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System Value Analysis for the UK Market

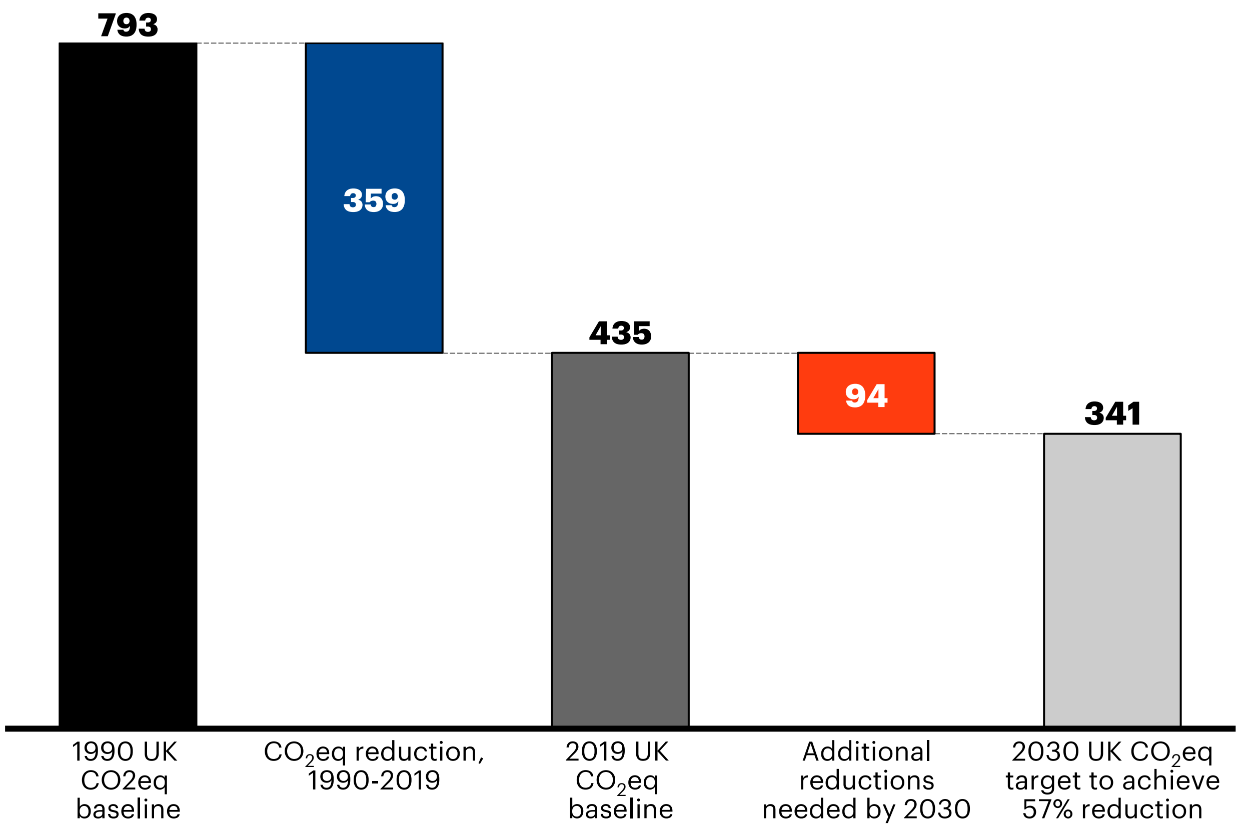
March 2021

The UK’s climate commitments

In July 2019, the UK became the first major economy to pass laws setting a net-zero target by 2050, with an interim 57% decrease in greenhouse gas (GHG) emissions by 2030 in accordance with the Paris climate agreement

What’s been promised	**By 2030** **57%** Decrease in CO2eq emissions from 1990 baseline, in accordance with Paris agreement	**By 2050** **100%** UK to achieve net-zero emissions across the economy (by 2045 in Scotland)
Progress to date	**1990-2019** **45%** Decrease in CO2eq emissions from 1990 baseline (359 million tonnes)	
Work left to do	**By 2030** **12%** Additional decrease in CO2eq emissions from 1990 baseline (estimated 94 million tonnes)	

GHG emission progress towards 2030 UK target (Mt CO2eq)



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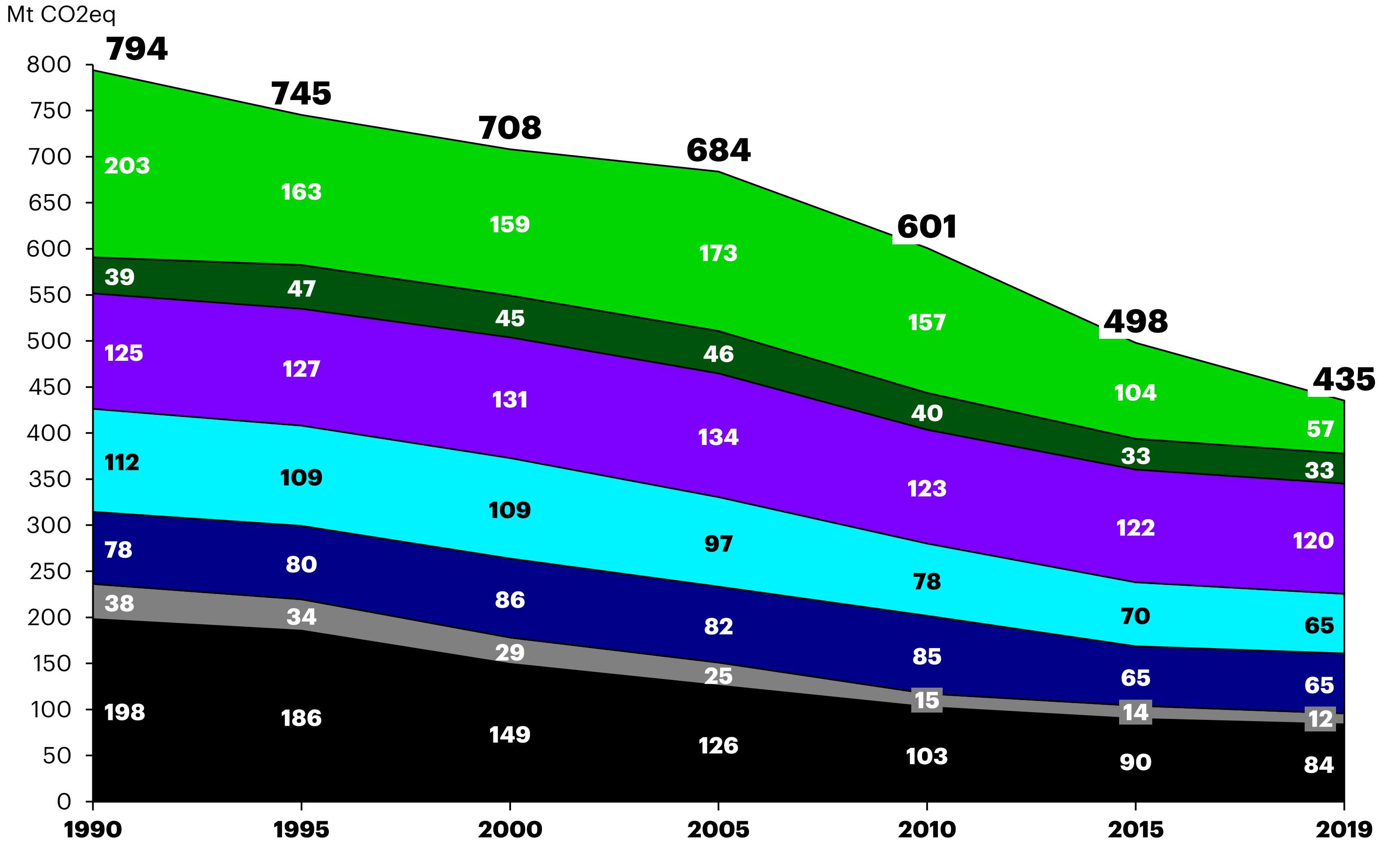
Note: 2019 figures are provisional UK government statistics published in March 2020. Greenhouse gas (GHG) emissions refer to CO_2 equivalent emissions (CO2eq). Mt = million (metric) tonnes.
Sources: UK Committee on Climate Change; UK Department of Business, Energy & Industrial Strategy (BEIS); GOV.UK; SSE; Accenture analysis

UK GHG emissions by source

The UK has made significant progress in decarbonising the electricity sector in recent years; however, other sectors such as transportation, heating and industry need additional focus to bring the UK economy to net-zero by 2050



- **Emissions from power stations have dropped nearly 72% since 1990**, largely due to coal being replaced by natural gas and renewables. This is despite consumption of electricity being 6% higher in 2019 than in 1990.
- **Transport and building** sectors (e.g. residential) **have seen little improvement** in emissions reduction, with continued dependence on petrol and diesel for road transport and natural gas for building heating.

Note: Greenhouse gas (GHG) emissions refer to CO_2 equivalent emissions (CO2eq). Mt = million (metric) tonnes.
"Others sectors" refers to public sector, agriculture, industrial processes, land use and forestry offsets
Sources: UK Department of Business, Energy & Industrial Strategy (BEIS); GOV.UK; Accenture analysis

