

The United Kingdom: Energy Transition, Trade, and Economic Pathways

Submitted by

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Chapter 1

Introduction

The United Kingdom is a country in northwestern Europe made up of four constituent parts: England, Scotland, Wales, and Northern Ireland. It is located on the British Isles and is surrounded by the Atlantic Ocean, the North Sea, the English Channel, and the Irish Sea. The United Kingdom has a parliamentary constitutional monarchy, with a king as the head of state and a prime minister as the head of government.

The country has one of the world's largest economies, combining free market principles with government regulation. It is highly developed and known for its global influence in finance, trade, science, technology, culture, and education. The economy is diverse, with strong industries in services, manufacturing, pharmaceuticals, aerospace, and energy.

The United Kingdom is also a significant player in the global energy sector, with natural gas, nuclear power, and a rapidly growing renewable energy industry, particularly offshore wind. It has set ambitious goals for reducing greenhouse gas emissions and achieving net zero by 2050.

The country is renowned for its high standard of living, strong institutions, and rich cultural heritage. It consistently plays an important role in international affairs and is recognized as one of the leading nations in terms of economic prosperity, innovation, and sustainability.

1.1 Population and Land

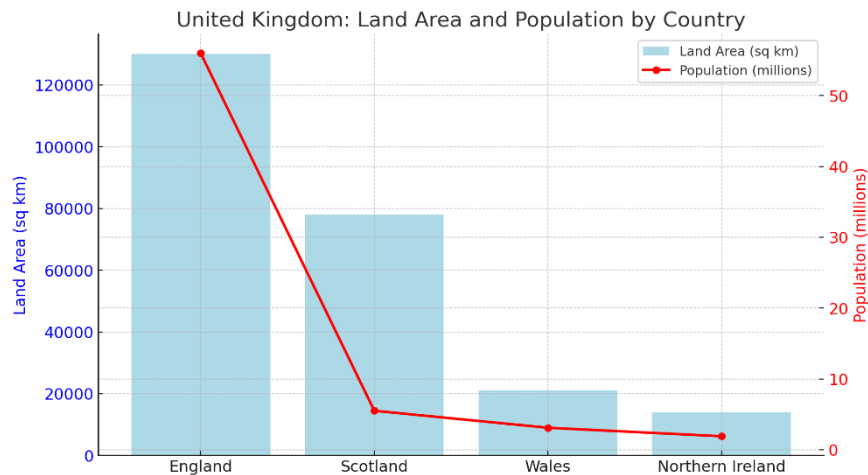


Figure 1.1: Land Area and Population

The land area and population of the four countries that make up the United Kingdom. England has by far the largest population, around 56 million people, while Scotland, Wales, and Northern Ireland have much smaller populations. In terms of land area, Scotland is the second largest after England, but it has a relatively low population compared to its size. Wales and Northern Ireland are both smaller in land area and population. This shows that England is the most densely populated part of the United Kingdom, while Scotland has large areas of land with fewer people.

1.2 Education

Education in the United Kingdom is well developed and highly regarded around the world. It is compulsory for children between the ages of 5 and 16, with many continuing to further education until 18. The system is divided into primary, secondary, further, and higher education. The country is home to some of the world's most prestigious universities, such as the University of Oxford and the University of Cambridge, along with many other well-known institutions. The UK attracts a large number of international

students each year, making education one of its important sectors both culturally and economically.

The structure is based on three main levels of study:

- Undergraduate Degrees – The most common qualification is the bachelor's degree, which usually takes three years in England, Wales, and Northern Ireland, and four years in Scotland. Some courses may include a placement year or study abroad option.
- Postgraduate Degrees – After completing an undergraduate degree, students may pursue a master's degree (typically one year full-time) or a doctoral degree (PhD), which usually takes three to four years.
- Vocational and Professional Qualifications – In addition to academic degrees, higher education institutions also offer diplomas, certificates, and professional training programs linked to careers in fields such as law, medicine, engineering, and business.

