November 2020

2020 Future Energy Scenarios Costing The Energy Sector

Expanding the context of the Future Energy Scenarios.

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Foreword

The 2020 Future Energy Scenarios (FES) were published in July this year and included three net zero scenarios. This year we have committed to costing the scenarios, in response to feedback from stakeholders.

The aim of the costing project was to cost the FES 2020 scenarios for the energy sector, providing a comparison across the four scenarios.

We last costed our scenarios after FES 2018, where we just costed 2050. This year, for FES 2020, a lot of things have changed, particularly the move to a net zero target, which has had major implications across society.

While we do not claim to present a cost-optimal pathway to meeting net zero, we hope this work provides insight into the relative costs and benefits of different pathways for decarbonisation as represented by our scenarios.

We are keen to hear your feedback on this work, please drop us an email at box.fes@nationalgrideso.com or get in touch by using social media via LinkedIn or Twitter.

Craig Dyke

Head of Strategy and Regulation, Electricity System Operator

Executive summary

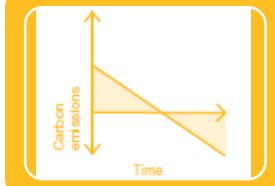
Each year we produce our Future Energy Scenarios (FES) - different pathways for the future of energy over the next 30 years. They are aimed at informing industry investment and supporting decisions on energy policy and this year sees net zero achieved in three out of the four scenarios.

In July 2020 we published this year's scenarios, based around a new framework. We have since undertaken work to cost each scenario for each year out to 2050. The Future Energy Scenarios are created bottom up using stakeholder feedback and market research. They are not cost optimised, but represent a range of credible pathways for the development of the energy system

This piece of work supports the key messages from our FES 2020 report, showing that the key messages in July not only were technologically sound but are also economically sound. The overall cost is broadly similar across the scenarios, indicating that the technology choices within our scenarios do not vary the outturn cost significantly.

This report sets out the results of this costing work in different sectors, the scope of what is included and excluded and the key sensitivities that have impacted the analysis. We have also published a data workbook alongside this report with full detail of the data behind this in order to be fully transparent.

FES 2020 Key Messages



Reaching net zero carbon emissions by 2050 is achievable. However, it requires immediate action across all key technologies and policy areas, and full engagement across society and end consumers.

Hydrogen and carbon capture and storage must be deployed for net zero. Industrial scale demonstration projects need to be operational this decade.

The economics of energy supply and demand fundamentally shift in a net zero world. Markets must evolve to provide incentives for investment in flexibility and zero carbon generation.

Open data and digitalisation underpin the whole system thinking required to achieve net zero. This is key to navigating increasing complexity at lowest cost for consumers.

Executive summary

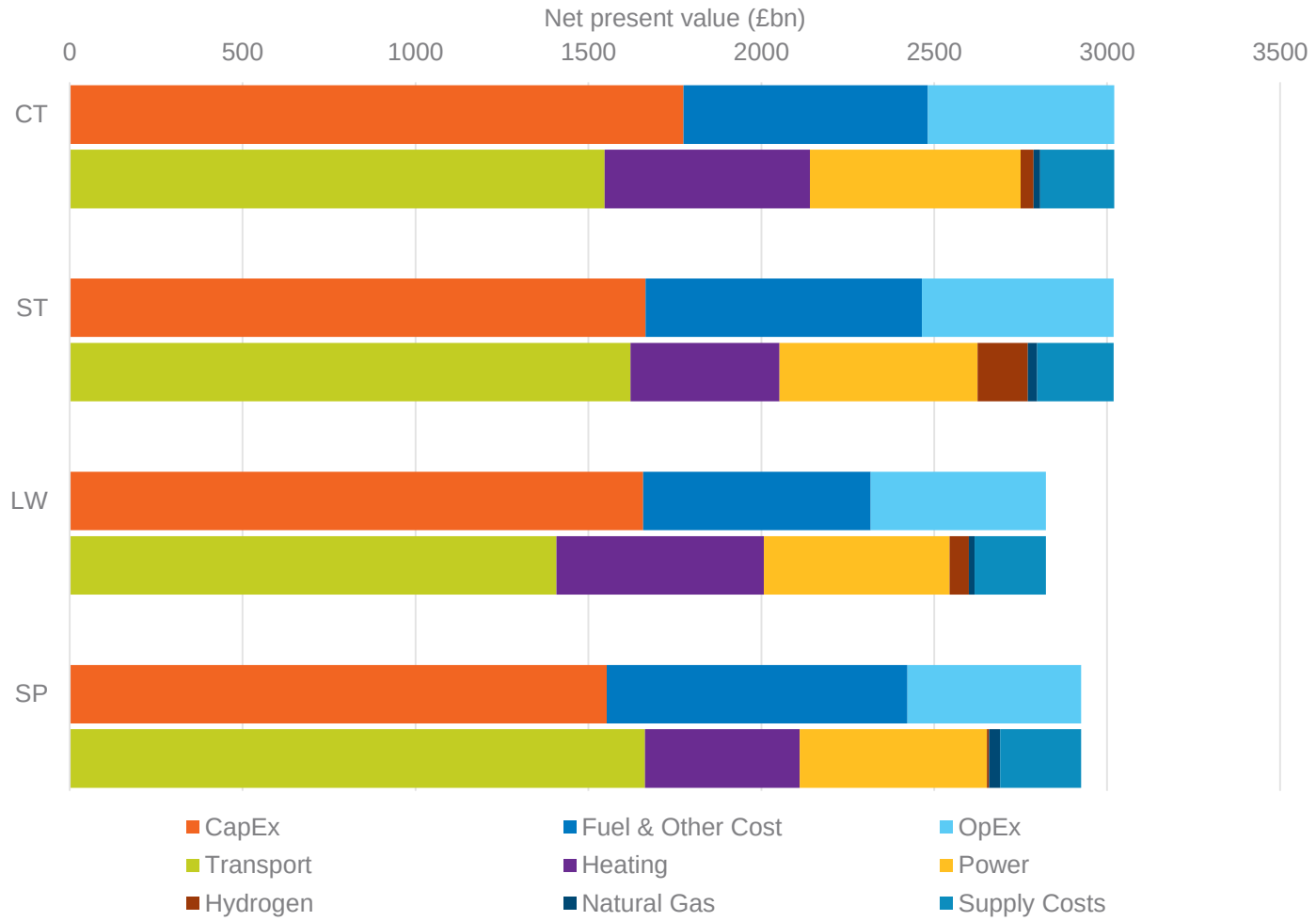
Our costing work supports the key messages from our FES 2020 report. The overall cost is broadly similar across the scenarios and costs are kept lower when consumers are engaged, energy efficiency is pursued, and we have negative emissions in the energy sector.

