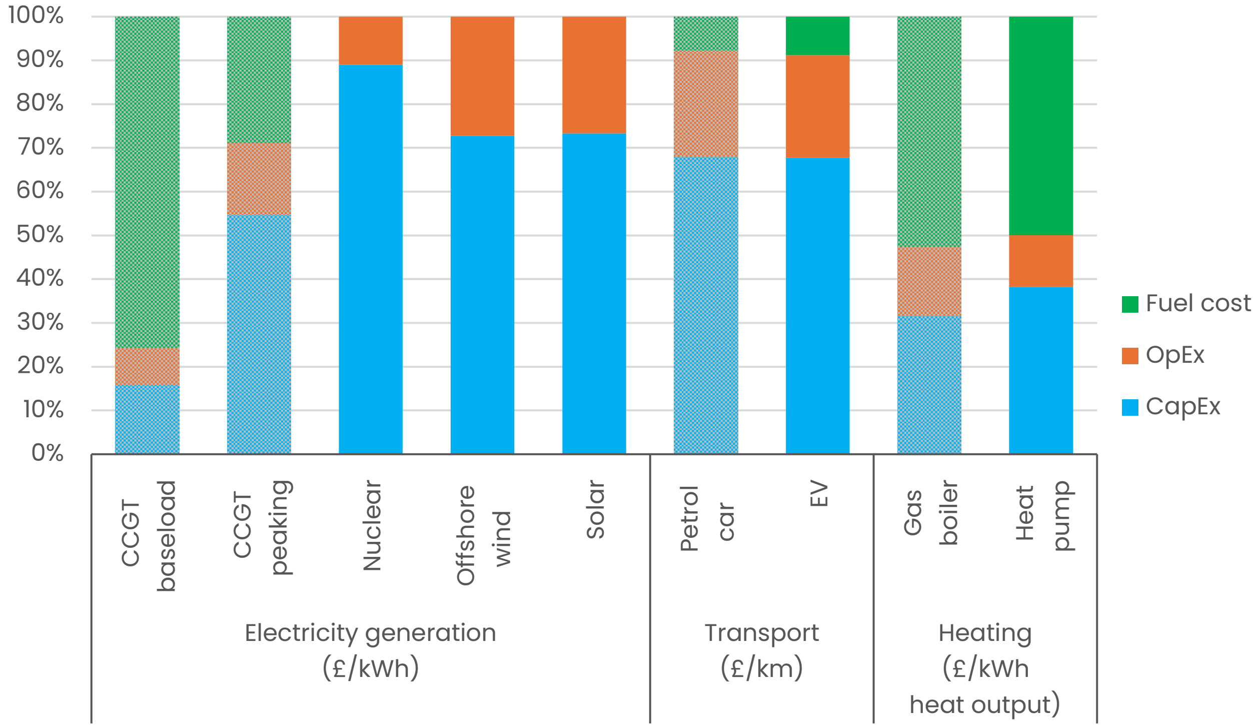
[12] For sensitivities typically testing +/-25%, with deviations from that default where evidence suggests otherwise and as detailed in our *Assumptions Log*.

factors are based on FES 2025 modelling outputs. See FES 2025 Economics Inputs Data Workbook for detailed assumptions. For other technologies, load factors are based on ex-ante assumptions to enable comparability across technologies. Capture rate for CCS is assumed to be 96%. Nuclear costs represent a weighted average across large nuclear and nuclear small modular reactors (SMRs). Fuel cost assumptions for Hydrogen CCHT are based on the premise that, when hydrogen is produced through electrolysis, the process uses excess electricity. LF: load factor; PV: photovoltaic; CCGT: combined cycle gas turbine; CCHT: combined cycle hydrogen turbine; CCS: carbon capture and storage.*

Figure 6: Capital intensity of energy technologies in 2035



Note: Hatched shading denotes conventional carbon-intensive technologies. CCGT Baseload assumes a 90% load factor to illustrate running a CCGT as baseload. CCGT peaking assumes an 8% load factor, which aligns with the FES 2025 modelling for the Holistic Transition pathway, in which unabated CCGTs are used as peaking plants in 2035. Efficiency estimates are kept at the same level regardless of the load factor, as in the FES 2025 modelling. Nuclear costs represent a weighted average across large nuclear and nuclear SMRs based on the split in the projected nuclear buildout in the 2030s. The fuel for EVs and heat pumps is electricity, which itself has a minimal fuel component once primarily produced by renewables and nuclear. Costs for 2035 include learning effects reducing capital costs from today. CCGT: combined cycle gas turbine.

4. Costs and savings in the Holistic Transition pathway

We first consider the costs of the Holistic Transition pathway, as this is a net zero pathway with a mix of solutions that meet net zero by 2050 and all UK carbon targets. We step through the results for operating costs and then capital investment, before bringing them together in total costs and considering uncertainties in the estimates.

We have not modelled consumer costs or energy bills for our pathways, as these depend on how investments are repaid and on taxes and transfers that are not included in this analysis. As stated above, the FES 2025 pathways are illustrative and not optimised for cost, so may not represent the most cost-effective way to achieve net zero and may differ from the actual route taken to reach net zero by 2050.

Falling operating costs in the Holistic Transition pathway

As the economy electrifies and use of other fuels falls, Holistic Transition sees a significant reduction in annual ongoing operational spend, which falls by £33 billion from 2025 to 2050. These savings continue beyond 2050.

- A major factor contributing to this reduction is the move to EVs, which reduces spend on petrol and diesel as well as vehicle maintenance costs.
- There are further operational savings as gas use in heating reduces as heating is increasingly electrified. Less gas is also used in industrial processes as these are either electrified or shift to hydrogen.
- Fuel use in the electricity sector drops as the amount of renewable generation increases. However, as the electricity sector grows 2.5-fold to 2050 compared to today, this saving is eventually offset by non-fuel operating costs and by the costs of imports.

Carbon costs associated with the energy system are eliminated by 2050 once emissions are reduced to net zero. Using the UK Government's carbon values for appraisal assigns a value to this reduction in carbon greater than the fuel saving, but even using 2024's average traded emissions price of around £56/tCO_2[13], this carbon saving would be worth £22 billion annually by 2050.

Higher investment in the Holistic Transition pathway

This fall in operational expenditure is enabled by a significant investment programme, averaging around £28 billion more per year through to 2040 than the modelled level of investment expected in 2025. Beyond 2040, lower levels of investment are needed as many required one-off investments have been completed and as costs per unit are assumed to fall with learning effects. We expect the majority of the investment to be undertaken by the private sector.

[13] Outturn UK ETS price in 2025 prices, with carbon price support added.

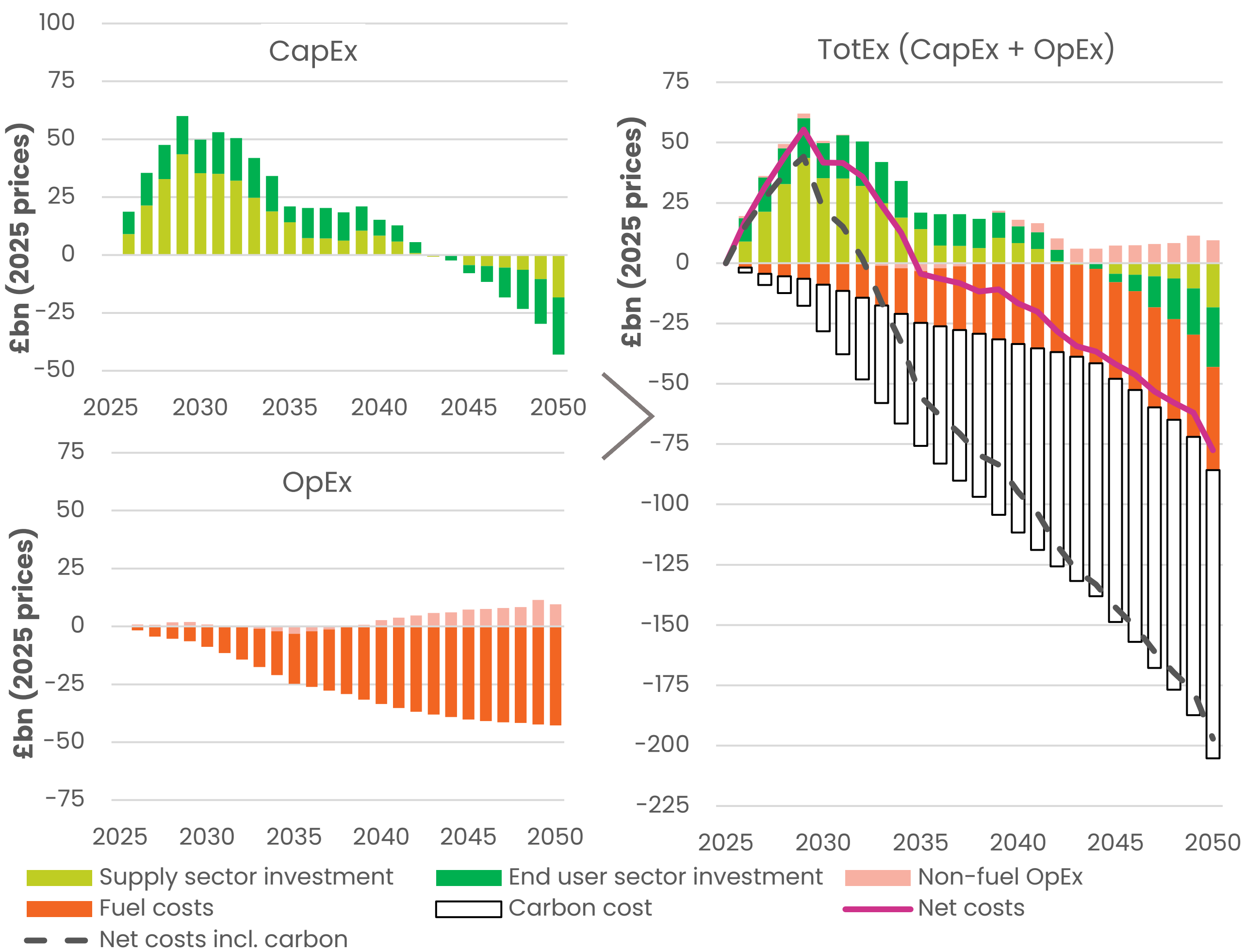
Most of the growth in investment is in the electricity sector as large amounts of capital expenditure take place to build new low-carbon generation assets as well as investment in the transmission and distribution networks. Similarly, capital expenditure in the residential and commercial sectors increases due to insulation measures and the decarbonisation of heating systems with a shift away from gas boilers to heat pumps or other forms of low-carbon heating.

The electricity sector investment would be repaid over later years under current policies. For example, some of the investment in 2030 is spending on offshore wind and nuclear plants that will be built over several years and come online later in the 2030s, then be repaid through their lifetimes, which would extend beyond 2050[14]. A significant proportion of heating investments are currently paid by the Exchequer, for example through the Boiler Upgrade Scheme, where the budget for financial year 2024/25 was £205 million and it has increased by £90 million for 2025/26[15].

Our modelling also suggests the potential for capital expenditure in the transport sector to reduce to 2050 as the saving from EVs begins to outweigh the costs of new charging infrastructure. This effect is furthered in the 2040s as fewer vehicles are bought, with increased use of shared autonomous vehicles and public transport.