The UK higher education system is known for its high academic standards, strong research output, and international recognition. Universities such as Oxford, Cambridge, Imperial College London, and many others rank among the best globally. The sector is also a major destination for international students, contributing significantly to the UK's economy and cultural diversity.

Chapter 2

Economic Overview of UK

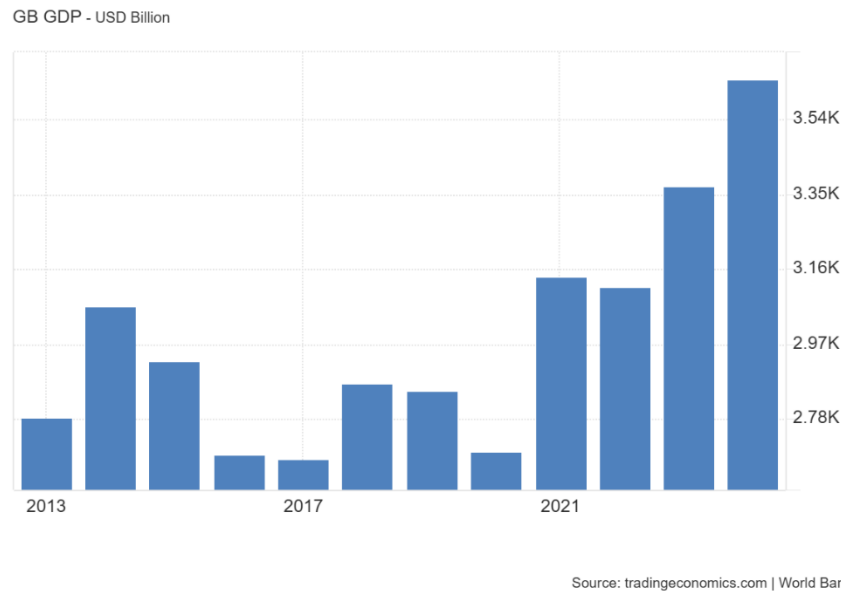


Figure 2.1: GDP STATS

Gross Domestic Product (GDP) of the United Kingdom in USD billions from 2013 to 2023. After fluctuations between 2013 and 2019, GDP dipped around 2020, largely due to the impact of the COVID-19 pandemic. From 2021 onwards, the UK economy rebounded strongly, with GDP rising steadily. By 2023, GDP reached its highest level in the period shown, exceeding 3.5 trillion USD, highlighting significant economic recovery and growth.



Figure 2.2: GDP PER Capita

The chart shows the GDP per capita of the United Kingdom in USD from 2013 to 2023. Overall, GDP per capita increased steadily from around 43,000 USD in 2013 to over 47,000 USD in recent years. There was a sharp dip in 2020, reflecting the economic impact of the COVID-19 pandemic, but it quickly recovered in 2021 and has since remained strong. By 2023, GDP per capita was close to its highest levels, highlighting resilience and steady growth in individual economic output.

2.1 Industrialization

Primary Sector: Extraction of Natural Resources

The primary sector plays a relatively small but essential role in supporting the UK's renewable energy economy. Although primary industries such as agriculture, forestry, and mining contribute less than 1% to UK GDP, they provide the land, biomass resources, and in some cases raw materials required for renewable projects. For example, large areas of land are used for onshore wind and solar farms, while biomass crops and forestry residues support bioenergy production. Although the UK imports most of its rare earth minerals for turbines and batteries, domestic resource management and recycling initiatives are becoming increasingly important.

Secondary Sector: Manufacturing & Industry

The secondary sector has a far greater influence, as it encompasses the manufacturing, processing, and construction activities that underpin renewable infrastructure. The UK has established major offshore wind hubs in regions such as Teesside and Hull, which manufacture turbine blades, foundations, and related components. Construction companies are heavily involved in building wind farms, solar parks, and emerging hydrogen production plants. This sector contributes around 17–18% of national GDP, with renewable electricity generation alone valued at about £14.5 billion in 2025. The expansion of manufacturing and construction linked to renewables has also brought significant regional investment and thousands of skilled jobs.

