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ORIGINAL PAPER

An investigation into UK government policy and legislation to renewable energy and greenhouse gas reduction commitments

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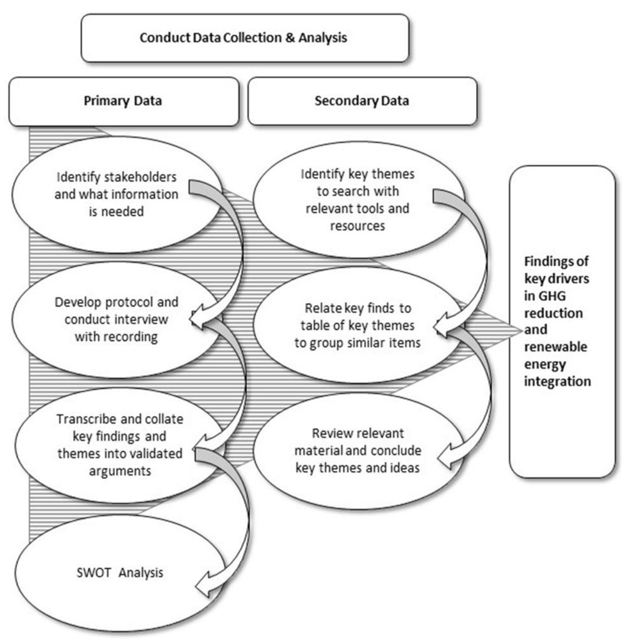
Abstract

The UK has committed to various legally binding targets with regard to renewable energy technology and greenhouse gas reduction. As a result, government policy and legislation have been significant in investing in renewable energy technology, driving innovation since 1990. The aim of this work identifies the key drivers behind commitments and to assess the role of government, business and organisations in the uptake of renewable energy and the development of a decentralised energy network as a result of greenhouse gas emission reduction target. This article presents quantitative analysis of primary research from government and industry. The novel aspect of this investigation is that the conclusive outcomes arise as a result of a unique research method by combining primary and secondary sources with support of company data from Nestlé and Transport for London. The main findings demonstrated that government support is one of the key drivers for innovation into renewable technology; however, business and the public are necessary to bring renewables to market. Strategies have been identified to incorporate decentralised generation into industry for the commitment of renewables and to develop the required energy network of the future.

Graphic abstract



Keywords Renewable energy · Carbon emission reduction · UK infrastructure · Centralised power network · Decentralised network

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Abbreviations

AD	Anaerobic digestion
CDP	Carbon disclosure project
DG	Decentralised energy
DSR	Demand side response
BEIS	Department for Business, Energy and Industrial Strategy
DECC	Department of energy and climate change
ESCos	Energy service companies
EU ETS	EU Emissions Trading System
FiTs	Feed-in-tariffs
GHG	Greenhouse gas
GDP	Gross domestic product
LCOE	Levelised cost of energy
Ofgem	Office of Gas and Electricity Markets
OECD	Organisation for Economic Co-operation and Development
PV	Photovoltaics
PPA	Power purchase agreement
RE100	Renewable Energy 100
RO	Renewables Obligation
SMEs	Small and medium enterprises
STA	Solar Trade Association
SWOT	Strength, Weakness, Opportunity, Threat
TfL	Transport for London
ULEZ	Ultra-low emissions zone
VRE	Variable renewable energy
YoY	Year-on-year

Introduction

With the carbon crises growing in damaging capability, there is the necessity to turn to greener energies and cleaner ways of generating and using power (Ellabban et al. 2014). The carbon footprint is a measure of the exclusive total amount of carbon dioxide emissions that is directly and indirectly caused by an activity or is accumulated over the life stages of a product' (Werdmann and Minx 2008). Government, business and other organisations have their part to play in renewables. Each organisation takes a different approach to tackling the carbon issue, and the motivations behind the actions have been theorised and argued. The renewable industry is growing at a fast pace, and this is predicted to increase over the next ten years (Gielen et al. 2019). The advantages and disadvantages of various methods of energy generation are present in large amounts, and data analysis of this area could help inform investment decisions to drive environmental sustainability and financial savings.

The UK has committed to various legally binding contracts which set out obligation to reduce greenhouse gas (GHG) emissions and implement renewable energy technology. Government cannot implement required changes on their own, but a collective effort is needed. The UK government has set out a plan to 2050 in the Clean Growth Strategy which acknowledges the need for the private sector to bring renewable energy to market (BEIS 2017a).

The UK infrastructure has been built around a centralised power network, with the majority of the energy coming from large fossil fuel power plants connected to a vast transmission network (Kaundinya et al. 2009). The integration of renewable energy technology into the power network will inevitably reduce the UK's dependency on fossil fuel generators. This investigation aims to understand the changes needed to facilitate the power network of the future.

The purpose of this research is to investigate government, business and other organisations commitments and actions in greenhouse gas reduction and renewable energy power generation in the UK. This will provide an understanding of how the UK is collectively combatting climate change and the challenges faced across different sectors. Key aspects will be to critically assess the benefits and challenges of onsite and offsite energy generation, to demonstrate how technologies can be integrated into the UK energy infrastructure most efficiently to provide a recommendation for businesses and government on commitments and direction in renewable energy technology implementation. The layout of this paper is as follows: the background of government policy, legislation and roles of different organisation within the UK are investigated. This follows by the research methodology and case studies. Finally, discussions and conclusion of the research findings are presented.

Relevant literature

Renewable power generation technologies can offer virtually no carbon emissions and are becoming increasingly cost competitive (Simons and Cheung 2016). In 2016, 165 GW renewable power capacity was implemented around the world, which accounted for approximately two-thirds of the total net new power capacity (Ozoemena et al. 2018). This decrease in price has resulted in an increase in renewable generation technologies, particularly in solar photovoltaics (PV) and wind (IEA 2017). The support policies put into place by government and organisations have had a large part to play in renewable production; however, the renewable economy has a direct impact on the rate of acceptance.

A report from the Department for Business, Energy and Industrial Strategy (BEIS) indicates a large decrease in the levelised cost of energy (LCOE) of renewables since the previous 2013 assessment (BEIS 2016a). The report also shows that onshore wind and large-scale solar generation will have a lower LCOE than combined cycle gas turbine generation (BEIS 2016a).

In 2016, coal, oil and gas accounted for 54% of the UK's total energy generation, whilst nuclear supplied 20% and renewable energy supplied 25% (Energy-UK 2017). Many of the coal power stations that were built in the UK are approaching the end of their life, and these stations can be decommissioned or regenerated. Fossil fuel stations can be converted into renewable energy plants with capital investment. Where applicable, renewable technology could potentially replace some of the existing infrastructure; substituting traditional fossil fuel plants with low-carbon alternatives (Mardoyan and Braun 2015).

Between 1990 and 2016, it is estimated that greenhouse gas emissions in the UK have fallen from approximately 800 to 470 MtCO2e. This reduction of over 300 MtCO2e has not been accredited to a single particular source; however, at certain points it may be possible to speculate what the key drivers of the change were.

The UK commitment to carbon reductions is set out in the 2009 EU Renewable Energy Directive (Maroušek et al. 2015), which imposes to achieve 15% of its energy consumption from renewable energy sources by 2020; this includes 30% of all electricity generation to be from renewables (Directive 2009/28/EC 2009). Furthermore, by 2050 the UK has committed to carbon emission reductions of 80%.