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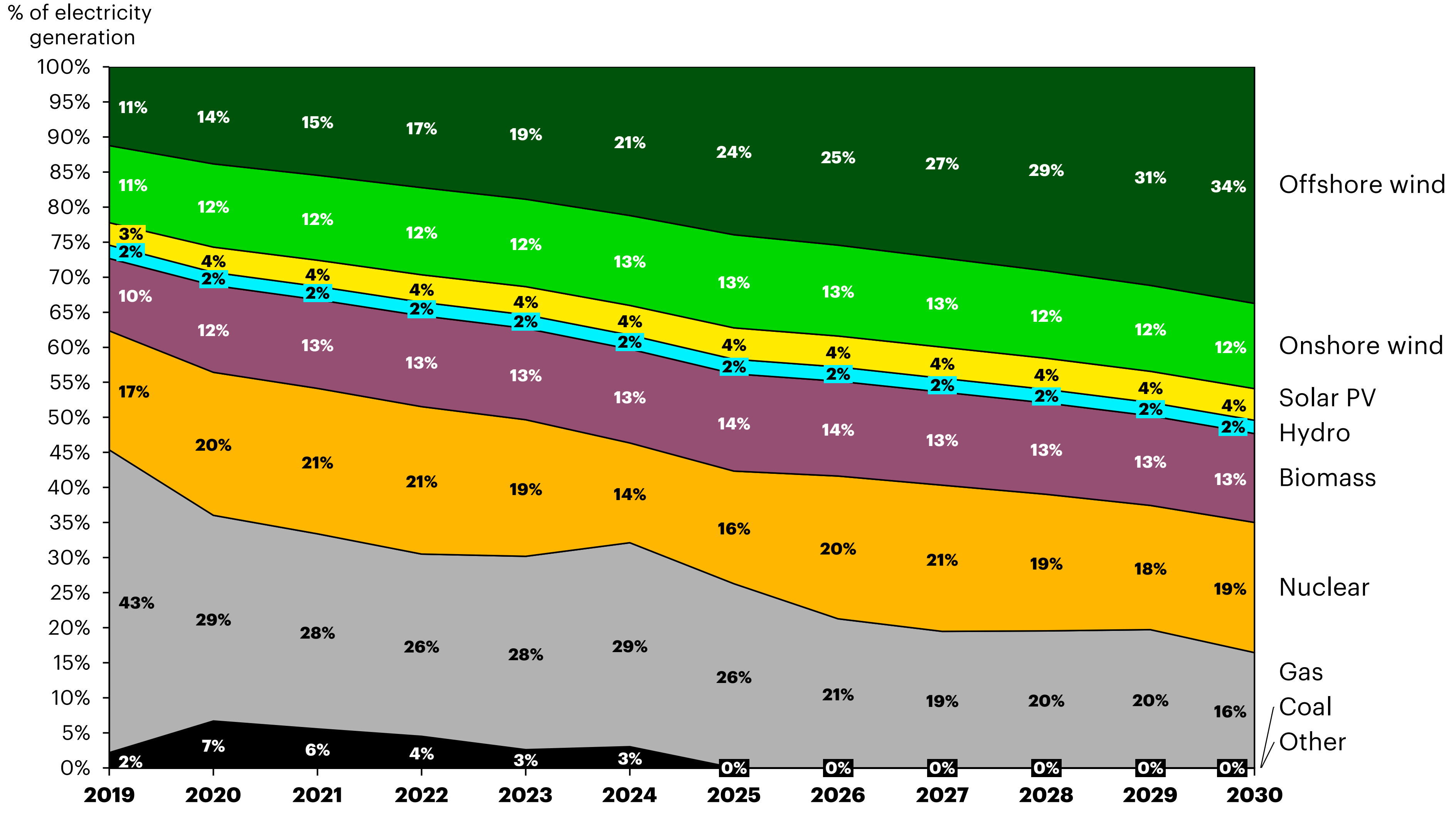
UK baseline generation forecast through 2030

According to BEIS, the UK's electricity generation mix is currently more than 40% renewable and 60% carbon-neutral, with the carbon-neutral proportion of electricity generation mix projected to rise to more than 80% by 2030



- Share of generation from **wind and solar set to rise** from 30% in 2020 **to at least 50% by 2030**
- **Coal electricity generation projected to zero** out by 2025
- **Natural gas could comprise less than 20%** of electricity generation **by 2030**

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Note: BEIS projections as of October 2020, reflecting policy analysis from August 2019 and modelling from March 2020
Source: UK BEIS

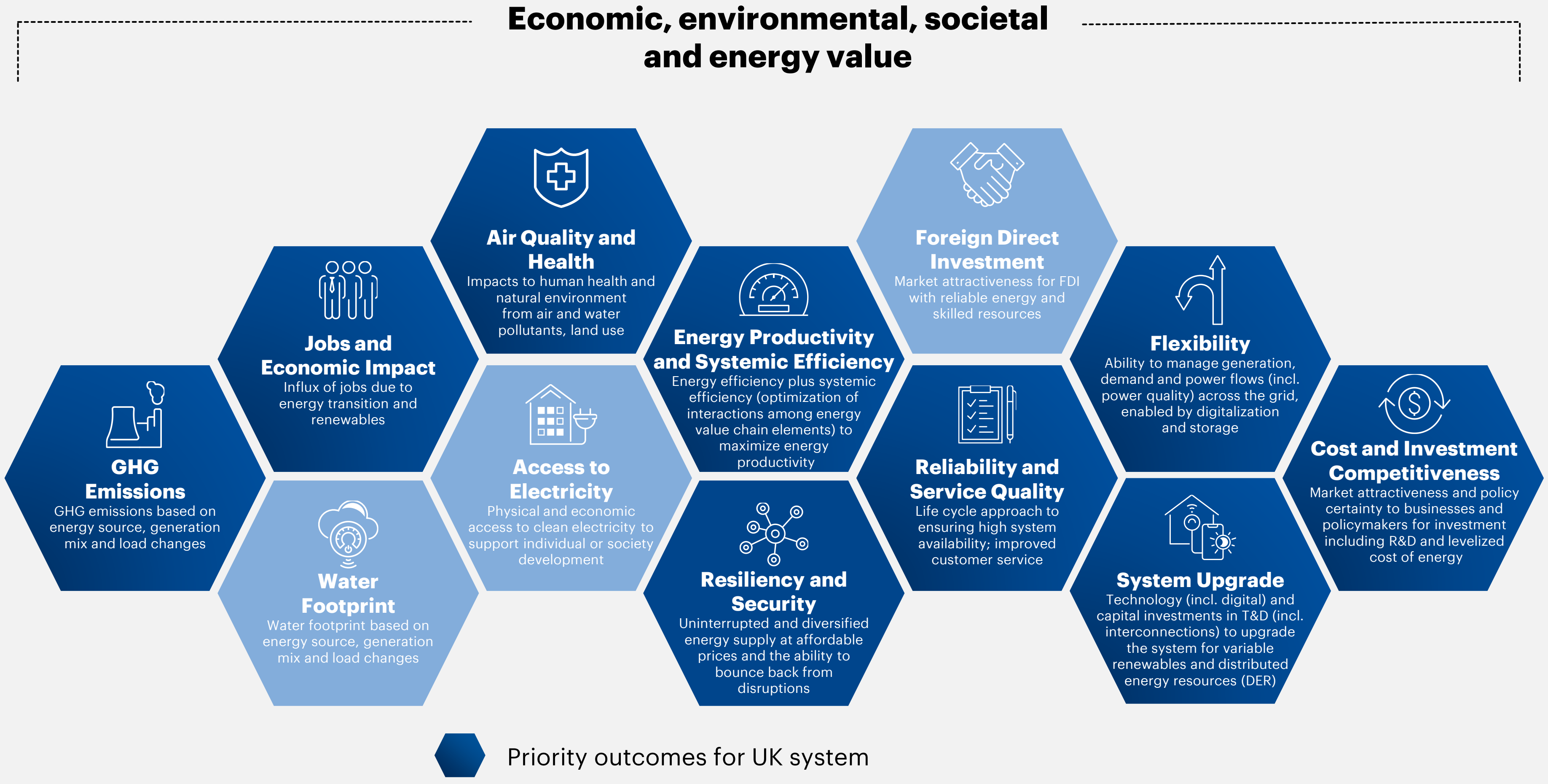
System Value of the clean energy transition in the UK

The System Value framework more holistically evaluates economic, environmental, social and technical outcomes of potential energy solutions across markets. The framework aims to **shift political and commercial focus beyond cost to include value.**

Each of these key dimensions represent **an outcome that delivers value to society or the energy system** (e.g. jobs & economic impact).

The framework considers both quantitative and qualitative outcomes.

Key dimensions for the UK have been prioritized based on current market dynamics and relative maturity of transition towards an integrated energy system delivering net-zero GHG emissions.



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Our proposed UK recovery solutions

Solutions to deliver the 2030 ambition

Renewables, Power Markets & Network of the Future

Transform power markets and networks to reach 35 GW offshore wind and 20 GW onshore wind by 2030 and meet increasing electricity demand from transport, heating, and industry.

- **43 Mt** Less CO_2 emissions from electricity generation in 2030
- **55k – 65k** Total incremental jobs created from expanding offshore wind target to 40GW
- **£4.7 bn** Human health benefits from air quality improvements through 2030

Energy Efficiency and Demand Optimisation

Increase smart efficiency of buildings and appliances; leverage digitalisation and demand optimisation to create a smart energy ecosystem and increase flexibility.

- **14 Mt** Less CO_2 emissions from improved building energy use efficiency in 2030
- **66k – 86k** Total additional annualized jobs created from energy efficiency
- **£2.7 bn** Human health benefits from air quality improvements through 2030

Electrification of Light Duty Vehicles

Accelerate EV deployment by moving timeline of petrol and diesel passenger vehicle ban up to 2030, with potential to add 5 million additional passenger vehicles over current projections (total over 10 million).

- **15 Mt** Less CO_2 emissions from passenger vehicles in 2030
- **7.5k – 22k** Incremental economy-wide jobs created by 2030
- **£2.4bn** Human health benefits from air quality improvements through 2030

Decarbonisation of Heating

Leverage multiple decarbonisation solutions (heat pumps, heat districts, biogas, hydrogen) to set foundation for net-zero ambition, with deployment target of 2.5 million heat pumps by 2030.

- **7 Mt** Less CO_2 from building heating in 2030 from increased heat pumps
- **24k** Incremental jobs created from heat pump deployment by 2030
- **£471m** Human health benefits from air quality improvements through 2030

Decarbonisation of Industrial Clusters & Surrounding Areas

Advance decarbonisation solutions such as CCS and hydrogen in at least four UK industrial clusters to set the UK industrial sector and adjacent communities on track for a net-zero future.

- **Up to 37 Mt** Less CO_2 emissions from industrial clusters, surrounding areas in 2030
- **30k – 35k** Incremental jobs supported from Humber, Merseyside, Teesside by 2030
- **1.5m** Energy-intensive industrial jobs protected by cluster investment (BEIS)

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System Value and the UK's ambition

Accenture's UK System Value analysis and the UK government's Ten Point Plan both outline strategies for emissions reduction towards a net-zero future in the UK

Accenture System Value Solutions	Mapping to UK Government Ten Point Plan	Takeaways
Renewables, Power Markets & Networks of the Future	Offshore Wind; Nuclear	• Ten Point Plan highlights **the role of nuclear** but has less emphasis on **network investment and power market transformation** to ensure resiliency and reliability of power • System Value pairs **renewables and networks as integrated solution** as offshore wind goal requires significant network investment. Also proposes increased onshore wind capacity
Energy Efficiency and Demand Optimisation	Homes and Public Buildings	• Ten Point Plan is aggressive on **building energy efficiency** as a decarbonisation lever • System Value couples the need for energy efficient homes with the **role of digital and demand-side response** to prevent over-building capacity and enable efficient balancing
Decarbonisation of Heating	Hydrogen; Homes and Public Buildings; Innovation & Finance	• Agreement on the need for a **multi-solution heat decarbonisation pathway** utilising solutions such as electric heat pumps, biomethane, hydrogen, and district heating networks
Decarbonisation of Industrial Clusters & Surrounding Areas	Hydrogen; Carbon Capture	• UK government has recently increased its goal to have **4 industrial clusters with CCUS by 2030**, with the capture of 10 Mt CO_2 per year and 5 GW of hydrogen capacity • Accenture also highlights CCUS and hydrogen for emissions reduction but emphasises the benefit of **systemic efficiency, circularity, direct electrification and renewable heat.** CO_2 abated is higher in Accenture estimates which are based on individual project targets
Electrification of Light Duty Vehicles	Electric Vehicles	• Aligned on 2030 ban on petrol and diesel car sales, Ten Point Plan extends **beyond EV adoption to include manufacturing support** • Accenture estimates accelerated 2030 ambition for light duty EVs could add **5m additional electric vehicles** to UK roads beyond previous projections
	Public Transport, Cycling & Walking; Nature; Jet Zero and Greener Maritime	• Ten Point Plan has **broad scope** that includes solutions to improving the natural environment and greener off-road transport