These total net present value (NPV) figures do not represent the overall cost of net zero, but rather the total capital, operating and fuel costs within the energy sector until 2050. Even without net zero some of these costs would be incurred anyway in the supply of energy, technology and asset replacement and network costs.

There is only a 7% difference in overall costs across the scenarios, including between the net zero compliant and non-compliant scenarios. This means that costs may not be the key driver in decarbonisation of the energy sector as there is little variance of total costs out to 2050 across the Future Energy Scenarios. The scenarios cover a range of technology pathways, with some that are more electrified and some more hydrogen or gas dominated. Despite this, overall costs remain similar between scenarios.

Leading the Way comes out as the cheapest scenario overall. Increased consumer engagement, negative emissions and energy efficiency drives this to be the cheapest scenario. Transport and heating continue to be big contributing factors in the overall costs. This drives the scenario total cost to be sensitive to these sectors.

Figure 1: Net present value breakdown of total costs per scenario (£bn)



Executive summary

There is no major difference in annual costs between scenarios until the mid 2040s.

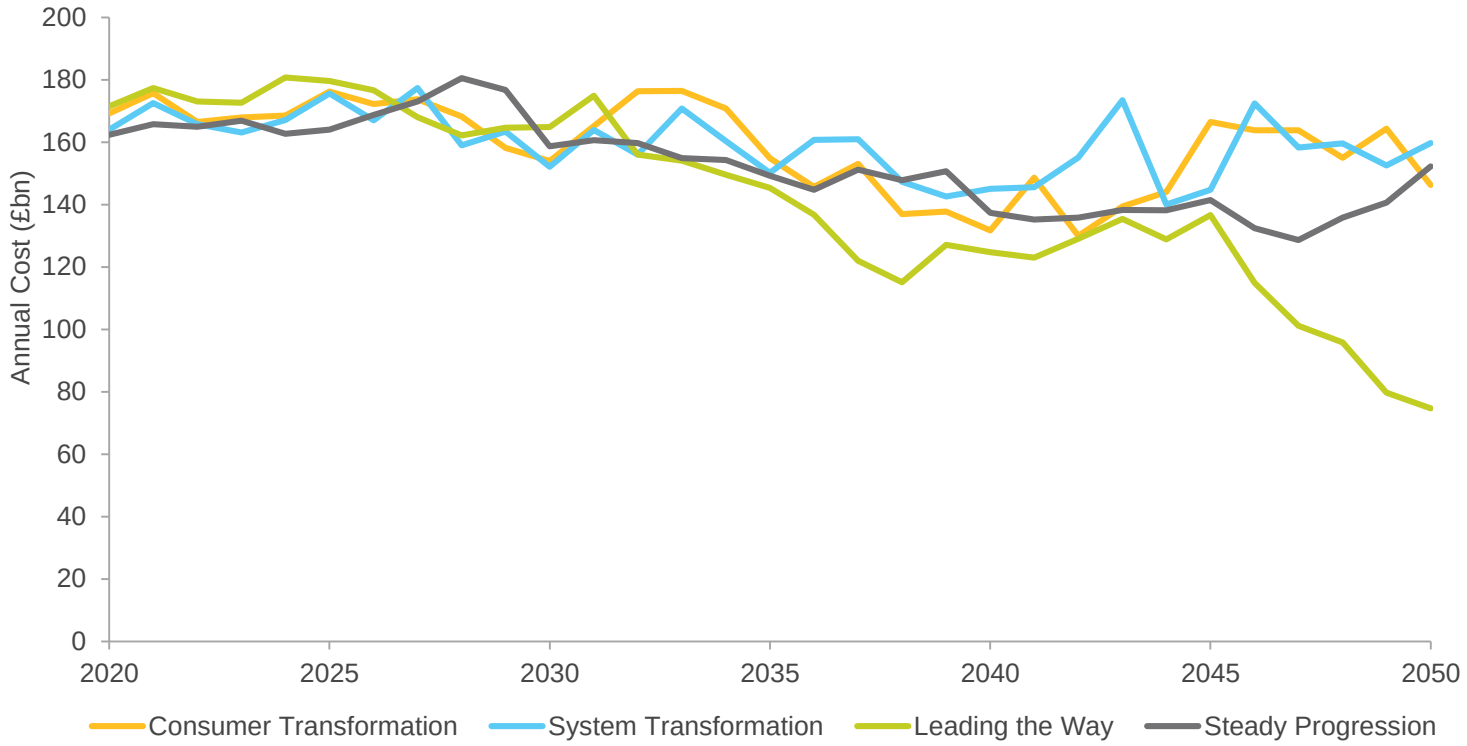
As can be seen in Figure 2, all scenarios are similar in annual cost up until mid 2040s. Despite their varying levels of carbon emissions and technology cost profiles.

Leading the Way has the lowest annual costs from 2033 onwards and shows significant divergence in the mid 2040s.

Investment in decarbonisation is brought forward in this scenario, and we see this having an effect, particularly for heating and transport. We therefore see lower costs and return on investment in this scenario while decarbonisation costs are still ongoing in the other scenarios.

After 2045, Leading the Way is mostly decarbonised and has met targets, including net zero carbon home heating, by this point. These factors cause a rapid reduction in annual cost of around £62 bn between 2045 and 2050.

Figure 2: Annual costs per scenario (£bn)