[14] Increased electricity sector investment was also a finding in NESO's *Clean Power 2030* published in November 2024. Figures do not match exactly to those published previously as capital expenditure here is assigned to the year in which projects are being built and therefore includes pre-2030 spend on projects commissioning after 2030. Figures in this report are also in a 2025 price base (rather than 2024). Allowing for these definitional differences, investment levels in this report are within the range of the scenarios in *Clean Power 2030* while reflecting the latest evidence at the time of the analysis, for example the business plans from the RIIO-T3 process for transmission.
[15] Boiler Upgrade Scheme (BUS) | Ofgem

Figure 7: Changes in investment and operational expenditure in the Holistic Transition pathway compared to 2025



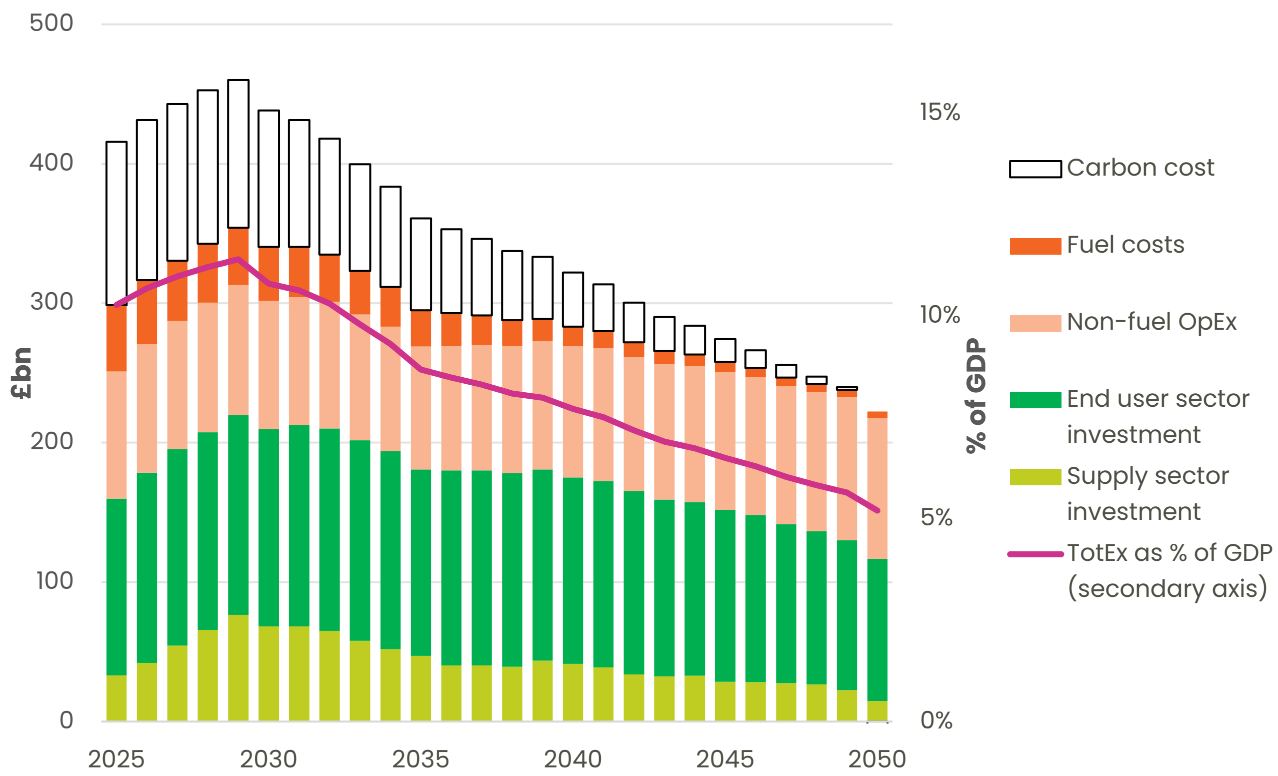
Note: Definitions as in Figure 4. In total energy cost for the net zero pathways, the cost in a few subsectors is the incremental value in comparison to the Falling Behind scenario due to the nature of the available datasets.

Falling total costs to 2050

Taken together, operational costs and capital expenditure see total energy costs in the Holistic Transition pathway fall to 2050 after an initial rise during the early investment period. As a proportion of GDP, the total amount spent on energy across investment and operational spend (not including carbon costs) drops, from around 10% of GDP in 2025 to around 5% of GDP in 2050.

Although there is considerably more energy infrastructure by 2050, the costs of deploying it are more than offset in the long run by reduced energy waste and savings in displaced (non-electric) fuels, supplemented by reductions in the expected cost of key technologies such as EVs and heat pumps.

Figure 8: Total energy cost in the Holistic Transition pathway (2025-2050)



Note: Definitions as in Figure 4. In total energy cost for the net zero pathways, the cost in a few subsectors is the incremental value in comparison to the Falling Behind scenario due to the nature of the available datasets.

Uncertainties in the cost estimates

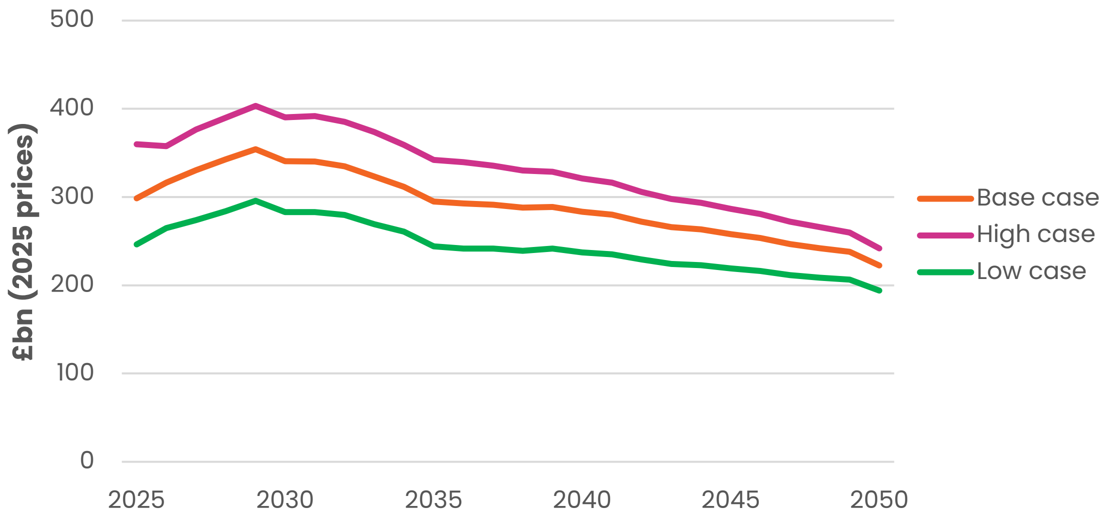
In considering the shifts in expenditure outlined above, there is a range of uncertainties and unknowns. These include consumer choices (for example, how often cars are replaced and what size vehicle consumers choose), international conditions (the prices of oil and gas), technology costs (such as for renewables and heat pump installations) and wider uncertainties (such as weather conditions, the growth of data centres, GDP and population growth). Many of these factors are outside of the direct control of industry and government.

We have not modelled all possible sources of uncertainty, but as an illustration we explore the impacts of uncertainty over fuel prices and capital cost of technologies drawing on a range of inputs from DESNZ's high and low case fuel price and power technology forecasts, supplemented by other in-house analysis. These are key cost parameters that are likely to have a significant impact on the costs and savings for each of the FES 2025 pathways. History has shown that there can be large shifts in each of these areas relatively quickly. For example, the global fuel price spikes discussed previously or rapid reductions in the cost of low-carbon technologies compared to original projections (considered in Section 5). Other uncertainties include the possibilities of new technological breakthroughs or rise of large-scale new energy demands.

In the early years, the sensitivities suggest that varying the costs of these two areas leads to a range of around +/-15% for total costs in Holistic Transition. This then falls to 2050 as fuel use declines and capital expenditure slows. Some of the other uncertainties outlined above, which are not included in our modelling, would tend to rise over time, suggesting a wider range in 2050 than captured here.

The reduction in uncertainty attributed to declining fuel use also implies a change in the nature of the uncertainty, specifically a reduction in volatility. Increased costs for investment in any given year are spread across their lifetime and so have less immediate impact on consumers. However, increased costs for fuels would all hit at the time of any price increase – assuming no government intervention, such as occurred during the 2022/23 gas price crisis, when over £65 billion of the increased cost[16] was paid by the Exchequer largely through government borrowing.

Figure 9: Sensitivities for total cost estimates under the Holistic Transition pathway based on fuel price and capital cost uncertainties



[16] Total spend on energy support, cost of living payments and other measures in 2022–23 (£58 bn), adjusted to 2025 prices.

5. Costs and savings across the FES pathways

Comparing between pathways

Comparing between the FES 2025 pathways can help identify opportunities to minimise costs and indicate wider uncertainties. However, care is needed in drawing conclusions. In some cases, cost differences reflect different assumptions across the pathways that reflect uncertainties over policy and consumer choice, rather than different choices in how to reach net zero.

- Data centres. Our pathways assume different growth rates for data centres, resulting in their 2050 electricity demand ranging from 30 to 71 TWh. The Falling Behind scenario projects the lowest demand, while Electric Engagement anticipates the highest. Higher electricity demand implies higher costs.
- Efficiency. Efficiency assumptions differ between pathways, with Holistic Transition assuming the highest efficiency for heat pumps and domestic appliances.
- Autonomous vehicles. The long-term future of mobility is uncertain, particularly the role of autonomous vehicles. This results in different assumptions across our pathways for the purchase of new vehicles, shaped by varying policy landscapes and consumer choices. Falling Behind and Hydrogen Evolution assume a broadly stable level of new car purchases out to 2050, while Holistic Transition and Electric Engagement see purchases fall in the long run as more travel demand is met by shared use of autonomous vehicles, alongside a shift to public transport, walking and cycling.
- Bioenergy supply. Bioenergy availability differs in the net zero pathways, from 173 TWh in 2050 in Hydrogen Evolution to 216 TWh in Holistic Transition. While there are costs attached to these energy sources, they can avoid other costs in deploying alternatives that are often more challenging/costly.
- EU energy markets: We have aligned our net zero pathways with EU scenarios that have been developed to share similar narratives. For example, in the Falling Behind scenario, connected markets also decarbonise more slowly and are therefore prepared to pay significantly more for electricity imports. This yields electricity export income (counted as negative non-fuel operating costs for the electricity sector) in the Falling Behind scenario that is higher than in the net zero pathways.

In addition, although various factors can influence the comparative cost of the pathways, a proportion of costs and savings are effectively already committed when looking forward to 2050 and so remain the same across all pathways. This would include costs such as the maintenance of existing networks and renewables, and committed network spend. There are also consistent savings across the pathways, particularly from EV uptake, which dominate the vehicle fleet by 2050 even in the Falling Behind scenario.

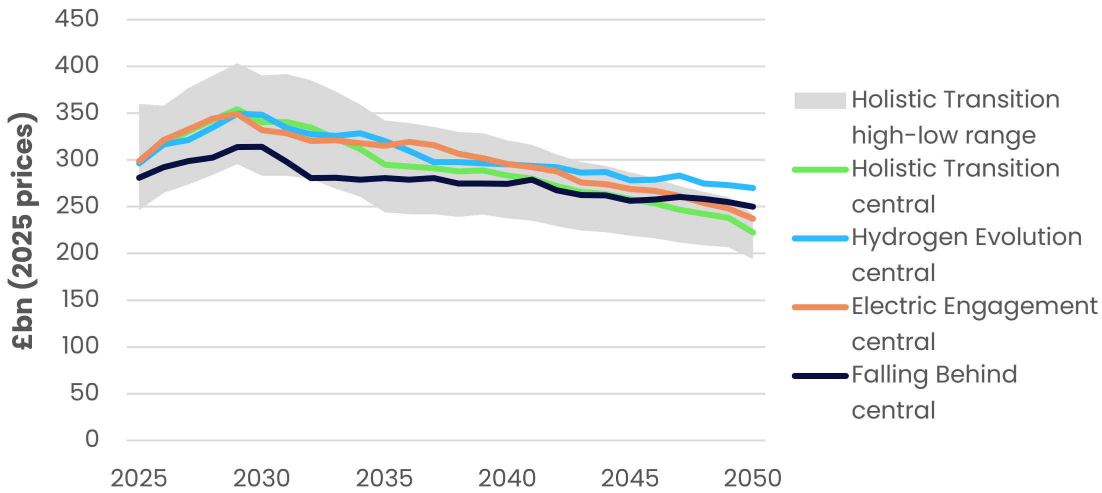
Comparisons are also limited by the analysis only running to 2050, while costs will also differ beyond 2050. For example, the Falling Behind scenario would need a further large investment programme after 2050 to complete the journey to net zero – it would be wrong to interpret a delay in this cost as implying that the cost is avoided entirely. Falling Behind would also incur ongoing higher fuel costs beyond 2050.

