Distribution Future Energy Scenarios 2022

Results and assumptions report

Appendix

Electricity Distribution

nationalgrid

Electricity Distribution

Contents

List of technology types analysed as part of the NGED DFES 2022:

DFES technology	DFES sub-technology	Equivalent Building block ID number
Biomass & Energy Crops (including CHP)	-	Gen_BB010
CCGTs (non-CHP)	-	Gen_BB009
Geothermal	-	Gen_BB019
Hydro	-	Gen_BB018
Hydrogen-fuelled generation	-	Gen_BB023
Marine	Tidal stream	Gen_BB017
Marine	Wave energy	Gen_BB017
Non-renewable CHP	<1MW	Gen_BB001
Non-renewable CHP	>=1MW	Gen_BB002
Non-renewable Engines (non-CHP)	Diesel	Gen_BB005
Non-renewable Engines (non-CHP)	Gas	Gen_BB006
OCGTs (non-CHP)	-	Gen_BB008
Other generation	-	-
Renewable Engines (Landfill Gas, Sewage Gas, Biogas)	-	Gen_BB004
Solar Generation	Commercial rooftop (10kW - 1MW)	Gen_BB012
Solar Generation	Domestic rooftop (<10kW)	Gen_BB013
Solar Generation	Ground mounted (>1MW)	Gen_BB012
Waste Incineration (including CHP)	-	Gen_BB011
Wind	Offshore Wind	Gen_BB014
Wind	Onshore Wind <1MW	Gen_BB016
Wind	Onshore Wind >=1MW	Gen_BB015
Storage	Co-location	Srg_BB001
Storage	Domestic Batteries (G98)	Srg_BB002
Storage	Grid services	Srg_BB001
Storage	High Energy User	Srg_BB001
Storage	Other	Srg_BB004
Domestic	-	Dem_BB001a
Non-domestic	A1/A2	Dem_BB002b
Non-domestic	A3/A4/A5	Dem_BB002b
Non-domestic	B1	Dem_BB002b
Non-domestic	B2	Dem_BB002b

Non-domestic	B8	Dem_BB002b
Non-domestic	C1	Dem_BB002b
Non-domestic	C2	Dem_BB002b
Non-domestic	D1	Dem_BB002b
Non-domestic	D2	Dem_BB002b
Non-domestic	Sui Generis	Dem_BB002b
Air conditioning	-	Lct_BB014
Demand	Block load	-
Electric vehicles	Hybrid car (non-autonomous)	Lct_BB002
Electric vehicles	Hybrid LGV	Lct_BB004
Electric vehicles	Pure electric bus and coach	Lct_BB003
Electric vehicles	Pure electric car (autonomous)	Lct_BB001
Electric vehicles	Pure electric car (non-autonomous)	Lct_BB001
Electric vehicles	Pure electric HGV	Lct_BB003
Electric vehicles	Pure electric LGV	Lct_BB003
Electric vehicles	Pure electric motorcycle	Lct_BB001
EV Charge Point	Car parks	Lct_BB012b, LCT_BB013b
EV Charge Point	Destination	Lct_BB012b, LCT_BB013b
EV Charge Point	Domestic off-street	Lct_BB010b
EV Charge Point	Domestic on-street	Lct_BB010b
EV Charge Point	En-route / local charging stations	Lct_BB012b, LCT_BB013b
EV Charge Point	En-route national network	Lct_BB012b, LCT_BB013b
EV Charge Point	Fleet/Depot	Lct_BB011b
EV Charge Point	Workplace	Lct_BB011b
Heat pumps	District heating	Lct_BB009
Heat pumps	Domestic - Hybrid	Lct_BB006
Heat pumps	Domestic - Non-hybrid ASHP	Lct_BB005
Heat pumps	Domestic - Non-hybrid GSHP	Lct_BB005
Heat pumps	Domestic - Hybrid + thermal storage	Lct_BB006
Heat pumps	Domestic - Non-hybrid ASHP + thermal storage	Lct_BB005
Heat pumps	Domestic - Non-hybrid GSHP + thermal storage	Lct_BB005
Hydrogen electrolysis	-	Dem_BB009
Resistive electric heating	Direct electric heating	-
Resistive electric heating	Night storage heaters	-