Note: Values are shown in NPV, annual and undiscounted throughout the report

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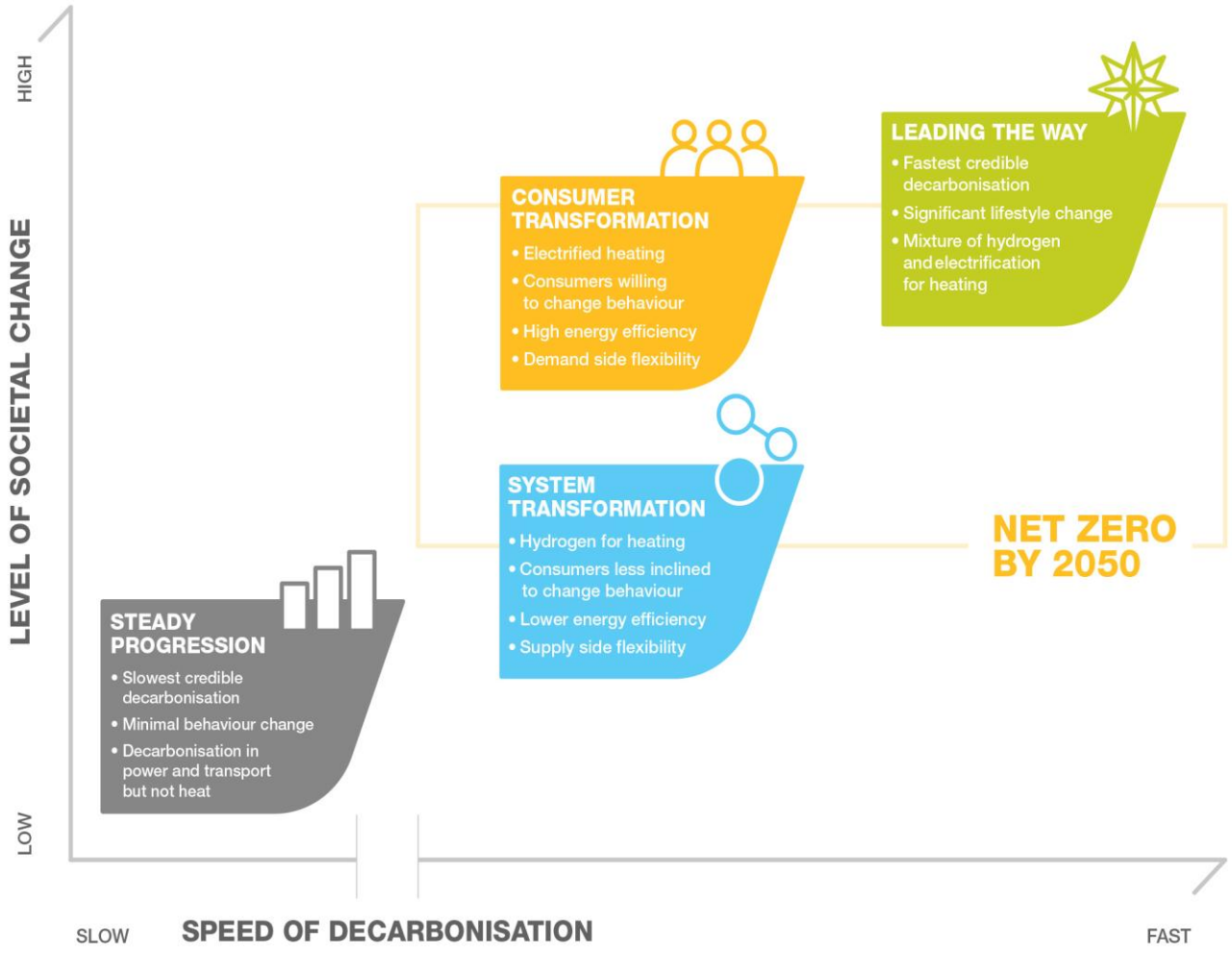
Introduction

The FES 2020 scenario framework is designed to explore the most fundamental drivers of uncertainty in the future energy landscape and reflects extensive analysis and consultation with industry. The scenario framework is shown on the right. The net zero target requires fundamental change across all elements of our energy system and society, but there is uncertainty around various paths to achieve net zero, with some paths requiring different levels of societal change than others.

This year we have committed to costing our 2020 FES scenarios to understand the relative costs of the different pathways to 2050. This is in order to elicit additional insight on the analysis and identify areas of opportunity and challenge. The FES 2020 framework and scenarios are shown on the right.

The costing work has been undertaken by Afry a recognised expert in this field whose costs have been used as the basis for several other reports.

Within this pack we present total undiscounted costs by sector and for annual figures, and net present values with discounted costs per scenario as total comparative figures. The modelling approach, and the costs included and excluded are shown on the following pages.



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Introduction / Scope

Total net present value (NPV) costs do not represent the overall cost of net zero, but rather the total capital, operating and fuel costs within the energy sector until 2050.

We are costing the energy sector in total to show the variance between the different pathways our scenarios show. We have therefore included capital, operating and fuel costs across the different areas of the energy system, however we have excluded some non-energy areas due to lack of data availability.

We have kept the prices the same between the scenarios to highlight the cost differences caused by our technology assumptions. The exception to this is the price on carbon, which varies across the scenarios, but we have also examined the sensitivity of scenario costs to this assumption.

We have included basic network cost assumptions. Note, these do not replace the network options assessment (NOA) process for the electricity transmission system or the equivalent on the electricity distribution system or gas transmission and distribution systems.

Included in costing

- **Electricity**
  - Networks
  - Generation
  - Fuel
  - Import
- **Natural Gas**
  - Networks
  - Fuel
- **Hydrogen**
  - Networks
  - Production
  - Storage
  - Import
- **Road Transport**
  - CapEx
  - OpEx
  - Charging facilities
- **Residential Heating**
  - Heating Solution
  - Insulation

Excluded from costing

- Areas outside the energy industry, i.e. Agriculture
- Other forms of non-road transport, i.e. rail, aviation, shipping
- Heat costs for the industrial and commercial sector
- Appliance capex costs (e.g. fridges, washing machines etc)