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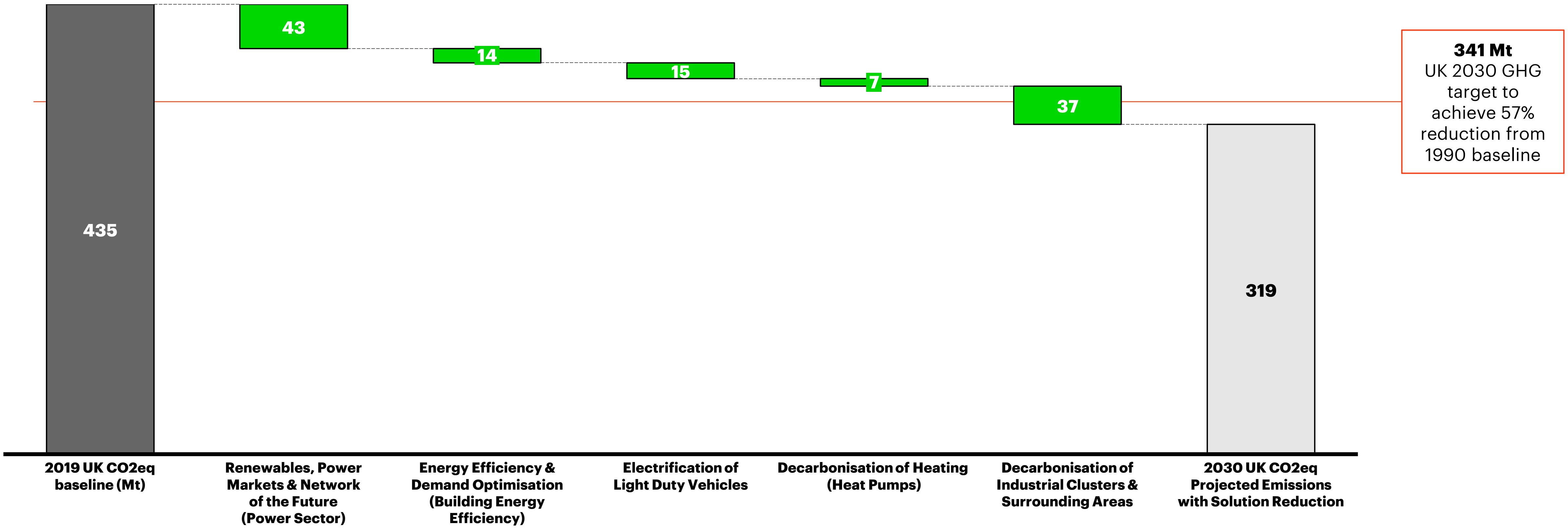
Sources: SSE Greenprint for Building a Cleaner More Resilient Economy; UK Prime Minister's Office; Accenture analysis

Additional progress to achieve UK 2030 GHG target

To meet its 2030 climate target, the UK will need to reduce future GHG emissions by 94 million tonnes of CO_{2eq} emissions, mainly from power, heating, transport and industry. However, significant decarbonisation will require comprehensive network transformation.



Sources: UK Committee on Climate Change; UK Department of Business, Energy & Industrial Strategy (BEIS); GOV.UK; Accenture analysis
2019 GHG figures are provisional UK government statistics published in March 2020. Greenhouse gas (GHG) emissions refer to CO_2 equivalent emissions (CO2eq). Mt = million (metric) tonnes.
**Note: Industrial cluster and surrounding area figures include emissions reduction from 4 UK industrial clusters (Humber, Merseyside, Teesside, South Wales), with emissions reduction within the cluster and surrounding area from industrial processes, power generation, heavy goods transport, residential heat provision. As of December 2020, Teesside and South Wales have announced future carbon abatement potential but not figures for the year 2030 specifically.*

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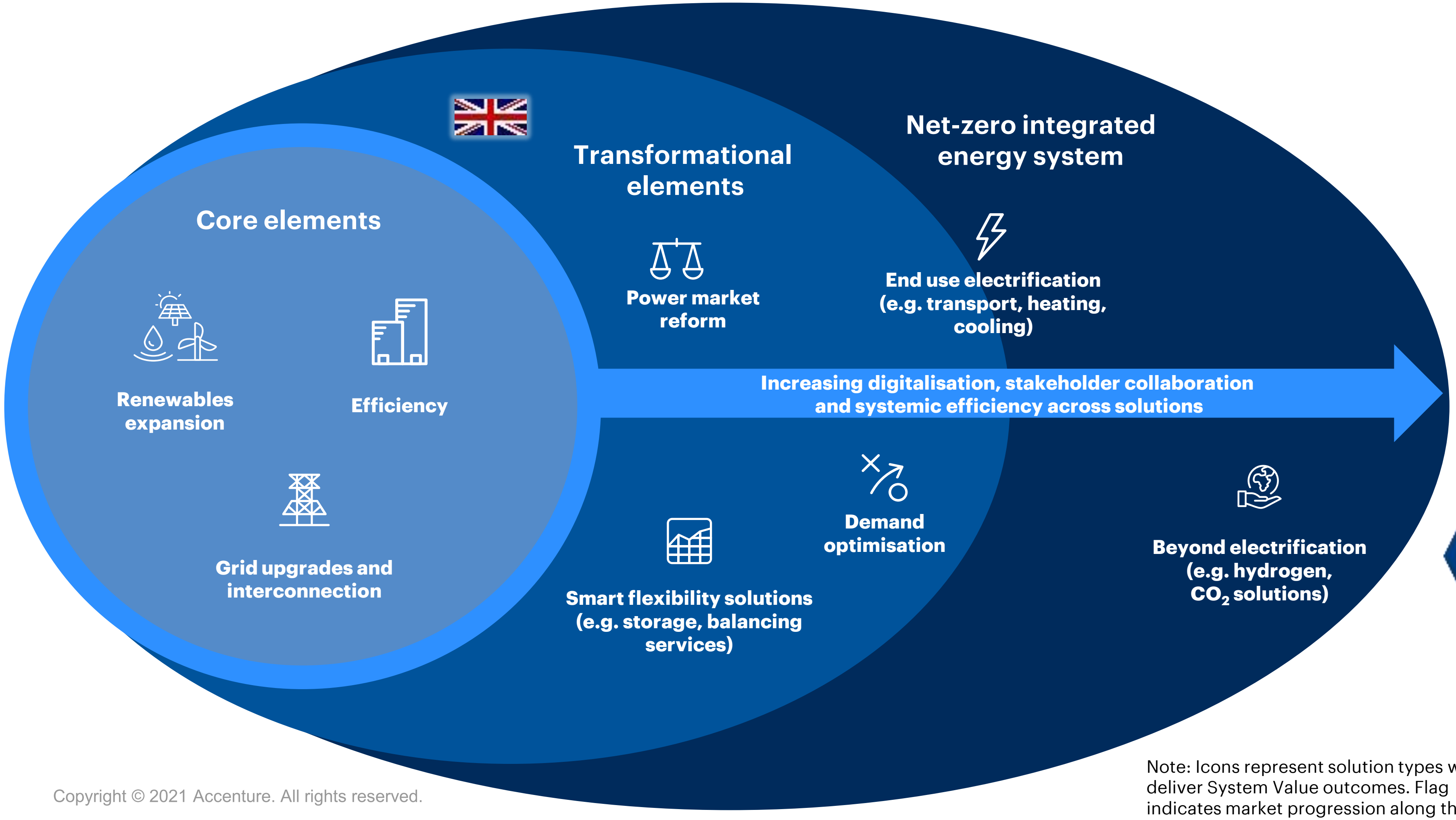
UK's path to maximise System Value

Markets are moving from addressing core elements of the electricity sector transition…

…through "pivot points" where generation mix hits 20%-30% annual variable renewables (>50% instantaneous) and transformational elements enable…

… acceleration to a net-zero integrated energy system with a strong focus on systemic efficiency



The UK is at the pivot point, with 25-30% variable renewables in its annual electricity generation mix

Transforming power market and networks, electrifying carbon-intensive sectors, and **advancing solutions beyond electricity such as hydrogen** will have increased importance through the 2020s and beyond

Note: Icons represent solution types which deliver System Value outcomes. Flag indicates market progression along the path.

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System Value outcomes for the UK

System Value Dimension with Quantitative Analysis: GHG Emissions, Job Impact, Air Quality & Health

System Value Dimension with Qualitative Analysis: Energy Productivity and Systemic Efficiency, Resiliency & Security, Reliability and Service Quality, Flexibility, System Upgrade, Cost and Investment Competitiveness

Solution Area	GHG Emissions	Job Impact	Air Quality & Health	Energy Productivity and Systemic Efficiency	Resiliency & Security	Reliability and Service Quality	Flexibility	System Upgrade	Cost and Investment Competitiveness
1 Renewables, Power Markets and Network of the Future	**43 Mt** CO_2 reduction in power sector in 2030	**55k – 65k** Economy-wide jobs by 2030	**£4.7bn** Cumulative human health benefits through 2030	High	High	High	High	High	UK offshore wind LCOE is projected to average €47/MWh in 2030
2 Energy Efficiency and Demand Optimisation	**14 Mt** CO_2 reduction from building efficiency in 2030	**66k – 86k** Additional annual sustained efficiency jobs by 2030	**£2.7bn** Cumulative human health benefits through 2030	High	Medium	High	High	High	Residential energy efficiency can reduce the avg. household energy bill by €270 annually
3 Electrification of Light Duty Vehicles	**15 Mt** CO_2 reduction in transport in 2030	**7.5k – 22k** Economy-wide jobs in 2030	**£2.4bn** Cumulative human health benefits through 2030	High	Medium	Medium	Medium	Medium	EV avg. lifetime ownership cost is US$132 cheaper annually vs. ICE
4 Decarbonisation of Heating	**7 Mt** CO_2 reduction in building heating in 2030	**24k** Heat pump mfg, installation, maintenance jobs by 2030	**£471m** Cumulative human health benefits through 2030	High	Medium	Medium	Medium	Medium	Energy bills can be reduced by >26% vs. traditional gas options
5 Decarbonisation of Industrial Clusters	**37 Mt** Less CO_2 emissions from clusters, surrounding areas in 2030	**30k – 35k** Incremental jobs from Humber, Merseyside, Teesside by 2030		High	High	Medium	High	Medium	UK has created funds of over £700m to support CCUS and low carbon hydrogen

System Value Dimension Benefit from Given Solution: High Benefit, Medium Benefit, Minimal-to-no Benefit

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Renewables, Power Markets and Network of the Future

To achieve a majority variable renewable electricity system, the UK must transform its power markets and network to maximise system value outcomes such as flexibility, reliability, and cost competitiveness

RENEWABLES EXPANSION

Propose increasing the 2030 offshore wind target from 30 GW to 35 GW and increasing total onshore wind capacity to 20 GW (additional ~6.3 GW)

Solution areas to spur renewables acceleration

- Increase departmental resources to ensure timely, cost-effective delivery
- Improve offshore transmission network planning and cost allocation
- Move to annual contracts for difference auction rounds
- Greater frequency and volume of leasing rounds
- Ensure robust carbon price trajectory
- Add geographical diversity of turbine locations

POWER MARKETS OF THE FUTURE

Shifting the mechanics of UK power markets is required to handle greater renewables and decommissioning of large conventional generators.

