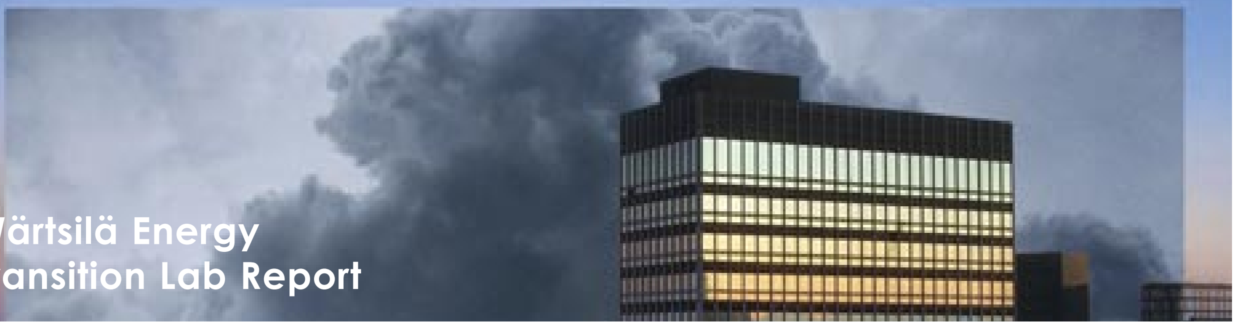
Optimising the UK's shift to a Renewable-powered Economy



Wärtsilä Energy Transition Lab Report

This report shows what is possible to achieve by 2030 based on current policy ambitions and the technical constraints and market structures that govern the UK energy system today. The UK can go further, faster. New developments we know are coming this decade – from electric vehicles to electric heating – will transform our energy system. They will also require more power and more flexibility to ensure the system can balance new supply and demand as millions of "batteries on wheels" are connected.

Flexibility is the key to unlocking higher levels of renewables in the next 10 years and enabling a pathway to a net-zero energy system by 2050 or before.

Content

Executive Summary

The global transition to renewable energy has been accelerating worldwide, driven by the urgent imperative to address the climate emergency and increasingly favourable economics. This has been supercharged by the impact of the Covid-19 pandemic, creating unique conditions to accelerate the transition, with the IEA recognising that renewable energy, such as wind and solar, showed 'a degree of immunity to the crisis'.[1]

The temporary acceleration of the share of renewable energy driven by Covid-19 has fixed the eyes of the world's energy leaders on the opportunity to realise the potential of renewables to reduce emissions, permanently.

The UK is one such test-case. The UK Prime Minister has increased the Government's offshore wind target from 30 GW to 40 GW by 2030 and pledged that offshore wind will power every home in the country in that time. This will form a keystone in the country's path to a net zero energy system.

The UK Government will soon release its energy white paper, detailing its strategy for the coming decade and beyond. This is an opportunity to set an ambitious target for renewable energy to become the primary source of power by 2030.

In 2019, the UK energy system reached 37% renewable energy. By 2030, modelling undertaken by Wärtsilä shows that the country could easily achieve a permanent 62% renewable generation, even with the energy system as it is today. The country should go further, setting a target to achieve 80% renewable energy by the end of the decade.

That may sound ambitious, but it is realistic. During the initial Covid-19 lockdown, when energy demand fell by up to 10%, the energy system as it is today coped with up to 60% renewables for short periods. Energy systems in other European countries, such as Germany and Spain, achieved over 70% renewable energy. If current systems can manage major spikes of renewable energy today, then – as this report shows – with investment in technologies that add system flexibility, we can be confident to set ambitious targets for permanently higher levels of renewables in the near future.

[1] *IEA Sustainable Recovery report June 2020*

The UK and indeed all countries stand at a fork in the road, between accelerating a cost-optimal shift to 100% renewable energy and economic decarbonisation, or locking in a slower, less effective transition that risks missing targets for decarbonisation and tackling the climate emergency. The decisions made in the next 6-12 months will define the next three decades.

At Wärtsilä, we believe in a simple three phase strategy:

1. Support faster renewable energy deployment to achieve 80% renewable generation by 2030.
2. Increase investment in flexibility to unlock renewable energy and deliver a cost-optimal transition for consumers.
3. Future-proof today's decisions to enable future technologies – such as Power-to-X – to achieve 100% renewable energy before 2050.

Optimising the UK energy transition

When Covid-19 hit, the lack of flexibility in the UK energy system created instability and price volatility. Network operators were forced to incentivise generators to take power plants offline or export power, costing millions. Substantially increasing the share of renewables will require action to address this, or the transition will become too expensive for consumers to accept.

In modelling energy systems worldwide,[2] regardless of the starting energy mix, Wärtsilä has consistently found that a combination of renewable energy and flexibility technologies, including energy storage and flexible thermal plants, drives the most value to society through cost savings and emission reductions.