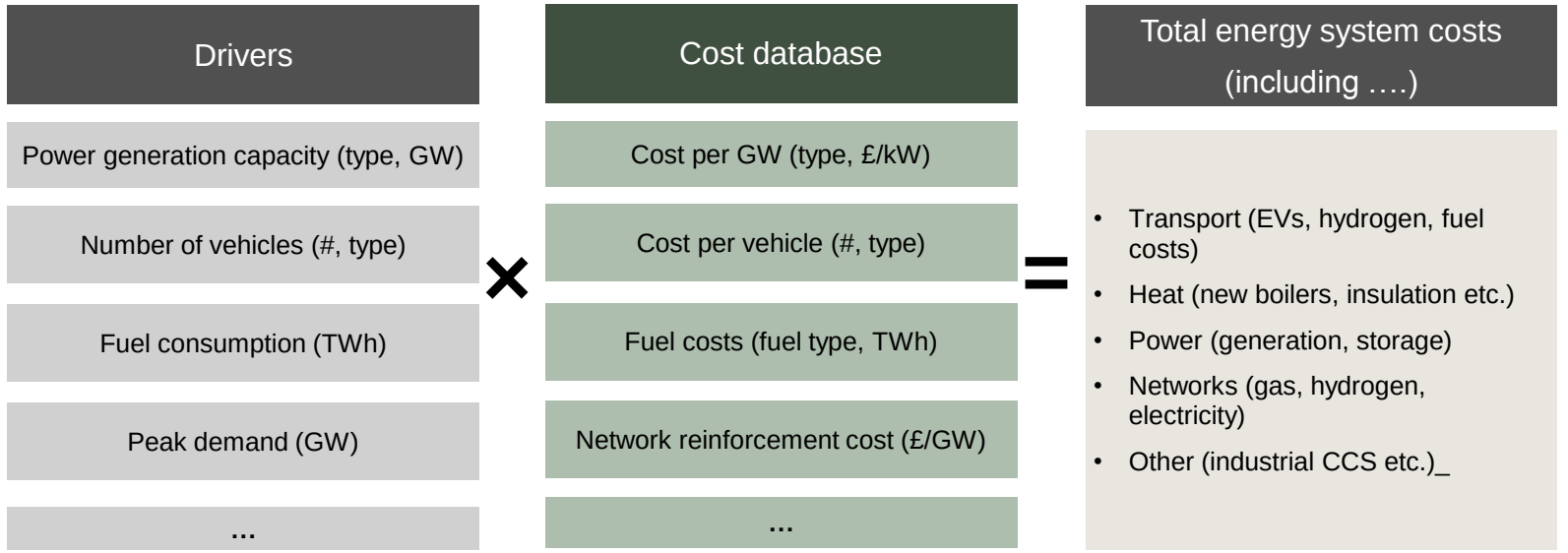
Introduction / Modelling approach

We have developed total costs as a combination of drivers – installed capacities of different technologies - combined with a database of costs. This modelling approach is set out in the graphic on the right.

All drivers come from outputs of the existing Future Energy Scenarios analysis, while costs used are based on Afry's cost database, with some updates to this based on costs published in FES.

FES modelling assumes energy networks are unconstrained, as network constraints and reinforcement are dealt with in downstream processes within the ESO. For the costing project we have, however, included some basic cost assumptions for networks between today and 2050.

We have included the costs at a fixed point for investment where the driver increases and not spread them over the lifetime of the asset. When presenting the net present value a 3.5% social discount rate has been considered as per HM Treasury Greenbook recommendation.



Annual costs

- **Transport costs dominate annually in all scenarios**
- **Leading the Way sees sharp annual cost reductions post-2045**
- **The other three scenarios see broadly similar annual costs out to 2050**

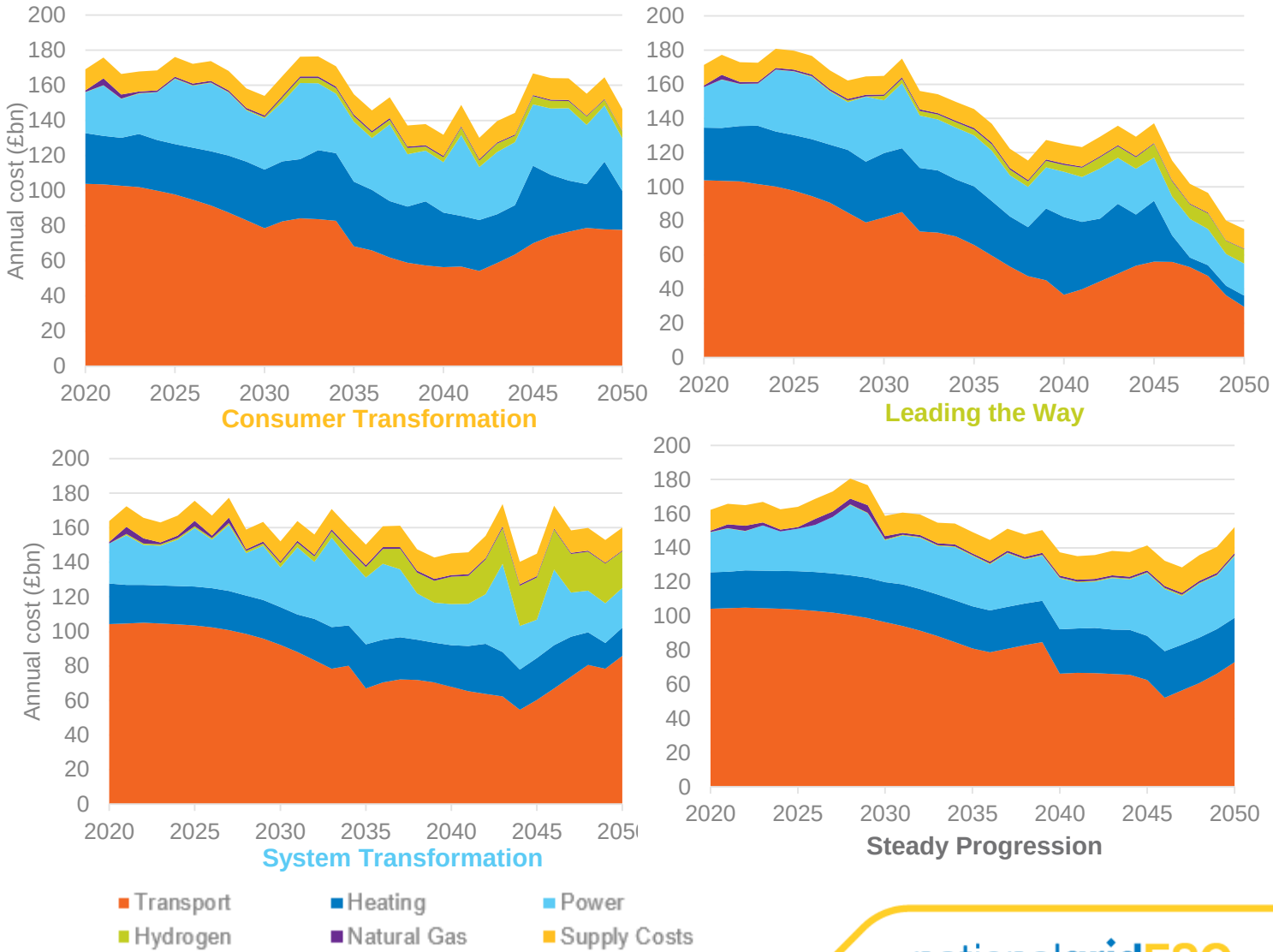
Annual cost breakdowns for each scenario are shown in Figure 3. From this transport, shown in orange, makes up 40-60% of total annual costs across all scenarios. The heating sector is one of the other areas that has the most influence on costs.

In System Transformation we see growing costs for hydrogen from the 2030s onwards, while in Consumer Transformation there is clear additional spend in the power and heating sectors.