Furthermore, the fact that the pathways are not fully cost optimised means that there is likely to be scope to deliver any given pathway in a largely similar way but with lower costs than modelled.

Uncertainty in costs between net zero pathways

More generally, comparisons between pathways should be made in the context of the inevitable uncertainty around future cost projections. The total costs of all the net zero pathways are within the wider uncertainty range for the costs of Holistic Transition based on our fuel and technology cost sensitivities for most of the analysed period to 2050. In addition, there will be cost differences in the years beyond 2050 that are not covered in our analysis but are relevant to any comparison.

Figure 10: Central cost estimates for the FES 2025 pathways are mostly within the uncertainty range for Holistic Transition



Note: The modelling starting point for FES 2025 is 2024 and, by 2025, we start to observe some divergence in pathways mainly due to the slower assumed build rates in the electricity sector in the Falling Behind scenario compared to the net zero pathways.

Relative costs compared to slower progress in the Falling Behind scenario

Given these caveats and uncertainties, our pathways cannot provide firm conclusions over the relative costs attached to the choices between pathways:

- In comparison to the Holistic Transition pathway under our central modelled assumptions, the Falling Behind scenario sees lower investment initially and then similar total cost in absolute value from around 2035 onwards as operational savings in Holistic Transition start to pay back on the higher earlier investment. Across the 2025-2050 period, ignoring carbon, costs are higher by around £14 billion per year on average in the Holistic Transition pathway compared to Falling Behind (Figure 11), equivalent to an average premium of around 0.4% of GDP, although it achieves the UK's carbon targets[17]. Ongoing savings in the Holistic Transition pathway compared to Falling Behind are expected beyond 2050, so this average cost would fall in the longer term.

- The Falling Behind scenario also implies a substantially higher carbon cost, as carbon emissions remain high even in 2050, and would secure fewer of the wider benefits such as for air quality and health (see Section 6). With the carbon cost included, the Holistic Transition pathway would be the cheapest. Using the *Green Book* carbon appraisal values, costs in the Holistic Transition pathway are on average £36 billion per year cheaper over 2025-2050 compared to Falling Behind, a difference equivalent to around 1% of GDP.
- Some of the cost difference reflects the different underlying assumptions rather than the choices implied by the pathways. For example, the higher data centre demand in Holistic Transition compared to Falling Behind increases 2050 costs by around £5 billion.
- Cost comparisons are highly dependent on underlying assumptions. For example, if fuel prices are high (as in the latest DESNZ high projections, which for gas are higher than mid-2025 levels but well below the 2022 peak), then the average premium, excluding carbon costs, for the Holistic Transition pathway over the Falling Behind scenario over 2025-2050 would fall to around £5 billion. If fuel prices were to drop (as in the latest DESNZ low projections) then the average annual costs in the Holistic Transition pathway compared to Falling Behind over 2025-2050 would increase by £19 billion.
- Cost comparisons also reflect the technology choices within the pathways. For example, the relative deployments of options such as gas CCS, biomass with CCS or hydrogen for heating were varied to explore technological possibilities during pathway design.
- With slight changes to the Holistic Transition pathway focused on cost minimisation, costs during 2025-2050 could be brought down towards those of the Falling Behind scenario under our central fuel price assumptions. We set these out in Section 7 of this report.

We reiterate that the costs discussed here do not represent the cost of achieving net zero emissions. The pathways have different background assumptions (such as for data centres and EU decarbonisation) and the Falling Behind scenario includes some action and progress towards decarbonisation goals. Specifically, Falling Behind still involves extensive electrification of the transport fleet and the major cost savings that involves. This is in contrast with the approach followed by the CCC's estimates comparing costs relative to a no-action baseline and finding an

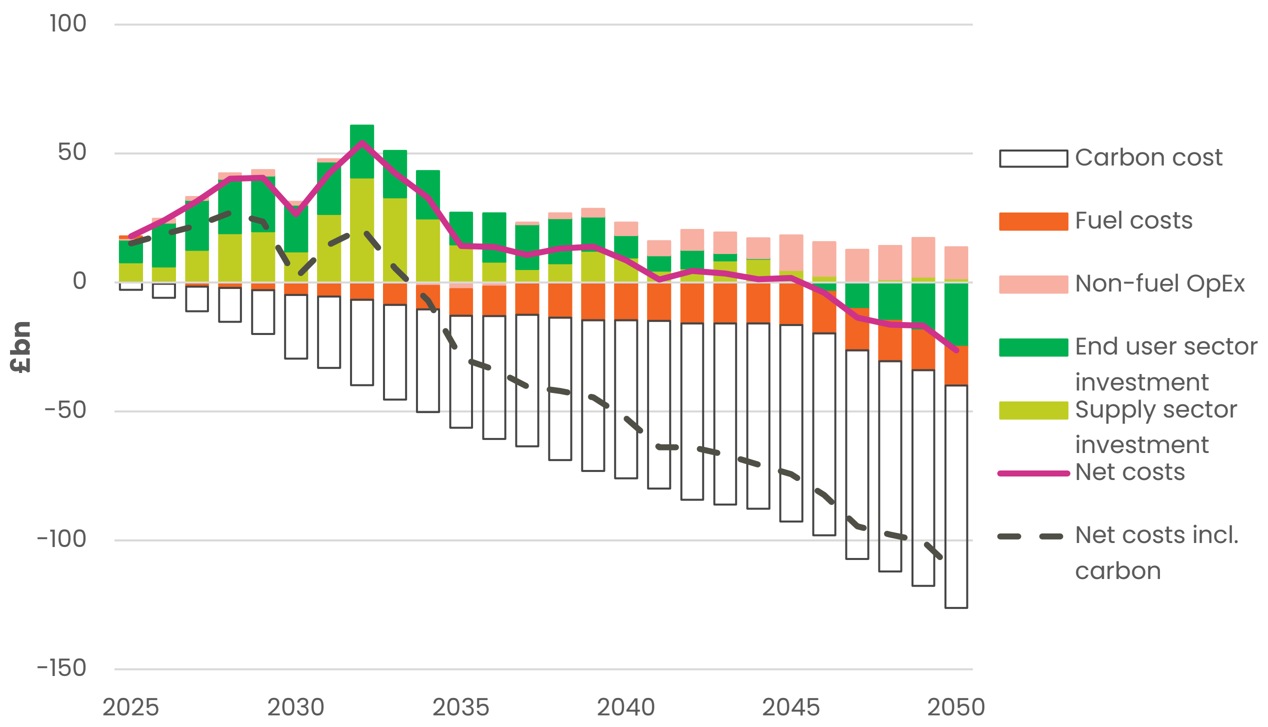
[17] In comparing between pathways, we include costs for all GB energy sectors that are reducing emissions. The agriculture, land use, aviation and shipping sectors and engineered removals are not included. These sectors are part of achieving net zero, but not in scope for GB energy and not fully modelled in FES. CCC report costs for these sectors relative to a no-action baseline – these total around £3 billion (equivalent to under 0.1% of GDP) on average annually over 2025 to 2050.

average cost attached to the net zero programme equivalent to around 0.2% of GDP[18]. Given this difference in approach, the estimates in this report cannot be compared directly to those of the CCC.

We also report cost comparisons between pathways on an annualised basis (Figure 12), for which the same challenges as above apply in making comparisons. The annualised estimates spread investment costs across the lifetime of investments and add a cost of financing. When comparing Holistic Transition to Falling Behind, the annualised results show lower costs initially than the in-year comparison, then higher in the long run, but still on average under 1% of GDP across the horizon. They would be expected to fall after 2050 as investments are paid off and operating savings continue.

The estimates are sensitive to the financing costs assumed – we have used technology-specific hurdle rates, which are often above the social discount rate (for example, we use an 8.3% real cost of capital for offshore wind for 2025-2030). If the social discount rate were used instead then the relative costs of the Holistic Transition compared to Falling Behind would be reduced.

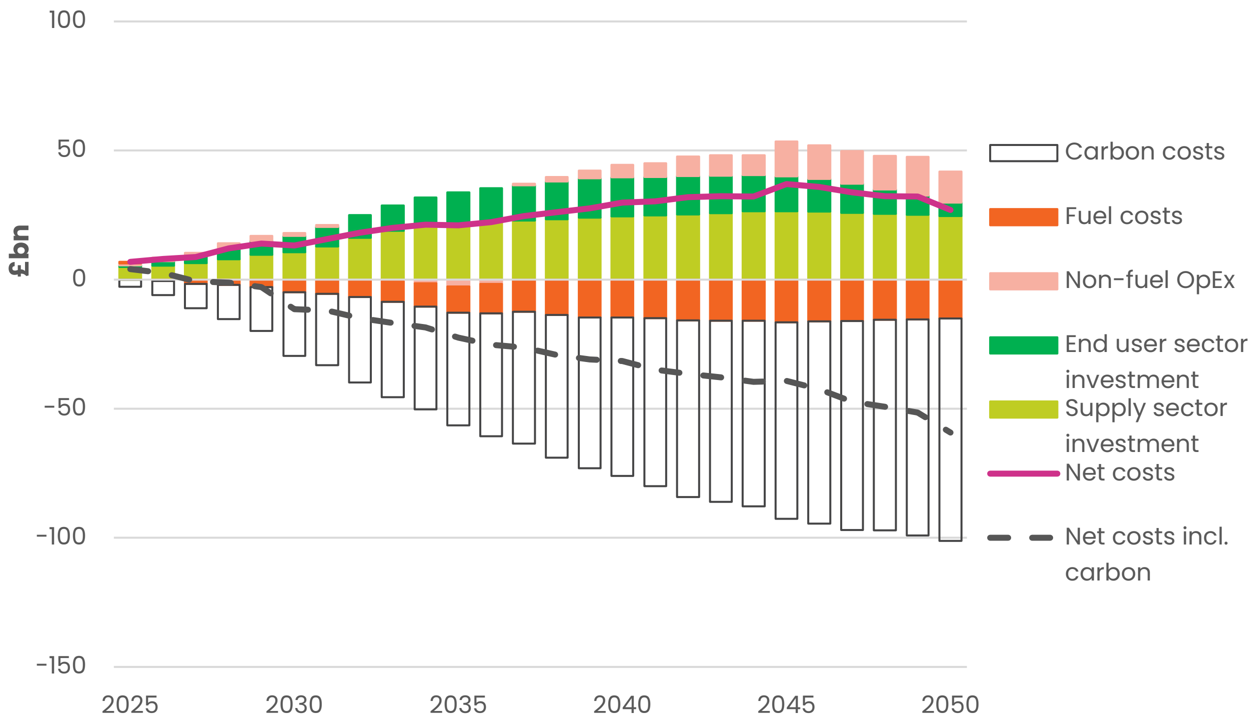
Figure 11: Total in-year energy cost of Holistic Transition pathway compared to Falling Behind scenario, central case



[18] Climate Change Committee (2025) *Seventh Carbon Budget*.

