CARBON-FREE EUROPE
A TECHNOLOGY-INCLUSIVE CLIMATE INITIATIVE

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COUNTRY SUMMARY: UNITED KINGDOM
ANALYSIS OF NET-ZERO PATHWAYS FOR THE EU AND UK

OVERVIEW OF MODELLING ANALYSIS

Carbon-Free Europe (CFE) modeled five potential pathways for the EU and UK to achieve net-zero emissions by 2050. The ***Core*** pathway is the least constrained, allowing countries to use all available clean energy technologies and assuming high levels of energy efficiency and electrification. This is the most feasible, cost-effective pathway to net-zero. The other four pathways are designed to explore how different policy and implementation constraints impact the route to carbon-neutrality. To learn more about the other pathways and our full analysis, visit www.carbonfreeeurope.org.

TODAY'S ENERGY SYSTEM

In 2019, 78% of the UK's energy supply came from fossil fuels (3.5% from coal, 39.5% from gas, and 35% from oil). Nuclear energy supplied 8% and renewable energy sources, including biofuels, provided 12%. The most emissions come from transportation (27% of total GHG emissions), followed by residential and commercial buildings (17%), electricity (13%), and industry (10%). 2019 is a good baseline year to understand Europe's long term energy demand and supply since impacts from the pandemic have heavily skewed data from 2020-2021. 2019 is also the most recent year for which final Eurostat energy balance data is available.

KEY TAKEAWAYS: THE CORE PATHWAY IN 2050

1. **The UK's most feasible and cost-effective pathway to net-zero is the *Core* pathway, which includes the use of every available clean energy technology including nuclear energy and carbon capture.** In this pathway, by 2050, the UK's estimated electricity mix is 51% wind, 9% solar, 39% nuclear, and 1% gas. The Core pathway requires 770 billion pounds of investment through 2050 in key technologies including electricity generation and storage, clean fuels, direct air capture, and heat pumps.

2. **In a carbon-free economy, the UK becomes a key energy producer, building more nuclear power and offshore wind than any EU country.** The UK expands its electric generation capacity by an additional 59 gigawatts (GW) of nuclear power and 96 GW of offshore wind in the *Core* pathway.

3. **Abundant domestic nuclear power and offshore wind enables the UK to become a leading producer of low-carbon hydrogen.** In the *Core* pathway, the UK becomes the

second largest producer of high-temperature electrolysis and fourth largest producer of low-temperature electrolysis supported by availability of offshore wind and nuclear heat.

4. **The UK becomes an essential exporter of electricity and hydrogen to mainland Europe.** To deliver this energy, the UK becomes the third largest constructor of new electricity transmission (39 GW of new connections to other countries in the *Core* pathway) and the tenth largest builder of new hydrogen pipelines (13 GW in the *Core* pathway up to 44 GW in constrained pathways).

5. **Carbon capture is used to reduce emissions from cement production and yield negative emissions in biofuel production.** Captured carbon is sequestered in geologic formations. The UK stores up to 71 million tons of CO2 in geologic storage reservoirs annually by 2050. In the *Core* pathway, UK is the fourth largest storer of captured carbon, storing 36 million tons.

6. **The UK ramps up biofuel production to replace fossil fuels primarily in aviation and chemical manufacturing.** By 2050, the UK becomes the sixth largest producer of biofuels, producing 6600 kilotons of oil equivalent (ktoe) in the *Core* pathway.

7. **The UK sees the second largest reduction in consumer gas demand and third largest in consumer oil demand.** This is because the UK is a relatively large consumer of oil and gas among EU + UK countries today, and can leverage a diverse array of clean energy resources to displace fossil fuels by 2050.

8. **Electricity demand will increase by 240%.** As the UK electrifies buildings, transport and parts of industry, and begins using electricity to produce hydrogen, electricity demand is modeled to increase by approximately 240% in 2050.

9. **The UK will need to ramp up the pace of renewables deployment by as much as 3.5 times to decarbonise.** From 2011 to 2020, the UK built on average 4 gigawatts of renewables a year. To meet demand, the UK will need to build 5-14 gigawatts annually (representing a 125-350% increase).

10. **The UK can dramatically reduce its dependence on natural gas-fired boilers for space and water heating.** Modelling shows natural gas consumption for residential space heating gas boilers can reduce from 14,445 ktoe to 8,235 ktoe by 2035, and further reduce to 2,275 ktoe by 2040—a 75% reduction in this timeframe.

KEY ENERGY METRICS

The table below shows key energy system metrics from the ***Core*** pathway, which is the most cost-effective, feasible trajectory to net-zero. The table also shows a range for each metric. That range is generated by comparing the ***Core*** pathway to four other modelled pathways designed to evaluate specific constraints.

The **Slow Demand Transformation** pathway imposes delays in electrification of surface transportation, heating, and industry. The **100% Renewables** pathway relies strictly on renewables, phases out nuclear power, and prevents carbon capture and sequestration. The **Limited Renewable Siting** pathway restricts the deployment of wind and solar to reflect land-

use and siting constraints. The **Domestic Preference** pathway prioritises domestic energy supplies and reduces transborder transmission lines and pipelines.

We provide a range for each metric in the table to indicate which model results are highly sensitive to constraints, and which are consistent across all scenarios such that they represent low-regret strategies. We also show the UK's rank in each metric relative to all EU + UK countries, to identify segments of the decarbonised energy economy where the UK has an opportunity to lead.

Category	Metric	Core Case	Min	Max	EU & UK Rank
Demand Transformation	electrification share (% of final demand)	57%	50%	57%	3
	reduction in end-use gas demand (ktoe)	-26,548	-19,074	-26,548	2
	reduction in end-use oil demand (ktoe)	-42,359	-36,588	-42,359	3
	zero-emission vehicles (million vehicles)	53	52	53	2
Electricity	battery storage (GW)	16	8	27	6
	nuclear (GW)	53	47	57	1
	solar (GW)	57	26	205	5
	offshore Wind (GW)	96	91	187	1
	onshore Wind (GW)	23	8	23	7
Fuels	biofuels (ktoe)	6618	4515	6649	7
	e-fuels (ktoe)	2,796	2,796	14,434	4
Hydrogen	electrolysis - high temperature (kilotonnes h2)	4,828	4,828	8,490	2
	electrolysis - low temperature (kilotonnes h2)	85	85	7,221	14
Other Resources	Biomass (million dry tons)	24	18	26	7
	geologic sequestration (million tons co2)	36	36	71	4
Transmission and Pipelines	new electricity transmission (GW)	39	9	40	2
	new h2 pipelines (GW)	13	7	44	10

Table 1: https://www.carbonfreeeurope.org/modeling

ENDNOTES

1. This takeaway is a 2050 projection based on 2019 historical data. It does not reflect recent prioritisation of gas phase-out for geopolitical reasons, which we do not expect to be a strong predictor of residual gas demand in 2050. All countries in our analysis significantly reduce gas consumption by 2050.