After 2045 Leading the Way is mostly decarbonised and costs fall sharply. For instance work to decarbonise residential heating is completed by 2045 and this causes a rapid reduction in annual costs of around £29 bn. There is also a significant reduction in the number of cars on the road between 2045 and 2050 in Leading the Way due to autonomous vehicles and changing consumer habits which reduces expenditure in this sector by £27bn annually.

In the other scenarios, annual energy system costs do not change by as much. However, despite this there is only a 7% difference in overall costs across the scenarios, including between the net zero compliant and non-compliant scenarios. This means that costs may not be the key driver in decarbonisation of the energy sector.

Figure 3: Year-on-year annual costs by sector and scenario



Leading the Way
Cost Reduction in 2045

- **Heating and transport are the areas with the biggest variation in costs across the scenarios**
- **In Leading the Way between 2045 and 2050:**
  - **Transport costs reduce by £27m**
  - **Residential heat costs reduce by £29m**

Residential heat and transport costs reduce sharply after 2045 in Leading the Way. In order to understand the impact of these on total annual costs we have broken down the impact of these compared to the total cost reductions in Figure 4 on the right.

In the road transport sector costs are significantly affected by our FES assumptions on levels of societal change. Leading the Way sees declines in car ownership, a greater shift to shared ownership transport models and increases in use of public transport.

In the heating sector, annual costs are affected by investment needed in the UK housing stock for both insulation and new heating technologies. While higher performing insulation and high efficiency technologies like heat pumps have higher capital costs, when combined they can lead to lower long term operating costs.

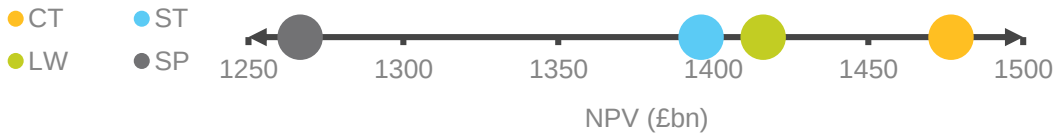
These areas are explored in more detail in the following slides.

Figure 4: Reduction in annual costs from 2045 to 2050 in Leading the Way (£bn/yr)

Sensitivity excluding road transport costs

Road transport has the most significant effect on total costs and this is particularly influenced by the total number of vehicles per scenario. The reduction in vehicles is a major component that drives the costs of Leading the Way lower than the other scenarios. A sensitivity has therefore been carried out, removing all direct road transport costs from the model. When removing Transport Opex and Capex, Steady Progression comes out as the cheapest scenario, as below.

Figure 5: Total scenario net present values excluding road transport costs



Road Transport

- **Leading the Way has fewer cars and hence lower total transport costs**
- **Road transport has the biggest swing in cost of scenarios**

Road transport decarbonisation is similar across all four scenarios, with the main variation being how quickly the scenario shifts from petrol to electric cars. HGVs are typically powered by hydrogen in the net zero scenarios and by natural gas in Steady Progression in 2050; we do not see significant variation in costs from this. System Transformation sees greater take-up of hydrogen vehicles, in other areas, but these make up a small proportion of overall costs.

The high level of societal change in Leading the Way assumes an increased usage of shared/pool vehicles and public transport/taxi services. This leads to some homes having fewer or no cars and to one third fewer cars in 2050 than Steady Progression (LW 20 million cars, SP 33 million cars). This has a significant effect on total costs in the road transport sector for Leading the Way compared to the other scenarios. System Transformation and Consumer Transformation see lower effects from automation and public transport, a lower reduction in total car ownership and therefore higher costs.

Figure 6: Undiscounted Accumulated Road Transport Cost £bn

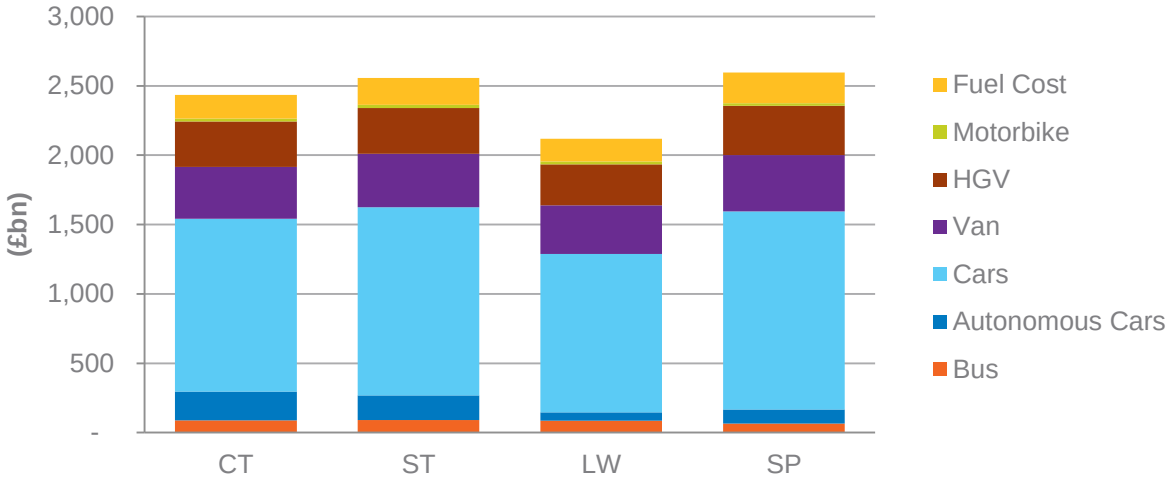
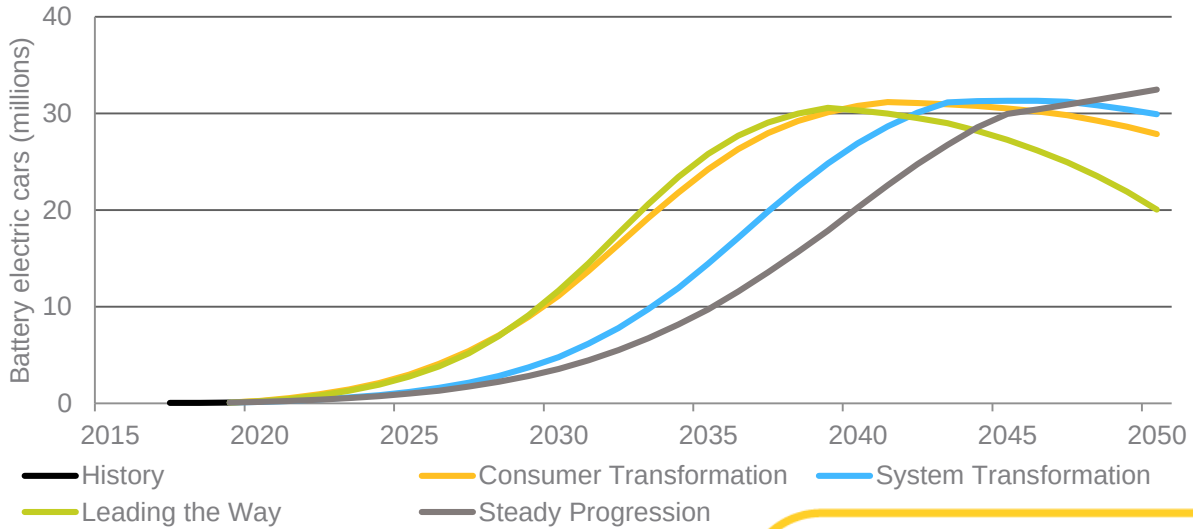