The need for greater power system flexibility to unlock the potential of renewable energy has been outlined by many organisations. The IEA, UK Energy Systems Catapult and Renewable UK have all recently made clear the need for such investment.3

To investigate the impact increased flexibility can have on renewable energy growth in the UK, we have modelled three scenarios for the energy system to 2030. These are based on current UK energy policy, pledges on renewable energy growth and predicted growth in renewable generation capacity[4]:

Our analysis revealed that employing significant flexible capacity enables higher levels of renewable power at a lower cost of energy than installing renewables alone, saving £270 million per year by 2030.

Our analysis also found that to add more nuclear to the system alongside renewables would add £660 million per year to the total cost of energy for the UK.

This report shows what is possible to achieve by 2030 based on current policy ambitions and the technical constraints and market structures that govern the UK energy system today.

The UK can go further, faster. New developments we know are coming this decade – from EVs to electric heating – will transform our energy system. They will also require more power and more flexibility to ensure the system can balance new supply and demand as millions of "batteries on wheels" are connected.

This is another vital reason why the UK must accelerate the growth of flexible technologies, such as energy storage and advanced flexible gas, to maximise the installation of new renewables. Flexibility is the key to unlocking higher levels of renewables in the next 10 years and enabling a pathway to a net-zero energy system by 2050 or before.

Finding an optimum path to accelerate Decarbonisation

Our modelling has shown that the UK's current ambition for offshore wind is just the beginning. With the right policy and investment, it can achieve more. Wärtsilä is calling on the UK and indeed all countries to accelerate ambition and put in place strategies that support faster renewable energy deployment this decade.

The choices we make today define our future. Let's ensure that those choices are based on understanding the optimum path to a renewablepowered economy in the UK, one that can serve as a blueprint for other economies to follow.

Let's be ambitious and seek to drive to 80% renewable energy by 2030.

Ville Rimali
Growth & Development Director
Africa and Europe
Wärtsilä Energy

[2] *www.wartsila.com/energy/towards-100-renewable-energy/atlas-of-100-percent-renewable-energy*

[3] *The IEA – Power Systems in Transition*
Energy Systems Catapult – Balancing Supply and Demand
Renewable UK – Enabling technologies and innovation

[4] *See page 19 for detail on the scenarios*

Introduction

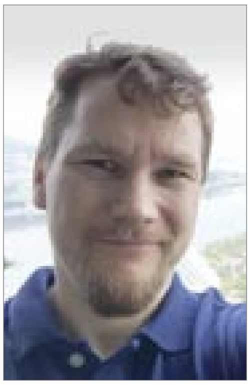
This is the decade of consequence for the global climate. The decisions taken today will influence the pace of decarbonisation for the next generation. Governments, industry and consumers must be able to understand the choices available, in order to act to accelerate the economic shift to clean energy.

This report models the impact of current UK Government policy options to increase the share of renewable energy on the UK electricity system and an alternative that could accelerate this transition, offering a guide towards an optimum path for the UK.

The Wärtsilä Energy Transition Lab enables us to model and analyse real and potential changes to existing electricity markets throughout Europe. It provides a 'crystal ball' to the future of European energy systems, visualising the impact that new emission-free energy sources such as wind, solar or nuclear could have on the generation mix, cost of energy, price volatility or utilisation of different generation. The tool reflects real bidding behaviour by the participants in the electricity markets, based on data published by the European Network of Transmission System Operators for Electricity (Entso-e).

This report illustrates realistic scenarios for the UK energy system to 2030. It shows what is achievable with today's energy system, modelling scenarios to higher renewable energy based on current technology and market structures. The aim is to inform the optimal investment choices that need to be taken today, to achieve a high-renewables, low-cost energy system this decade.

New developments in the coming decade will undoubtedly present significant opportunities and challenges for accelerating the decarbonisation of energy. This report sets out to analyse what is possible given what we know today. We do not make predictions about the future impact of new technologies, policies and consumer behaviours that may or may not materialise.



The analysis in this report shows the immediate actions the UK can take to accelerate the deployment of renewable energy and set itself on an optimal pathway towards 100% renewable energy.

Jyrki Leino

Senior Manager
Business Development
Wärtsilä Energy

The importance of flexibility

The impact of Covid-19 on European power systems, including the UK, has shown that existing systems have the capability to absorb far higher levels of renewable power than expected. Europe as a whole regularly achieved high levels of renewable generation, including a new record of 55% on 5 July. Germany achieved more than 70% renewable energy, as did Spain. However, the UK lagged behind, achieving less than 60%.

Covid-19 also highlighted energy system inadequacies across the continent, with extreme price volatility and regular negative prices due to the lack of sufficient system flexibility. On one occasion, Germany paid almost £800,000 per hour to export 10.5 GW of generation. In the UK, National Grid took the radical decision to pay the Sizewell B nuclear generator to halve its output over the initial lockdown – costing £73 million.