Tertiary Sector: Services & Knowledge Economy

The tertiary sector remains the dominant driver of the UK's renewable economy, reflecting the overall service-based structure of the national economy. Contributing around 80% of GDP, this

sector includes finance, consultancy, R&D, and energy supply services. London has positioned itself as a global hub for green finance, channelling billions into offshore wind and solar projects. Consultancy, engineering, and legal services support planning, compliance, and innovation, while universities and research institutes lead on developing next-generation technologies such as energy storage and carbon capture. Retail energy companies also play a central role in distributing renewable electricity to homes and businesses. In 2022, the low-carbon and renewable energy economy generated £69.4 billion in turnover and supported more than 272,000 jobs, underlining the scale of the sector’s contribution.

2.2 Exports and Imports

2.2.1 Major Exports

Rank	Export Category	Export Value (USD, 2024)
1	Machinery, nuclear reactors, boilers, mechanical appliances	\$ 84.9 B
2	Pearls, precious stones, metals, coins (incl. gold, jewelry)	\$ 81.5 B
3	Vehicles (excluding railway/tramway	\$ 48.2 B
4	Mineral fuels, oils, distillation products	\$ 34.7 B
5	Electrical & electronic equipment	\$ 29.9 B
6	Pharmaceutical products	\$ 27.5 B
7	Optical, photographic, technical & medical apparatus	\$ 21.9 B
8	Commodities not specified by kind	\$17.55 B
9	Aircraft & spacecraft	\$ 15.86 B
10	Plastics and plastic articles	\$ 11.73 B

Table 2.1:UK Top 10 Exports by Value

The United Kingdom’s exports are dominated by high-value manufactured goods, precious metals, and advanced technology. In 2024, the top export categories included machinery and mechanical appliances (\$84.9 billion), precious metals and stones such as gold and jewellery (\$81.5 billion), and vehicles (\$48.2 billion). Other significant export items were mineral fuels, electrical equipment, pharmaceuticals, and aircraft. These exports reflect the UK’s strength in engineering, financial services linked to commodities trade, and pharmaceuticals, while also underlining the importance of its aerospace and automotive industries in global markets.

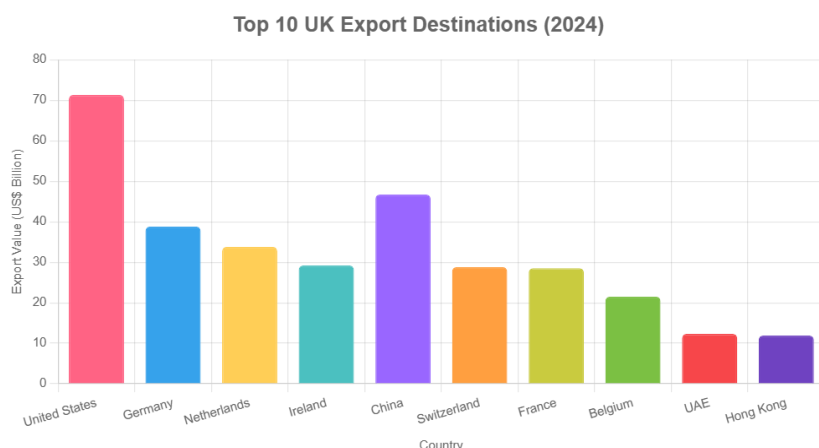


Figure 2.3: UK's Top 10 Export Sources

2.2.2 Major Imports

Rank	Import Category	Import Value (USD, 2024)
1	Machinery (including computers, nuclear reactors, boilers)	\$ 95.2 B
2	Precious stones & metals (gems, gold, jewelry)	\$ 92.8 B
3	Vehicles (excluding railway/tramway)	\$ 89.1 B
4	Mineral fuels (incl. crude oil, petroleum products)	\$ 81.7 B
5	Electrical machinery & equipment	\$ 72.2 B
6	Commodities not specified by kind	\$ 30.4 B
7	Pharmaceutical products	\$ 30.0 B
8	Optical, photographic, medical apparatus	\$ 23.7 B
9	Plastics & plastic articles	\$ 19.8 B
10	Aircraft & spacecraft	\$ 14.6 B