Figure 7: FES scenario projections for uptake of battery electric cars



Residential Heating

- **Heating sector costs vary significantly, driven by insulation levels and heating technology type**
- **The cheapest solution varies according to assumptions on electricity and hydrogen unit prices**

Aside from the ongoing fuel costs, Consumer Transformation and Leading the Way are considerably more expensive than System Transformation and Steady Progression due the capital cost of heat pumps compared to hydrogen boilers and due to the higher levels of insulation. In Leading the Way and Consumer Transformation, the cost of insulation accounts for a third of the total cost for the heating sector. However, by favouring high insulation and more efficient technology types this reduces the fuel cost to the homes.

Which heating solution has lower costs for an average property in 2030?

Figure 8 shows hydrogen and electricity prices for an average domestic property in 2030 assuming a 15-year lifespan for the relevant heating unit. It considers which is cheaper over this lifespan - a hydrogen solution with less insulation or an electric heat pump solution with improved insulation.

Overlaying a range of electricity prices of the electricity required for heat pumps, we can see what the breakeven cost would be for the high hydrogen installation. If the price to the consumer for hydrogen is less than 4.7 p/kWh then we expect hydrogen with less insulating measures to be the favoured solution.

Figure 8: Undiscounted Accumulative Cost of Residential Heating (£bn)

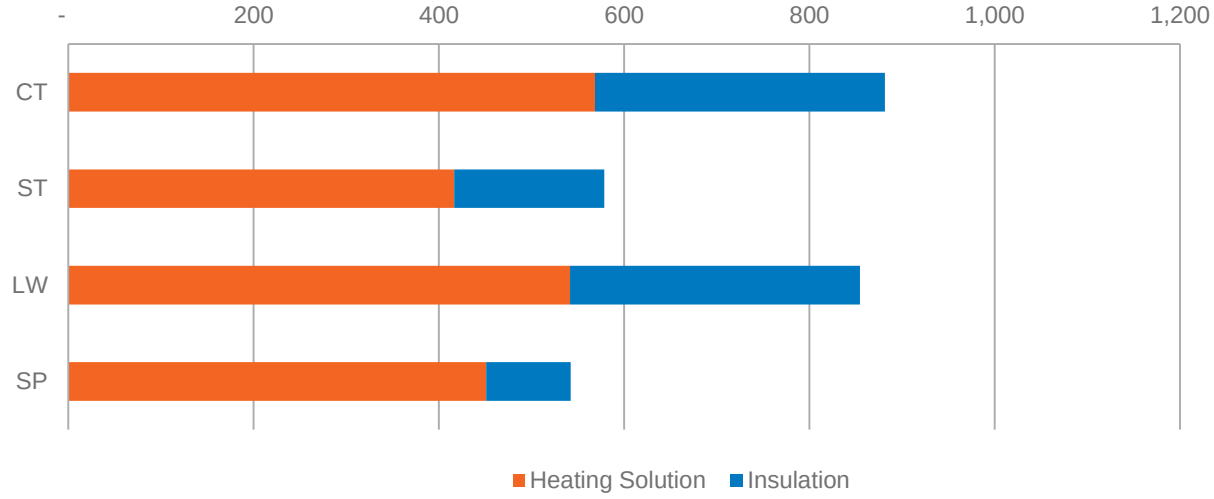
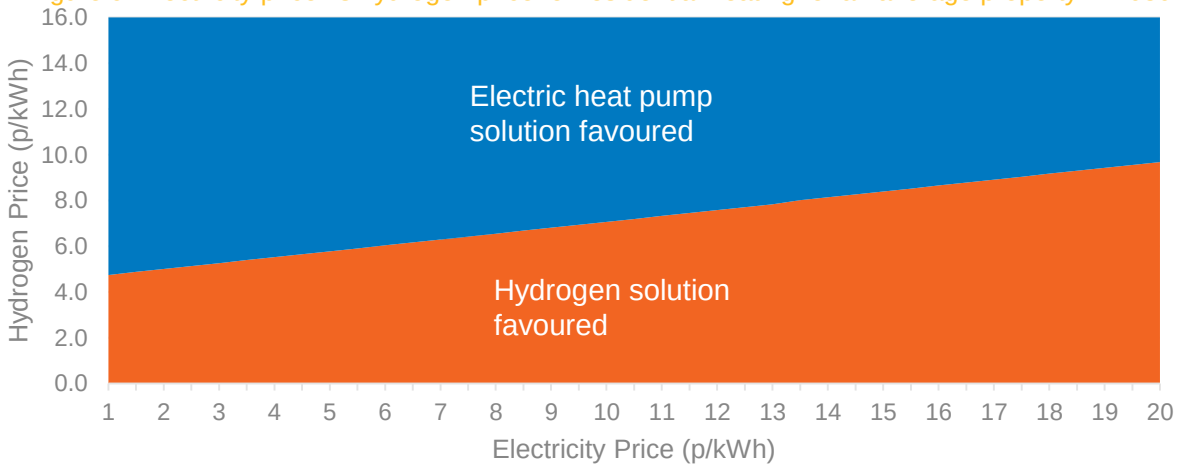


Figure 9: Electricity price vs hydrogen price for residential heating for an average property in 2030



Electricity Generation

- **Leading the Way has the lowest electricity generation costs**
- **The production of negative emissions from BECCS offsets some costs in this sector in the net zero scenarios**

Consumer Transformation comes out the most expensive for the power sector largely due to having the highest electricity demands leading to higher generation requirements.