Solution areas to transform power markets

- Updated and consolidated suite of balancing products
- DSR and DER aggregation
- Renewables participation in balancing markets
- Scale up of grid-scale battery storage
- Greater visibility of renewables power production
- Increased connection and direct communication

NETWORK OF THE FUTURE

The UK will need to transform its network to support a system with majority variable resources by 2030.

Solution areas to develop next-gen networks

- Digital system operation R&D
- Investment support for interconnections and joint market operations
- Network planning and distribution-level flexibility
- Continual network innovation

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Power Markets and Network Of The Future

The UK must accelerate the deployment of next-generation power markets and network to realise its renewable and net-zero ambition

Power Markets of the Future

New Balancing Products & Markets

- Implement faster-acting response and reserve market products suitable for a future system with higher VRE penetration
- DNO collaboration on distribution flexibility services (e.g. "Flexible Power" programme)

DSR and DER

- Encourage aggregation of DSR and DERs to provide peak load and congestion management
- Programs like "Power Responsive" and DSR products like "Demand Turn-Up" will boost flexibility

Renewables participation in balancing markets

- Balancing market changes to increase VRE transmission connected participation
- E.g., reduced procurement timescales and removing requirement for part-loaded operation (when feasible)

Scale up of grid-scale battery storage

- Balancing market changes to increase transmission connected battery sources
- Fast-acting response products, increased DSR participation and facilitating BMU aggregation all incentivise battery investment

Greater visibility of renewables power production

- Accurate generation data is needed to ensure system safety when instructing renewables assets to provide balancing (e.g., "Power Available" programme)

Increased connection and direct communication

- Strengthen connection with BM participants
- Strengthen inter-control room connections with DNOs and smaller generators

Network of the Future

Digital system operation R&D

- Digital technologies to manage variable and distributed resources e.g. real-time inertia measurements; demand forecasting; DR platforms for consumers

Investment support for interconnections and joint market operations

- Interconnection and participation in European reserve markets will reduce congestion, variability, reserve capacity requirements and cost to consumers

Flexible Network Planning

- Network investment to increase the north-south transfer capacity and address system constraints
- Modular and flexible build out solution which minimizes risk of sunk investment
- Expand distribution infrastructure to accommodate EV demand, leveraging smart charging and batteries to avoid over-building

Continual network innovation

- NG ESO should build on and look to scale up pioneering work such as: the *Stability Pathfinder* program for procurement of zero-carbon inertia, provision of reactive power from solar inverters at night, delivering black start from onshore wind and many others

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System Value Outcomes of Renewables, Power Markets and Network of the Future

Carbon emissions	43 million tonne reduction in electricity sector CO_2 emissions in 2030 compared to 2020 due to less coal and gas generation, due to increased renewables and enabling next-generation power markets and network
Job creation	Estimated 55,000 – 65,000 jobs supported from additional 5 GW offshore wind and raising onshore wind to 20 GW (additional 6.3GW)
Air quality and health	£4.7 billion cumulative human health benefits through 2030 due to decreased air pollution (NO_X, SO_2, PM2.5)
Energy productivity and systemic efficiency	Increasing interconnection and expanding demand-side response will enable more efficient and productive use of energy resources and minimise curtailment
Resiliency and security	Expanding renewables increases self-sufficiency in power production, while investment in diverse storage solutions and enablement of renewables assets to provide restoration services (e.g. black start) will shield against supply interruptions
Reliability and service quality	Improving congestion management coupled with incentivising digital solutions for forecasting, DSR, DER participation will boost reliability and service quality
Flexibility	Increased DER and demand-side and wind and solar participation in the balancing mechanism as well as scaling up storage and interconnection will serve to increase system flexibility
System upgrade	Investment in network capacity to reduce constraints and improving coordination across National Grid ESO, DNOs and interconnectors will contribute to system upgrade
Cost and investment competitiveness	Incorporating cost-effective balancing products to maximise benefits of supply and demand matching can keep energy costs low and UK business environment competitive during its net-zero carbon transition

Revenue growth opportunity

- The transformation of the power markets to facilitate greater renewables participation in providing **system balancing services opens up a new revenue pool** for the industry
- Leading industry experts believe that **balancing services can grow from 2% today to 25% of revenue in the future for renewables companies**
- **Balancing services revenue growth will benefit assets that have the technical capability** to provide services and encourage investment in balancing capabilities for future renewables assets, **diversifying revenue away from only the day ahead electricity price. It will also foster greater competition in the market** to ultimately drive down costs to the consumer

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Energy Efficiency and Demand Optimisation

Overview
With one of the most energy inefficient building stocks in Europe, the UK will need to improve building efficiency in order to achieve its 2030 and 2050 climate targets.

Enabler of the decarbonisation of heat
The Committee for Climate Change has stressed that widespread deployment of energy efficiency across UK buildings will be key to any cost-effective, net-zero strategy and is critical to decarbonising heat in particular. Without efficiency improvements, total system cost for decarbonisation of heat could be £6.2 billion higher per year.

Government backing
In July 2020, the UK announced a £3 billion fund to address building energy efficiency and has ongoing programmes such as the Energy Company Obligation (ECO) scheme and a variety of policies under its Clean Growth Strategy (CGS). However, research shows that much more is required to meet the UK's fourth and fifth carbon budgets.

Consumer buy-in
As variable renewable generation is projected to grow to at least 50% share by 2030, consumer participation in managing consumption will be essential to demand optimisation and flexibility. This will be coupled with increased electrification, digitalisation and energy storage.

System Value impacts of residential energy efficiency

14 Mt	66k-86k	£2.7bn
↓ CO_2 reduction from increased building efficiency in 2030	↑ Additional annual sustained efficiency jobs by 2030	↑ Cumulative human health benefits through 2030

Solutions for UK Energy Efficiency and Demand Optimisation

Address energy poverty and upgrade building efficiency
- Mitigating household energy poverty is critically important with 1-in-10 UK households (ca. 2.5m people) already in energy poverty prior to COVID-19 and energy prices set to rise with more renewables on the system
- The UK needs stronger support for energy efficiency in residential buildings, especially for low-income households to prevent them being disproportionately affected

Smart, efficient appliances
- Increasing the deployment and requirements of smart, efficient appliances and electric heat pump systems, particularly in existing buildings, can accelerate energy management, curb building emissions and grow DR participation

Energy consumer engagement
- The National Grid ESO's Future Energy Scenarios (FES) 2020 estimate that by 2050 up to 45% of homes will be actively helping to balance the grid and up to 8 million homes will be actively manging heating demands by storing heat to shift use outside peak periods
- Targeted investments in and testing of digital platforms for consumer engagement is needed to drive this fundamental shift in consumer behaviour

Energy consumer incentives
- Increasing the ambition and incentives of demand response programmes, dynamic pricing and time-of-use (ToU) rates can increase consumer participation, further reduce wind and solar curtailment, and reduce consumer energy bills

Smart energy ecosystem development
- Advance development of smart energy management technology and smart batteries (e.g. MOIXA) to reduce household energy consumption through demand optimisation, particularly with higher demand from EV penetration

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Sources: Innovate UK; BEIS; CGS; Guardian; National Grid ESO (1, 2, 3); Power Responsive

Electrification of Light Duty Vehicles

Overview

- The UK has announced intent to accelerate EV adoption by bringing forward the ban on the sale of new internal combustion engine (ICE) passenger vehicles to 2030 from 2035.
- Bringing forward the timeline of the policy to accelerate EV adoption would put the UK ahead of France, which proposes a 2040 ban, and would be more aligned with EU countries such as Germany and the Netherlands.

Implications of accelerating EV adoption

1) Electricity Demand Increase

- Accelerating the ban on ICE passenger vehicles to 2030 could see nearly 5 million more EVs on the road by 2030, leading to an estimated 10.7 million total EVs (34% of passenger cars).
- The resulting incremental increase in electricity demand is expected to be >12 TWh by 2030.

2) Infrastructure Investment

- Public charging requires substantial investments, with infrastructure costs estimated to total approximately US$150 billion.
- Electricity demand from EVs will require additional investment in distribution network to accommodate uptick in load at local levels; however, digital technology and smart charging can help manage load, avoiding overbuilding infrastructure and minimising network costs.

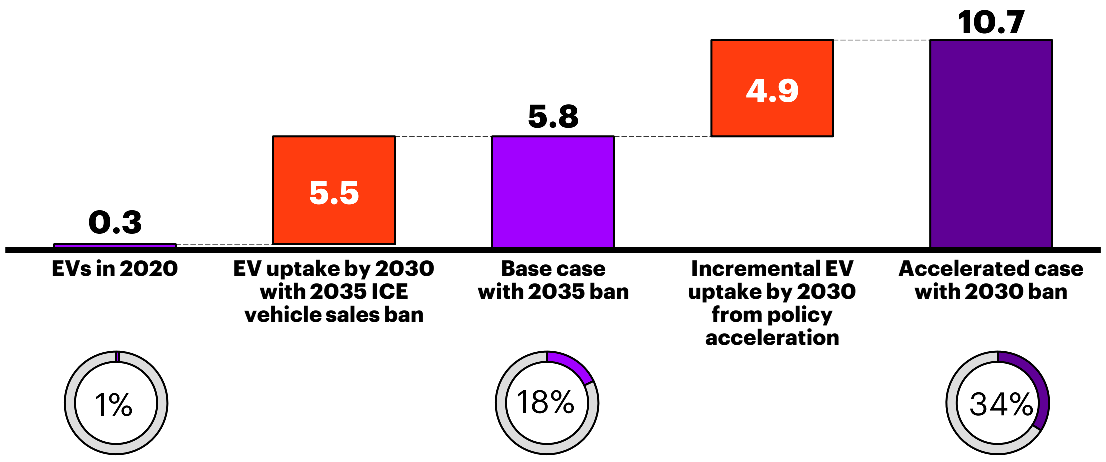
3) Business Innovation

- EVs present an estimated $250 billion value opportunity for utilities, start-ups, OEMs, and energy companies, with a number of innovative business models under consideration to maximise value and encourage the customer journey toward EV adoption.
- Examples include: Bundled services such as at-home charging station installation and maintenance, full scale platforms that enable other services such as integrated home-EV energy management, charge point navigation, charging reservations, battery management.