Electricity Distribution

Demand technologies

Results and assumptions

Domestic electric heat

Technology specification		
Domestic dwellings where electricity is the primary fuel for space heating and hot water, delivered through a heat pump or resistive electric heater. This category is divided into a number of technologies and sub-technologies based on the heating technology and configurations that represent different loads on the electricity distribution network:		
Heat pumps		
Building block	**DFES subtechnologies**	**Units**
Lct_BB005 – Domestic - Non-hybrid	Domestic – Non-hybrid ASHP Domestic – Non-hybrid GSHP Domestic – Non-hybrid ASHP + thermal storage Domestic – Non-hybrid GSHP + thermal storage	Number of homes
Lct_BB006 – Domestic - Hybrid	Domestic - Hybrid	Number of homes
Lct_BB009 – District heating	District heating	Number of homes
Resistive electric heating		
No building block	Night storage heaters Direct electric heaters	Number of homes

Key modelling references	
National Grid ESO FES 2022 data	Energy Performance Certificates (EPC) data
ONS Census data	English Housing Survey / Welsh Housing Conditions Survey
BEIS Heat Network pipelines	BEIS Opportunity areas for district heating networks in the UK

Relevant assumptions from National Grid ESO FES 2022 **3.1.3 – Heat pump adoption rates**	
Falling Short	Low disposable income and low willingness to change lifestyle means consumers buy similar appliances to today.
System Transformation	Medium disposable income, an increase in energy prices relative to today through carbon price but low willingness to change lifestyle and consumer preference is to minimise disruption to existing technologies.
Consumer Transformation	Medium disposable income, high energy prices relative to today through carbon price incentives and a change in zeitgeist drive behavioural change to adopt new heating technologies.

Leading the Way	High disposable income, high energy prices relative to today through carbon price incentives and a change in zeitgeist drive behavioural change to rapidly adopt and experiment with new heating technologies.
3.2.2 – Regionality (district heat)	
Falling Short	Low levels of decarbonisation and a uniformly distributed technology mix across the country. Gas boilers dominate building heating but blended with hydrogen at low blend ratios.
System Transformation	High levels of heat decarbonisation but a uniformly distributed technology mix across the country. Hydrogen boilers dominate building heating. Moderate levels of district heating in cities.
Consumer Transformation	High levels of local and community autonomy on decarbonisation policy development and implementation leading to solutions optimised for each area of the country. High levels of district heat uptake in cities and hydrogen for building heating around industrial clusters.
Leading the Way	High levels of local and community autonomy on decarbonisation policy development and implementation leading to solutions optimised for each area of the country. High levels of district heat uptake in cities and hydrogen for building heating around industrial clusters.
4.1.22 – Home thermal efficiency levels	
Falling Short	Low level of energy efficiency improvements as based solely on enthusiastic consumers and new build homes.
System Transformation	High level of support for building efficiency improvements and high willingness of society to accept the levels of disruption associated with implementing deep retrofits.
Consumer Transformation	High level of support for building efficiency improvements and high willingness of society to accept the levels of disruption associated with implementing deep retrofits.
Leading the Way	High level of support for building efficiency improvements and high willingness of society to accept the levels of disruption associated with implementing deep retrofits
4.2.18 – Residential thermal storage	
Falling Short	Most homes still use gas boilers for heating and thermal storage not required.
System Transformation	Thermal storage use not widespread as the grid-supplied hydrogen provides all the flexibility required.
Consumer Transformation	High levels of thermal storage because of the high levels of heat electrification and the opportunity to participate in demand side response to help reduce heating bills.
Leading the Way	Moderate levels of thermal storage because of the high levels of technology hybridisation. Buildings heated exclusively by electricity however use storage where it's economically feasible to take advantage of the opportunity to participate in demand-side response to help reduce heating bills.

4.2.27 – Uptake of hybrid heating system units	
Falling Short	Gas boilers still dominant and very low levels of hybridisation.
System Transformation	Hydrogen boilers dominant. Higher amounts of hybrid hydrogen boilers + ASHP systems than FES21. However, low levels of other hybrid technologies.
Consumer Transformation	Moderate levels of heating hybridisation. Even in a highly electrified heat landscape, the availability of other fuels makes hybridisation cost optimal in certain localities.
Leading the Way	The drive to get to net zero early means taking the best from each fuel source and each technology to achieve optimum overall outcome for individual consumers and the system at large.
5.1.2 – Hydrogen boiler adoption rate	
Falling Short	Low levels of policy support for hydrogen and no widespread development of hydrogen networks. Adoption is limited to local private networks or a handful of small towns.
System Transformation	High levels of policy support for hydrogen and a national hydrogen transportation network is developed. Adoption is widespread across all areas of the country.
Consumer Transformation	Hydrogen has been removed as a heating source for CT. Model results gave hydrogen levels too high, similar to LW and so hydrogen was removed. This reflects the priority for electrification of heat in this scenario. The low efficiency of hydrogen for heating, along with the high cost of hydrogen by electrolysis make hydrogen less cost-effective in this high electrification scenario.
Leading the Way	Moderate to high levels of policy support for hydrogen and a national hydrogen transportation network is developed. Adoption is widespread across all areas of the country with some local bias. Boilers mainly used in hybrid systems.