Leading the Way has the second lowest cost of electricity generation ahead of Steady Progression, but net costs are lowest. This is due to modelled revenue from electricity exports and from carbon pricing of electricity from Biomass with Carbon Capture and Storage (BECCS) of which this scenario has the highest levels of deployment.

Not all the carbon prices are equal across the net zero scenarios. Consumer Transformation and System Transformation both have a central case for the carbon price, Leading the Way has a higher price, while Steady Progression has a lower price.

Since the power sector is where a vast majority of the negative emissions are coming from, we have also considered the difference in the net present value when carbon prices are the same. Sensitivities are shown for Steady Progression and Leading the Way where the carbon price also assumes the value of the central case. This reduces the difference between the scenarios and sees LW and ST as the joint lowest cost.

Figure 10: Undiscounted accumulative electricity generation cost (£bn)

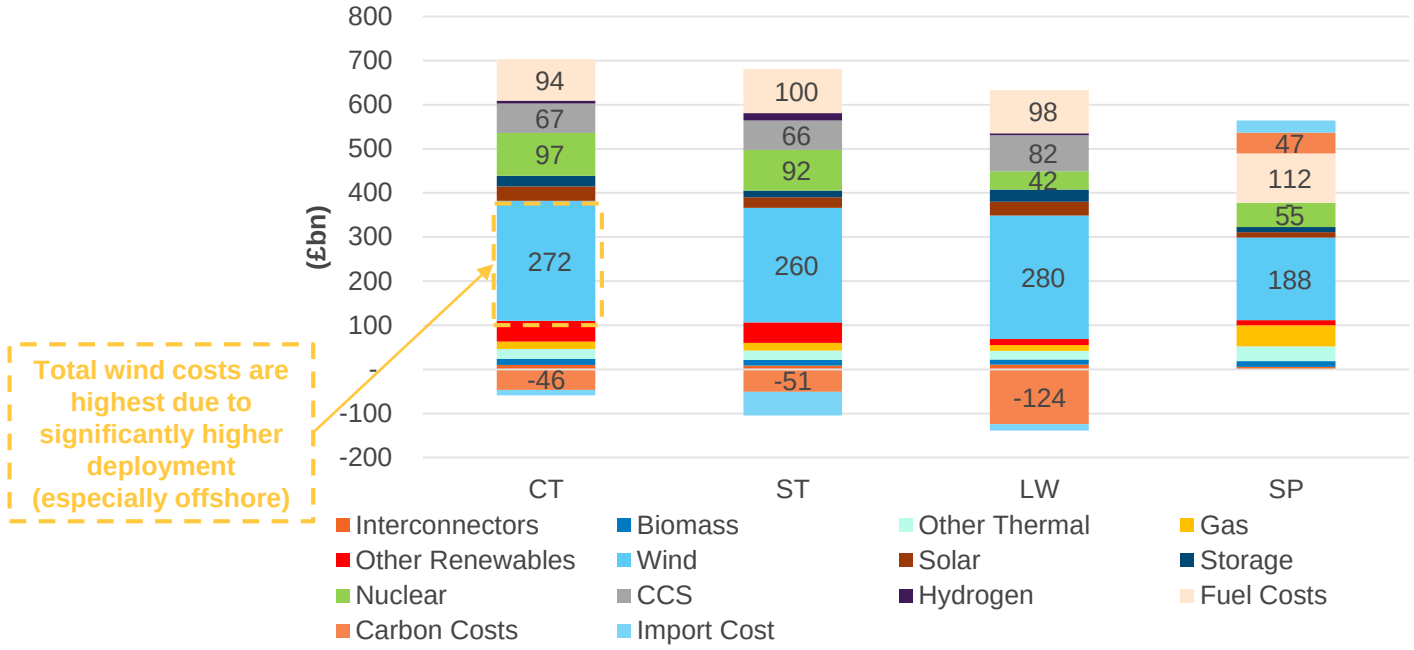
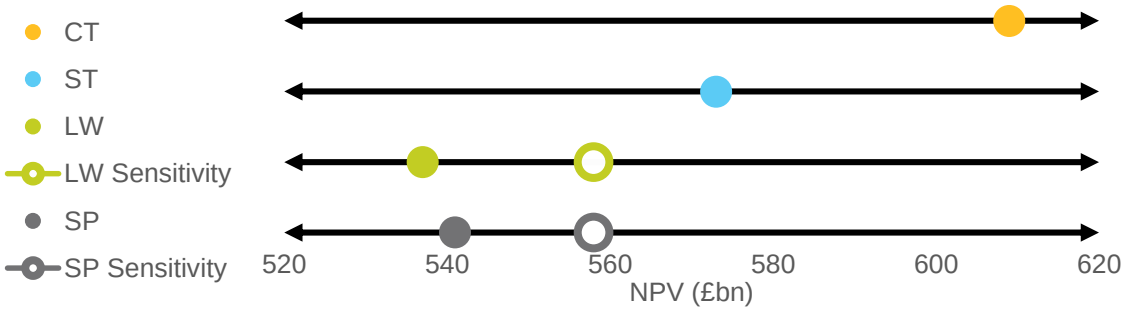


Figure 11: Electricity sector net present value costs per scenario – sensitivity is central carbon price



Hydrogen

- **Hydrogen costs per scenario correlate with levels of hydrogen demand**
- **Hydrogen network costs do not contribute significantly to costs for the sector overall**

Hydrogen production

Total costs associated with hydrogen are correlated with the level of hydrogen demand. System Transformation has the highest hydrogen demand and produces the majority of this from methane reformation (blue hydrogen), so sees significant cost associated with this. Consumer Transformation has limited blue hydrogen penetration, with most produced from electrolysis (green hydrogen). Leading the Way assumes most hydrogen is green hydrogen, so production costs are mainly from electrolysis. However, additional costs are seen in this scenario for imported hydrogen and deepwater offshore wind electrolysis which are not seen in the other scenarios.

Electrolysers are modelled as operating flexibly in all scenarios, running predominantly when electricity supply exceeds demand and prices are low. This means they absorb excess electricity, rather than consume at peak times. This results in higher capex costs but reduced operational costs.

Hydrogen network costs

Hydrogen network costs are comparatively low comparing to those of electricity. There is a mixed approach across the scenarios, with some scenarios blending hydrogen and gas in the existing gas network, some areas where the existing gas network is repurposed to carry hydrogen and others where new dedicated hydrogen networks are needed. The ability to repurpose existing infrastructure reduces overall costs.