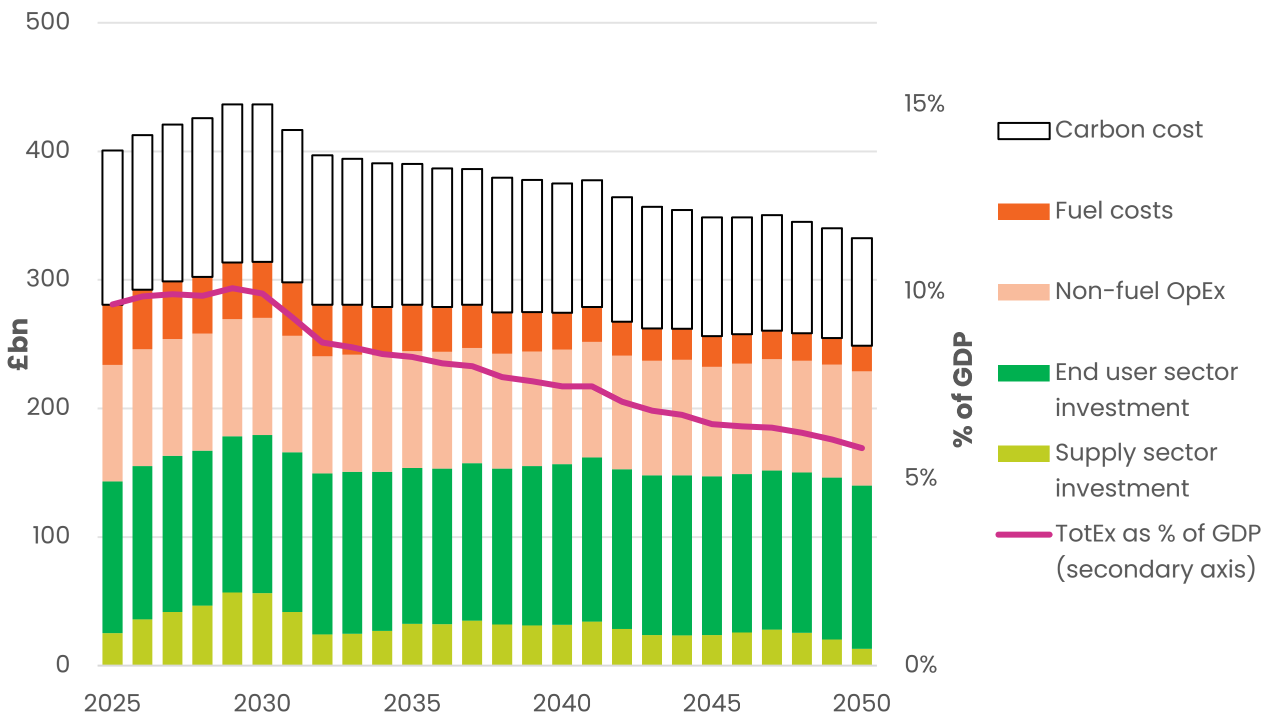
Note: This is the difference in the in-year CapEx and in-year OpEx in each modelled year between Holistic Transition and Falling Behind. Definitions as in Figure 4.

Figure 12: Additional annualised total energy cost in Holistic Transition pathway compared to Falling Behind scenario



Note: This is the difference in the annualised CapEx and in-year OpEx in each modelled year between Holistic Transition and Falling Behind. Annualised values smooth capital spending and combine this with in-year operating costs. Sector definitions as in Figure 4.

Figure 13: Total energy cost for Falling Behind (2025-2050)

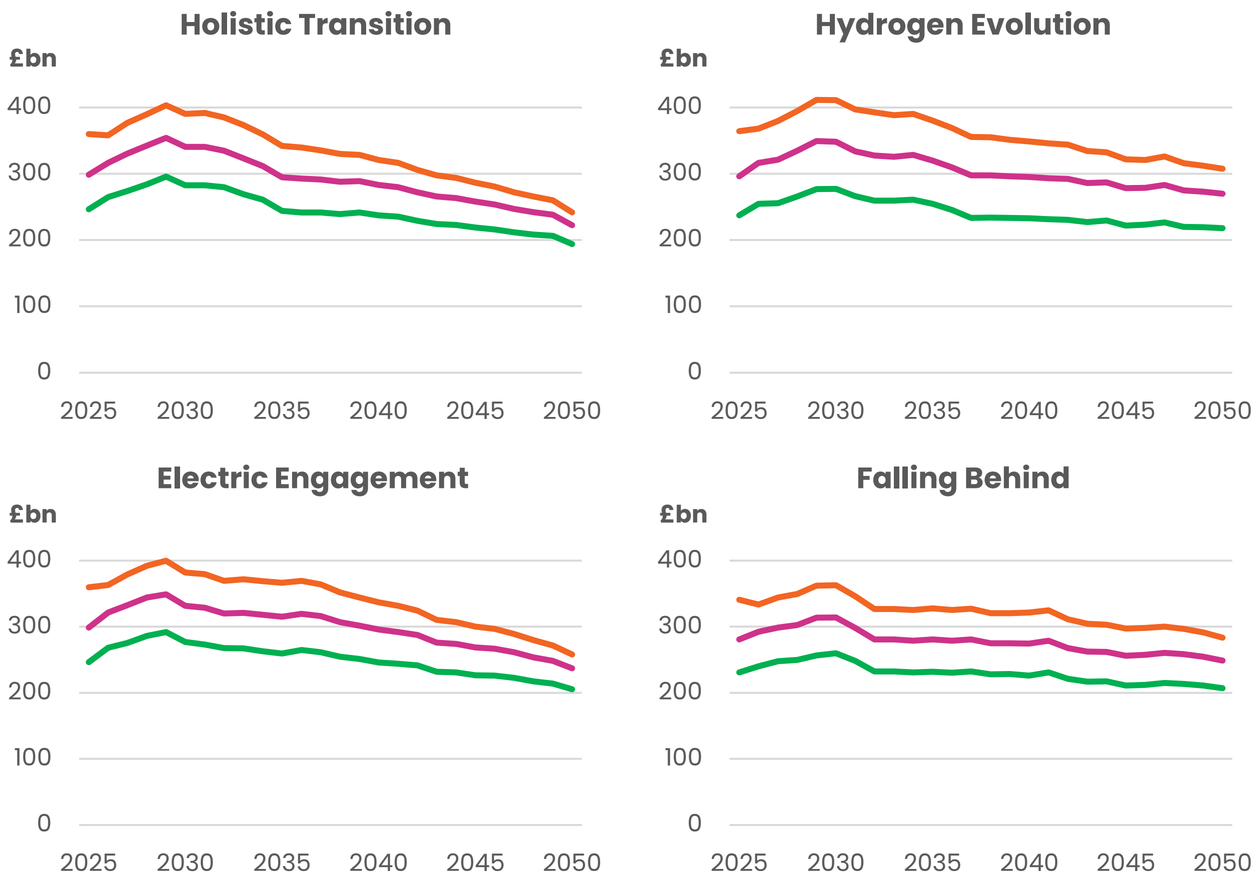


Note: Definitions as in Figure 4. In total energy costs in Falling Behind, certain elements are not included because, for these areas, only incremental values relative to the Falling Behind scenario are available.

Cost uncertainty in the Falling Behind scenario and net zero pathways

The range of uncertainty remains higher in 2050 in the Falling Behind scenario compared to Holistic Transition. This particularly reflects a higher ongoing use of fossil fuels in the Falling Behind scenario. This effect is also evident in the Hydrogen Evolution pathway, which has higher use of gas in methane reformation with CCS to produce hydrogen.

Figure 14: Total energy cost sensitivities for all pathways (£bn 2025 prices)



Cost differences between the net zero pathways

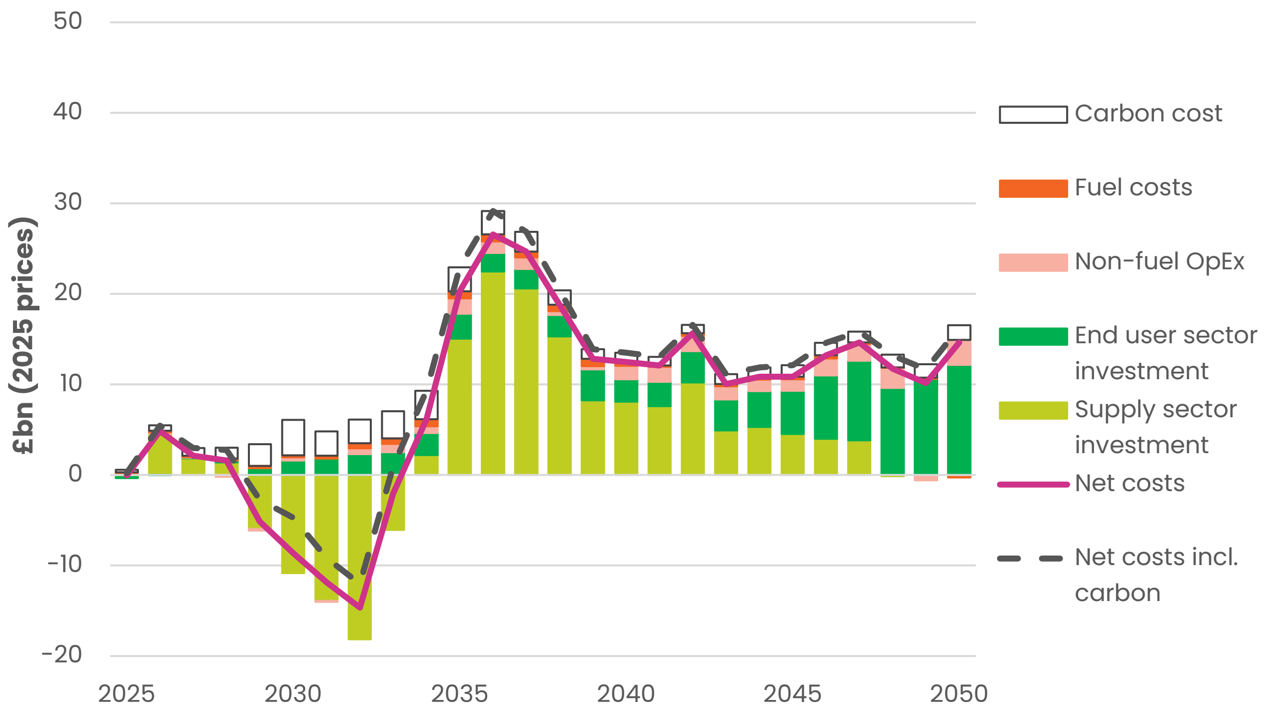
Electric Engagement and Hydrogen Evolution have higher costs on average across 2025-2050 compared to Holistic Transition, based on our central assumptions for the costs of individual technologies in each sector. Higher transport capital costs are a key driver in the long term, reflecting the assumption of more cars being purchased after 2035 in the Electric Engagement and Hydrogen Evolution pathways. Without this effect, the annual costs between 2025-2050 would be around £5 billion to £6 billion higher in the Electric Engagement and Hydrogen Evolution pathways relative to the Holistic Transition pathway rather than £8 billion and £13 billion higher, respectively.

It is plausible that if the costs of specific technologies reduce more quickly, the Electric Engagement or Hydrogen Evolution pathways could be lower cost pathways than Holistic Transition. For example, if hydrogen can be produced in the region of half the cost assumed in a central case (and if the vehicle fleet is the same size as in Holistic Transition), costs would be comparable in the Hydrogen Evolution pathway. Reducing the cost of hydrogen production could be achieved through technological advancements and increased innovation. Economies of scale, driven by higher production volumes, can play a role, along with collaboration and partnerships between industries and governments.

To date, and notwithstanding recent supply chain pressures and interest rate rises, many decarbonised technologies have experienced cost reductions well beyond their original cost projections[19]. It is therefore possible that one or more of the technologies in our pathways will reduce in cost (much) more quickly than anticipated, particularly given the length of the time horizon (25 years) being considered.