Since 2010, Feed-in-tariffs (FiTs) have been in effect and are used to incentivise investment into small scale renewable electricity generation. Generators of less than 5 MW can install renewable generation technology and export energy to the grid which would be viable for payment from the FiT. Between 2010 and 2016, almost 6000 MW of capacity was added and confirmed on the FiT scheme (UK Government 2016), and between 2010 and 2015, there was a 35% reduction in emissions from the power sector, with further predicted success in low-carbon generation for 2020 (BEIS 2016b). However, within the report it identifies that direct savings from some governmental policies are difficult to quantify.

The EU Emissions Trading System (EU ETS 2018) is another policy based on a cap and trade principle which drives emissions down over time and promotes investment in green energy. This policy currently limits emissions from more than 11,000 heavy energy using installations. The EU Climate Action group identifies that 'robust policies at EU and country level and the application of low-carbon technologies have contributed to carbon reductions. Evaluations confirm that innovation on renewable energy and energy efficiency has been the main driver behind the emission reductions in recent years, while the shift between economic sectors has had a marginal effect (European Commission 2017)'.

Business and industrial processes in the UK have accounted for approximately 25% of the total reduction in GHG emissions since the 1990 baseline, with a total reduction of 83.2 MtCO2e across the two sectors (BEIS 2018a). Today, the business and industry sector accounts for over 50% of the electricity used in the UK representing the largest consumption of electricity across all sectors (BEIS 2017b). Energy expenditure contributes to a large proportion of a company's costs, with the average industrial business in the UK spending £7346 on electricity (Business Energy 2018). Energy saving can therefore contribute to cost savings, resulting in higher operating profits. It is estimated that by 2030, £6 billion could be saved through investment in cost-effective energy-efficient technologies (BEIS 2017a).

Environmental sustainability has become part of some leading organisations market strategies. An increase in media attention around climate change and corporate responsibility has been found to have a statistically significant effect on public opinion (Brulle et al. 2012), and corporate social responsibility campaigns have been proven to enhance people perceptions of sponsor image, reputation and credibility (Pfau et al. 2008). This could be an opportunity for corporations to build brand recognition and increase reputation through implementing carbon reduction across the value chain. Jolly (2014) argues that an increase in revenue and expansion of markets is driven by the motivation that a green economy brings. For example, Siemens Real Estate saved approximately £4 million in 2012 through reduced energy costs, reducing emissions by a further 17,000 t of CO_2 (Epstein and Buhovac 2008).

As well as having the potential to increase the uptake of renewable energy generation in the UK, DG (decentralised generation) has been suggested as a key opportunity for UK government to react to the ageing electricity infrastructure and forecast capacity constraints; rather than replacing the centralised infrastructure like for like, there is the opportunity to redesign the infrastructure to incorporate a decentralised network with significant benefits. It is estimated that up to £50 billion may be needed to invest in the UK energy network to provide energy security for a future that has increasing demand for electricity (Strbac et al. 2016). The increased provision of a decentralised network has been explored as an opportunity to reduce the cost of a network capacity upgrade.

DG (also known as distributed energy) differs from the traditional centralised energy network. Rather than large power plants providing the grid with energy which is then transported through transmission cables across the country, a DG network typically consists of a single standing or small array of electricity generation devices between 1 kW and 5 MW which are located close to where the energy is being consumed (Ho et al. 2015). The generator can be connected to the electricity grid to export excess energy for payment (Chmutina and Goodier 2014). Industrial energy users wanting to generate electricity can do so via onsite and offsite energy generation. As previously discussed, energy price volatility is expected to cause an increase in prices and DG has been argued as a way to mitigate the risk of market price fluctuation to provide a stable price and energy security (Carley 2009). Typically, wind, solar, biomass heating and anaerobic digestion have been installed as onsite renewable technologies which can also add benefit to cost savings and energy security (Jolly 2014).

A few challenges exist with onsite DG; for example, high levels of initial investment, time and resource allocation to the project, lack of expertise in energy management and physical footprint of technology (Berkes 2009). Although it may be possible to install an anaerobic digestion (AD) system onsite to provide some of the total energy required in industry, larger operations such as a wind farm will require lots of space and licensing (Maroušek et al. 2018). This has led to some corporations implementing an offsite generation approach.

With an increase in electricity demand and supply, a smart grid could provide support for energy management at a local level, being an ancillary service to demand shifting and renewable DG (DECC 2014). The innovation aims to enable a more flexible system where generators can communicate in real time with consumers, and vice versa, with incentives to use energy away from peak time thus mitigating risk of network congestion (Energy and Climate Change Committee 2016).

Demand side response (DSR) has been identified as a potential to delivering a secure energy future (Ho et al. 2013). DSR can mitigate risk by shifting demand where there are constraints or opportunities within the electricity network (Chen and Yin 2017). The DECC have concluded that the cost of deployment of DSR schemes would be made economically viable (Strbac et al. 2012). It is estimated that in the UK, the DSR potential of industrial and commercial consumers is between 4 and 30% of their corresponding peak demand, totalling 15% of flexible demand resources by 2030 (Imperial College London and Element Energy 2014).

From the literature findings, several knowledge gaps have been identified:

- The UK government has made multiple incentives, both positive and negative, around carbon emissions. There is a need to investigate the effectiveness of government policy and the limitations.
- The key incentives behind renewable energy generation are difficult to place definitively. This research investigated specific organisations committed to renewable energy, identifying the key benefits and incentives of carbon reduction.
- This work also investigated the benefits and challenges of onsite and offsite DG from an industry perspective and offers a conclusion on what strategies could be used to implement DG technologies for business to reduce emissions and benefit financially.
- The benefits and challenges associated with the introduction of a decentralised network and smart grid is being assessed in this research, and conclusions made to help strategic direction for business and industry.

A methodology is needed to investigate these missing elements which are discussed in the following section. The novel aspect of this investigation is that the conclusive outcomes arise as a result of a unique research method by combining primary and secondary sources with support of company data from Nestlé and Transport for London.

Methodology

The research primarily utilises qualitative research from primary and secondary sources to identify key trends and motivations with regard to the key drivers of renewable energy and carbon reduction. This methodology is considered a valid technique when conducting research that is not numerical, but rather verbal and descriptive.

As seen in Fig. 1, the overall approach is divided into two stages, namely primary data and secondary data gatherings:

1. Primary data gathering is used to identify companies of whom are willing to participate in in-depth, one to one interviews. These focus sessions were conducted with multiple professionals working in industry and government.