4) Grid Flexibility

- Opportunity for utilities to actively use EV charging to balance supply and demand—and optimize grid and portfolio performance—much as they do to accommodate wind or solar.
- Vehicle to grid (V2G) technology would allow EV batteries to store energy and discharge it back to the electricity network during peak periods.

Cumulative EV uptake in the UK by 2030 (million passenger vehicles)



EVs as percentage of total UK passenger vehicles

System Value impacts of electrification of passenger vehicles

Benefits

15 Mt (↓)
Reduction of CO_2 emissions from passenger EVs in 2030; 8.3 Mt from base case plus an additional 7.1 Mt in the accelerated case

7.5k-22k (↑)
Additional economy-wide jobs in 2030 from incremental EV deployment in accelerated case

£2.4bn (↑)
Cumulative human health benefits through 2030 due to decreased air pollution (NO_X, PM) from accelerated case EV adoption

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Sources: The Guardian; SMMT; EDF Energy; Europa; Accenture analysis
Mt = Million (metric) tonnes

Decarbonisation of Heating

Building heating is a significant GHG contributor

- Buildings account for 18% of the UK's 2019 GHG emissions, largely from heating.
- 85% of UK households use gas for heating, so adapting existing networks to use zero carbon gases such as green hydrogen and biomethane will expedite decarbonisation of heating infrastructure.
- The UK is a leader in renewable gas and biogas with the Renewable Heat Incentive in place since 2011 and over 400 biogas plants in operation (100+ grid-connected).
- However, the UK lags EU nations in heat pump installations. As of 2018, 207,600 were installed in the UK (approx. 20,000 new installations per year) compared to over 37 million in the EU.
- The UK's Committee on Climate Change (CCC) indicates that phasing out new gas boilers installations will need to occur by 2035 to be on track for net zero by 2050, with 2.5 million heat pumps targeted by 2030 and 19 million by 2050.

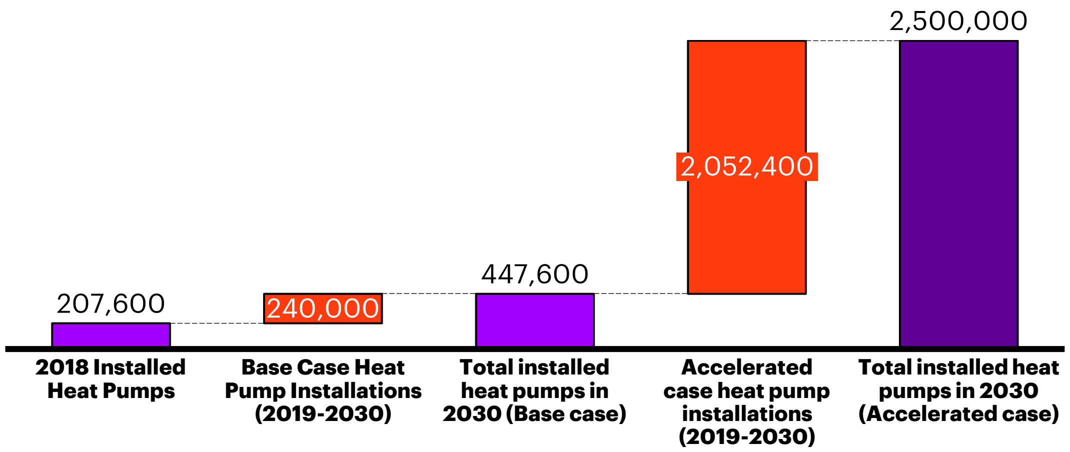
Combination of solutions to decarbonise UK heating is likely

- Heat pumps: Replace gas boilers with electric heat pumps that allow for smart, flexible heat consumption through IoT.
- Heat networks: Further utilize and expand networks of underground insulated water pipes that service multiple buildings within a district.
- Green gas production: Production of biomethane (gas from agriculture, landfill, and wastewater) for onsite use and injection into grid, and green hydrogen to be blended with or replace natural gas.
- Gas grid connection: Facilitate connection of green gas plants into the gas network grid; UK gas network operators have successfully connected more than 100 green gas plants to date.

Enabling actions to realize decarbonised heating solutions

- Continued education of consumers, particularly around heat pumps.
- Upskill heating system installers to be able to install low-carbon heating methods.
- Financial support: Move from grants to interest-free loans for home and business owners making their properties net-zero ready. Couple financial support with other incentives such as council tax or stamp duty reforms and regulatory measures that favour low-carbon heating over fossil.
- Encourage connections to heat networks where efficient to do so to spur low-carbon city-wide district heating.
- Infuse hydrogen into gas network from hydrogen production within adjacent industrial clusters.
- Standardize grid connection requirements for low carbon gases and implement grid capacity solutions to facilitate injection of biomethane or hydrogen gas into grid.

UK Committee on Climate Change has set a target of 2.5 million new heat pump installations by 2030



System Value impacts of increased heat pump deployment

Benefits

↓ 7 Mt
Estimated reduction in 2019 CO_2 heating emissions in 2030 due to incremental ~2.3 million heat pump installation

↑ 24k
Additional manufacturing, installation, and maintenance jobs from incremental heat pump installation

↑ £471m
Cumulative human health benefits through 2030 due to decreased air pollution from incremental heat pump installation

Sources: CCC; Statista; SSE; Heat Pumps Association UK; BEIS; IEA; SGN; Energy Networks; Accenture analysis
Mt = Million (metric) tonnes

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Net-zero Solutions for Industrial Clusters

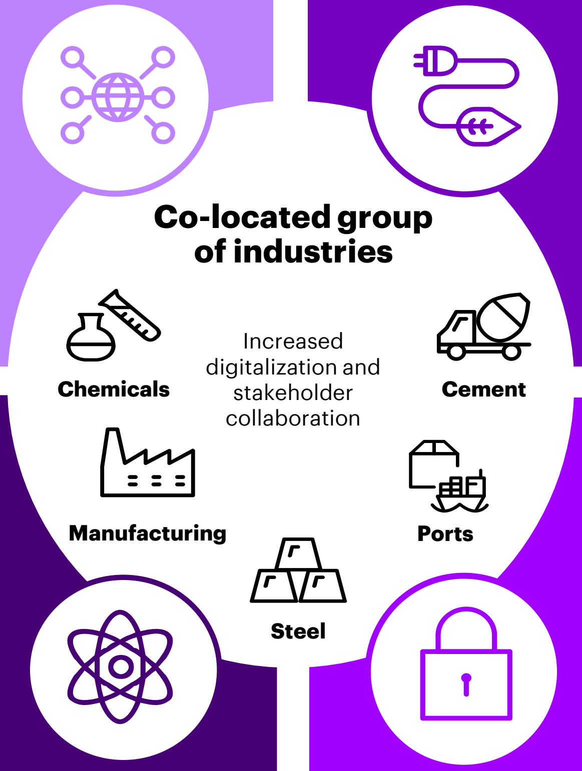
Industrial clusters are geographic areas where industry is co-located and for emissions reduction, they provide opportunities for scale, sharing of risk and resources, aggregation and optimization of demand – below is a menu of abatement opportunities. A holistic approach to industrial clusters is required to optimize emissions reduction solutions that maximizes system value outcomes.

Systemic Efficiency and Circularity

- Increase circularity within a cluster through cross-entity waste utilization
- Integrate processes within a cluster to share energy and material streams
- Provide cost-effective system benefits outside the cluster

Direct Electrification and Renewable Heat

- Electrify low-to-medium temperature and pressure processes
- Generate low-cost, renewable electricity and heat onsite (e.g., rooftop solar, biomass, concentrated solar power)
- Pursue shared infrastructure (e.g., microgrid, storage, flexibility)



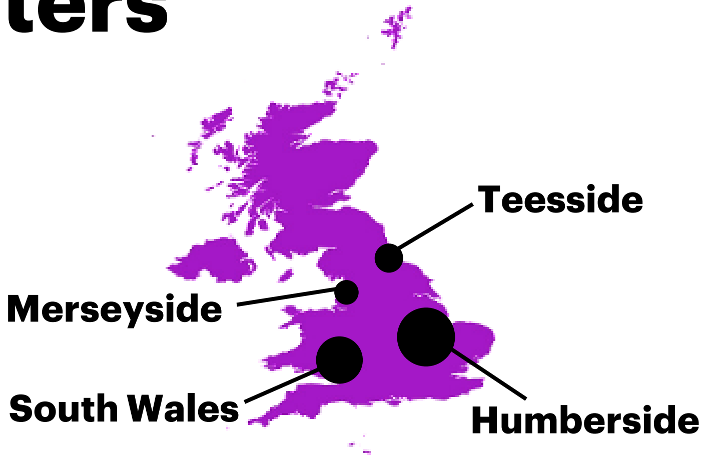
Hydrogen

- Leverage electricity and heat from nearby zero-carbon sources (wind, solar, nuclear, biomass)
- Produce low-to-zero carbon hydrogen from the most economical source (e.g., blue, green)
- Use produced hydrogen as an alternative fuel for hard-to-electrify industrial processes, building heating and transport

Carbon Capture, Utilization and Storage (CCUS)

- Capture carbon from energy and hydrogen production
- Use captured carbon for industrial and manufacturing processes
- Store carbon underground where feasible

Snapshot of Prominent UK Industrial Clusters



Overview of UK Industrial Clusters:

- The industrial sector accounts for approximately **a quarter of all UK GHG emissions**
- In its December 2020 Energy White Paper, the UK government **pledged to invest £1 billion** up to 2025 to facilitate the **deployment of CCUS in two industrial clusters by the mid-2020s, and a further two clusters by 2030**
- **A more ambitious approach has been suggested** by groups such as SSE that are advocating for carbon capture, utilisation and storage (CCUS) and hydrogen infrastructure deployment in at least 5 industrial clusters by 2030

Humberside

- **Primary industries** include steel, chemicals, and refineries
- UK's largest cluster by industrial emissions, with coalition **Zero Carbon Humber (ZCH) working towards net-zero cluster by 2040**
- **Decarbonisation will be underpinned by CCS**, including negative emissions from Drax biogas plant
- **Blue and green hydrogen** to be produced at scale to replace fossil fuels for transport, and heat provision for industrial and residential use
- **Main Groups:**

Merseyside

- **Primary industries** include refining, chemicals, and fertilizer production
- North West, the region that Merseyside is located, has created **a blue hydrogen project called HyNet** to reduce CO_2 emissions by 10 million tonnes annually by 2030
- The project aims to develop blue **hydrogen production and distribution network backed by CCS**. This includes a proposed hydrogen pipeline network to supply local industry
- **Main Groups:**

Teesside

- **Primary industries** include advanced manufacturing, chemicals, and steel
- Teesside's cluster is home to five of the UK's top CO_2-emitting companies, and **produces 50% of the UK's hydrogen**
- **Net Zero Teesside** is **focused on blue hydrogen** and will require **CCUS** in order to reach its net zero targets
- **Main Groups:**

South Wales

- **Primary industries** include refining, steel, paper
- Target to reach zero carbon by 2050 (**"Zero2050"**) was announced in late 2019
- While **no interim 2030 targets** have been set, the project is exploring avenues for hydrogen use, carbon capture, and heat decarbonisation through electrification
- **Main Groups:**