EVs and EV chargers

Technology specification		
Pure electric and plug-in hybrid electric vehicles, and the associated domestic and non-domestic electric vehicle chargers required to charge them. This relates to a number of technology building blocks, as detailed below:		
Electric vehicles		
Building block	**DFES subtechnologies**	**Units**
Lct_BB001 – Pure Electric (vans, cars & motorbikes)	Pure electric car (non-autonomous) Pure electric car (autonomous) Pure electric LGV Pure electric motorcycle	Number

Lct_BB002 – Plug-in-hybrid (vans, cars and motorbikes)	Hybrid car (non-autonomous) Hybrid LGV	Number
Lct_BB003 – Pure Electric (road vehicles other than vans, cars and motorbikes)	Pure electric bus and coach Pure electric HGV	Number
Lct_BB004 – Plug-in-hybrid (road vehicles other than vans, cars and motorbikes)	n/a	Number
Electric vehicle chargers		
Building block	**DFES subtechnologies**	**Units**
Lct_BB010a – Domestic	Domestic off-street Domestic on-street	Number
Lct_BB011a – Workplace	Workplace Fleet/Depot	Number
Lct_BB012a – Public Slow/Fast	Destination Car parks	Number
Lct_BB013a – Public Rapid	En-route / local charging stations En-route national network	Number
Key modelling references		
National Grid ESO FES 2022 data	National Chargepoint Registry	
Department for Transport statistics	Open Charge Map	

Relevant assumptions from National Grid ESO FES 2022	
1.1.6 - Transport: Ultra Low Emission Vehicle (ULEV) subsidies	
Falling Short	Plug-in Grant for cars & vans modelled as ending in 2022
System Transformation	Private ULEV subsidies extended to combat low consumer willingness to change. Plug-in Grant for cars & vans ends in 2023
Consumer Transformation	Plug-in Grant for cars & vans modelled as ending in 2022
Leading the Way	Private ULEV subsidies extended to achieve policy ambitions. Plug-in Grant for cars & vans ends in 2023
1.3.4 - Transport: Public Road Transport	
Falling Short	Air pollution acts as a driver for urban investment but on the whole consumers are reluctant to shift from private transport.
System Transformation	Consumers are somewhat more reluctant to shift from private vehicles and reduce household car ownership, limiting growth.

Consumer Transformation	Consumers' demand for public transport increases as attitudes change. Some two-car households shifting to one-car leads to further growth.
Leading the Way	Consumers' demand for public transport increases as attitudes change. Growth is limited by the growth in Robotaxis for urban transport in this scenario.
3.3.2 - Autonomy	
Falling Short	Uptake limited by technology readiness and consumer trust. Has no effect on car ownership. Vehicle does more miles due to ease of travel. Some efficiency gains, particularly through improved off-peak motorway traffic flow.
System Transformation	Significant uptake of private vehicles. Enables some urban households to switch from two to one-car families with a corresponding increase in miles for the autonomous vehicle.
Consumer Transformation	Consumer acceptance leads to earlier uptake. Allows a significant number of urban households to become one-car families with a corresponding increase in miles. Cars do further increased miles e.g. serving underserved populations. Significant vehicle efficiency gains through improved traffic flow and appropriate vehicle sizing
Leading the Way	Urban areas adopt shared autonomous taxis, allowing some urban households to go car-free. Vehicle does significantly more miles due to being a highly utilised asset. High efficiency gains.
3.3.5 - Battery electric vehicles (BEVs)	
Falling Short	BEV adoption is slow, and doesn't meet policy ambitions. By 2035, 100% of car sales are ULEV. By 2040, 100% of van sales are ULEV. For both sectors this is dominated by BEVs. Slower uptake of BEVs in the Bus and HGV sectors out to 2050.
System Transformation	The right conditions are not fully achieved to create the consumer confidence needed for the market to achieve 100% sales of ULEVs. This is achieved for cars and vans in 2032 and 2035 respectively and dominated by BEVs. Uptake in the HGV >26t sector is limited by strong Hydrogen Fuel Cell Vehicle uptake.
Consumer Transformation	The government target of 100% of new car and van sales being ULEV by 2030 is met, and dominated by BEVs. There's significant uptake in the bus sector and across all HGVs.
Leading the Way	The government target of 100% of new car and van sales being ULEV by 2030 is met, and dominated by BEVs. Uptake in the HGV sector is strong across all weight classes. There's significant uptake in the bus sector.
4.1.25 - Plug-in hybrid electric vehicles (PHEVs)	
Falling Short	Availability from manufacturers to meet EU emissions standards is met from demand by fleets looking to gradually reduce emissions and drivers who are unwilling to shift to BEVs. No new sales from 2040
System Transformation	Higher demand for PHEVs as a transitional vehicle due to a higher proportion of consumers reluctant to transition to BEVs. No new sales from 2035