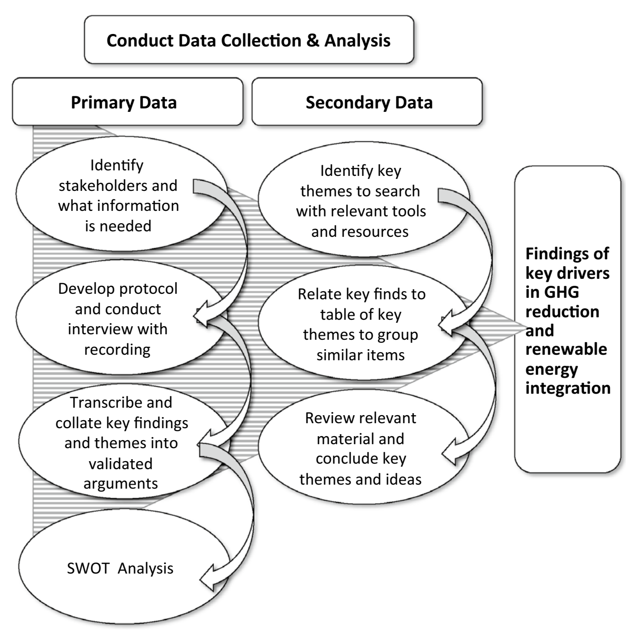


Fig. 1 Research approach

2. Secondary sources were analysed to provide additional views in relation to the research. These sources were used to verify, falsify or contextualise information sourced from primary research (Stewart and Kamins 1993).

Primary research

An exploratory, in-depth interview is appropriate to ascertain detailed information about a person's thoughts relevant to the general aims and objectives of a research topic (Gillham 2005). The interview is used to demonstrate organisation-specific drivers in relation to GHG reduction and renewable energy technology and will distinguish the different views of the various organisations. The process follows a tried and tested method, with the key instrument being the interviewer.

- Identify stakeholders
- Identify potential sources of information—what is needed
- Develop an interview guide that lists questions or issues to be explored during the interview
- Ensure ethical research standards are followed
- Conduct pilot interview to ensure the proposed interview will investigate the research statement effectively
- Set up interviews with stakeholders
- Conduct interview, recording all information electronically
- Transcribe data
- Verify any information necessary through further research
- Analyse data and interpret into report

The interviews were conducted with UK-based companies Nestlé and Transport for London. Each interview takes about 40 min. Role of interviewees ranges from customer and marketing manager, and head of sustainability. Additionally, there was an anonymous interviewee whose role is the chairman of company A.

The advantage of an in-depth interview is the ability to get more detailed data surrounding the topic, from professionals working in the industry. A key disadvantage is that interviewees may be naturally biased towards their organisation due to their stake in the work carried out. Therefore, focus is on open-ended questions around the total environment to try to eliminate bias (Boyce and Palena 2006). It is also key to build up a rapport with the interviewee to get the most valuable information (Given 2008).

A SWOT analysis was used to offer a strategy for business and government in relation to decentralised generation implementation. This initially involved gaining primary research from professionals working in the industry via a general conversation to generate a map of strengths, opportunities, weaknesses and threats. This individual contribution was an attempt to gain a broad range of answers and remove dominant views and bias that could have resulted from a group discussion. Once all answers were mapped, the total list was sent out to the participants to rate each option from 1 to 5, where 5, for example, was an opportunity not to be missed and 1 was an opportunity that was not viable. An average was drawn, and those options above and equal to 3 were identified and put forward. Strategies were then applied to relevant factors. These can be identified in "Appendix".

Secondary research

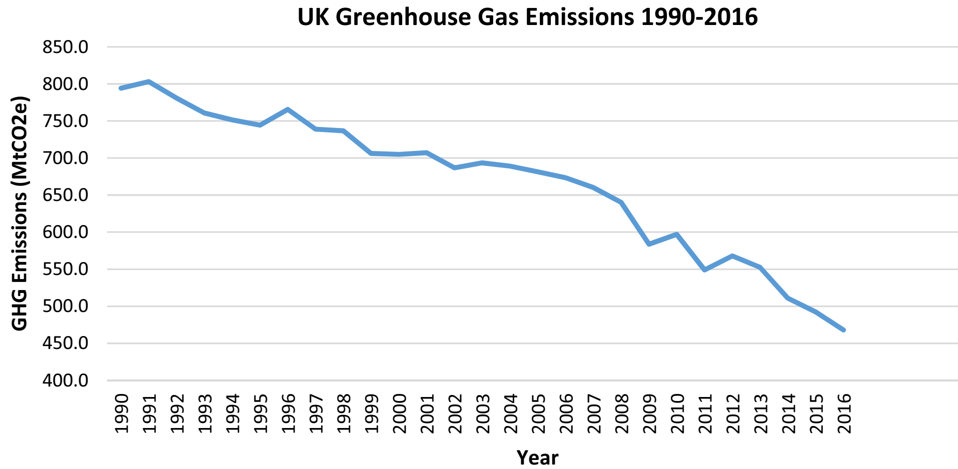
Goodwin (2012) argues that secondary analysis can be used in the absence of, or as a supplement to primary research. Throughout this research, secondary research is used to highlight areas where primary research could offer more insight and also to verify and falsify primary research. Secondary research allows quantitative analysis of the large amount of data including statistical analysis and policy review.

One of the main reasons the proposed method deploys a secondary research approach is because primary research involves the generation of data, whereas secondary research uses primary research as a source for data analysis. Secondary research was from relevant sources including books, journals, articles and reports. Bibliographic databases and search engines were used to explore key themes. Key themes such as renewable obligation for energy generators, comparing emissions in the energy sector, greenhouse gas emissions by sector and these key sources were then added to a spreadsheet which was split into different categories. Each category was then analysed, validated and summarised to present a conclusion within the article. For example, in the next section under "Result and findings", Figs. 3, 4, 5, 6 and 7 are generated from secondary sources used to explore different key themes.

Result and findings

The research in case studies ("The role of UK government" to "The Role of Organisations" sections) is to understand the actions taken by various organisations in the UK to understand the drivers behind GHG reductions and integration of renewable energy technology. The final case study ("Decentralised generation" section) is focussed on decentralised generation in industry, presenting the key benefits and challenges.

Fig. 2 GHG emissions national statistics 1990–2016 (BEIS 2018b)



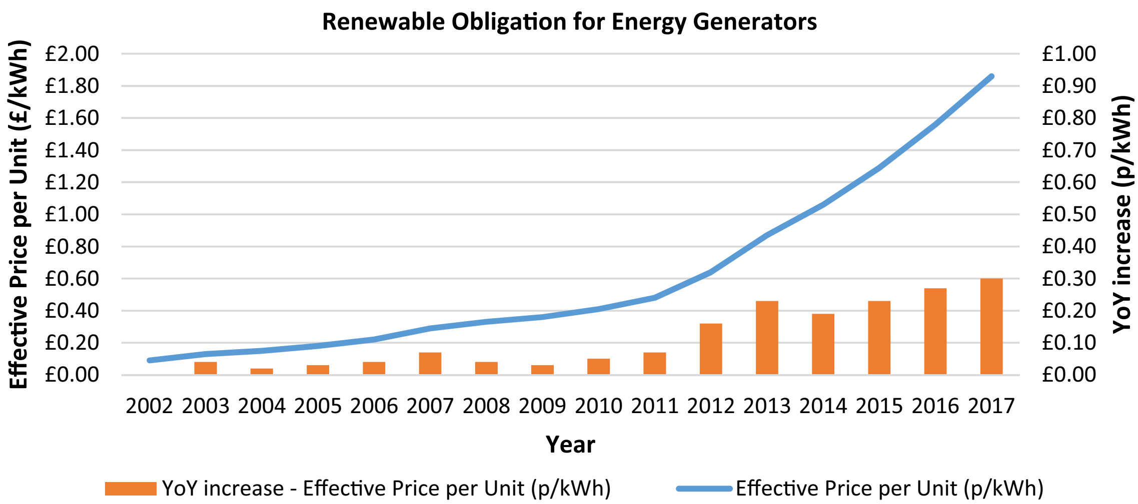


Fig. 3 Buy-out and mutualisation ceiling 2010–2017 (Ofgem 2018)

The role of UK government

Between 1990 and 2008, there was a steady decline in the rate of emissions at approximately 10 MtCO2e per year. As seen in Fig. 2, there is a turning point between 2008 and 2009 where the emissions reduced by 57 MtCO2e. This is most likely due to the economic crises and the subsequent collapse in the economy. The financial crash resulted in the UK gross domestic product (GDP) decreasing by 17.6% and $507 billion resulting in the deceleration of industrial output which would have had a significant effect on GHG emissions (Campello et al. 2010). The trend, however, continues and in between 2009 and 2016 GHG emissions reduce at an average rate of 14.5 MtCO2e per year.