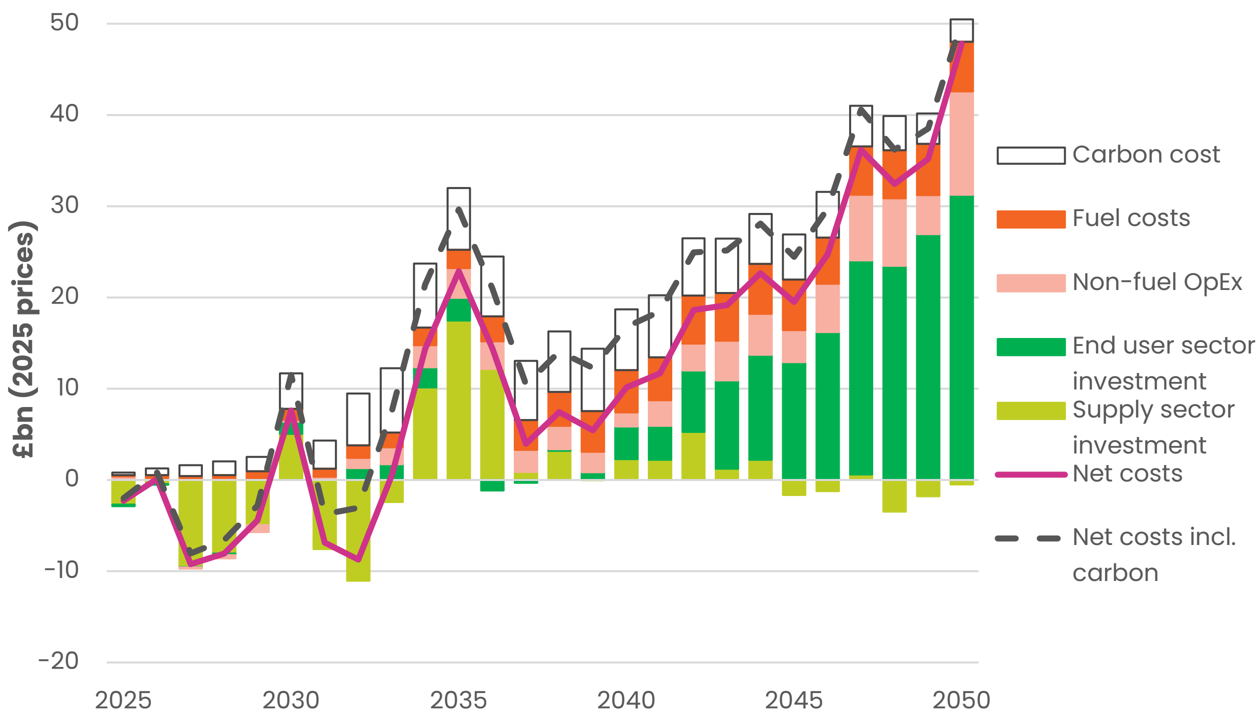
[19] See for example, Applied Energy Volume 390 (15 July 2025)' *Are we too pessimistic? Cost projections for solar photovoltaics, wind power and batteries are over-estimating actual costs globally'*

Figure 15: Additional total energy cost in Electric Engagement compared to Holistic Transition



Note: This is the difference in the in-year CapEx and OpEx in each modelled year between Electric Engagement and Holistic Transition. Sector definitions as in Figure 4.

Figure 16: Additional total energy cost in Hydrogen Evolution compared to Holistic Transition



Note: This is the difference in the in-year CapEx and OpEx in each modelled year between Hydrogen Evolution and Holistic Transition. Sector definitions as in Figure 4.

6. Wider costs and benefits

Economic growth, job creation, trade and macroeconomic effects

The capital investment programme in our pathways, with significant private sector investment and activity spread across the country, has the potential to provide additional economic opportunities as the UK economy shifts expenditure away from imported fossil fuels towards domestic investment in the UK. This could bring local economic benefits and support future employment.

We have not estimated such impacts for this report. Previous analyses have considered these areas, such as the Confederation of British Industry (CBI) and the Energy & Climate Intelligence Unit (ECIU)[20], the UK Energy Research Centre Green Job creation report[21] and the CCC's *A Net Zero Workforce* report[22]. While a wide range of estimates exist, they point to employment opportunities in regional economies outside London and the potential for more jobs to be created than lost in the transition to net zero.

We also have not estimated any negative consequences for trade for the Falling Behind scenario, attached to the failure to meet emissions targets in that scenario. Such effects could occur, given over half of the UK's exports go to trade partners that have net zero targets in law, and that jurisdictions such as the EU are implementing Carbon Border Adjustment Mechanisms (CBAMs) that would penalise trade from jurisdictions with weaker climate action.

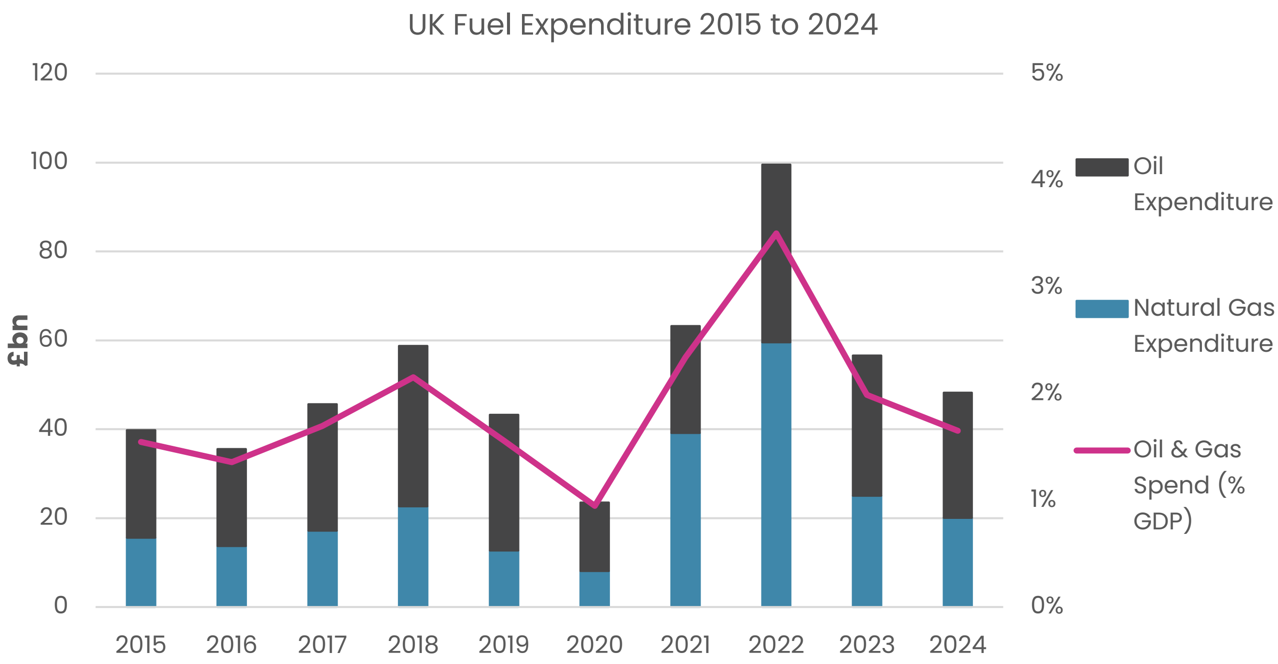
Energy security and exposure to global volatility

As discussed in Section 2, fossil fuel price shocks have played a major role in economic downturns in the UK, most recently in 2022 following the Russian invasion of Ukraine and the subsequent sharp increase in the price of natural gas.

The UK's spending on fossil fuels more than doubled in 2022 compared to pre-crisis years[23], rising to 3.5% as a proportion of GDP. This was reflected in household and business energy bills and in costs to the Exchequer and illustrates the inherent volatility in an economy dependent on imported, internationally priced fuels.

[20] CBI Economics (2025): The Future is Green: The economic opportunities brought by the UK's net zero economy
[21] https://ukerc.ac.uk/publications/green-jobs/download
[22] Climate Change Committee (2023): Net Zero Workforce
[23] Pre-crisis refers to the 2015-2019 five-year average fuel spend (using brent crude oil and gas spot prices).

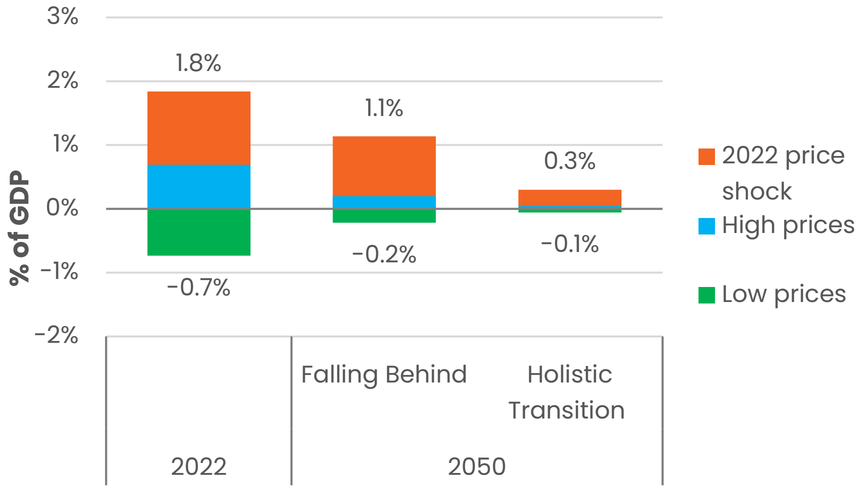
Figure 17: Value of UK fuel spend 2015 to 2024 – expenditure and proportion of GDP[24]



The net zero pathways can reduce this exposure to volatile international fossil fuel prices. As the economy decarbonises, an increasing proportion of the energy used in Great Britain will be produced domestically, reducing reliance and expenditure on imported fuels. For example, an oil and gas price shock of the same magnitude as in 2022 would increase energy costs in 2050 by around 0.3% of GDP in the FES 2025 net zero pathways. In the Falling Behind scenario, costs would still increase by over 1% for an equivalent shock.

[24] Source: Fuel demand data from DUKES, using historical annual spot prices to determine total fuel spend.

Figure 18: Change in energy costs (% of GDP) under fossil fuel price shocks[25]



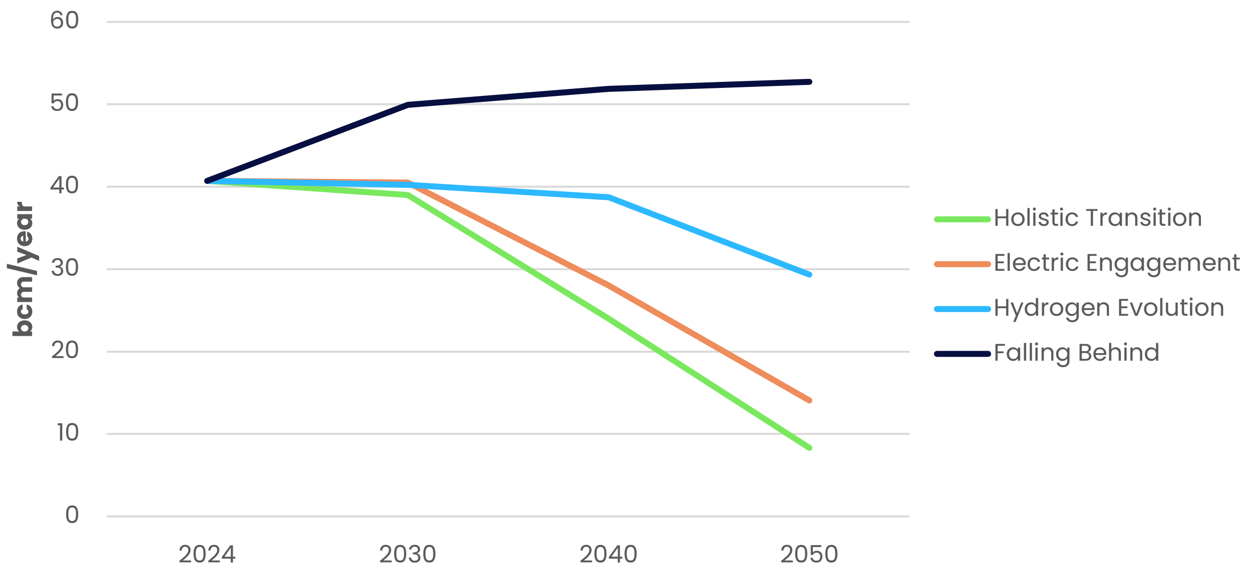
Note: Spot prices for gas (National Balancing Point close price) and Brent crude oil were applied to estimate total fuel spend. Brent crude was used as a proxy for valuing petroleum products to capture volatility impacts as fluctuations in underlying commodity prices tend to drive overall energy spend more significantly than the relatively less volatile refining and distribution margins.

GB's import dependency for gas is set to increase over the coming years, as the UK Continental Shelf declines in output. As set out in FES 2025, decarbonisation can materially reduce this import dependency, while efforts to increase extraction make a more marginal difference.

In Holistic Transition, gas imports fall by 78% from 2025 to 2050, while they increase by 35% in Falling Behind, despite higher UK production in the latter. GB gas imports initially stay broadly flat in Holistic Transition as reductions in the use of gas broadly match the decline in domestic gas production. Later as gas use declines further, particularly for heating, the amount of imported gas declines sharply.