Table 2.2:UK Top 10 Imports by Value

The UK's imports in 2024 were led by machinery (\$95.2 billion), precious metals (\$92.8 billion), and vehicles (\$89.1 billion), alongside significant imports of mineral fuels, electrical equipment, and pharmaceuticals. This reflects the UK's reliance on global supply chains for high-tech goods and energy, while reinforcing its role as a key European trade hub. These imports also highlight the country's need to balance industrial demand with consumer needs. Looking ahead, reducing dependency on volatile global markets could strengthen the UK's economic resilience.

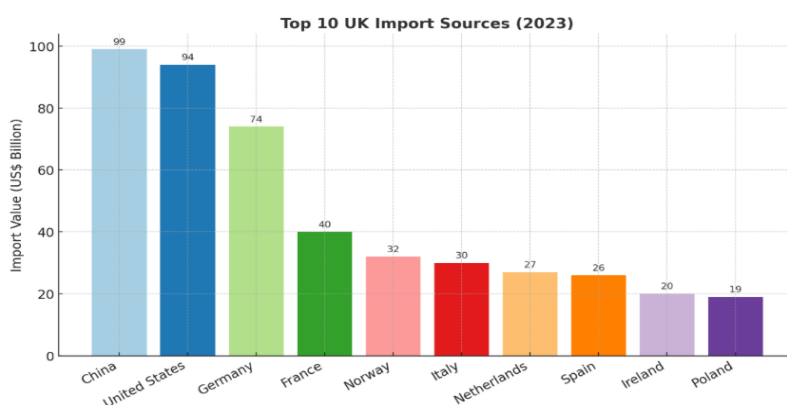


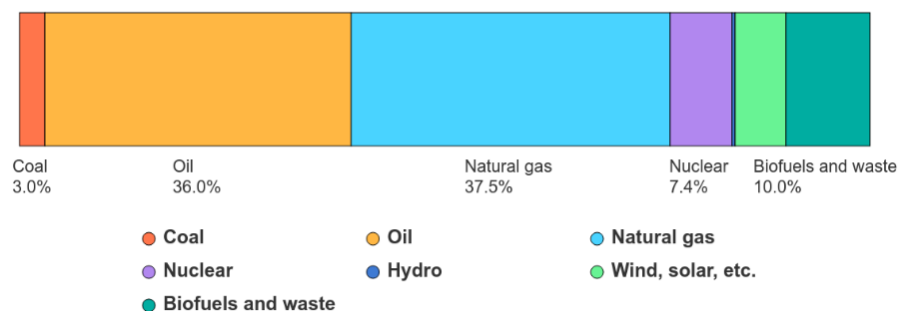
Figure 2.4: UK's Top 10 Import Sources

Chapter 3

Energy sector

The UK has set legally binding climate targets to reach net-zero greenhouse gas emissions by 2050, positioning itself as a leader in the global energy transition. Historically reliant on coal, the UK has undergone a rapid shift toward cleaner sources, phasing out nearly all coal generation and making renewables the backbone of its electricity system. Wind power, both onshore and offshore, has become the dominant renewable, supported by solar, nuclear, and biomass. Affordable and expanding clean energy sources have enabled the UK to reduce carbon intensity significantly while maintaining energy security. At the same time, as a country still dependent on natural gas for heating and part of electricity generation, the UK faces challenges in balancing energy affordability, security, and decarbonisation. With strong policies, investment in offshore wind, and grid expansion projects, the UK has the potential to lead Europe in large-scale renewable deployment and clean technology innovation.