The renewable obligation (RO) was introduced as a UK policy in 2002, and Fig. 3 shows that between 2002 and 2009 the effective price per unit rose by 0.27 £/kWh. Furthermore, from 2009 through to 2017 the effective price per unit rose by 1.04 £/kWh with an average YoY increase of 0.18 £/kWh (Ofgem 2018). Figure 4 shows that the increase in effective unit price has an inverse correlation with respect to the amount of GHG produced by the energy supply sector. In an investigation into the policy of a renewable portfolio standard, Sun and Nie (2015) conclude that schemes such as RO worldwide are effective in reducing carbon emissions.

As seen in Fig. 5, since 1990 the energy supply sector had the largest impact on the reduction of GHGs (BEIS 2018b). This 56% reduction has resulted in 157.7 MtCO2e not being emitted into the atmosphere per year compared with 1990 baseline. The energy supply sector now accounts for 21% of total emissions compared with 34.9% in 1990. Further analysis shows that the biggest YoY reduction in GHG emissions happened between 2012 and 2016 at an average rate of 20.7 MtCO2e per year, compared with the average decrease of 6 MtCO2 per year between 1990 and 2016.

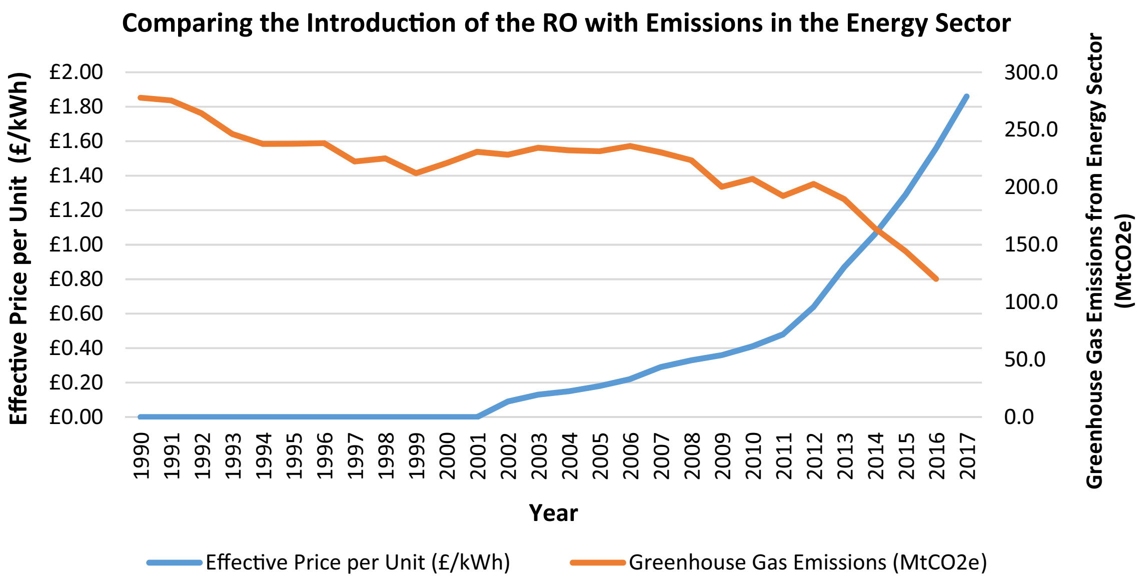


Fig. 4 (RO) buy-out and mutualisation ceiling 2010–2017(Ofgem 2018) and UK GHG emissions 1990–2016 (BEIS 2018a)

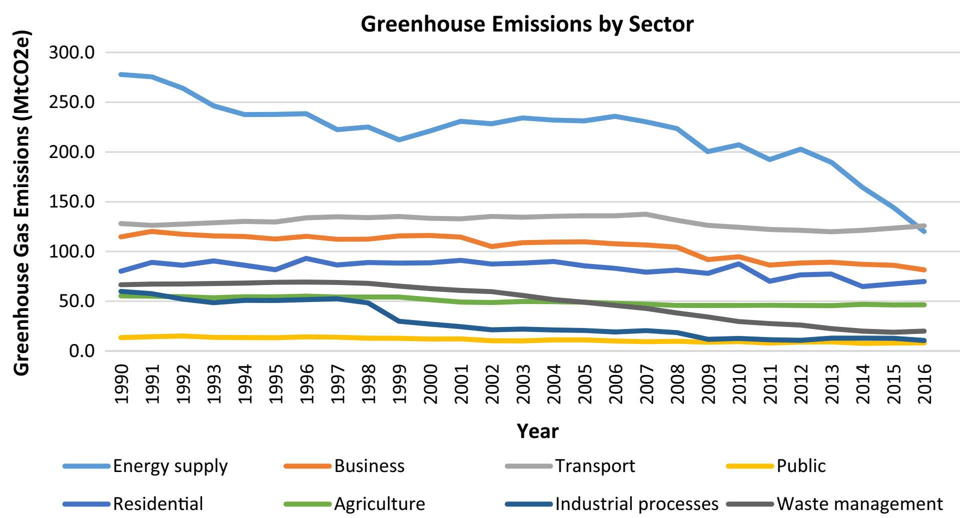


Fig. 5 UK GHG emissions 1990–2016 (BEIS 2018a)

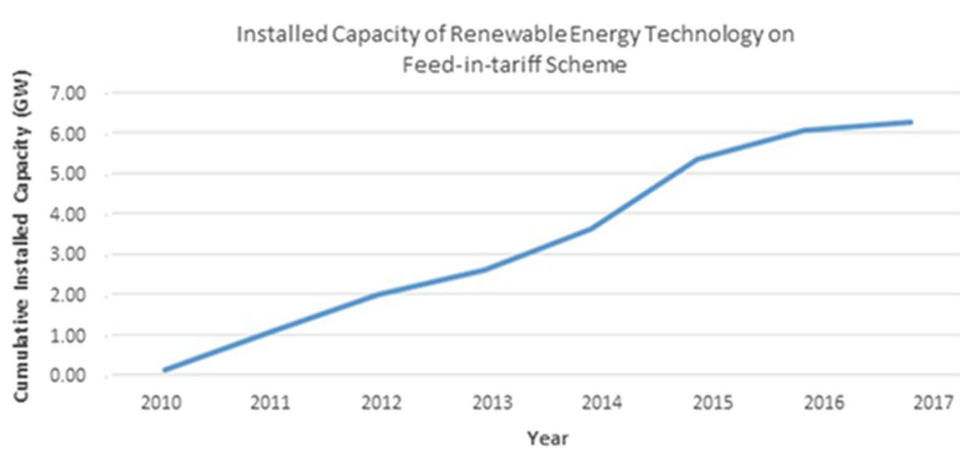


Fig. 6 Feed in tariffs: commissioned installations by month, December 2017 (BEIS 2017a)