Consumer Transformation	Subsidy environment, falling battery costs and increased consumer willingness to accept BEVs limit PHEV growth. No new sales from 2035
Leading the Way	Higher initial demand for PHEVs (in addition to BEVs) as society seeks to decarbonise quickly. Subsidy environment, falling battery costs and increased consumer willingness to accept BEVs limits PHEV growth. No new sales from 2032
4.2.13 – Level of home charging	
Falling Short	There's a lack of solutions to residential charging, for those without off-street parking, which consumers are willing to adopt. These consumers charge at destinations such as work
System Transformation	There's a lack of solutions to residential charging, for those without off-street parking, which consumers are willing to adopt. Emphasis on public rollout of fast chargers allows near-home rapid charging.
Consumer Transformation	Emphasis on home and on-street residential chargers (for those with adequate on-street parking), taking advantage of consumer engagement levels in flexibility. Emphasis on public rollout of fast chargers also allows near-home rapid charging.
Leading the Way	Widespread innovation & behaviour change allows majority of those with on-street parking to charge overnight. This limits market for near-home rapid charging

Hydrogen electrolysis

Technology specification	
Capacity (MW) of distribution connected hydrogen electrolysers. This does not include electrolysers directly powered by renewable energy without a dedicated grid connection ('behind-the-meter') or large-scale electrolysers connected to the transmission network. Nor does it include CCUS-enabled hydrogen produced via reformation of natural gas. Technology building block: Dem_BB009 – Hydrogen electrolysis.	
Key modelling references	
FES 2022 data workbook	• National-level distribution connected electrolysis capacity and scenario assumptions. • Distribution connected onshore, offshore and solar projections to show areas of high renewable resource for collocated hydrogen production.
National Atmospheric Emissions Inventory and BEIS energy consumption dataset	• Data on emissions from industrial processes by location and BEIS data on industrial demand. Aggregated to represent demand from industrial processes, which could be a major driver of hydrogen electrolyser locations.
Department for Transport traffic count data	• Volumes of transport mileage and vehicles for a variety of different vehicle types. Used to indicate areas of heavy transport demand for hydrogen.

Census data, 2011	• Data for houses with central heating technologies. Areas with access to the gas network are more likely to have hydrogen for heating and could be more likely to see hydrogen production facilities in the area under some scenarios for blending.
Relevant assumptions from National Grid ESO FES 2022 **4.2.19 – Hydrogen (electrolysis exc. from nuclear)**	
Falling Short	High cost limits rollout of electrolysis - used mainly in transport.
System Transformation	Competition from SMR (blue hydrogen) limits rollout of electrolysis - used mainly in transport. Hydrogen is produced from both networked and non-networked electrolysers, increasing with time as green hydrogen becomes more attractive compared to blue.
Consumer Transformation	Electrolysis used to decarbonise heat, transport and some I&C - medium as begins later than in **Leading the Way**.
Leading the Way	Electrolysis used to decarbonise heat, transport and I&C but rollout starts in the mid-2020s.

New developments

Technology specification
New-build property developments, including new housing and new non-domestic sites such as business space, retail, public and leisure buildings. These are components of technology building blocks Dem_BB001a and Dem_BB002b.
Key modelling references
Data on planned domestic and non-domestic developments is gathered through engagement with all local authorities in the licence area. Alongside historic build rates, this is used to inform local-level projections for future housing numbers and non-domestic floorspace (sqm).
Relevant assumptions from National Grid ESO FES 2022
There are no specified assumptions in the FES concerning new developments. At a national level, the FES data shows that the total number of domestic customers increases equally in every scenario.