Total energy supply, United Kingdom, 2023

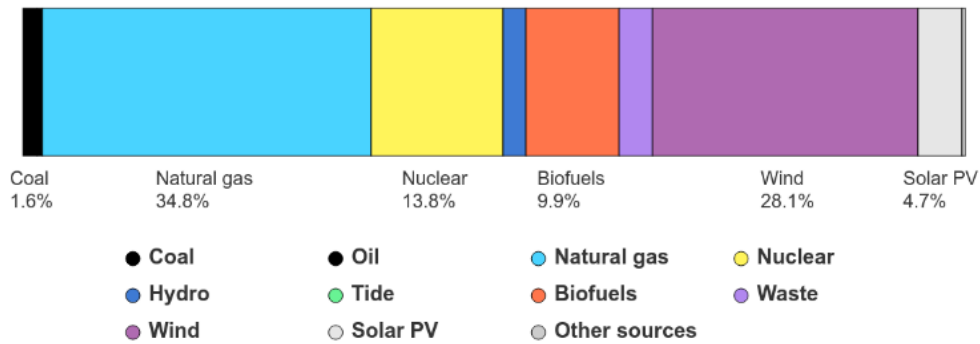


Source: International Energy Agency. Licence: CC BY 4.0

Figure 3.1 :Total Energy Supply

The electricity supply mix of the United Kingdom is dominated by natural gas (37.5%) and oil (36%), together making up nearly three-quarters of the total generation. Coal contributes only 3%, reflecting its near phase-out, while nuclear power (7.4%) and biofuels and waste (10%) provide important low-carbon alternatives. This mix shows that although fossil fuels still play a major role, the UK is steadily moving towards cleaner sources, reducing coal use and increasing reliance on nuclear and bioenergy to support its energy transition goals.

Electricity generation, United Kingdom, 2023



Source: International Energy Agency. Licence: CC BY 4.0

Figure 3.2: Total Electricity Generation

This chart shows the composition of electricity generation by source. Natural gas leads with 34.8%, followed by wind at 28.1% and nuclear at 13.8%. Renewable sources like wind, solar PV (4.7%), biofuels (9.9%), and waste (3.6%) together make up a significant portion, reflecting the growing shift toward cleaner energy. Coal contributes minimally at 1.6%, highlighting the decline of traditional fossil fuels in the energy mix.

3.1 Renewable Energy in UK

The UK has emerged as a leader in renewable energy, with renewables now providing nearly half of the country's electricity. In 2024, wind power became the largest single source, generating about 30% of total electricity, followed by solar, biomass, and hydropower, which together contribute around 12–13%. This growth has been supported by strong government policies and investment frameworks, including the Energy Act 2023 and the Great British Energy Act 2025, which created a state-owned energy company to accelerate clean energy deployment. The UK has set ambitious goals of reaching 50 GW of offshore wind by 2030, 70 GW of solar by 2035, and 24 GW of nuclear by 2050, with an overall aim of delivering 95% carbon-free electricity by 2030.

Economically, the renewable and net-zero sector has become a driver of growth, adding £83 billion to the UK economy in 2024 and expanding at more than 10% annually. Public support is also very strong, with more than four out of five people backing renewable technologies such as solar, offshore wind, and tidal energy. Together, these advances show that the UK is not only reducing its reliance on fossil fuels but also positioning itself as a global leader in the transition to a low-carbon economy.