A key reason for these energy system inadequacies is the lack of flexible capacity, such as energy storage or flexible thermal generation, to absorb excess renewable power and discharge when it is needed. The need for substantially greater flexible capacity is outlined by the recent IEA 'Power Systems in Transition' report, which states that a "fast increase of flexibility in power systems" will be required for the international share of renewable energy to rise to (just) 45% by 2040.

Increased flexibility would also future-proof the system, with flexible gas generation designed specifically for fuels, such as hydrogen and hydrogen-based renewable synthetic methane, that will be important to decarbonise the final 20% of the electricity system and hard-to-electrify sectors of the economy, such as transport, heating and heavy industry, before 2050.

Scenarios to 2030

The Wärtsilä Energy Transition Lab Report models three scenarios for increasing renewable energy generation in the UK to 2030. These scenarios are based on:

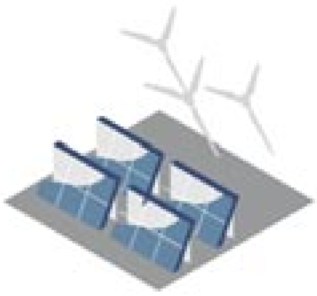
- The current electricity system, including technical and market constraints.
- Existing government policy on renewable energy and potential decisions on new generation capacity, such as offshore wind and/or new nuclear.
- Forecast market growth in renewable energy generation capacity.
- Forecast investment costs for new generation and flexible technologies to 2030.

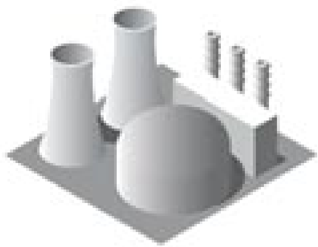
Scenarios

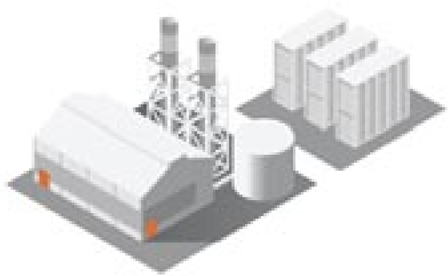
Adding Renewables Only models the impact of adding pledged new offshore wind and anticipated onshore wind and solar by 2030.

Renewables plus Nuclear models the effect of adding the same renewables plus an additional new nuclear plant in the 2020s.

Max Renewables plus Flex models the impact of focusing on installing substantial flexibility that includes energy storage and flexible gas to enable installation of more renewable capacity without increasing costs, compared to Adding Renewables Only.







Scenario	Additions compared to current system (GW)					
	Solar	Onshore wind	Offshore wind	Nuclear	Energy storage	Flexible gas
Adding Renewables only[5]	20	16	31	-	-	-
Renewables plus Nuclear	20	16	31	3	-	-
Max Renewables plus Flex[5]	20	18	34	-	5	2

5 *This matches the UK Government pledge for 40 GW of offshore wind and current anticipated capacity growth in onshore wind and solar.*

6 *The addition of at least one additional new nuclear plant in the next decade, anticipated to be approx. 3GW total capacity, is under consideration by the UK Government.*

Summary of Results

The modelling shows that Max Renewables plus Flex scenario is the most cost effective for the UK to accelerate its ambitions over the next decade. Speeding up the transition to renewable energy does not need to cost more – in fact, it can cost less.

Under this scenario, by adding 7 GW flexible capacity to the system, the UK can install 5 GW more renewable energy capacity and achieve a lower total cost of energy compared to the Adding Renewables Only scenario – costing £270 million less per year by 2030. It is also £660 million per year less than the Renewables plus Nuclear scenario.

Under Max Renewables plus Flex, the UK can power an additional 710,000 homes with renewable energy and cut a further 2 million tonnes CO_2 per year from the UK electricity system, compared to Adding Renewables Only.

In addition, by incorporating significant new flexible capacity, the system provides greater resilience, reducing price volatility and risk of blackouts.

The Energy Transition Lab

The Wärtsilä Energy Transition Lab was specifically developed as an open-data platform for the energy industry to understand the impact of Covid-19 and help accelerate the energy transition.

It provides detailed data on electricity generation, demand and pricing for all 27 EU countries and the UK, combining Entso-E data in a single, easy to use interface.

The Lab is made possible by Wärtsilä's team of power system modelling experts. We have invested in building world-class knowledge on modelling and analysing the long-term impacts of the energy transition towards high renewable power systems.