Air conditioning

Technology specification
Number of domestic air conditioning units, based on a typical portable or window-mounted air conditioner. Technology building block: Lct_BB014 – A/C Domestic units
Key modelling references

National Grid ESO FES 2022 data	UK cooling degree days data
OS Addressbase	Future Homes Standard / Welsh government Building Regulations Part L

Relevant assumptions from National Grid ESO FES 2022 **3.1.2 - Uptake of Residential Air Conditioning**	
Falling Short	Low willingness to change means society takes the easiest route to maintain comfort levels, therefore increased levels of air conditioning.
System Transformation	Medium uptake as society takes a mix of actions to maintain comfort levels (mix of air conditioning, tolerance of higher temperatures, changes to building design)
Consumer Transformation	Medium uptake as society takes a mix of actions to maintain comfort levels (mix of air conditioning, tolerance of higher temperatures, changes to building design)
Leading the Way	Low uptake as society changes to minimise uptake (e.g. personal tolerance of higher temperatures, changes to building design)

Electricity Distribution

Generation technologies

Results and assumptions

Large-scale solar generation

Technology specification		
Solar PV generation above 1 MW in scale, typically ground-mounted, connecting to the distribution network. Technology building block: Gen_BB012 -- Solar Generation - Large (G99)		
Key modelling references		
National Grid ESO FES 2022 data	Renewable Energy Planning Database	Engagement with developers

Relevant assumptions from National Grid ESO FES 2022 **4.2.15 - Solar generation (plant greater than 1 MW)**	
Falling Short	Slower pace of decarbonisation.
System Transformation	Transition to net zero results in strong growth in large solar.
Consumer Transformation	Transition to net zero results in strong growth in large solar.
Leading the Way	Very high ambition to decarbonise drives a focus on technologies that are low carbon. Supports production of hydrogen by electrolysis.

Small-scale solar generation

Technology specification	
Solar PV sites of less than 1 MW capacity. This has been split into domestic-scale solar PV of under 10 kW capacity, and commercial-scale solar PV of 10 kW to 1 MW capacity. Technology building block: Gen_BB013 – Solar Generation, Small (G89/G83)	
Key modelling references	
National Grid ESO FES 2022 data	Stakeholder engagement
New housing development data	Desk research

Relevant assumptions from National Grid ESO FES 2022 **4.1.5 - Solar generation (plant smaller than 1MW)**	
Falling Short	Slower pace of decarbonisation.
System Transformation	Transition to net zero results in strong growth in small solar. Supports production of hydrogen by electrolysis.
Consumer Transformation	Very high growth in small solar as it supports the transition to net zero and is highly aligned to the high societal change.
Leading the Way	Very high growth in small solar as it supports the transition to net zero and is highly aligned to the high societal change.

Onshore Wind

Technology specification		
Onshore wind generation connecting to the distribution network. Technology building blocks: Gen_BB015 -- Onshore Wind >=1MW and Gen_BB016 – Onshore Wind <1MW		
Key modelling references		
National Grid ESO FES 2022 data	Feed-in Tariff register (Sites of 100 kW and below)	Renewable Energy Planning Database

Relevant assumptions from National Grid ESO FES 2022 4.1.3 - Wind generation (onshore)	
Falling Short	Slower pace of decarbonisation.
System Transformation	Focus on renewables but limited by societal preference for offshore turbines (less impact on land use and visibility)
Consumer Transformation	Strong support for onshore wind across all networks. Some of these projects may be in community ownership.
Leading the Way	High growth driven by the decarbonisation agenda and high demands for hydrogen production from electrolysis.

Offshore wind and marine

Technology specification	
Offshore wind electricity generation, including both fixed and floating foundations, and marine electricity generation sites, encompassing tidal stream and wave power. Tidal lagoons are not anticipated to connect at distribution level. Technology building blocks: Gen_BB014 – Offshore Wind; Gen_BB017 – Tidal Stream, Wave Power, Tidal Lagoon	
Key modelling references	
National Grid ESO FES 2022 data	Developer engagement

Relevant assumptions from National Grid ESO FES 2022 4.1.2 - Other renewables including marine and hydro generation	
Falling Short	Low support and therefore other renewables cannot compete with low-cost solar and wind generation.
System Transformation	Support for large-scale renewable technologies (i.e. tidal marine).
Consumer Transformation	Potential for a lot of small-scale projects that will have larger societal impact coupled with support for marine technologies across all scales.