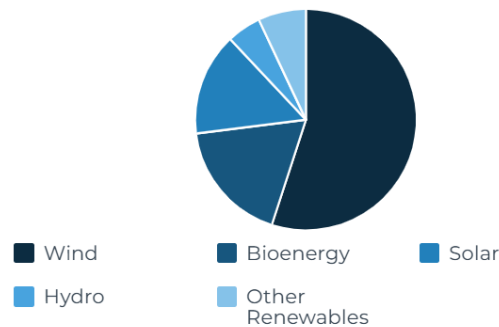


Figure 3.3: Electricity Generation from Renewables

3.3 Net Zero Transition

The UK has committed to reaching net-zero greenhouse gas emissions by 2050 and is among the first major economies to enshrine this target into law. The transition is being driven by a rapid expansion of renewable energy, with wind, solar, and biomass now supplying almost half of the country's electricity, and nuclear energy providing a stable low-carbon share. In 2024, the UK recorded its cleanest electricity mix ever, with 58% coming from low-carbon sources. Government policies such as the Energy Act 2023 and the Great British Energy Act 2025—which created a state-owned clean energy company backed by £8.3 billion—are accelerating investments in offshore wind, solar power, hydrogen, and carbon capture. Ambitious targets include 50 GW of offshore wind by 2030, 70 GW of solar by 2035, and 24 GW of nuclear by 2050, with the aim of ensuring 95% carbon-free electricity by 2030.

Beyond energy, the net-zero strategy covers decarbonising transport, industry, and heating, while supporting innovation in emerging technologies. The net-zero economy added £83 billion to the UK economy in 2024, growing by over 10% in a single year, and is creating thousands of green jobs across the country. Public support for the transition remains strong, with more than 80% of people backing renewable energy. However, challenges remain, particularly with grid connection delays, planning obstacles, and balancing rising demand with supply. Despite these hurdles, the UK is positioning itself as a global leader in the low-carbon transition and is on track to make its economy more sustainable and resilient for the future.

3.3.1 Plans for Achieving Net Zero in UK

The UK government has set out a comprehensive roadmap to achieve net-zero emissions by 2050, focusing on clean energy expansion, efficiency improvements, and innovation. A central goal is to deliver 95% carbon-free electricity by 2030, driven by massive investments in renewables, including 50 GW of offshore wind, 70 GW of solar capacity by 2035, and 24 GW of nuclear by 2050. To complement this, policies are promoting the development of green hydrogen, carbon capture and storage (CCS), and flexible energy systems to balance supply and demand. In addition to the power sector, the UK plans to decarbonise transport by phasing out new petrol and diesel car sales by 2035, expanding electric vehicle (EV) infrastructure, and supporting public and low-carbon transport. Buildings and heating will transition through wider adoption of heat pumps, energy efficiency upgrades, and the gradual replacement of gas boilers. Heavy industry will be supported by hydrogen and CCS, while agriculture and waste sectors will adopt low-carbon practices. These measures are backed by major legislation such as the Energy Act 2023 and the Great British Energy Act 2025, alongside financial incentives and partnerships with private industry.

Together, these plans aim not only to cut emissions but also to boost green jobs, attract investment, and strengthen energy security, making the UK a global leader in the net-zero transition.

Chapter 4

Renewable Energy Regulation in UK

4.1 OFGEM-Office of Gas and Electricity Markets

The regulation of renewable energy in the UK is overseen by Ofgem (the Office of Gas and Electricity Markets), which ensures fair competition, protects consumers, and promotes investment in clean energy. Working alongside the Department for Energy Security and Net Zero (DESNZ), Ofgem manages key schemes such as the Contracts for Difference (CfD) to support renewable projects and plays a central role in driving the UK's transition towards a reliable, affordable, and low-carbon energy system.

Ofgem plays a crucial role in the UK's energy sector by regulating the electricity and gas markets, ensuring that energy is delivered securely, fairly, and at the lowest possible cost to consumers. It promotes competition, sets price controls, and enforces standards for energy companies. Importantly, Ofgem also drives the transition to net zero by supporting renewable energy investment, managing incentive schemes like the Contracts for Difference (CfD), and enabling upgrades to the grid to integrate more clean power sources.