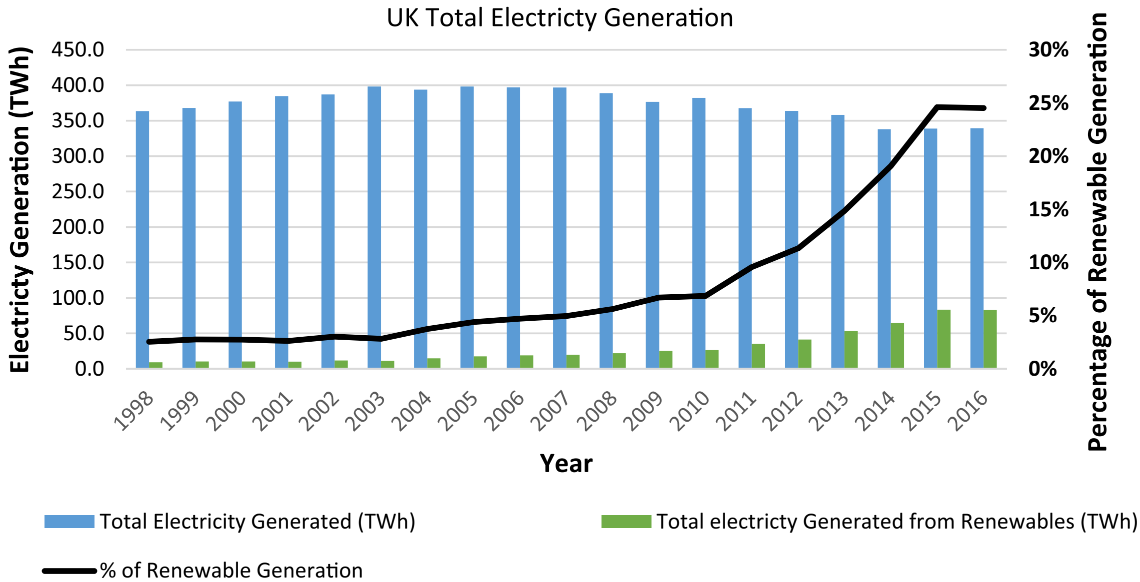


Fig. 7 Fuel used in electricity generation and electricity supplied (BEIS 2018b)

Figure 6 shows that the cumulative capacity commissioned by the FiT scheme rose from 117 MW in 2010 to 6251.7 MW in 2017 resulting in a net increase of 6134.7 MW of capacity in the UK. In 2016, this resulted in 20% of total installed renewable capacity falling under the FiT scheme. Sun and Nie (2015) have identified that FiTs around the world are widely recognised as being a key driver in increasing the amount of installed capacity of renewable energy.

An interview was conducted with Transport for London (TfL) to understand how government organisations are working to reduce GHG emissions. It was discussed in the interview that the implementation of the ultra-low emissions zone (ULEZ) in London is scheduled for 2019 which will aim to incentivise low-emission vehicles with the aim to reduce pollution from cars in the capital. Benefits will be a cleaner London and will showcase the UK as a leader in GHG emission reduction incentives.

With the transport sector now accounting for the largest percentage of GHG emissions of any sector, TfL, amongst other organisations, is implementing changes to combat climate change. TfL commented that "Climate change is the number one issue impacting transport in the UK and around the world today. In London, we want eighty per cent of all journeys to be made by foot, walking, running, cycling or public transport and all new road vehicles driving in London to be zero emission by 2040".

At the end of 2016, 25% of total electricity generation in the UK was met by renewable energy technology as shown in Fig. 7. In order to meet the 2020 target of 30%, another 18.8 TWh of electricity generation will be needed assuming demand stays same. Members of Parliament on the climate change committee reportedly warned that the UK, at its current rate, is likely to fail in its 2020 commitments (Cowburn 2017).

One key issue that has been argued is that policy needs to be focussed on broader investment conditions (OECD 2017). The Organisation for Economic Co-operation and Development (OECD) have highlighted that lack of a financial framework around climate change investment has led to a difficult market to drive change (Ang et al. 2017). Changes to banking regulations over the last decade have meant long-term debt financing has been more difficult to secure which affects funding of capital investment into renewable projects. The UK government responded to this issue by initiating the setup of the Green Investment Bank in 2012. In 2016, £770 million was committed for capital investment, resulting in 30 projects being financed. In 2016, this resulted in an additional 13,428 GWh potential generation in the UK (The Green Investment Bank 2016).

BEIS presented The Clean Growth Strategy in 2017 (BEIS 2017a), which sets out the plan for clean economic growth up to 2050. Between 2015 and 2021, the government has committed to invest £2.5 billion in low-carbon innovation, with an additional £4.7 billion from the National Productivity Investment fund, which represents "the largest increase in public spending on UK science, research and innovation since 1979" (HM Treasury 2016). The report sets out where the funding will be allocated, detailing 73% being shared between transport, power and cross-sector. It is argued that the key role for government in aiding the green growth in economy is to set out the framework for action across the economy. The report suggests business, civil society and people will be key drivers in delivering key changes.

The role of UK businesses

Nestlé has made efforts to work towards a sustainable supply chain by procuring 80% of their resources from audited and compliant suppliers by 2020. Nestlé UK&I commented on the drivers of sustainability within the industry, "Traceability and accountability are now key drivers of consumer behaviour, and it is necessary to ensure that companies are sourcing. Unsustainable practice today could result in a more volatile global supply chain, with increased costs and risk associated with procuring raw materials".

However, it is argued that business sustainability should be driven by the improvement to bottom line finances. The CEO of General Electric announced that increased revenues and competitiveness must be the primary focus of environmental sustainability efforts (Epstein and Westbrook 2001). This argument was replicated by "Company A" who highlighted finances are the driver of capital investment: "There's a big driver on company's reputation. When a company has a capital expenditure opportunity, they would usually require a maximum of three years before they hit the break-even point. However, they wouldn't have seen that break-even point on the capital until nine or ten years down the line".

Responsibility for shareholder return has been argued to drive investment decisions. In all ten of the world's top ten companies, growth and responsibility to shareholders are part of their key strategy in some description. "Company A" explained: "Externally corporations always promote the benefits of what they are doing, but internally, because a business is a business and there is a responsibility to give back to the shareholders, everything comes back to money".

Onsite decentralised generation can contribute to both energy and carbon savings for an organisation. In 2012, Kraft foods commissioned a combined heat and power system which used waste coffee to generate power and heat which served the site. The overall project resulted in an electrical capacity of 250 kW and thermal capacity of 265 kW which resulted in 1400 t of GHG being saved annually through CO_2 neutral production (Kraft Foods 2012).

PPAs can establish more stable energy prices for the future, whilst contributing to the addition of new renewable energy resources. Nestlé UK has recently demonstrated their commitments to renewable energy by committing to a PPA with Community Wind power. This investment will provide almost half of the electricity needed for its UK operations and will serve for at least 15 years. Nestlé UK commented:

> This is a newly commissioned wind farm, generating new energy, creating capacity that didn't previously exist and capable of providing half of our electricity needs. It's a proud moment for us and means we have reached another key milestone in our efforts to become a sustainable business.