Leading the Way	Focus on rapid decarbonisation results in prioritising renewables that are available at lowest cost today (i.e. solar and wind). Innovation in other flexible solutions results in less need for a wide range of renewables.
4.1.4 - Wind generation (offshore)	
Falling Short	Slower pace of decarbonisation.
System Transformation	Strong growth in offshore wind as it has lower societal impact (land use and visibility) than onshore wind. Build-out is limited versus other scenarios as there is less demand (e.g. less hydrogen production from electrolysis).
Consumer Transformation	Strong growth in offshore wind as it has lower societal impact (land use and visibility) than onshore wind. Build-out is limited versus other scenarios as there is less demand (e.g. less hydrogen production from electrolysis).
Leading the Way	High growth driven by the decarbonisation agenda and high demands from hydrogen production from electrolysis.
DFES notes	The above scenario assumptions refer primarily to transmission-scale offshore wind generation, which represents the majority of offshore power generation capacity. At a distribution scale, the FES data shows limited capacity growth, as beyond pre-commercial floating offshore wind arrays, future offshore wind is anticipated to connect at a transmission level in every scenario.

Hydro

Technology specification	
Hydropower generation connecting to the distribution network. This does not include pumped hydroelectric storage. Technology building block: Gen_BB018 – Hydro	
Key modelling references	
National Grid ESO FES 2022 data	Feed-in Tariff register
Relevant assumptions from National Grid ESO FES 2022 **4.1.2 - Other renewables including marine and hydro generation**	
Falling Short	Low support and therefore other renewables cannot compete with low-cost solar and wind generation.
System Transformation	Support for large-scale renewable technologies (i.e. tidal marine).
Consumer Transformation	Potential for a lot of small-scale projects that will have larger societal impact coupled with support for marine technologies across all scales.
Leading the Way	Focus on rapid decarbonisation results in prioritising renewables that are available at lowest cost today (i.e. solar and wind). Innovation in other flexible solutions results in less need for a wide range of renewables.

Geothermal

Technology specification	
Geothermal energy sites producing electrical power Technology building block: Gen_BB019 – Geothermal	
Key modelling references	
National Grid ESO FES 2022 data	Developer engagement

Relevant assumptions from National Grid ESO FES 2022 4.1.2 - Other renewables including marine and hydro generation	
Falling Short	Low support and therefore other renewables cannot compete with low-cost solar and wind generation.
System Transformation	Support for large-scale renewable technologies (i.e. tidal marine).
Consumer Transformation	Potential for a lot of small-scale projects that will have larger societal impact coupled with support for marine technologies across all scales.
Leading the Way	Focus on rapid decarbonisation results in prioritising renewables that are available at lowest cost today (i.e. solar and wind). Innovation in other flexible solutions results in less need for a wide range of renewables.

Biomass

Technology specification	
Biomass power generation, as standalone power generation or combined heat and power. Excludes biomass used solely for heat. This could include bioenergy with carbon capture and storage (BECCS). However, BECCS technology is not expected to connect at a distribution level. Technology building block: Gen_BB010 – Biomass & Energy Crops (including CHP)	
Key modelling references	
National Grid ESO FES 2022 data	Renewable Energy Planning Database

Relevant assumptions from National Grid ESO FES 2022 4.1.11 - Unabated Biomass and Energy from Waste (EfW) generation	
Falling Short	Unabated biomass generation does not convert as rapidly to BECCS. No significant change in waste management from society, leaving waste available as a fuel source for unabated generation.
System Transformation	Unabated biomass is supported for longer than in Leading the Way as slower to adopt CCS. Less waste to burn in general due to a highly conscious society adapting to low-waste living.

Consumer Transformation	Unabated biomass is supported for longer than in Leading the Way as slower to adopt CCS. Less waste to burn in general due to a highly conscious society adapting to low-waste living.
Leading the Way	Unabated biomass drops away rapidly as BECCS and other uses for biomass increase. Less waste to burn in general due to a highly conscious society adapting to low-waste living.
DFES notes	The above scenario assumptions refer primarily to transmission-scale biomass generation, which represents the majority of biomass power generation capacity. At a distribution scale, the FES data shows consistent capacity reduction under **Consumer Transformation** and **Leading the Way** and a slightly slower reduction under **System Transformation**.

Renewable engines

Technology specification	
Electrical capacity of gas engines and CHP fuelled by renewable and low carbon gas, including sewage gas, landfill gas and biogas from anaerobic digestion of biogenic feedstocks such as crop waste and animal slurry. Technology building block: Gen_BB004 – Renewable Engines (Landfill Gas, Sewage Gas, Biogas)	
Key modelling references	
National Grid ESO FES 2022 data	NGED connections data
Relevant assumptions from National Grid ESO FES 2022	
4.1.2 - Other renewables including marine and hydro generation	
Falling Short	Low support and therefore other renewables cannot compete with low-cost solar and wind generation.
System Transformation	Support for large-scale renewable technologies (i.e. tidal marine).
Consumer Transformation	Potential for a lot of small-scale projects that will have larger societal impact coupled with support for marine technologies across all scales.
Leading the Way	Focus on rapid decarbonisation results in prioritising renewables that are available at lowest cost today (i.e. solar and wind). Innovation in other flexible solutions results in less need for a wide range of renewables.