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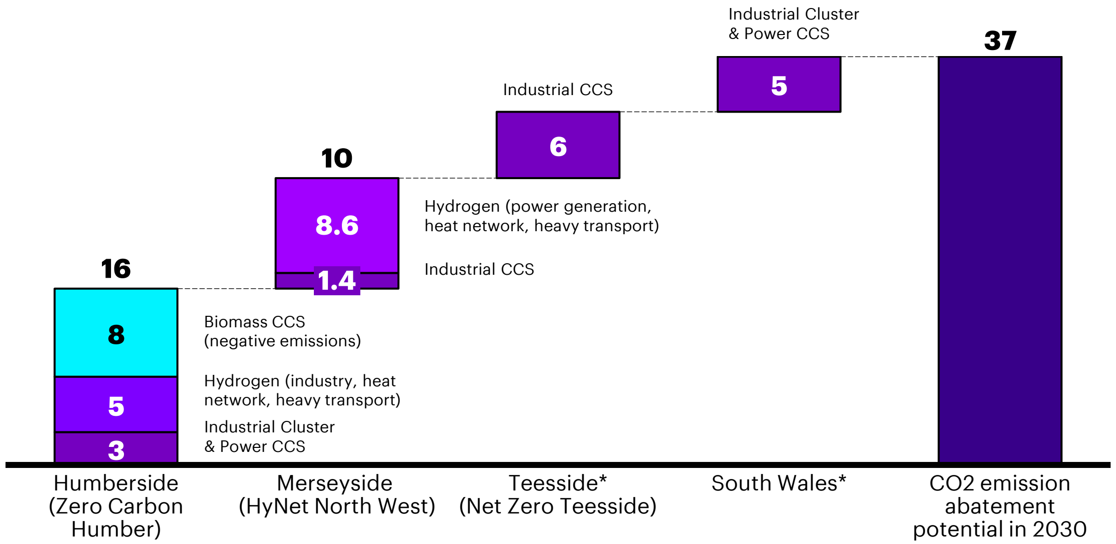
Mt = million (metric) tonnes
Sources: UK Industrial Strategy; Zero Carbon Humber; ICIS; HyNet Co; Net Zero Teesside; Zero2050; SmarterNetworks

Decarbonisation of Industrial Clusters and Surrounding Areas

Solution areas to decarbonise industrial clusters

- System efficiency and circularity initiatives building on progress in energy efficiency and expanding into cross-entity waste utilisation, waste valorisation, industrial symbiosis, waste heat recovery and distribution etc. Projects are currently underway in the UK glass and steel industries for cross-industry waste utilisation and valorisation.
- Electrification of low and medium-temperature processes in light industry such as paper, food and beverage, and equipment manufacturing as well as use of renewable heat from sources such as biomass and solar thermal
- Enabling fuel switching for industrial processes for energy intensive industries such as refining, cement production, chemicals
- Green hydrogen production with projects like **Gigastack**, a government-funded collaboration between Orsted, ITM, Phillips 66 and Element Power, that aims to develop low cost, zero carbon hydrogen via gigawatt-scale polymer electrolyte membrane (PEM) electrolysis powered by offshore wind
- Blue hydrogen production via Autothermal Reforming or Steam Methane Reforming with CCS for use in industrial processes and heating networks
- Development of CCS infrastructure to transport and store CO_2 emissions from industrial processes, power sector, and blue hydrogen production. The **Northern Endurance Partnership** was formed in October 2020 to accelerate the development of offshore transport and storage infrastructure for CO_2 in the North Sea. It aims to sequester emissions from two industrial clusters – Zero Carbon Humber and Net Zero Teesside.
- Development of next generation nuclear technology such as Small Modular Reactors (SMR) and Advanced Modular Reactors (AMR) to provide heat and power for hydrogen production and industrial processes

Potential annual CO_2 emissions abatement for industrial cluster and surrounding areas in 2030 (Mt)



Note: Provided cluster and surrounding area CO_2 abatement figures include cross-sector emissions reduction within the cluster and surrounding area from industrial processes, power generation, heavy goods transport, residential heat provision.
*As of December 2020, Teesside and South Wales have announced future carbon abatement potential but not figures for the year 2030 specifically; Net Zero Teesside projects to have first CCS online by the mid-2020s.
Sources: Humberside; Merseyside (HyNet); Teesside; South Wales

System Value impacts of decarbonisation of industrial clusters

Up to 37 Mt
Reduction in base case industry CO_2 emissions and surrounding areas in 2030

30k-35k
Incremental jobs supported from Humberside, Merseyside and Teesside industrial clusters by 2030

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Sources: CCC; SSE; The Chemical Engineer; UK Government; FT; ITM Power; Gigastack; Carbon Trust, ICIS; HyNet; CBI; Zero Carbon Humber; Accenture analysis
Mt = Million (metric) tonnes

Case Study: Zero Carbon Humber

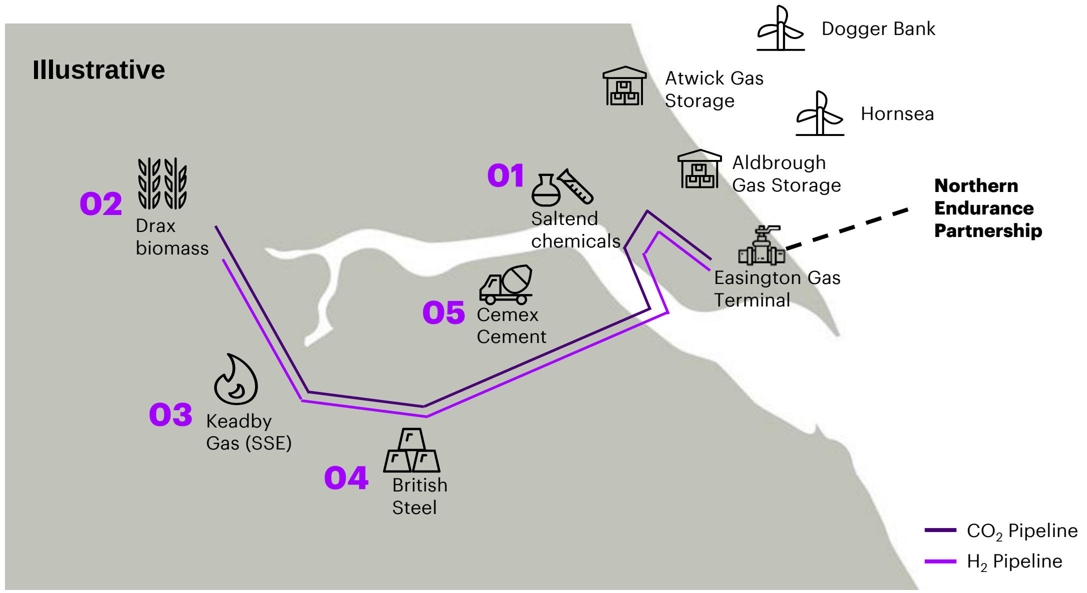
ZERO CARBON HUMBER

Zero Carbon Humber is a coalition of 12 entities collaborating on joint CCS and hydrogen infrastructure projects.

Zero Carbon Humber (ZCH) Overview

- ZCH is aiming to establish the **world's first net-zero industrial cluster by 2040** via creation of CCS infrastructure and production of blue and green hydrogen.
- H2H Saltend will be a **first mover** in utilizing the **shared CO_2 and hydrogen transport and storage infrastructure.** This will eventually enable multiple carbon abatement projects (e.g., SSE Thermal, British Steel, Drax BECCS) in the region to scale quickly to achieve net-zero targets for the cluster and the UK.
- Industrial users will be able to reduce emissions by capturing carbon and transporting it via shared pipelines for offshore storage as part of the **Northern Endurance Partnership** – the offshore component and sister project to ZCH.
- **Access to shared hydrogen infrastructure will spur demand** for use as feedstock in industrial processes and enable potential for further use outside the cluster.
- The coalition recently applied for **£75 million in private and public sector funding** to advance Phase 2 operations, with the first infrastructure expected to go online by 2026.
- **There will be three major areas of project work:**
  1. Develop a carbon-capture usage and storage network.
  2. Produce low-carbon hydrogen and create shared hydrogen infrastructure.
  3. In the longer term, produce green hydrogen using offshore wind electrolysis.

Map of Planned Operations



Zero Carbon Humber Partners

Associated British Ports	PX
British Steel	National Grid Ventures
Centrica	SSE Thermal
Drax	Triton Power
Equinor	Uniper
Mitsubishi Power	University of Sheffield – AMRC

System Value dimension: Energy productivity and systemic efficiency

Efficiency improvements to increase energy productivity and optimise the UK's energy system across the value chain can be achieved through identified solutions

Energy productivity and systemic efficiency benefits by recovery solution		
Renewables, Power Markets, and Network of the Future	High benefit	• Greater UK interconnection and transmission line build-out can improve systemic efficiency by reducing congestion and curtailment. • Facilitating DERs and demand response participation in the transmission and distribution balancing markets can ensure efficient system operation.
Efficiency and Demand Optimisation	High benefit	• Improvements in energy productivity can be achieved across sectors through smart appliances, greater building efficiency, and energy conservation, achieving same work or economic output for less consumption. • Demand optimisation can improve systemic efficiency by better aligning supply and demand to ensure cost-effective, green generation and minimal curtailment.
Electrification of Light Duty Vehicles	High benefit	• Electric vehicles are more energy efficient than their fossil fuel counterparts, converting over 77% of the electrical energy to power at the wheel, whereas gasoline vehicles only convert 12%-30% of the energy stored in gasoline.
Decarbonisation of Heating	High benefit	• Heat pump systems can have three to five times the efficiency of a comparable fossil fuel system. • Power-to-heat systems can reduce or eliminate renewables curtailment by taking excess electricity and storing it in thermal storage systems such as large electric boilers.
Decarbonisation of Industrial Clusters	High benefit	• While hydrogen is the best decarbonisation solution for many hard-to-electrify industrial applications, energy and cost-efficient electrification opportunities (e.g. industrial heat pumps) can be deployed where appropriate for select industrial processes. • Hydrogen has greater energy content per weight than natural gas, and its higher efficiency than LNG holds promise for industrial and non-road transportation applications.