Marks and Spencer highlighted that they have over 2,000 suppliers sourcing from an estimated 20,000 farms and 100,000 small holdings, with over 2 million individuals being involved in the global supply chain, this identifies that a proportion of a manufacturers product comes from third party suppliers (Marks and Spencer 2018). GSK demonstrated this issue by publishing their carbon footprint evaluation (GSK 2015). This identified that 51% of its total carbon contribution came from purchased goods and services which was valued at 10.5 MtCO2e per year. This compared with only 18% of its total carbon emissions coming from operations and logistics that the company has direct control over. The final 31% was evaluated to be at the consumer end in product use and disposal. "Company A" confirmed this argument commenting: "For most businesses, the biggest carbon footprint is coming from their supplier, which they don't have direct control over. They can obviously have influence by not offering business, but in reality, they can't really do that".

The role of organisations

Organisations have responded to the challenge of climate change by leveraging the strength of collaboration and power in numbers. The climate change group Renewable Energy 100 (RE100) now has over 100 members committed to procuring 100% of their energy from renewables. Commitments from business have been argued to emphasise the importance of energy management and help bring energy management into the core business strategy. Offering advice and guidance for renewable energy integration into business portfolios has helped the world's largest corporations make changes more efficiently, realising the cost savings that come from decarbonisation. Nestle agreed with this philosophy stating: "It can be challenging to stay up to date with the changing policies on a global basis and being part of the RE100 makes it easier to innovate and make changes within the business. By working with others, we can increase demand for renewable energy worldwide, reducing costs and mitigating risk".

Decentralised generation

The 2050 carbon target brings challenges that face the electricity network across the UK. The government has proposed to decrease emissions by increasing the application of low-carbon generation, electrification of the transport and heating sectors, and by decommissioning high-carbon energy generators like unabated coal by 2025 (HM Government 2017).

The ageing equipment and dated planning systems are currently used around the UK (Shezan et al. 2015). The current value of transmission assets in the UK is estimated at approximately £13 billion. The volume increase in renewable generation expected to 2050 will require a forecasted infrastructure upgrade of between £23 billion and £53 billion by 2030. The University of Cambridge energy policy research group acknowledges that the introduction of a functioning smart network will allow more flexibility in the system. They also pointed out that "the cost of the distribution network reinforcements could be reduced by more than 50%" (Strbac et al. 2016).

In 2006, it was estimated that DG systems accounted for less than 10% of total electricity supply in the UK (Department for Trade and Industry 2007), growing to an estimated capacity of between 8.24 and 17.30% in 2010 (Allan et al. 2015). In the Clean Growth Strategy, the UK government identifies an additional £80 million to support deployment of necessary infrastructure changes to the UK power network. Not only does this include network upgrades, but also the implementation of a UK "Smart Grid" which will be designed to reduce the cost of energy consumption for households and business, with a forecast potential saving of £40 billion to 2050. Renewable energy deployment is a key opportunity to meeting emissions targets, and the UK government has committed to investing an additional £440 million in the smart network and further reducing the cost of renewables to advance the uptake into the private sector (BEIS 2017a).

As well as the potential of postponing upgrades to the centralised energy network, another potential opportunity is the reduction in transmission costs with the implementation of DG. Further to a reduced demand for physical transmission assets, costs are saved in energy losses through cables. Approximately 6.5% of generated electricity is lost as it is transmitted and distributed to consumers (The Association for Decentralised Energy 2016), so the implementation of decentralised network can present more efficient distribution through less waste.

It was estimated that in the past decade the rate at which the global population is using resources is fourfold the amount earth can sustain (Bjørn et al. 2017). Public concern surrounding climate change has stimulated business to become more involved in actions protecting the environment. By focusing on waste management and energy efficiency, businesses can leverage decentralised generation to incorporate sustainability into their operations and business model.

The implementation of an anaerobic digestion (AD) system at a Nestlé confectionery manufacturing site in the UK resulted in carbon and financial savings alongside recognition in becoming a leader on the Dow Jones Sustainability Index. During an interview, Nestle explained,

> The implementation of an AD system onsite in Fawdon has allowed us to demonstrate our ability to lead the industry in sustainable manufacturing. The system reduces the sites carbon emissions by 10% and accounts for 8% of the total energy used on site.

Additionally, the implementation saves approximately £300,000 per annum through direct energy savings and incentive pay-out from the FiT, as well as a further £200,000 per annum on costs associated with disposal and discharge of waste. At a cost of approximately £3.6 million, the payback period is estimated to be 4–5 years, which is considered low risk compared to other renewable energy technologies (Clearfleau 2013). Nestle commented that "The longer payback period of 4–5 years can be justified through our commitments to reducing our environmental impact. The installation has acted as a catalyst to help the wider business understand what actions they can take to be a sustainable business".

The Nestlé and Community Wind Power collaboration brings together capital investment from Nestlé and technical expertise from Community Wind Power to demonstrate the feasibility of offsite DG. Large companies across the globe are using PPAs to scale up their use in renewable energy by procurement directly from the generator. Unilever demonstrates the use of PPAs can aid renewable energy commitments, and they concluded that: "Renewable energy is cost as technology costs fall and infrastructure capital costs remain at historically low rates. Power purchase agreements are a simple way to achieve this, by enabling companies to contract directly with producers of renewable energy".

One key benefit of a PPA is the ability for corporate buyers to collaborate and share risk in one renewable energy project. This risk sharing solution can be an attractive proposition for buyers without the capital necessary for an individual PPA. Another benefit of having a shared PPA is the ability to have a termination clause built into the contract. This shared option is becoming an increasingly popular choice with energy buyers, especially small and medium enterprises (SMEs) that do not need total energy generated from a wind farm (World Business Council for Sustainable Development 2016). PPAs are generally long term of 10+ years, and this structure provides price security by hedging against market price volatility (World Business Council for Sustainable Development 2016). NRG BEIS (2016c) renewables validated this theory by commenting that "Long-term power purchase agreements bring predictability, reduce risk and allow renewable energy developers throughout the energy system to plan, manage and finance the new projects. These factors help drive new projects, bringing more and more renewables into the energy system".

Growing electricity demand and decommissioning of centralised energy networks create an uncertainty around energy prices and availability. Industrial electricity prices in 2016 were approximately 7.8 p/kWh, and by 2031, this is expected to rise by 56.4% to 12.2 p/kWh (BEIS 2016c).