Figure 12: Undiscounted accumulative hydrogen costs (£bn)

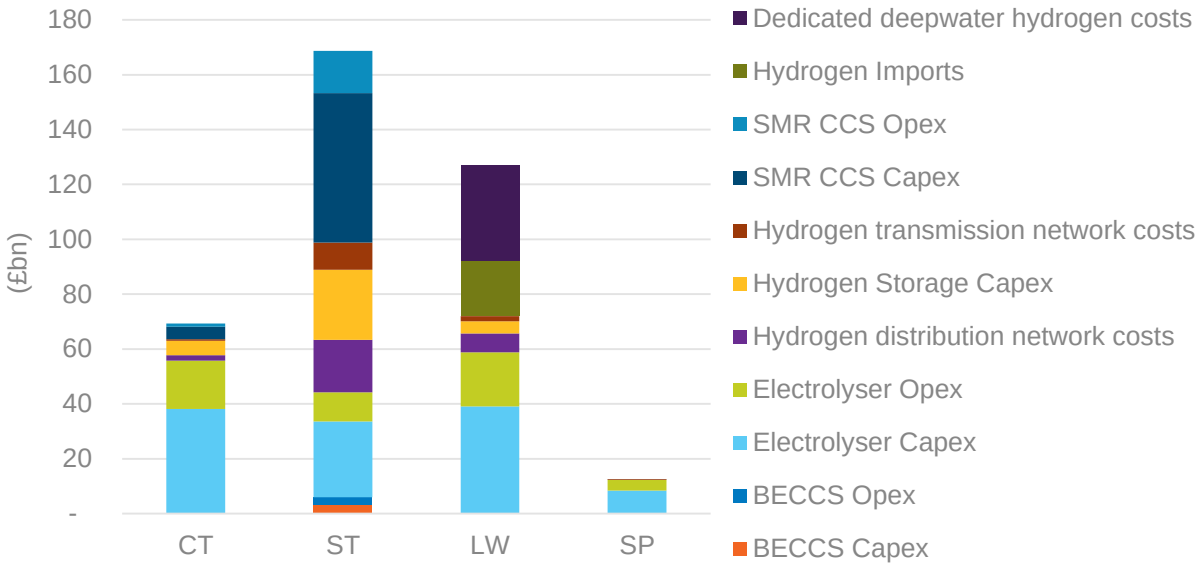
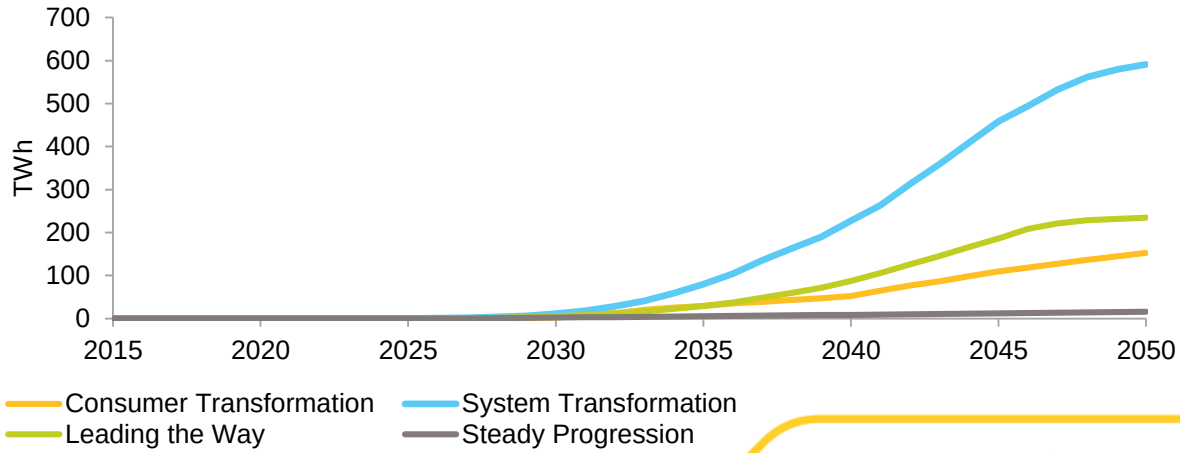


Figure 13: Future Energy Scenarios hydrogen demand per scenario – FES page 72



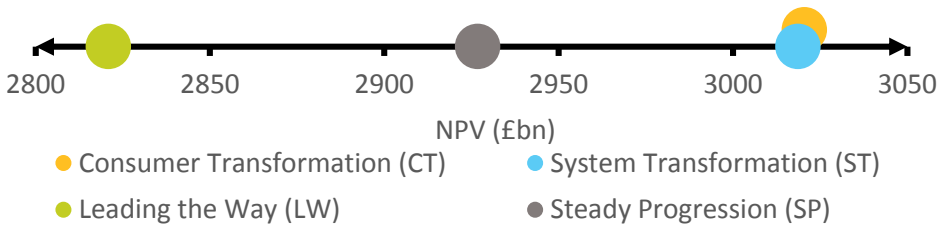
Conclusion

This piece of work supports the key messages from our FES 2020 report, showing that the key messages in June not only were technologically sound but are also economically sound. The overall cost is broadly similar across the scenarios, indicating that the technology choices within our scenarios do not vary the outturn cost significantly.

From the analysis we see:

- The overall cost is broadly similar across the scenarios
- Costs are kept lower when consumers are engaged, energy efficiency is pursued, and we have negative emissions in the energy sector
- The biggest individual sectors with potential cost saving are transport and heat.

Figure 14: Total range in net present value per scenario (£bn)



The final Net Present Value cost for each of the scenarios are;

Leading the Way	**£2,821bn**
Steady Progression	**£2,927bn**
System Transformation	**£3,019bn**
Consumer Transformation	**£3,020bn**

These total net present value (NPV) figures do not represent the overall cost of net zero, but rather the total capital, operating and fuel costs within the energy sector until 2050.

There is only a 7% difference across the scenarios which is considered small when compared to the margin of error in producing the costs. This shows that policy choices won't vary the outturn cost significantly.

FES 2020 said reaching net zero carbon emissions by 2050 is achievable but requires immediate action across all key technologies and policy areas, and full engagement across society and end consumers. Leading the Way is the scenario with the lowest total cost and has many different elements to it that drive the cost down across the board while achieving net zero before 2050. The largest of these are transport, residential heating and negative carbon emissions. Lower costs are partly due to investment in decarbonisation being brought forward in this scenario. We therefore see lower costs and return on investment in this scenario while decarbonisation costs are still ongoing in the other scenarios.

Minimising costs of road transport and residential heating should be the primary focus in general. How early this investment is made is also important as it can reduce cumulative costs to 2050.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