4.2 Energy Act 2023

The Energy Act 2023 provides the UK with its most comprehensive framework for achieving net zero, covering carbon capture and storage (CCUS), low-carbon hydrogen, and renewable expansion. It establishes Ofgem as regulator for CO₂ transport and heat networks, creates the Independent System Operator (ISOP) for holistic energy planning, and gives legal clarity to electricity storage. The Act also streamlines offshore wind approvals, launches Great British Nuclear (GBN) to support new nuclear projects, and promotes smart meters, heat pumps, and energy-efficient appliances. Overall, it is designed to unlock over £100 billion of private investment and generate nearly 480,000 green jobs by 2030, while strengthening the UK's clean energy transition

4.3 Renewable Obligation

The Renewables Obligation (RO), introduced in 2002, required UK electricity suppliers to source an increasing share of power from renewables such as wind, solar, hydro, and biomass.

Generators were issued Renewables Obligation Certificates (ROCs), which suppliers used to prove compliance or otherwise contributed to a buy-out fund. Money from this fund was redistributed to suppliers meeting their obligations, creating a financial incentive for renewable investment.

The RO played a crucial role in scaling up large renewable projects, especially onshore and offshore wind farms. It provided long-term revenue certainty that encouraged private sector investment. In 2017, the scheme closed to new entrants and was replaced by the Contracts for Difference (CFD) mechanism, which offers price stability for renewable generators. However, projects accredited before closure continue to receive ROCs for up to 20 years, ensuring ongoing support for clean energy.

4.4 Energy Company Obligation

The Energy Company Obligation (ECO) is a UK government energy efficiency scheme, regulated by Ofgem, that places legal obligations on larger energy suppliers to help households reduce carbon emissions and tackle fuel poverty. Introduced in 2013, it requires suppliers to fund and deliver measures such as insulation, efficient heating systems, and low-carbon technologies in homes. The scheme is mainly targeted at vulnerable, low-income, and fuel-poor households to lower energy bills while cutting greenhouse gas emissions. Now in its fourth phase, ECO4 (2022–2026), the programme is aligned with the UK's net zero goals and focuses on whole-house retrofits, aiming to improve energy performance and reduce reliance on fossil fuels.

4.5 Feed in Tariff

The UK's Feed-in Tariff (FiT) scheme, launched in 2010, encouraged small-scale renewables like solar, wind, hydro, and micro-CHP by paying households and businesses for electricity generated and exported to the grid. It boosted uptake by providing steady income and making renewables more attractive. Although closed to new applicants in 2019, existing participants still receive payments for up to 20–25 years.

It provided financial incentives through two main tariffs:

1. Generation Tariff – Paid to households, businesses, or organisations for every unit (kWh) of electricity they generated from eligible renewable sources, whether they used it

themselves or not.

2. Export Tariff – An additional payment for surplus electricity exported back to the national grid.

4.6 Support by Government to Energy Sector

The UK supports its clean energy transition through schemes like ECO4 and the Great British Insulation Scheme, funding efficiency upgrades in millions of homes. The Boiler Upgrade Scheme offers grants for heat pumps and biomass boilers, while the Public Sector Decarbonisation Scheme invests £2.4 billion to cut emissions from public buildings. Alongside the Clean Flexibility Roadmap, these programs lower bills, boost renewables, create green jobs, and drive progress toward net zero by 2050.

These initiatives also promote innovation in energy efficiency, encourage wider adoption of low-carbon heating, and strengthen energy security. By reducing waste and supporting flexible energy use, they help households save while easing grid pressures. Together, they ensure a fair, affordable, and sustainable energy transition for the UK, while building long-term resilience. They also position the UK as a global leader in clean energy solutions.