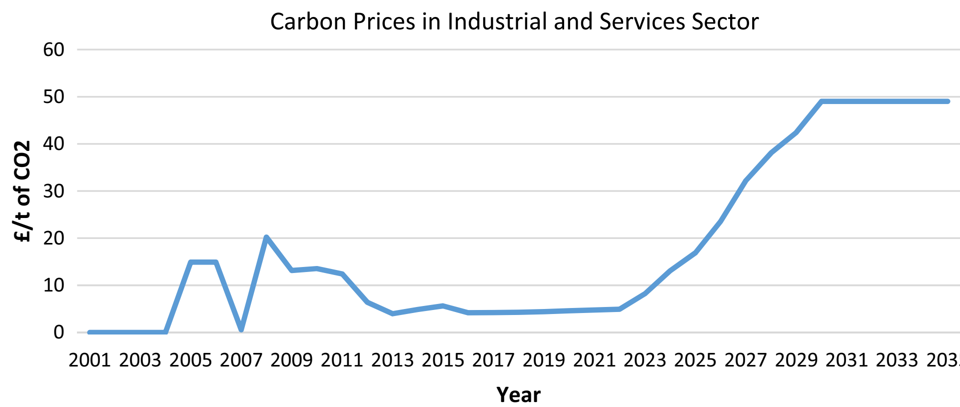


Fig. 8 Growth Assumptions and Prices (BEIS 2016c)

This will have an impact on corporation overheads; thus, by investing into renewable energy, savings can be made.

The price of carbon is forecast to increase at its highest rate since 2007, reaching a peak in 2030 as shown in Fig. 8. Between 2022 and 2030, BEIS forecasts the price of carbon to increase YoY at a mean £5.5/t of CO_2, to £49/t of CO2 in 2030 compared with the current price of approximately £4.2/t of CO_2. At over 12 times the current trading price, this will have the biggest effect on companies who make no changes to reduce their impact on carbon emissions. The use of renewable DG could provide a secure source of low carbon power for those companies that implement the technologies.

Capital investment is argued to remain a key barrier for businesses of all sizes and in particular SMEs. The cost and payback period of DG remain significantly longer than what is usually expected for business, with technologies typically falling between 5 and 15 years assuming continued incentivised payments of relevant schemes (Carbon Trust 2012). For SMEs it may not be commercially viable yet to invest capital into DG.

To establish a smart system where businesses can export excess energy to the grid additional connections are required. These connections cost the consumer and are made up from asset costs and the wider infrastructure costs (Ofgem 2014). It has been identified that this can be higher than 10% of the total cost of a DG project, and these alone are identified as barriers for DG implementation. Nestle endorses these sources arguing that:

> The UK government has been relying excessively on business to facilitate the upgrade in network infrastructure in order to increase capacity. For multiple projects the connection and upgrade costs were too high. Investment from government into the network is necessary if decentralised network is truly to become integrated into business.

Technical ability in energy management has been identified as being a barrier for businesses that have never had such an in-depth engagement in the operation (Defra 2008). The in-house team would require resources and additional technical skill which may be more than the "business as usual" previously used on energy procurement (Defra 2008). However, in large corporations where the implementation of PPAs would be beneficial economically, environmentally and socially, the gradual development of skill and experience through using professional advisors may be viable. Nestle commented,

> Energy management can be a critical barrier to the adoption of decentralised energy, even if the case has been approved economically. Partnering with specialists has been a favourable option to leverage their expertise and skill in an area we continue to develop and learn in.

A SWOT analysis was conducted as described in the methodology with the aim of quantifying the benefits and challenges of decentralised generation. The tables are shown in "Appendix: SWOT analysis". The analysis showed that the balance of the items was in favour of opportunities and strengths suggesting an offensive rather than defensive orientation to the statement "For business, it is beneficial to implement decentralised generation technology to secure carbon neutral energy, compared with traditional sourcing from the grid". Onsite generation and offsite generation were then compared against each other to offer a strategy for which could be used in industry. The results show that offsite generation provided a stronger offensive orientation compared with onsite, suggesting more benefits and less challenges.

Strategies were aligned to each significant factor to understand the key elements necessary to successfully implement onsite and offsite DG. With both onsite generation and offsite generation, the key strategies for business to implement DG successfully were suggested to be:

- Bring energy management into core business strategy
- Create ambitious and stretching carbon reduction targets

- Collaboration for technical expertise and to leverage scale and "one team" action
- Have a mixed portfolio of sourced energy to provide reliability and flexibility

Discussion

The 2009 EU Energy Directive was suggested to be an influencer of carbon reduction in the last decade. "The role of UK government" section demonstrates the negative correlation between the subsequent introduction of energy policies and the acceleration in decrease of GHG emissions with the biggest decrease happening between 2009 and 2016. The achievements of the RO and FiT can be considered two of the most successful policy implementations for GHG reduction and renewable energy implementation. The findings concur with the statement from the EU Climate group suggesting that policy and subsequent innovation have been somewhat responsible for driving the GHG reduction and implementation of renewable generation technology.

It was verified that the energy supply sector had the biggest reduction in GHG emissions of 56% which validates government targets to affect this sector. This shows the direct impact of the FiT scheme and the positive correlation on renewable energy technology. The UK government policy has therefore had success in implementing the GHG reduction strategy and the subsequent commitment in renewable energy technology.

The UK government has announced they will primarily target the transport and power sectors with incentives and investment. Although investment will initiate the change, the UK government has called for business and society to interact with the movement for it to be successful; government will lead investment and innovation, but business will take renewables to market. It highlights the need for a less complex and more flexible trade and financial market. The OECD argues that traditional licensing and regulatory pathways need to be revised and amended to allow for the accelerated uptake of renewables into the energy market. The associated costs and time needed for such barriers can be deterrents for business, especially smaller investors who have less flexibility. They present data showing that such regulatory barriers have a statistically significant effect on investment in renewables suggesting a significant obstruction for investors.

It was identified that the cost benefits associated with renewable energy savings and DG have been shown to be a key driver for business in efforts to become carbon neutral. Although benefits are attained in terms of brand reputation and corporate social responsibility, the focus for business is on mitigating risk of increasing energy prices, and long-term strategic solutions to securing energy security.

The UK government has suggested that business will need to contribute by bringing renewables to market. However, businesses have argued that the government is relying too heavily on them for investment into the electricity grid. The costly connection charges and lack of investment into the electricity infrastructure have resulted in capacity constraints, and this has to 2020 commitments being at risk. It is therefore suggested that the application of renewable energy could be accelerated if more investment was made in energy infrastructure. It has been identified that the RE100 engages corporations to collaborate and work towards zero carbon business, using a "power in numbers" approach. The research found that the RE100 has an impact on corporate reputation, as well as bringing clarity and advice to complex energy markets which confirms the mission of stimulating businesses to achieve a net-zero carbon future for all.

Additionally, by committing to renewable energy targets with the RE100, energy management is brought into core business practice which starts to overcome the barrier to decentralised generation implementation. It was argued by "Company A" that businesses have not traditionally come together to work as one team to any large extent. In "The role of organisations" section, this was counter argued by Nestlé and other members of the RE100 with a conclusion that the RE100 is having a positive effect on some of the world's largest organisations and is making an impact on the accessibility to renewable energy for business.

Decentralised generation is a key implementation necessary for the UK's future electricity network, as it is for several other nations too. The benefits and challenges for business have been highlighted, and a resulting SWOT analysis has suggested DG brings more benefits than challenges for business sourcing renewable energy. The primary and secondary research shows agreement with DG implementation having a positive effect for businesses in terms of finances, corporate social responsibility and energy security. With the implementation of DG and a successful smart network, business will be able to benefit from the added visibility and flexibility by using energy away from peak times for financial gain. The SWOT analysis was used to compare the benefits and challenges associated with decentralised generation. The results showed that offsite generation proved to be of bigger benefit to a company to source renewable energy in comparison with onsite generation.