The Wärtsilä Energy Transition Lab can be accessed at: www.wartsila.com/energy/ transition-lab

Methodology

The modelling in this report has been undertaken using Plexos, the leading power system modelling software. A pan-European Plexos model was developed to study possible future scenarios and their impact on the European power system. The modelling uses publicly available data from Entso-E. Multiple potential scenarios were modelled to identify the final scenarios presented in this analysis.

The modelling is based on the energy system as it is today, using the last full year of data available (2019). The modelling uses existing generation capacities, demand levels, transmission infrastructure and market behaviour. The hourly price of electricity is determined by the Plexos model based on demand, available generation and exports.

Independent estimates of prospective additional generation capacity were used to establish the scenarios. Nuclear generation capacity included in the scenarios is based on current nuclear fleet decommissioning and commissioning plans, including the addition of the Hinkley Point C plant. Based on current decommissioning plans, the following nuclear plants are included in the generation mix in 2030: Torness, Heysham 2, Sizewell B, Dungeness B and Hinkley Point C. The Renewables plus Nuclear scenario includes an additional as yet unconfirmed 3 GW new nuclear plant that would be in operation by 2030, as under consideration by the UK Government.

Estimated generation and flexibility asset capex figures for 2025-30 are set out on page 24. Investment costs were not included in the Plexos model, but the monetary effect of building different generation capacities was calculated by annualising the investments. This was taken into account when comparing the scenarios.

The annualised investment cost and revenue generated from selling electricity was used to calculate how much additional revenue each new technology would need in terms of capacity payments to be suitable for investment. This was undertaken to enable fair comparison of the different scenarios.

The following carbon emission factors are in use in the model to determine carbon intensity and total emissions:

Lignite	990 kg CO2 / MWh
Coal-derived gas	850 kg CO2 / MWh
Gas	450 kg CO2 / MWh
Hard coal	850 kg CO2 / MWh
Oil	675 kg CO2 / MWh
Peat	950 kg CO2 / MWh
Waste	360 kg CO2 / MWh
Other non-renewable	450 kg CO2 / MWh

No carbon cost has been included in the calculations.

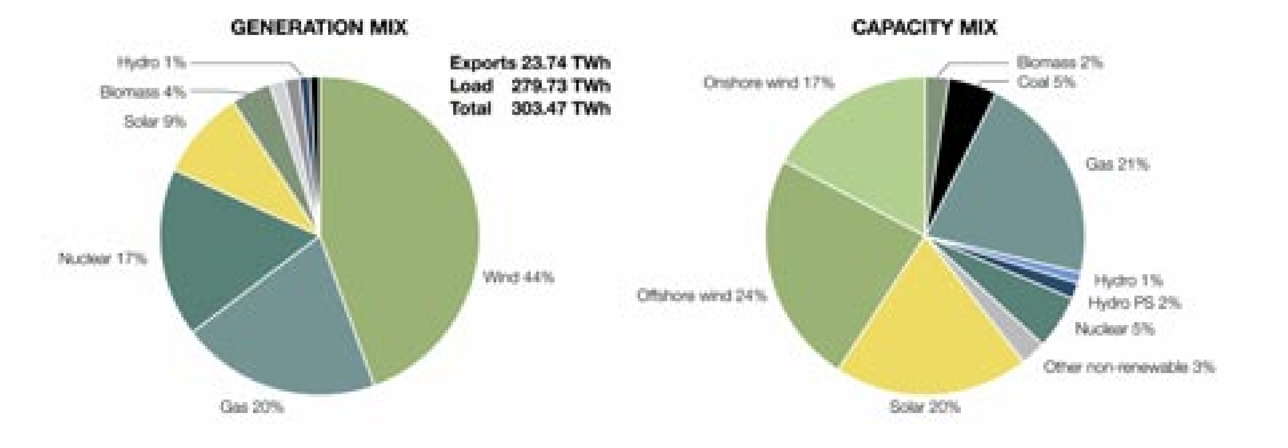
Glossary

Total (TWh):	Total annual power generation in terawatt hours.
Load (TWh):	Total annual power demand in terawatt hours.
Export (TWh):	Total annual power exported abroad in terawatt hours.
Share of renewable generation:	Percentage of renewable generation as a share of overall electricity supply, including on/offshore wind, solar, hydro and biomass.
CO_2 intensity (gCO_2/kWh):	Grams of carbon dioxide emitted per kilowatt hour of electricity generated. For example, a 100 watt lightbulb uses 0.1 kilowatt per hour.
Curtailment:	Average percentage of wind or solar power that is curtailed off the system over the course of a year. Curtailment occurs when there is too much energy generated for the electricity system to accommodate. Payments are made to generators to stop generating.