[25] Source: DESNZ 2050 high/low projections; 2022 shock reflects post-Ukraine invasion scale.

Figure 19: GB gas imports by volume



Great Britain is also a net importer of oil, as GB supply has fallen since 2019. FES 2025 does not project oil production or therefore net imports. Oil demand falls strongly in all FES 2025 pathways, especially the net zero pathways, implying a reduced import dependency for oil as well.

GB also imports bioenergy feedstocks, albeit in much lower volumes than gas. All FES 2025 pathways see a reduction in bioenergy imports compared to today. The fastest reduction is seen in Falling Behind (as bioenergy demand decreases) and in Hydrogen Evolution (as domestic production of bioenergy increases the fastest). In Holistic Transition, bioenergy imports are less than half of today's levels by 2050 and less than half the level of gas imports.

GB was a net importer of electricity in 2024. In all FES 2025 pathways it switches to be a net exporter for most of the 2030-2050 period. Interconnection with other markets is an important provider of flexibility, with increased flows in both directions for most of the pathways across most of the period.

Wider impacts

The FES 2025 pathways offer the opportunity for other co-benefits, such as positive health outcomes due to warmer, less damp homes and improved air quality inside and outside.

We have not attempted to quantify these in the pathways, but their potential impact is likely to be significant. For example, the CCC estimated co-benefits in its Balanced Pathway (which meets the UK carbon targets and net zero by 2050) as providing £2.4 to £8.2 billion per year in net benefit by 2050[26]. Health benefits from improved air quality are the largest contributor.

[26] Climate Change Committee (2025) *Seventh Carbon Budget*.

Wider costs of climate change

We do not adjust any of our estimates for the costs of climate change, although these could be higher in the slower action path compared to the net zero pathways.

The Office for Budget Responsibility (OBR) considers the costs of climate damages in its most recent *Fiscal Risks and Sustainability Report* published in July 2025[27].

- The latest estimates of fiscal costs from climate-related damage to the economy are materially higher than previous estimates. Costs result from lower productivity and employment resulting from higher, more variable temperatures and changed rainfall patterns. This implies lower tax receipts, leading to higher borrowing and debt.
- The OBR estimates that a warming scenario of below 3°C (broadly the current trajectory) would cause long-term harm to the UK, reducing GDP by approximately 8% by the early 2070s. If warming is limited to below 2°C (requiring full delivery of global emissions pledges and net zero commitments), this could reduce to 3%.[28]

7. Minimising costs in the pathways

Part of the value of exploring a range of pathways and their costs is in identifying opportunities to minimise costs, either through strategic choices or policy design.

Insights from the pathways on how to keep costs as low as possible

Our pathways point to several opportunities that will reduce energy costs:

- **Accelerated switchover to EVs.** Based on the CCC figures we have used as part of this costing analysis, we expect the average electric passenger car will cost less than a petrol or diesel car, both to buy and to run, by 2027. The closer to this date that there is a full switchover of purchases to EVs, the greater the cost savings will be. Our net zero pathways assume a full switchover by 2030. Our Falling Behind scenario also assumes no fully petrol/diesel purchases from 2030, but plug-in hybrid electric vehicles (PHEV) can be purchased until 2035.
- **Lowering energy demand.** Our net zero pathways involve lower vehicle mileage and fewer new vehicle purchases in the long run due to greater use of shared autonomous vehicles, public transport and increased walking and cycling, reducing costs in the transport sector. We do not assume ongoing savings in heating costs from behavioural changes, but these would also reduce costs. The CCC's pathways additionally involve limited growth in

[27] OBR Fiscal Risks & Sustainability Report (July 2025)
[28] The 2025 UNEP Emissions Gap Report projects warming of 2.8°C by 2100 under a continuation of current policies, and warming of 1.9°C if all (conditional) NDCs and net zero pledges are fully delivered (both 66% chance).

aviation demand coupled with greater efficiency of aircraft, and therefore lower aviation costs.

- **Flexibility in the electricity sector.** Flexibility in demand or from storage can maximise the utilisation of intermittent renewables while reducing the reliance on more costly dispatchable power plants. This tends to reduce costs for the system as a whole[29].
- **Efficient dispatch.** Our pathways assume that, once built, energy assets are used in line with their 'merit order', meaning that the plants with the lowest cost to run are dispatched first. This is in line with current electricity market operation, but will become more complex as the share of intermittent renewables grows, as greater levels and variety of storage come online, and as multiple energy systems (electricity, hydrogen, CCS) increasingly interact.

The pathways also see some changes where alternative routes may yield lower costs:

- **Reduced build of renewables and nuclear in the 2030s.** The FES 2025 net zero pathways reflect the government's clean power goals by 2030. However, reflecting the high volume of projects in development, they then continue high deployment of renewables and nuclear through the 2030s, at a faster pace than demand growth or the pace required to maintain clean power. This leads to higher levels of curtailment and export, which tend to add to costs of the GB system. With less build beyond demand growth in the 2030s, initial investment could be lower, in the order of £3 billion per year over 2030-2040, although some of this investment would be delayed into the 2040s and these savings would be moderated slightly by reduced export revenues. The Strategic Spatial Energy Plan (SSEP) will play a key role in optimising the timing, technologies and location of generation build. It will design pathways that support the most economically efficient and spatially optimal way to meet GB energy needs while meeting carbon targets.
- **Focusing on lower-cost technologies.** The pathways deliberately explore a range of technology options. Some of these, such as hydrogen HGVs and large nuclear power plants are assumed to be higher cost in our central assumptions than alternatives such as electric HGVs and renewables. Focusing on the lowest-cost options (while still ensuring that wider system requirements are met) or delivering these alternatives at equivalent costs could reduce annual total costs by up to £3 billion in the Holistic Transition pathway or £2 billion in the Hydrogen Evolution pathway to 2050. Given uncertainty over future technology costs, achieving this goal is likely to require market mechanisms that encourage the lowest-cost solutions to emerge.
- **Limiting expensive energy efficiency measures.** Most energy efficiency in our pathways reduces energy demand at relatively low cost and supports lower overall costs. However, we also include higher cost measures such as solid wall insulation (around 4 million installations over 2025-2035). These help meet near-term emissions targets and would

[29] See, for example, supporting evidence to the Second National Infrastructure Assessment.

help tackle fuel poverty but deliver relatively limited demand reduction for relatively high cost (around £3 billion per year of capital investment over 2025-2035), so they tend to add to overall energy costs. There are often good reasons for pursuing these measures besides reducing emissions, but they should be carefully targeted given their relatively high costs.

Policy implications

These insights support the value of strategic energy planning alongside a continued role for markets in delivery. NESO's work on strategic planning considers reducing the overall cost of the energy system as a key goal, alongside consideration of spatial constraints and community and environmental impacts. The coordination enabled by strategic planning reduces the risk of over-build of energy supply compared to demand, or ahead of network capacity, which will support a lower-cost system overall. Policy should continue to support the efficient use of generation technologies day to day, making sure that long-term investment instruments to encourage deployment of new low-carbon options do not incentivise inefficient operation of existing and new assets.

Strategic planning may also help to keep costs of capital low, which is a clear priority for keeping costs to consumers low given the shift of spending towards investment. Policy also has an important role in this context, where for example the Contract for Difference regime for renewable generation has a strong track record of supporting low costs of capital.

Alongside strategic planning there will remain an important role for markets in finding the best ways to deliver against the strategic plans, in driving down costs through competition and innovating to keep driving costs lower and finding the most cost-effective solutions to the changing challenges for the energy system.

Appendix – Repeat of results charts, with greater granularity

Figure A.1: Changes in operational expenditure in the Holistic Transition pathway compared to 2025

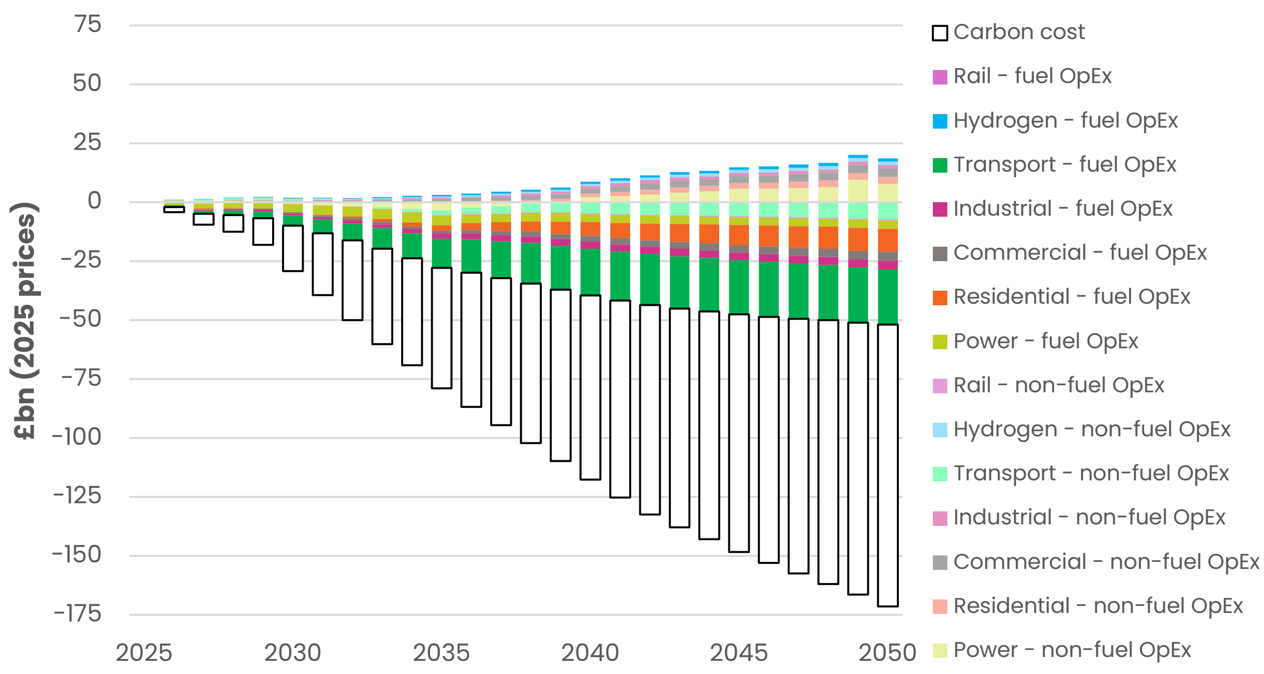


Figure A.2: Changes in capital expenditure in the Holistic Transition pathway compared to 2025

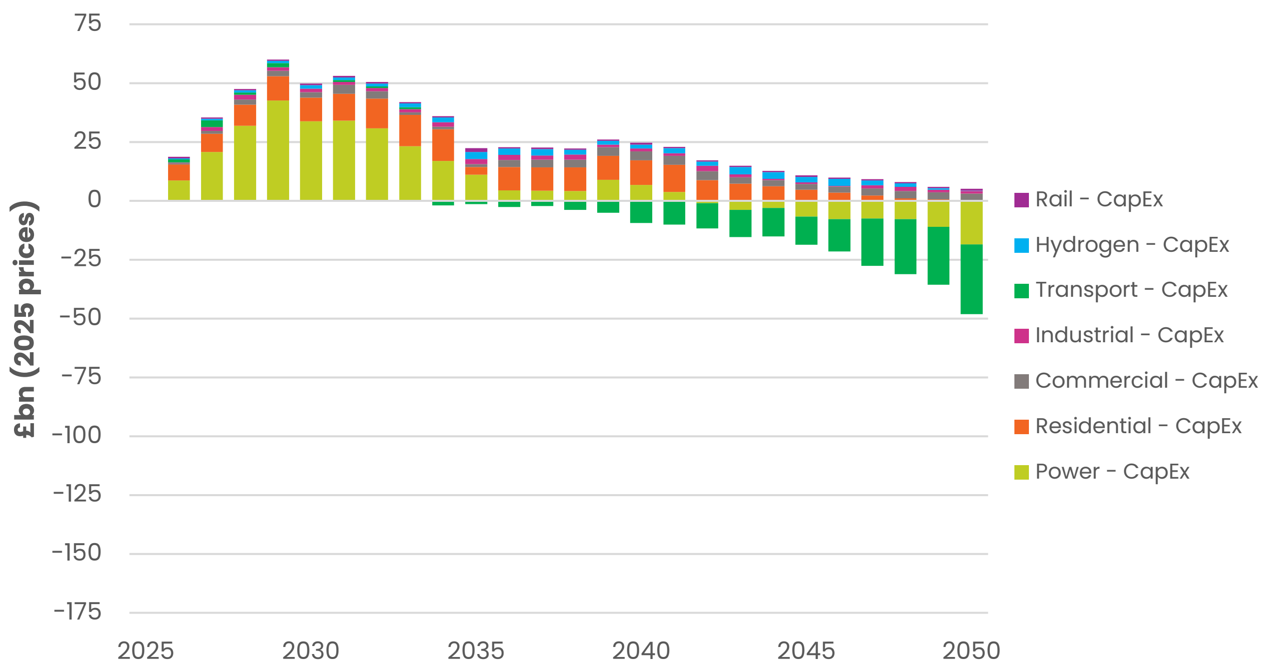


Figure A.3: Total energy cost in the Holistic Transition pathway (2025-2050)