Relative System Value dimension benefit for given recovery solution within market: High benefit; Medium benefit; Minimal-to-no benefit

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Sources: IRENA; US Department of Energy (1, 2); Energy & Environmental Science

System Value dimension: Resiliency and security

Clean energy transition enables greater resiliency and security through greater domestic production and secure digital operations, better insulating UK's system from foreign shocks and cyber attacks

Resiliency and security benefits by recovery solution		
Renewables, Power Markets, and Network of the Future	●	• Renewables expansion supported by next-generation power markets reduces import and physical supply risks. • More products can be compensated to encourage build-out of storage and virtual power plants, which can aid during longer outages. • Increased investment in smart digitalisation of networks can provide greater security to detect cyberthreats.
Efficiency and Demand Optimisation	◐	• Digital solutions and storage systems (e.g. fuel cell, batteries, with solar) can boost local resiliency during outage events. • Reduced energy need lessens reliance on energy imports.
Electrification of Light Duty Vehicles	◐	• Greater energy security through electrification of on-road vehicles via renewables as foreign oil dependence is reduced. • EV battery technology can be leveraged as a local power source for longer-term outages, e.g. during natural disasters.
Decarbonisation of Heating	◐	• Greater local energy usage through power-to-heat systems rather than foreign imports of natural gas. • Thermal storage, either at district or building level, would allow continued deployment of heating and cooling to overcome multi-hour shocks.
Decarbonisation of Industrial Clusters	●	• Industrial clusters can create hydrogen that can be stored and utilised during resiliency events across sectors. • Decreased reliance on foreign fossil fuel resources reduces supply risks.

Relative System Value dimension benefit for given recovery solution within market: ● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

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System Value dimension: Reliability and Service Quality

Ensuring grid reliability for a majority variable renewable system will be critical for the UK in the coming decade, with investments in batteries and hydrogen storage needed alongside the creation of next-generation network and power markets

Reliability and service quality benefits by recovery solution		
Renewables, Power Markets, and Network of the Future	●	• Congestion and constraints markets can support wider solutions, such as combining TSO and DSO congestion management. • Incentives can be increased for digital technologies, including start-ups, that support capabilities needed by TSOs and DSOs to manage variable resources such as forecasting wind, solar production and other DERs and management of real-time auctions for ancillary services products.
Efficiency and Demand Optimisation	●	• Customers can be incentivised to participate in balancing markets through user-friendly business models and favourable rates. • Digital solutions and IoT can enable greater communication and education to consumers around system status.
Electrification of Light Duty Vehicles	◐	• Smart charging and associated pricing schemes can serve as dynamic load to assist grid reliability, while serving as a revenue stream for EV owners. • Roll-out of smart chargers with V2G/V2H/V2B capabilities will enable two-way electricity transfers, allowing for balancing services.
Decarbonisation of Heating	◐	• Thermal storage systems can provide smart load balancing to reduce strain on the grid. • Reduced maintenance needs from heat pump systems compared to conventional fossil fuel heating system.
Decarbonisation of Industrial Clusters	○	• No material benefit.

Relative system value dimension benefit for given recovery solution within market: ● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

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System Value dimension: Flexibility

Solutions result in numerous flexibility benefits for UK's electric and energy systems, creating a more distributed and connected system

Flexibility benefits by recovery solution		
Renewables, Power Markets, and Network of the Future	●	• Digital system operations can be instituted that allow DERs and renewables to participate in the Balancing Mechanism facilitating real-time signal integration and bidding automation. • Connecting markets into a larger balancing and reserve area will reduce congestion, variability and individual reserve capacity requirements.
Efficiency and Demand Optimisation	●	• Initiatives that encourage aggregation of DSR/DERs can provide peak load and congestion management. • Increasing the ambition & incentives of demand response programs can give operators greater tools to balance variable demand.
Electrification of Light Duty Vehicles	◐	• EVs can act as flexible loads and decentralised storage resources, with smart charging as an enabler for EVs to provide flexibility (supported by dynamic or ToU tariffs and other incentives). • EVs can enhance the integration of solar and wind generation by aligning EV charging with resource availability. • In development, V2G capabilities can be utilized in the future to use EV battery to serve as a flexibility resource.
Decarbonisation of Heating	◐	• Aggregation of heat pumps and thermal storage systems can aid flexibility through coupled renewable energy and heating systems, smart load management.
Decarbonisation of Industrial Clusters	●	• Natural gas provides flexibility to the market, so removing this fuel will reduce flexibility. • However, hydrogen will provide valuable, cheap storage and industrial clusters can provide demand optimisation capabilities and can continue to participate in flexibility markets. • Timing of hydrogen production can be set to match periods of excess renewable generation from sources such as offshore wind and utility-scale solar.

Relative system value dimension benefit for given recovery solution within market: ● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

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System Value dimension: System Upgrade

Digital and capital investments to upgrade the system for variable renewables and DER will support the UK in achieving a majority variable renewable electricity mix by 2030

System Upgrade benefits by recovery solution		
Renewables, Power Markets, and Network of the Future	●	• Increased incentives for digital technologies, including start-ups that build capabilities to manage variable and distributed resources, can support the transformation of UK networks (e.g. improved accuracy of VRE production forecasting on real-time response, allow for greater DER participation in balancing markets). • Investment support to increase interconnection among UK markets will be key to transform to a more variable system, where larger balancing and reserve areas will reduce congestion, variability, and individual reserve capacity requirements.
Efficiency and Demand Optimisation	●	• Investment in BtM storage and digitalisation allows for more dispatchable renewable energy, while the installation of smart devices (e.g. smart meters) will enable improved system balancing and better management of grid congestion and constraints.
Electrification of Light Duty Vehicles	◐	• Investment in grid upgrades to enable smart charging and other emerging technologies such as V2G, allows for a seamless shift to VRE sourced power, aligning with resource availability, as road transport transitions to EVs.
Decarbonisation of Heating	◐	• Smart solutions such as smart thermostats or smart heat pumps can better manage and save energy use alongside renewable heating technologies (biomass boilers, solar heating systems).
Decarbonisation of Industrial Clusters	◐	• Green hydrogen generation and storage can reduce VRE curtailment and build a stronger case for further investment in renewables capacity additions.

Relative system value dimension benefit for given recovery solution within market: ● High benefit ◐ Medium benefit ○ Minimal-to-no benefit

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Cost and Investment Competitiveness

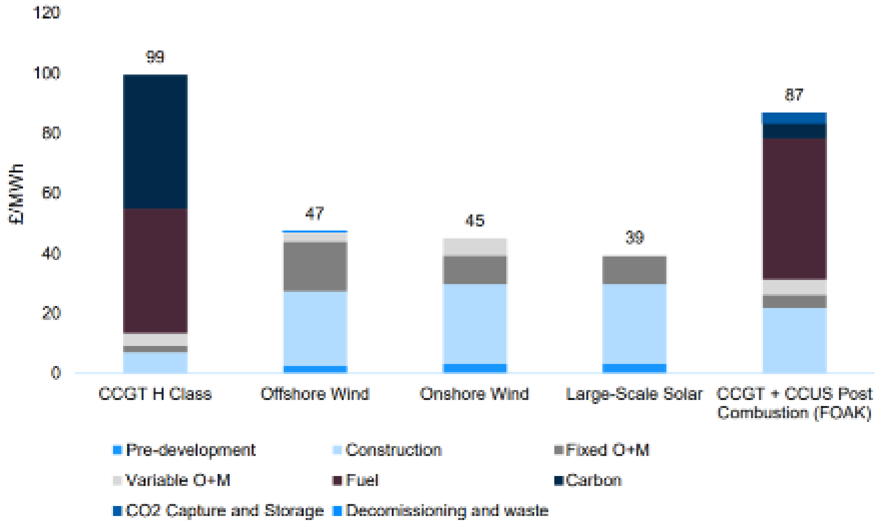
Renewables: Offshore Wind Expansion

- According to the UK's Department for Business, Energy and Industrial Strategy (BEIS), the LCOE for UK offshore wind LCOE is projected to average €47/MWh in 2030, a sharp drop compared to 2016 predictions of €103/MWh.
- The offshore wind sector is expected to boost annual exports fivefold by 2030 to reach €2.6 billion and add over 12,000 jobs to the UK economy.
- Wind power will be one of the cheapest source of UK electricity by 2025, and offshore will be cheaper than onshore by mid-2030s due to larger turbine sizes.

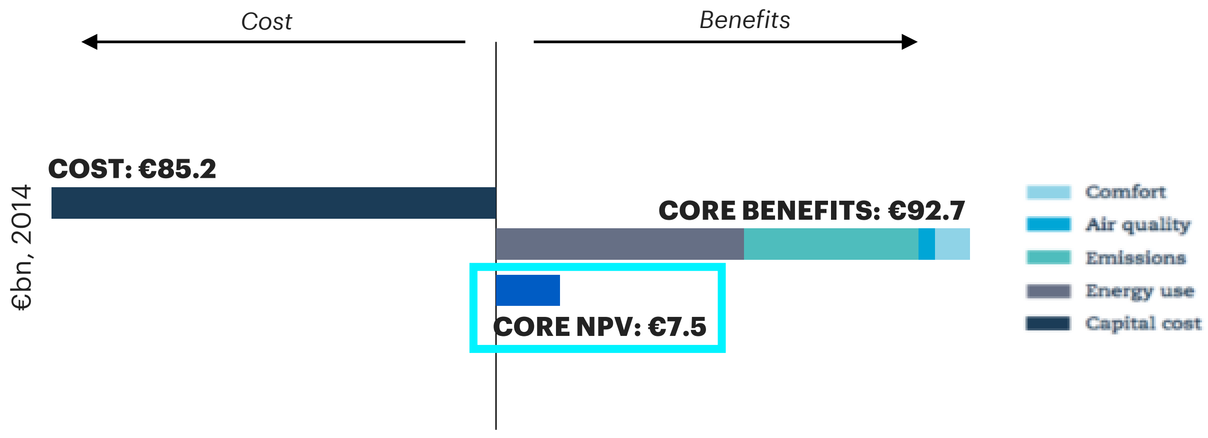
Efficiency and Demand Optimisation

- It is estimated that energy efficiency measures in households could cut the UK's costs by €7.5 billion and could save up to 140 TWh of energy by 2035.
- Energy efficiency improvements in home heating, insulation, lighting, and appliances could reduce energy consumption in UK households by 25% and reduce the average household energy bill by €270 annually by 2035.
- The Green Homes Grant offers up to two-thirds the cost of upgrading home energy efficiency, with a maximum voucher amount of €10,000.
- If just 5% of peak electricity demand is met by demand-side response, the UK's energy system would be €200m/year cheaper to run.