Summary of 2030 Generation Mix for each Scenario

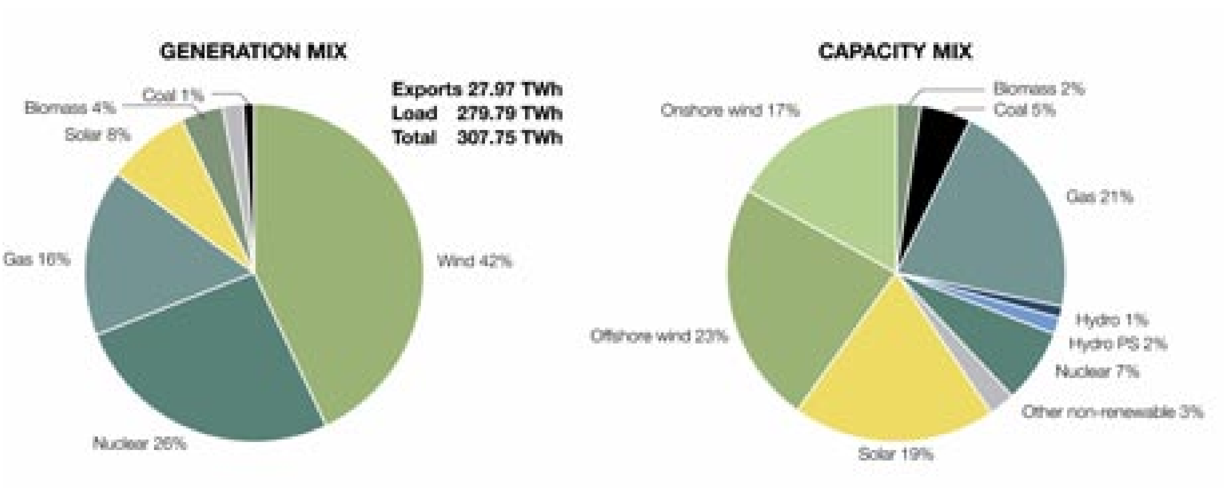
Adding Renewables Only

In the Adding Renewables Only scenario, wind and solar combined represent 61% of the installed capacity by 2030. These two technologies represent 53% in terms of generated energy. On the thermal side, gas is responsible for a 20% share of energy and 21% of the capacity mix. Nuclear is producing a significant share of energy, 17%, even though it only represents 5% of the capacity mix.



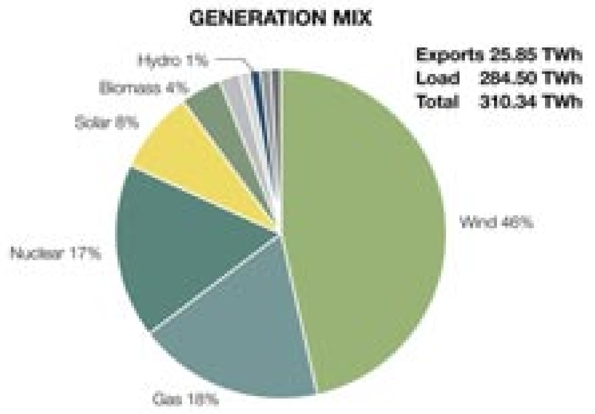
Renewables plus Nuclear

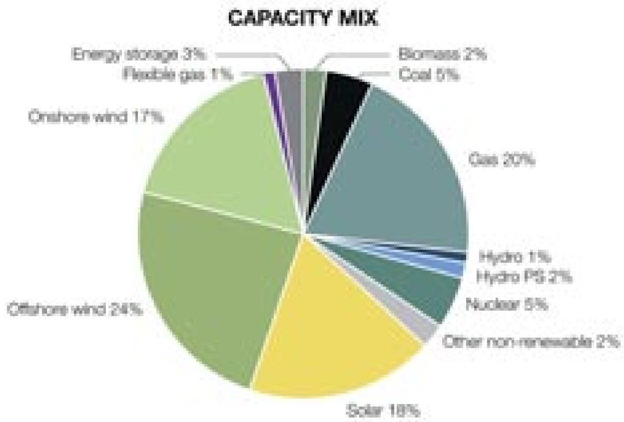
Adding more new nuclear by 2030 only increases its share in the capacity mix from 5% to 7%. However, nuclear generates over a quarter of UK electricity. In addition, the existing gas fleet, which is relatively inflexible, generates 16% of UK electricity. This combined impact will inhibit the transition significantly beyond 60%
renewable energy either before or after 2030.