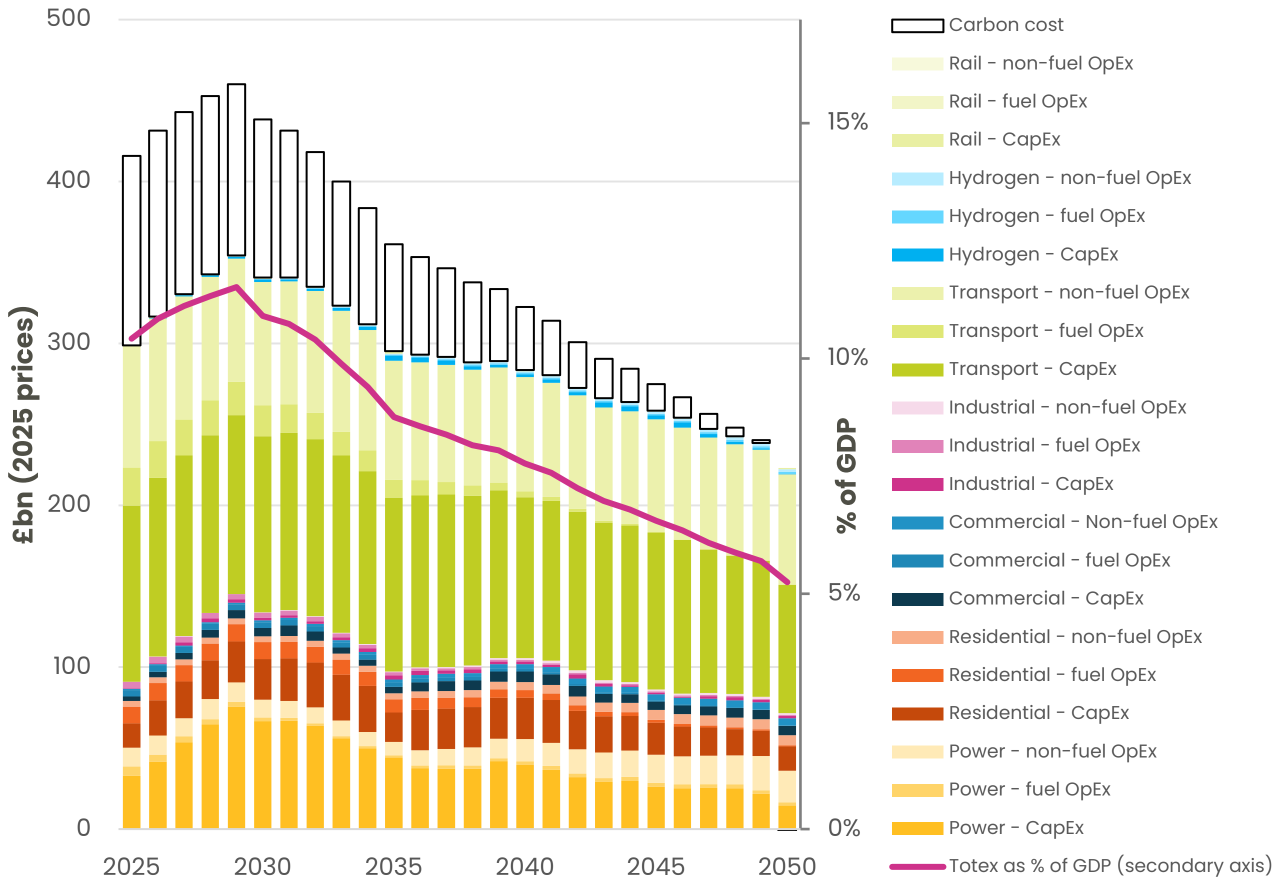


Figure A.4: Total energy cost of Holistic Transition pathway compared to Falling Behind scenario, central case

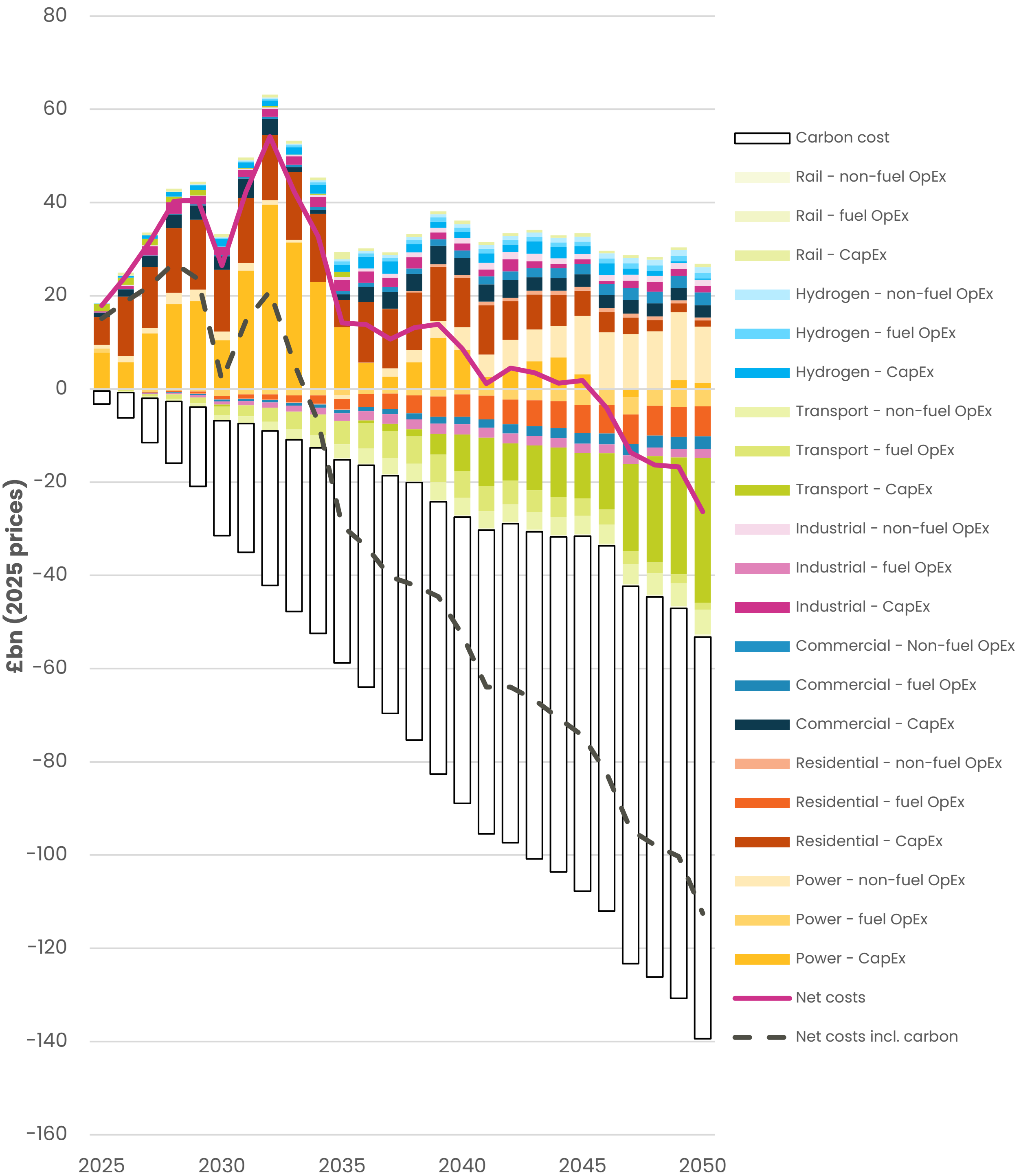


Figure A.5: Additional annualised total energy cost in Holistic transition pathway compared to Falling Behind scenario

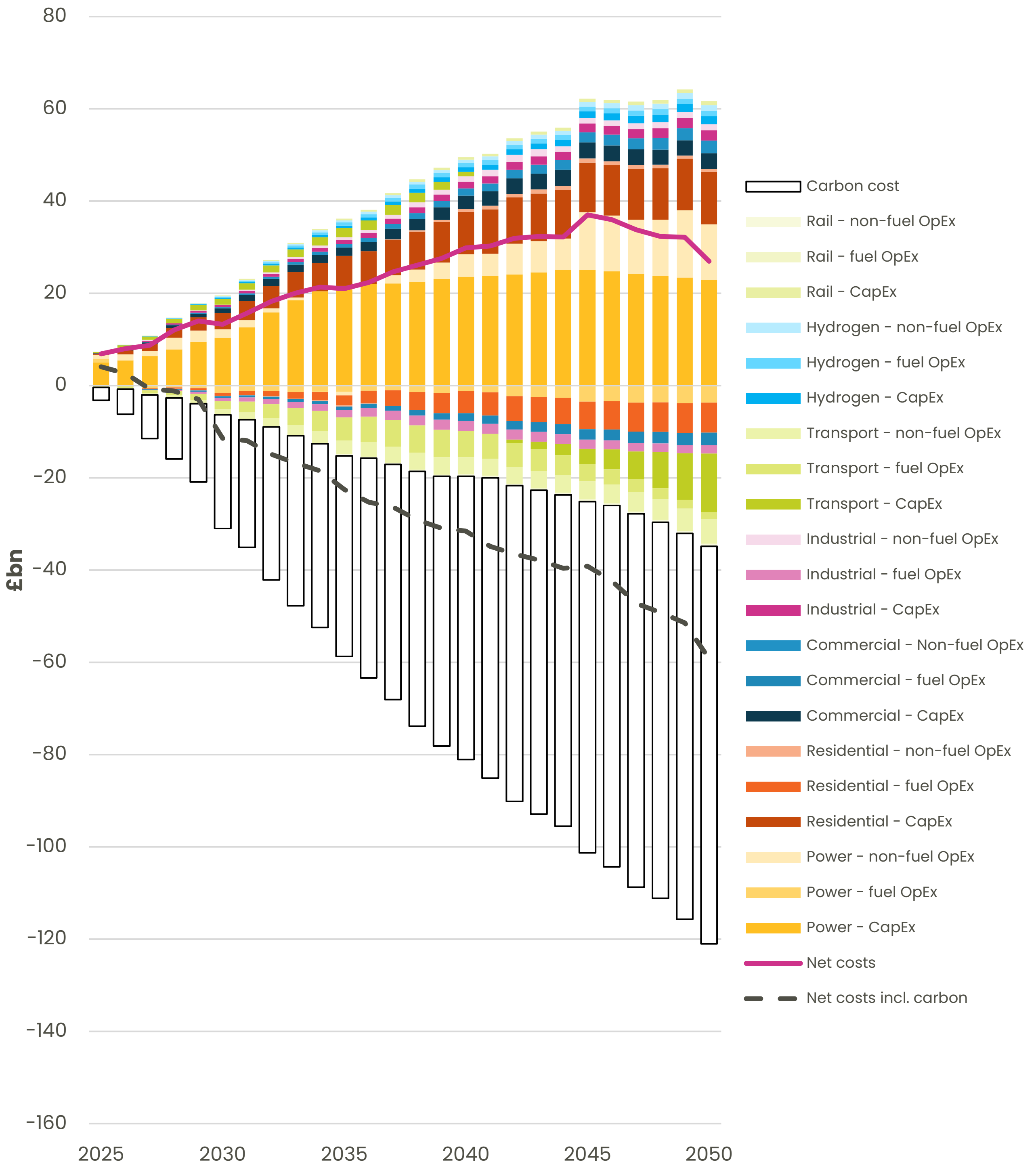


Figure A.6: Total energy cost in the Falling Behind scenario(2025-2050)