Renewables LCOE in the UK is lower today and projected to be nearly half that of natural gas in 2030



Aggregated total cost and benefits of energy efficiency measures from 2016 to 2035



Source: Carbon Brief

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Cost and Investment Competitiveness

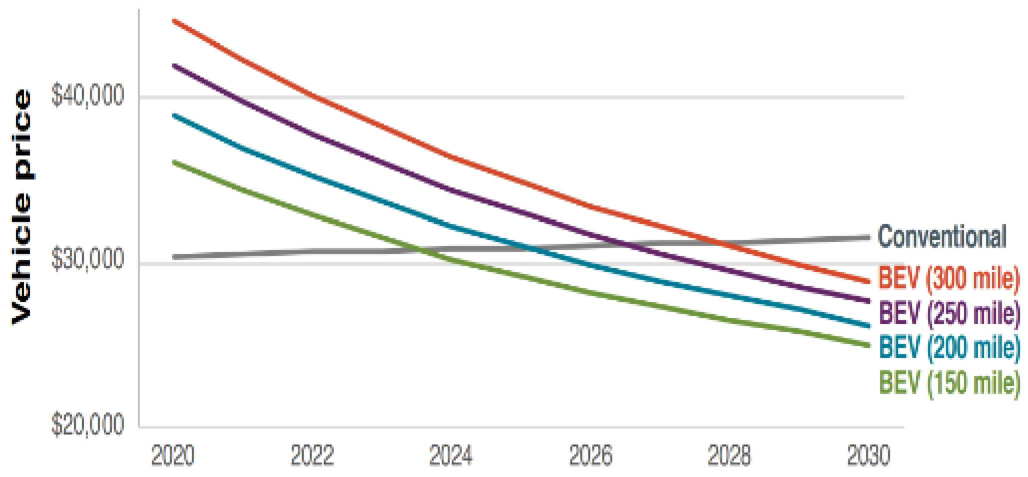
Electrification of Light Duty Vehicles

- EV average lifetime ownership cost in the UK is USD $132 cheaper annually compared to ICE for a 14-year ownership lifespan.
- Further, EV tax and maintenance costs are 49% lower and refueling costs are 58% lower annually.
- Estimated total cost savings for the UK are up to €17 billion per year by switching towards EV.
- The UK offers many incentives for both purchasing of EVs and EV chargers, including up to €3,000 for the purchase of EVs and up to €350 for the cost of installing a wall-box EV charger at home. Other benefits include workplace grants, tax benefits and parking perks.

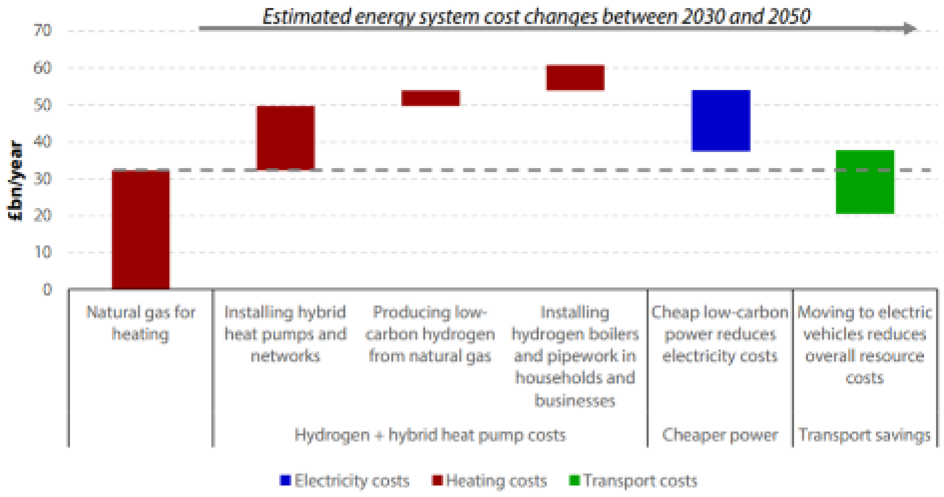
Electrification of Heating

- Heat pumps have low operational costs, with potential to save up to €1,350 per year compared to conventional heating options, despite higher upfront costs.
- Energy bills can be reduced by at least 26% compared to traditional gas options.
- The Domestic Renewable Heat Incentive (RHI) grants quarterly payments for 7 years for the amount of clean, green renewable heat estimated to be produced by each home.

Globally, EV upfront cost is expected to match ICE vehicles from 2024-2029 depending on EV battery range



There are System-wide benefits of switching to low-carbon heating and transport



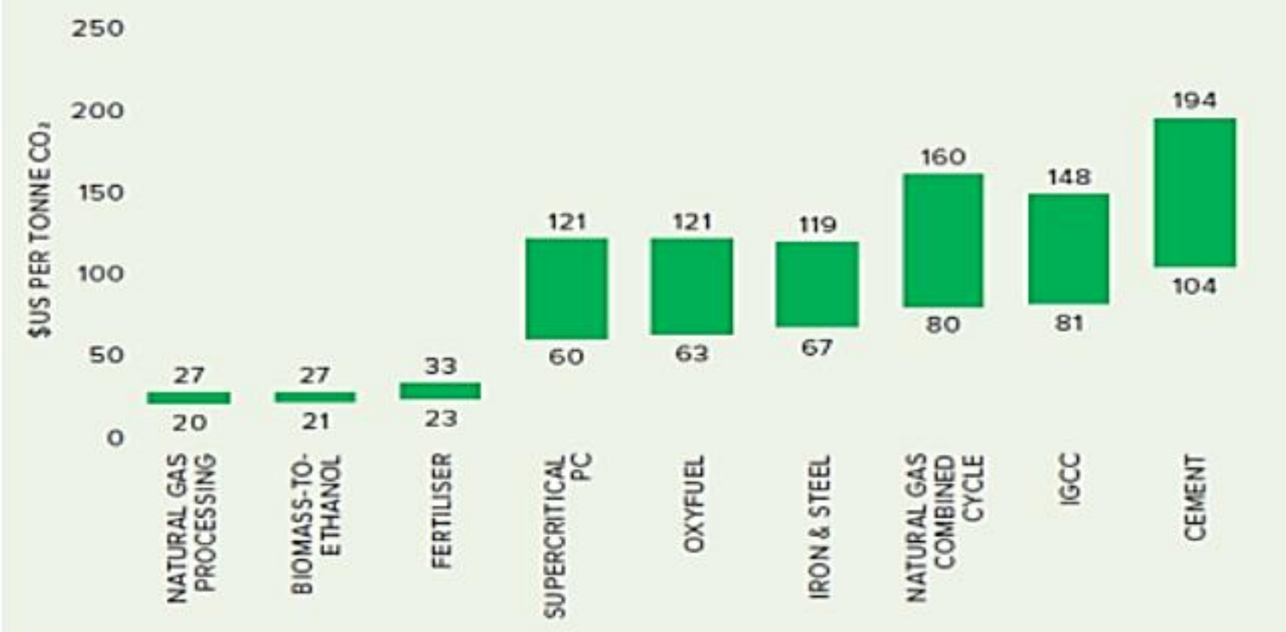
Copyright © 2021 Accenture. All rights reserved. Sources: *Eletrek*; *Global CCS Institute*; *Hydrogen in a Low Carbon Economy*

Cost and Investment Competitiveness

Decarbonisation of Industrial Clusters

- It is estimated that widescale deployment of CCUS could result in energy bills that are £82/year lower per household by 2030.
- Investment into CCUS could make low carbon hydrogen production more financially feasible for industrial clusters, helping to further decarbonize.
- Full-chain CCUS costs can be as low as £85/MWh in the UK and the method has the potential to safely store up to 15% of current UK CO_2 emissions by 2030.
- The UK has created multiple funds totaling around £800 million to support industry transitions to CCUS and low carbon hydrogen production.

CCS costs vary depending on industry



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Sources: Oil and Gas Climate Initiative; UK Parliament

UK Public and Private Investments into Solution Areas

Public Investments

- The newly announced Green Industrial Revolution plan will **mobilize £12 billion of government investment** and support up to 250,000 new jobs in the UK. Further, the Plan is expected to create three times as much private sector investment by 2030
- Alongside the investments outlined by Boris Johnson in the Plan, the UK has already invested £800 million into CCS, £5 billion to create alternative greener ways of travel, and £1 billion in technological innovation to support emissions reduction
- **The Industrial Strategy Fund consists of £4.7 billion** allocated to address pressing industrial and societal challenges using R&D. Private companies are eligible to apply for grants to help further industrial decarbonisation

Private Investments

- **Equinor:** Plans to invest heavily in carbon-efficient solutions and won contracts to develop the largest offshore wind farm in the world, Dogger Bank, which represents a £9 billion investment
- **Iberdrola:** The company's integrated energy arm in the UK invests approximately £1.5 billion a day into wind energy, smart grids, and electrification. They also have invested into a 3.1 GW wind hub project off the British coast that is expected to cost $8 billion
- **National Grid UK:** Plans to invest almost £10 billion over five years to transition the UK's gas and electricity networks to greener energy
- **SSE:** Outlined plans for over £7 billion of low-carbon investments in the UK and Ireland over the next five years. Additionally has partnered with Total to create a 1.1 GW offshore wind farm expected to cost around £3.7 billion

Investments from the newly announced Green Industrial Revolution Plan

RENEWABLES, POWER MARKETS, AND NETWORKS OF THE FUTURE
£525 million to help develop large and smaller-scale nuclear plants as well as R&D for advanced modular reactors. This investment will help provide more baseload generation for power markets and networks of the future

EFFICIENCY AND DEMAND OPTIMISATION
The plan will be supported by 2019 investments into cleaner energy. This includes a **£1 billion energy innovation fund** to stay ahead of the latest technologies and thereby improve efficiency

ELECTRIFICATION OF PASSENGER VEHICLES
£1.3 billion to accelerate the rollout of chargepoints, **£528 million** in grants, and **£500 million** for development and deployment of electric vehicle batteries

DECARBONISATION OF HEATING
£1 billion for making homes and public buildings more efficient, and supporting current grant schemes, and **£500 million** for new hydrogen production facilities and to trial homes using hydrogen for heating and cooking

DECARBONISATION OF INDUSTRIAL CLUSTERS
£200 million to create two carbon capture clusters by mid-2020s and another two by 2030, and **£20 million** for a competition to develop clean maritime technology, such as site feasibility studies

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Sources: UK Gov Green Industrial Revolution, Investable Universe, WEF, Iberdrola, Energy Voice, National Grid, SSE

UK Ten Point Plan for a Green Industrial Revolution

The UK's Ten Point plan will mobilise £12 billion of government investment to create and support up to 250,000 jobs in the green sector

Offshore Wind

- Produce enough offshore wind to power every home
- Achieve 40GW by 2030, supporting up to 60,000 jobs

Hydrogen

- Generate 5GW of low carbon hydrogen production capacity by 2030
- Develop the first town heated entirely by hydrogen by 2030

Nuclear

- Advance nuclear as a clean energy source by developing the next generation of small and advanced reactors
- Efforts could support 10,000 jobs

Electric Vehicles

- Support car manufacturing bases throughout the UK to help accelerate the transition to EVs
- Advance the national infrastructure to better support EV adoption

Public Transport, Cycling, and Walking

- Make cycling and walking more attractive ways to travel
- Invest in zero-emission public transport of the future

Jet Zero and Greener Maritime

- Support difficult-to-decarbonise industries to become greener through research projects for zero-emissions planes and ships

Homes and Public Buildings

- Make homes, schools, and hospitals greener and efficient
- Create 50,000 jobs by 2030 and install 600,000 heat pumps every year by 2028

Carbon Capture

- Become a world-leader in CCS technology
- Target to remove 10MT of CO_2 by 2030, equivalent to all emissions of the industrial Humber today

Nature

- Protect and restore the natural environment by planting 30,000 hectares of trees every year

Innovation and Finance

- Develop cutting-edge technology that can support outlined ambitions
- Make the City of London the global center of green finance

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Source: UK Prime Minister's Office