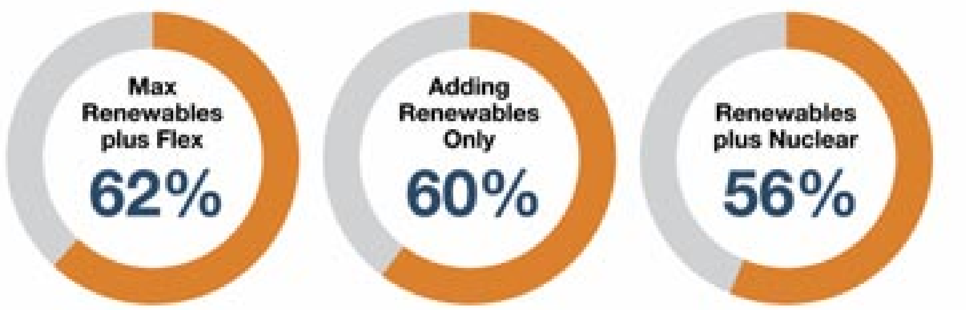
Max Renewables Plus Flex

Adding flexibility enables the economic installation of more wind power and the highest share of renewables generation of all the scenarios. Energy storage enables shifting of energy from low demand to high demand and flexible gasbased generation using internal combustion engine (ICE) technology provides energy at times of low renewable generation. The capacity factor of flexible gas in this scenario is just 17%, showing that it is operating only when needed. The total load in this scenario is 5 TWh higher than in Adding Renewables Only due to anticipated losses in the energy storage systems.





Impact on the UK Energy System



Total share of Renewable Generation

Max Renewables plus Flex provides 5 GW more renewable power, increasing the total share of renewables by almost 2 percentage points, equating to an additional 711,000 UK households powered by renewable energy compared to Adding Renewables Only. As the analysis below shows, this is achieved at a lower total cost of energy compared to Adding Renewables Only.

Carbon intensity compared to 2019

Renewables plus Nuclear	80 g CO2 per kWh -65% on 2019 24.4 million tonnes in total per year 5.4 million tonnes less than Adding Renewables Only
Max Renewables plus Flex	92 g CO2 per kWh -60% on 2019 27.7 million tonnes total per year 2.1 million tonnes less than Adding Renewables Only
Adding Renewables Only	100 g CO2 per kWh -56% on 2019 29.8 million tonnes total per year

Carbon intensity of Renewables plus Nuclear is lower overall due to the inclusion of nuclear as non-fossil fuel baseload power alongside renewables. However, as the analysis below shows, the additional cost per year is substantial compared to a relatively small improvement in carbon intensity.

Adding Renewables Only	5.4% £245 million per year
Max Renewables plus Flex	6.7% £75.6 million per year more than Adding Renewables Only
Renewables plus Nuclear	9.2% £170.8 million per year more than Adding Renewables Only

Curtailment of renewables required

Adding Renewables Only has the lowest renewable curtailment cost due to less total renewable energy generation than Max Renewables plus Flex and less inflexible baseload power than Renewables plus Nuclear.

Despite higher curtailment costs, the flexibility provided in the Max Renewables plus Flex scenario enables a lower overall annual total cost of energy, compared to Adding Renewables Only, as shown on page 24.

Curtailment costs under Renewables plus Nuclear are more than twice that of Max Renewables plus Flex, costs ultimately paid by consumers.

Adding new nuclear baseload causes nearly 10% curtailment costs even at a low total level of renewable power (56%). As more renewable generation is added to the system, periods of 70% renewables share of generation become increasingly common, as seen in Germany this year. As nuclear plants need to run at 100% capacity, adding more renewables increases curtailment costs further, making them more expensive as the proportion on the system increases.

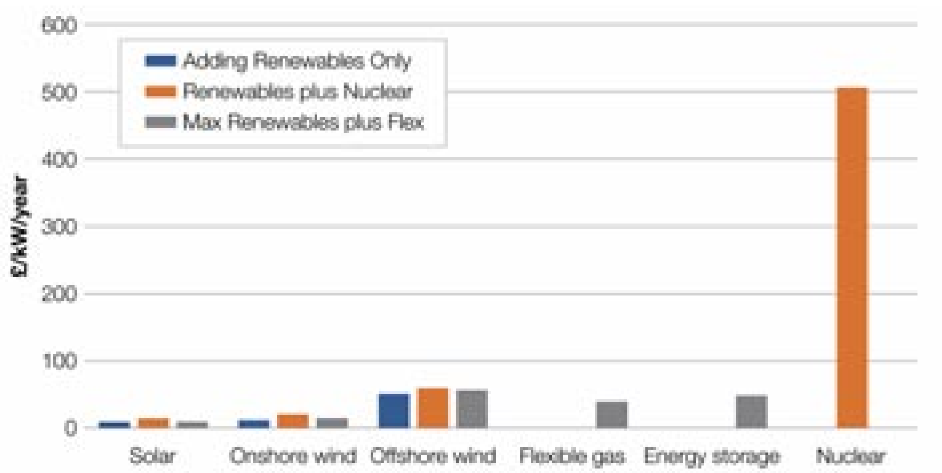
The lack of additional flexibility technologies in the Adding Renewables Only system means that total annual capacity market cost is lowest.

However, the total cost of the Max Renewables plus Flex scenario is ultimately £270 million per year less expensive than Adding Renewables Only, due to the intermittency of renewable power and the price balancing stability that additional flexibility provides (see page 24).