Diesel generation

Technology specification	
Diesel-fuelled electricity generation, including standalone commercial diesel plants and behind-the-meter diesel backup generators. Technology building block: Gen_BB005 – Non-renewable engines (diesel) (non-CHP).	
Key modelling references	
National Grid ESO FES 2022 data	Decommissioning timelines and licence area projections for reconciliation.
Environment Agency	New environmental permits required under the Medium Combustion Plant Directive have influenced the decommissioning timelines of standalone commercial diesel plants in the net zero scenarios.

Fossil gas-fired power generation

Technology specification	
Fossil gas-fired power generation connected to the distribution network, covering four known fossil gas generation technology types: • Close cycle gas turbines (CCGT) – Building block Gen_BB009 • Open cycle gas turbines (OCGT) – Building block Gen_BB008 • Gas reciprocating engines – Building block Gen_BB006 • Gas combined heat and power plants (gas CHP) – Building block Gen_BB001 The analysis does not include backup gas CHPs or engines located on some commercial and industrial premises that are only operated when mains supply failure occurs and cannot export.	
Key modelling references	
National Grid ESO FES 2022 data	Stakeholder engagement
Capacity Market auction results and data	Local authority planning portals
Nationally Significant Infrastructure Projects (NSIP) register	Embedded Capacity Register (NGED)
Relevant assumptions from National Grid ESO FES 2022 **4.1.6 – Unabated large-scale fossil-fuelled generation**	
Falling Short	Low gas prices and a lower focus on decarbonisation promote gas as the source of flexible generation.
System Transformation	High levels of decarbonisation, plus other sources of flexibility reduce the need for unabated gas.
Consumer Transformation	High levels of decarbonisation, plus other sources of flexibility reduce the need for unabated gas.

Leading the Way	Highest level of decarbonisation significantly reduces the amount of unabated gas.
4.1.32 – Dispatchable peaking generation	
Falling Short	Initial strong growth in unabated gas reciprocating engines stays high as gas generations (small and large) plays an increasingly important role as flexible generation in the absence of strong growth in other technologies (e.g. storage, interconnection).
System Transformation	Initial slow growth (low deployment of gas reciprocating engines). Later strong growth in hydrogen plant to support system flexibility.
Consumer Transformation	Initial slow growth (low deployment of gas reciprocating engines). Later moderate growth in hydrogen plant to support system flexibility.
Leading the Way	Low throughout: initial growth of gas reciprocating engines is low as not aligned to decarbonisation and low long-term growth as other flexible solutions dominate in this scenario.

Hydrogen-fuelled generation

Technology specification	
Hydrogen-fuelled electricity generation, which has been modelled to connect to the distribution network in areas where there is the potential for hydrogen gas supply. This links to the analysis undertaken for fossil gas and diesel capacity. Technology building block: Gen_BB023 – Hydrogen-fuelled generation	
Key modelling references	
FES 2022 data workbook	National-level distribution connected electrolysis capacity and scenario assumptions. Distribution connected onshore, offshore and solar projections to show areas of high renewable resource for collocated hydrogen production.
National Atmospheric Emissions Inventory and BEIS energy consumption dataset	Data on emissions from industrial processes by location and BEIS data on industrial demand. Aggregated to represent demand from industrial processes, which could be a major driver of hydrogen electrolyser locations.
Department for Transport traffic count data	Volumes of transport mileage and vehicles for a variety of different vehicle types. Used to indicate areas of heavy transport demand for hydrogen.
Census data, 2011	Data for houses with central heating technologies. Areas with access to the gas network are more likely to have hydrogen for heating and could be more likely to see hydrogen production facilities in the area under some scenarios for blending.
National Grid Electricity Distribution	The location of existing and known commercial gas and diesel sites. This is in accordance with our engagement with National Grid ESO, who said that they "expect most of the dedicated hydrogen generation to be new build (albeit located at existing sites) and optimised for peak running".