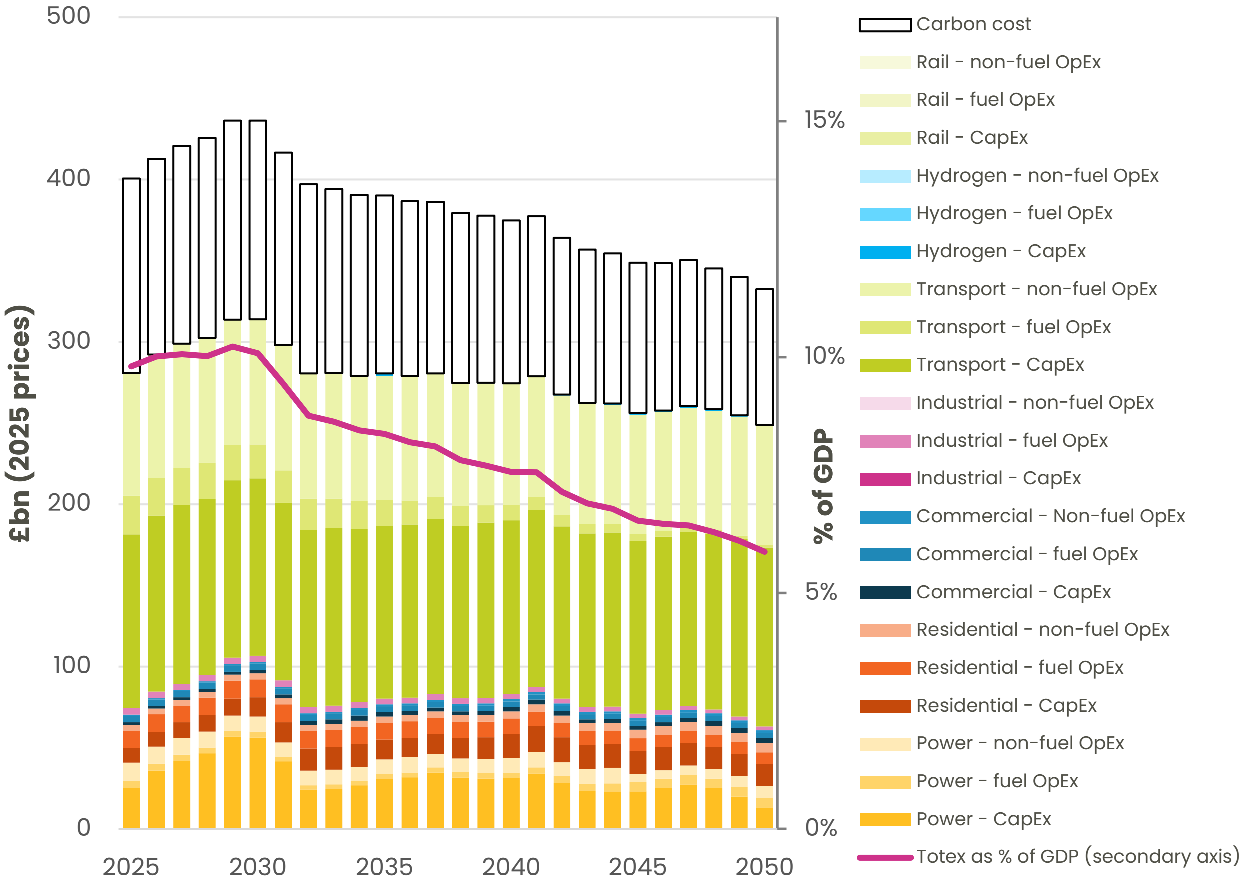


Figure A.7: Additional total energy cost in Electric Engagement compared to Holistic Transition

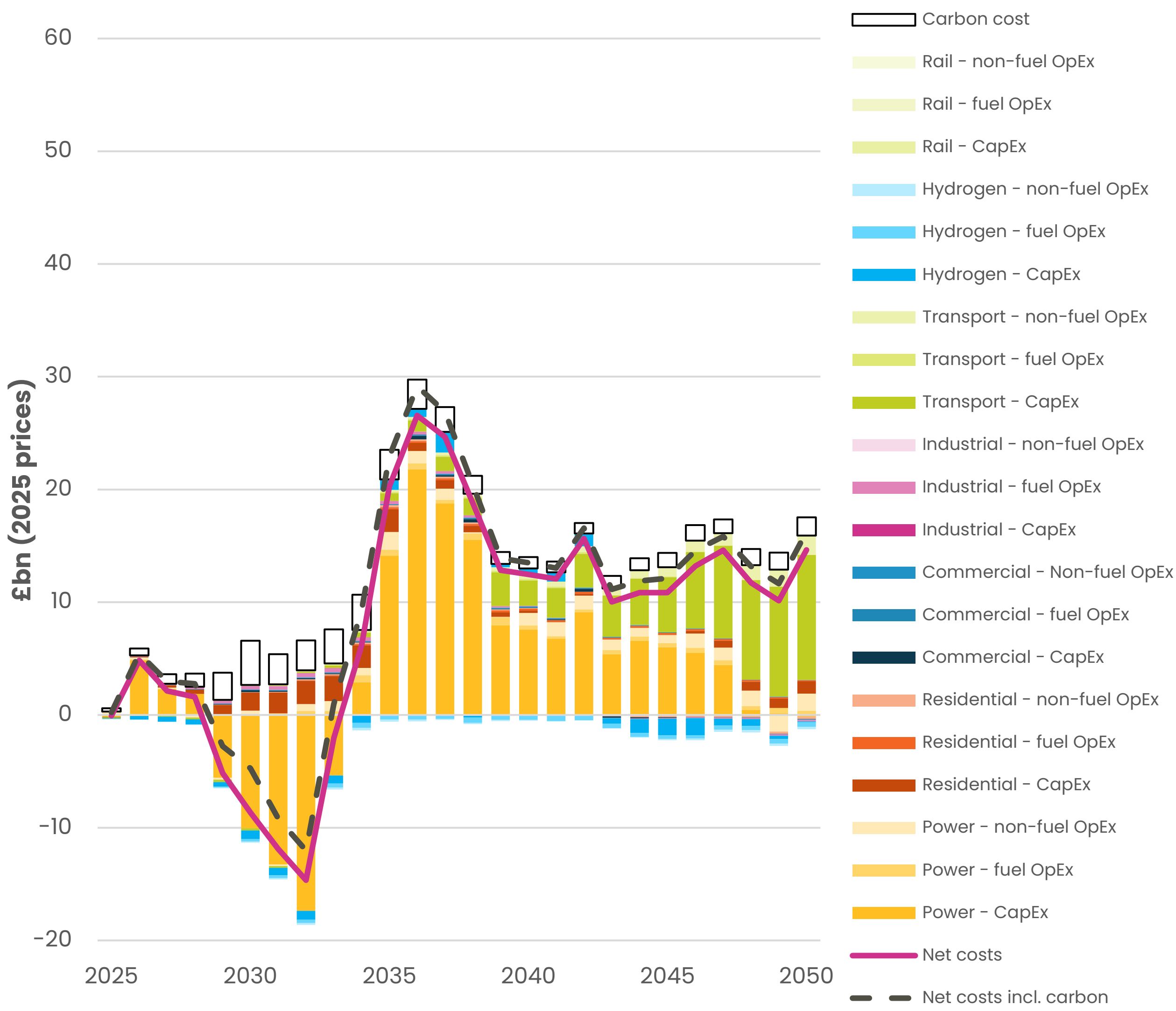
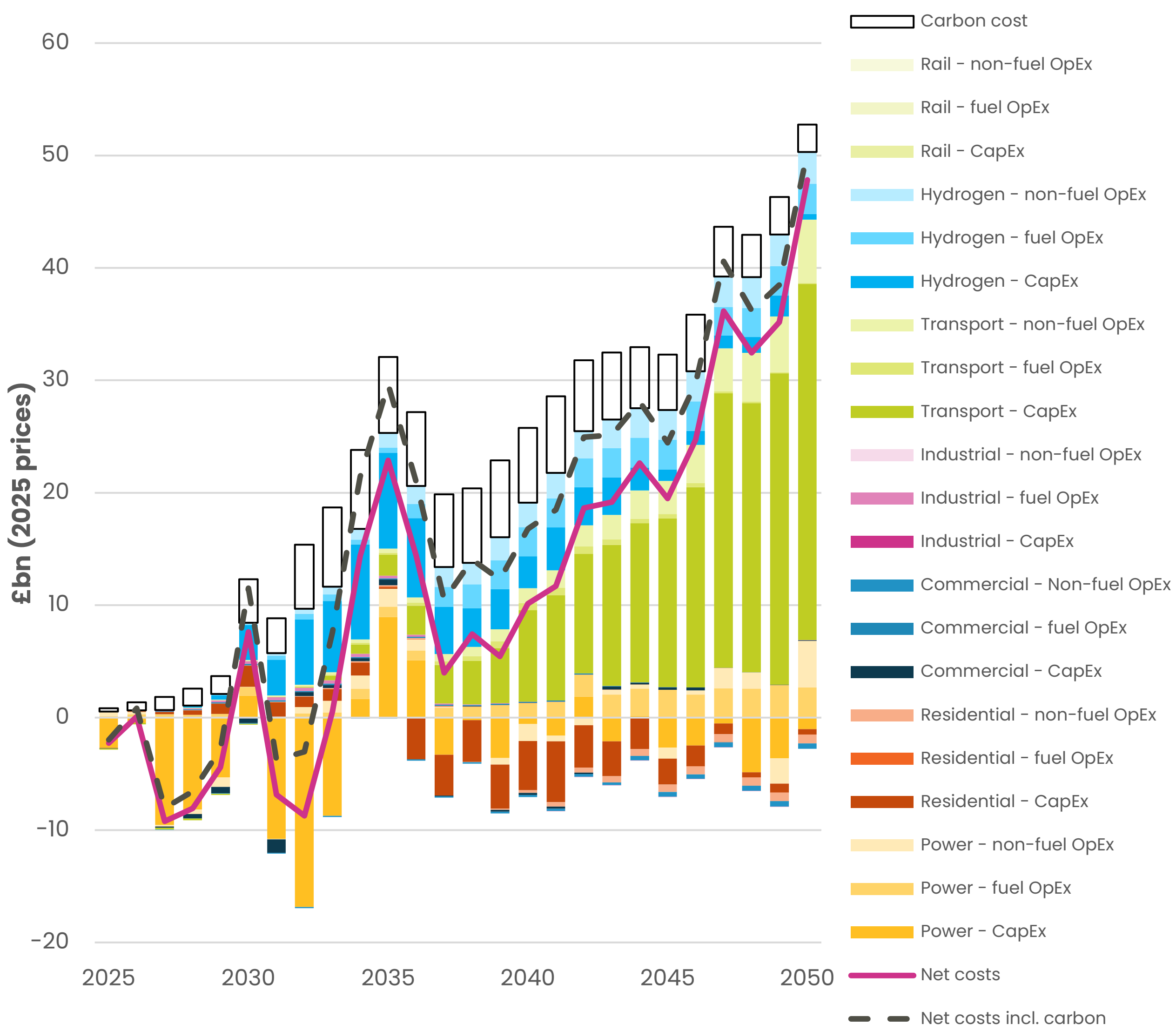


Figure A.8: Additional total energy cost in Hydrogen Evolution compared to Holistic Transition



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