Under the Renewables plus Nuclear scenario, capacity payments would be 2.25 times higher than under the Max Renewables plus Flex scenario, and 3.25 times higher than under Adding Renewables Only.

This is because nuclear runs all the time, and cannot benefit from price volatility in the same way that flexible energy storage or even gas plant can.

Annual Capacity Market Payments



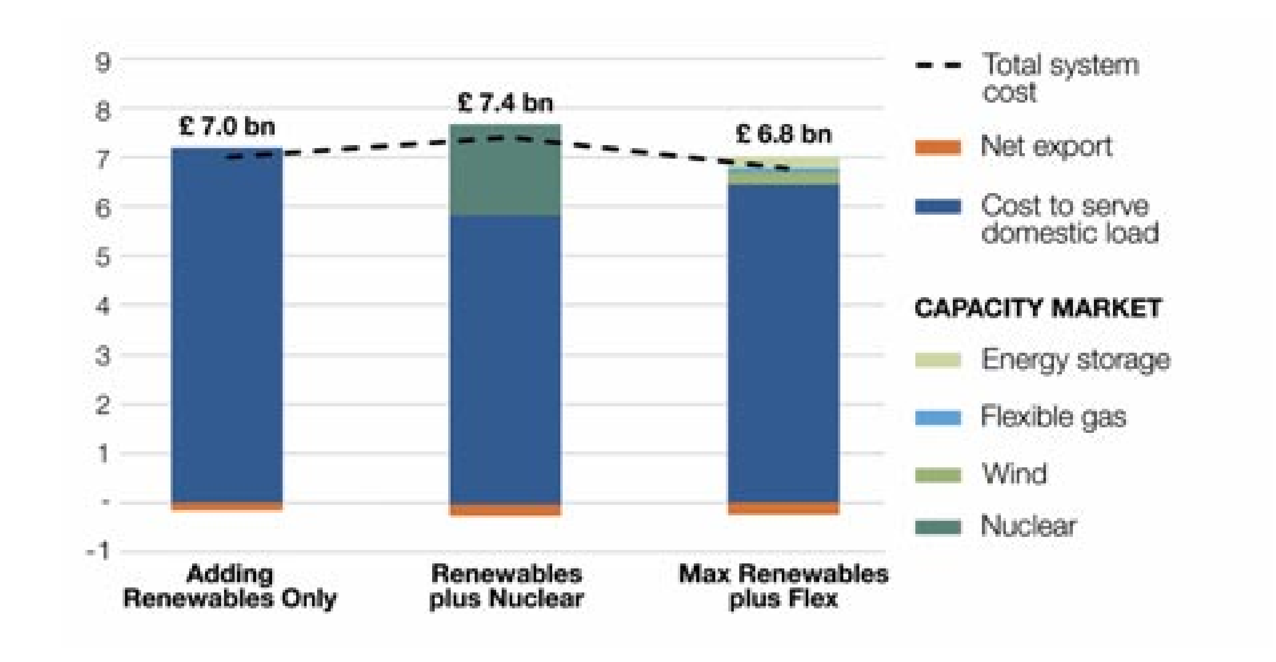
£/kW/year						
	Solar	Onshore wind	Offshore wind	Flexible gas	Energy Storage	Nuclear
Adding Renewables Only	11	12	52	–	–	–
Renewables plus Nuclear	15	21	61	–	–	506
Renewables plus Flex	12	16	57	42	50	–

The Capacity Market

The Capacity Market ensures security of electricity supply by providing a payment for reliable sources of capacity. More renewable power on the system causes spot market prices fall, requiring other forms of new build generation capacity to be subsidised in order to be financially viable.

There are several mechanisms through which this problem can be tackled, including capacity payments, corporate power purchase agreements or additional margins on spot prices. In order to enable like-for-like comparison of the three scenarios, we calculated the additional financial support each technology would require to be viable.

Total Annualised System Cost



Max Renewables plus Flex costs £270 million less per year to deliver than Adding Renewables Only.

This means that by installing new flexibility to support additional renewable generation, it is possible to increase renewable energy to 72 GW by 2030 and reduce the cost of energy for the UK.

In comparison, Renewables plus Nuclear would cost an additional £660 million per year. This is due to the extremely high expected capex cost of new nuclear:

- 7 times more expensive per kilowatt hour than offshore wind.
- 13 times more expensive than onshore wind.
- 11 times more expensive than energy storage.

This cost would ultimately be passed on to consumers.

Anticipated capex cost per technology, based on anticipated cost £GBP/kWh installed capacity 2025-2030.