4.7 Support by Government to Consumers

The UK government also offers a range of direct supports to help households manage energy costs and transition to cleaner heating. The Warm Home Discount (WHD) provides an annual £150 rebate on electricity bills for low-income and vulnerable households, extended through 2025/26 to cover nearly 3 million people. The Household Support Fund, running until March 2025, enables councils to provide financial assistance for essentials like energy, food, and water. Alongside this, the smart meter rollout is being expanded with stronger consumer protections, while a proposed £200 annual bill discount for heat pump users complements grants like the £7,500 Boiler Upgrade Scheme. Additional help comes through regional bill support and one-off payments, with some households receiving up to £500 or aid in replacing old heating systems and managing energy debts. Together, these measures aim to reduce fuel poverty, protect vulnerable groups, and accelerate the UK's shift toward low-carbon energy use.

4.8 Innovations and emerging energy trading methods in the UK

1. Peer-to-Peer (P2P) Energy Trading & Community Platforms

UrbanChain (Manchester): Uses AI and blockchain to let small-scale renewable producers trade directly with consumers, bypassing utilities. OFGEM-licensed and expanding globally .Verv (London): Completed the UK's first physical blockchain-based energy trade in Hackney, enabling residents to trade surplus solar locally. Project CommUNITY (EDF & UCL): Pilots rooftop solar trading in Brixton using blockchain, allowing neighbours to buy and sell clean energy within their community. These platforms decentralize energy markets, increase renewable adoption, and empower communities to manage local electricity flows.

2. Local Energy Markets & Virtual Power Plants (VPPs)

Orkney Blockchain Market: Enables generators, storage, and EVs to trade energy locally, reducing renewable curtailment in high-generation areas. Piclo Flex: A digital flexibility marketplace where participants trade energy flexibility to ease network congestion and support DNO operations .Virtual Power Plants (VPPs): Aggregate batteries and solar units to act as a single provider, e.g., Power Vault in London or Tesla + Octopus Energy for households.

These solutions optimize distributed energy, balance supply-demand, and create revenue opportunities for small-scale producers.

3. Innovative Tariffs & Demand Flexibility

Octopus Energy Tariffs: Tracker (daily wholesale prices), Agile (half-hourly dynamic pricing), Go (off-peak EV charging) incentivize flexible consumption. Demand Flexibility Service (DFS): Pays households to reduce peak consumption, rewarding flexibility and supporting grid stability. Dynamic tariffs and flexibility programs align consumer behaviour with grid needs, reduce costs, and encourage renewable use .They transform consumers into active participants in a smarter, more efficient energy system.

4. Market Reform & Future Pricing Models

Locational Marginal Pricing (LMP): Sets electricity prices based on real-time local supply-demand, reflecting congestion and losses, used in the US. LMP encourages infrastructure where needed, improves renewable integration, and reduces system-wide costs. By embedding local efficiency into pricing, it complements P2P trading, VPPs, and dynamic tariffs for a flexible, decentralized energy future. It offers a market-driven path to a more resilient, cost-effective, and renewable-friendly electricity system

Chapter 5

Conclusion

The UK energy sector is rapidly transforming as the country moves towards a low carbon future. Coal has almost disappeared from electricity generation, replaced by gas, wind, solar, nuclear, and biomass as the main energy sources. The Energy Act 2023 and Ofgem's regulatory role provide a clear framework for decarbonisation, while government schemes like the Energy Company Obligation (ECO4), Boiler Upgrade Scheme, Warm Home Discount, and the Great British Insulation Scheme support households and encourage renewable energy adoption. These policies aim to cut emissions, improve energy efficiency, and protect low income and vulnerable households from rising costs.

At the same time, the UK has developed one of the most innovative electricity markets in the world. New methods such as peer to peer energy trading, blockchain platforms, virtual power plants, and flexible tariffs are changing the way energy is produced, traded, and consumed. Combined with initiatives like the National Grid's Demand Flexibility Service, these innovations are helping balance the grid while giving consumers a more active role in the energy transition. Together, regulation, innovation, and consumer support are creating a cleaner, fairer, and more sustainable energy system, positioning the UK as a global leader in the net zero transition

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