Relevant assumptions from National Grid ESO FES 2022	
4.1.32 – Dispatchable plant generation	
Falling Short	Initial strong growth in unabated gas reciprocating engines stays high as gas generations (small and large) plays an increasingly important role as flexible generation in the absence of strong growth in other technologies (e.g. storage, interconnection)
System Transformation	Initial slow growth (low deployment of gas reciprocating engines). Later strong growth in hydrogen plant to support system flexibility.
Consumer Transformation	Initial slow growth (low deployment of gas reciprocating engines). Later moderate growth in hydrogen plant to support system flexibility.
Leading the Way	Low throughput: initial growth of gas reciprocating engines is low as not aligned to decarbonisation and low long-term growth as other flexible solutions dominate in this scenario.*

*These assumptions represent dispatchable hydrogen-fuelled generation assets connecting at both distribution and transmission levels. By 2050, under Leading the Way, 11 GW of hydrogen-fuelled electricity generation connects to the distribution network and 5.5 GW to the transmission network. Therefore, the DFES analysis has reflected a much stronger adoption of distributed hydrogen generation under this scenario than indicated by the above scenario assumption suggests.

Waste incineration

Technology specification	
Capacity (MW) of distribution connected Energy from Waste (EfW) sites, including incineration and Advanced Conversion Technologies (ACT). Technology building block: Gen_BB011 – Waste Incineration (including CHP).	
Key modelling references	
Renewable Energy Planning Database	Data on average planning time for incineration and ACT projects.
Relevant assumptions from National Grid ESO FES 2022	
4.1.11 – Unabated Energy from Waste (EfW) generation	
Falling Short	No significant change in waste management from society, leaving waste available as a fuel source for unabated generation.
System Transformation	Less waste to burn in general due to a highly conscious society adapting to low-waste living.
Consumer Transformation	Less waste to burn in general due to a highly conscious society adapting to low-waste living.
Leading the Way	Less waste to burn in general due to a highly conscious society adapting to low-waste living.

Electricity
Distribution

Storage technologies

Results and assumptions

Battery storage

Technology specification
Battery storage, comprising four business models: • **Standalone network services** – typically multiple megawatt-scale projects that provide balancing, flexibility and support services to the electricity network. • **Generation co-location** – typically multiple megawatt-scale projects, sited alongside renewable energy (or occasionally fossil fuel) generation projects. • **Behind-the-meter high-energy user** – typically single megawatt or smaller scale projects, sited at large energy-user operational sites to support on-site energy management or to avoid high electricity cost periods. These three business models combine to form the FES building block Batteries Srg_BB001 • **Domestic batteries** – typically 5-20 kW scale batteries that households buy to operate alongside rooftop PV or to provide backup services to the home. This business model aligns with the FES building block Domestic Batteries (G98) Srg_BB002. The analysis also considered other forms of electricity storage, Srg_BB003 (pumped hydro) and Srg_BB004 (other technologies, liquid air, and compressed air). However, no evidence was found for these technologies seeking to connect to the distribution network in any of the NGED licence areas. The building block Srg_BB005 (Vehicle-to-Grid) was not within the scope of the analysis.

Key modelling references	
National Grid ESO FES 2022 data	Developer engagement
NGED connection offer data	Renewable Energy Planning Database
Local authority online planning portals	EMR Delivery Body Capacity Market registers

Relevant assumptions from National Grid ESO FES 2022 4.2.24 - Short duration electricity storage	
Falling Short	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios.
System Transformation	Not as much deployed compared to other scenarios due to high use of hydrogen within this scenario.
Consumer Transformation	High levels of variable clean generation and flexibility requirements encourage new storage technologies to emerge.
Leading the Way	Even higher levels of flexibility requirements encourage new storage technologies to emerge at distributed and transmission levels.
4.2.25 - Medium duration electricity storage	
Falling Short	Lower flexibility requirements mean that this technology does not come forward at the volumes seen in the other scenarios.
System Transformation	Moderate levels of flexibility requirements encourage new storage. Not as much deployed compared to other scenarios due to high use of Hydrogen within this scenario.
Consumer Transformation	Flexibility requirements encourage new storage.

Leading the Way	High levels of flexibility requirements encourage new storage.
4.2.26 – Long duration electricity storage	
Falling Short	Lower flexibility requirements mean that this technology does not come forward at the volumes seen in the other scenarios.
System Transformation	Presence of high volumes of hydrogen limits the need for long-duration storage.
Consumer Transformation	High levels of variable clean generation and flexibility requirements encourage new storage technologies to emerge.
Leading the Way	Even higher levels of flexibility requirements encourage new storage technologies to emerge at distributed and transmission levels.

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