	Capex (GBP/kW)	Economic lifetime(years)	WACC
Solar	338	20	6%
Wind onshore	540	20	6%
Wind offshore	990	20	6%
Flexible gas	630	20	6%
Energy storage	612	15	6%
Nuclear	6868	20	6%

Calculating Total System Cost

Total system cost combines the cost to serve UK domestic load, net export/import of electricity through existing UK interconnectors (in order to balance supply/demand), and additional capacity market payments needed for generation and flexibility technologies.

The payments are calculated by subtracting the revenue received from the electricity wholesale spot market for power generated from the annualised capex cost of the investment required (GBP/kWh). Calculations for annualised capital expenditure cost were made with a weighted average cost of capital of 6%.

Optimising the Pathway towards 100% Renewable Energy

Of the scenarios modelled, Max Renewables plus Flex offers the best prospect for the UK to accelerate its transition to a high renewables system over the coming decade. Combining new renewables generation with significant flexible energy capacity would enable more renewables, less carbon emissions and all for a lower total cost of energy – saving £270 million every year by 2030, when compared with Adding Renewables Only.

The Max Renewables plus Flex scenario also has significant long-term benefits, future-proofing the UK's electricity system and supporting an accelerated transition towards much greater levels of renewable power and wider economic decarbonisation.

In contrast, Renewables plus Nuclear would add £660 million per year to the cost of energy by 2030. As nuclear must run 24/7 to recoup its investment costs and its lack of flexibility means it continues generating during periods of high renewable output and low demand, it creates further potential costs to export power or curtailment charges to stop renewable generation. With a multi-decade lifecycle, this would significantly affect the UK's ability to achieve 100% renewable energy before 2050.

Indeed, even without new nuclear, the nature of the current UK electricity system makes the economic shift beyond 60% renewables challenging. As we move into this decade, there must be an engaged discussion on the potential to decommission more inflexible baseload generation. In the past six months we have seen substantial payments having to be made to existing baseload generators to ensure system stability during the Covid-19 crisis. As more renewables come on stream, such costly 'firefighting' will only increase, if we do not take action today.

Covid-19 has provided a rare opportunity to realign priorities. The UK must ensure it is making the right choices today to enable long-term decarbonisation. Government and industry must focus on the most effective and cost-optimal pathway to achieving net-zero.

This report is based on today's energy system. But change is coming, fast. A surge in electrification, digitalisation and decentralisation is expected over the coming decade, which will further drive decarbonisation.

If we can achieve 60%+ renewable energy with the system as it is today, then with the right investment to create more flexible systems, countries can and should set an even bolder ambition to achieve at least 80% renewable energy by 2030.

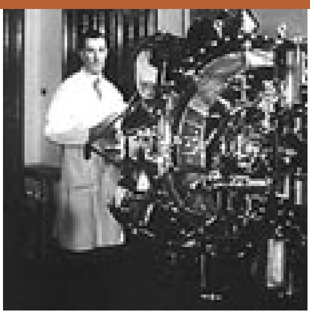
This will underpin economic growth, achieve net-zero carbon emissions, and create a better world for us all.

The UK is at a fork in the road. It can either:

- Maintain the status quo resulting in a less resilient, lower renewables system,
- Install new large-scale inflexible generation that could increase costs and limit the long-term transition to renewables, or
- Focus on greater renewable generation combined with flexibility to accelerate the transition without adding cost to consumers. ■

Saturday 15th May 2021 marks 80 years since the first flight of the British Jet Engine

Heritage News



Saturday 15th May is a significant date in aviation history, for it was on this day 80 years ago that Sir Frank Whittle's Jet Engine made its first flight, at RAF Cranwell, near Sleaford in Lincolnshire. There, eighty years ago Whittle's first engine, the Power Jet W.1, fitted to the British aircraft Gloster E.28/39 airframe, made its first test flight on 15th May 1941, flown by Gloster's Chief Test Pilot, Flight Lieutenant Gerry Sayer, in a flight lasting 17 minutes.

Experience with the E.28/39 paved the way for Britain's first operational jet fighter aircraft, the Gloster Meteor. The Meteor was powered by the Rolls-Royce Welland engine, which was the next stage in development from the Power Jets W.1.

The Jet Engine has a strong connection with the North West of England. In 1943, Frank Whittle's engines for the RAF's first jet fighters were built at the Rolls-Royce plant (initially Rover), in Barnoldswick, Lancashire, which gave the initials RB — Rolls Barnoldswick — to generations of the company's jet engines. Jet Engine components are still manufactured at the two Rolls-Royce sites in Barnoldswick today.

Below is a link to a short film 'The Wonder Jet'. The film follows Air Commodore Sir Frank Whittle. Sir Frank plays himself in the film. It moves from his days as a young Royal Air Force (RAF) cadet struggling against all obstacles to realise his dream of the jet engine. ■

https://www.nationalarchives.gov.uk/films/1945to1951/filmpage_twj.htm

Film: Crown copyright – used by permission.