Increasing the resource and development allocated to energy management has been identified as a necessary strategy to increase energy security through increased visibility, flexibility and reliability. The creation of ambitious carbon reduction targets has been suggested as a strategy for DG implementation. This approach could have a positive impact on brand reputation, challenge businesses to make real changes and help drive the decrease in LCOE of renewable technology. This would aid corporate social responsibility and sustainable sourcing, which also indicates a financial benefit as discussed in "The role of UK businesses" section.

A challenge for business implementation of DG was suggested to be a lack of expertise and practice in energy management to the scale required. Collaboration with ESCos and organisations such as the RE100 could ensure that technical management is trained throughout organisations and also aids the economies of scale necessary to further reduce the LCOE for renewables. Additional flexibility was highlighted as being a key benefit of DG in business, and a mixed portfolio can allow a business to adapt to changing energy requirements. Rather than focussing all capacity requirement on one source, the results suggest that a broader portfolio of energy income would be more beneficial.

Conclusions

This research has successfully identified the key drivers of GHG reduction based upon the UK experience. The four main findings are as follows:

1. It has been concluded that government policy and legislation has been significant in investing in renewable energy technology, driving innovation since 1990. Business and other organisations have since collaborated to drive the uptake in renewable energy which has had a positive effect on emissions and the LCOE.
2. Distributed energy is verified as being a key measure to implement renewable energy into the future electricity grid. This will benefit supply and demand by reducing capacity constraints that are inevitable without a change in the centralised energy infrastructure. For the private sector to fully integrate distributed energy, additional support is needed from government to decrease complexity of financial and energy markets.
3. Onsite generation and offsite generation have been analysed, and it concludes that both offer more benefits than challenges to drive renewable energy generation in the UK, compared with traditional fossil fuel energy sourcing. Offsite generation was presented to provide a better alternative for more consumers compared with onsite generation.
4. Four key strategies have been suggested which can be incorporated into business plans. This has the potential to increase the application of decentralised generation in the business and industrial sector, thus aiding carbon reduction commitments on the path to 2050.

Further work such as strategies should be implemented into a selection of businesses in the industrial sector with the aim of accelerating the implementation of decentralised generation into the private sector. This test could then provide the basis for government legislation and policy, specifically around carbon reduction in the industrial sector and assistance with technical expertise. The national government (the UK in this case but equally applicable in many other countries) and sponsored organisations should establish a programme to ensure technical ability and development are available for the future electricity network. This will help the UK and other nations implement similar schemes and ensure that appropriate skill and knowledge is available to successfully build and maintain the future power grid.

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Appendix: SWOT analysis

1. "For business, it is beneficial to implement decentralised generation technology to secure carbon neutral energy, compared with traditional sourcing from the grid".

Strength	Score
Carbon reduction commitments	4.8
Increased flexibility	4.6
Increased reliability—broader portfolio	4.4
Increased visibility	4.4
Negotiable contracts	4.4
Securing energy at a fixed price (volatility)	4.2
Investing in large-scale offsite—big potential	4.2
Income generating capacity	4
Reducing risk through multiple investors	3.6
Reduce reliance on external companies	3.2
Bringing energy into core business strategy	3
Total ≥ 3	11
Weakness	**Score**
High "cap ex" investment	4
Lack of expertise	4
Long-term contracts	3.6

Weakness	Score
Complexity of contracts	3.2
Owning additional assets—Illiquid	3.2
Complexity of internal approval	3
Longer payback period	3
Total ≥ 3	7
Opportunity	**Score**
Increasing sustainable resourcing	5
Corporate social responsibility	4.6
Increasing price of electricity	4.6
Decreasing LCOE	4.2
Smart network	4.2
Forecast increase in the price of carbon	4.2
Brand reputation	4
Acceleration of technology innovation	4
Commitments from government	3.6
One team, i.e. RE100	3.6
DSR and ANM	3
Total ≥ 3	11
Threat	**Score**
Complex energy markets and legislation	4.6
Matching demand and supply	4.4
Government relying on business	4
UK infrastructure—centralised	3.6
Declining government fund	3.4
Total ≥ 3	5

2. Benefits of onsite generation

Strength	Score	Strategy
Carbon reduction commitments	4.8	Ambitious carbon reduction targets for impact
Increased flexibility	4.6	Bring energy management into core business model
Increased reliability—broader portfolio	4.4	Bring energy management into core business model
Income generating capacity	4	Bring energy management into core business model
Reduce reliance on external companies	3.2	Bring energy management into core business model
Bringing energy into core business strategy	3	Demonstrate economic viability
Total ≥ 3	6	
Weakness	**Score**	**Strategy**
High "cap ex" investment	4	Multiple investors/collaboration
Lack of expertise	4	Collaboration
Owning additional assets—Illiquid	3.2	Collaboration
Complexity of internal approval	3	Demonstrate economic viability
Longer payback period	3	Mixed portfolio of energy procurement
Total ≥ 3	5	
Opportunity	**Score**	**Strategy**
Increasing sustainable resourcing	5	Ambitious carbon reduction targets for impact
Corporate social responsibility	4.6	Ambitious carbon reduction targets for impact
Increasing price of electricity	4.6	Bring energy management into core business model
Decreasing LCOE	4.2	Leverage scale
Smart network	4.2	Bring energy management into core business model
Forecast increase in the price of carbon	4.2	Bring energy management into core business model
Brand reputation	4	Ambitious carbon reduction targets for impact
Commitments from government	3.6	Collaboration
Total ≥ 3	8	
Threat	**Score**	**Strategy**
Complex energy markets and legislation	4.6	Collaboration with RE100/technical experts
Matching demand and supply	4.4	Mixed portfolio of energy procurement
Government relying on business	4	Leverage scale
UK infrastructure—centralised	3.6	?
Declining government fund	3.4	?
Total ≥ 3	5	

3. Benefits of offsite DG

Strength	Score	Strategy
Carbon reduction commitments	4.8	Ambitious carbon reduction targets for impact
Increased flexibility	4.6	Bring energy management into core business model
Increased reliability—broader portfolio	4.4	Bring energy management into core business model
Increased visibility	4.4	Bring energy management into core business model
Negotiable contracts	4.4	Collaboration with RE100/technical experts
Securing energy at a fixed price (volatility)	4.2	Bring energy management into core business model

Strength	Score	Strategy
Investing in large-scale offsite—big potential	4.2	Ambitious carbon reduction targets for impact
Income-generating capacity	4	Bring energy management into core business model
Reducing risk through multiple investors	3.6	Collaboration
Reduce reliance on external companies	3.2	Bring energy management into core business model
Bringing energy into core business strategy	3	Demonstrate economic viability
Total ≥ 3	11	
Weakness	**Score**	**Strategy**
High "cap ex" investment	4	Multiple investors—collaboration
Long-term contracts	3.6	Termination clause
Complexity of contracts	3.2	Collaboration with RE100/technical experts
Complexity of internal approval	3	Demonstrate economic viability
Longer payback period	3	Mixed portfolio of energy procurement
Total ≥ 3	5	
Opportunity	**Score**	**Strategy**
Increasing sustainable resourcing	5	Ambitious carbon reduction targets for impact
Corporate social responsibility	4.6	Ambitious carbon reduction targets for impact
Increasing price of electricity	4.6	Bring energy management into core business model
Decreasing LCOE	4.2	Leverage scale
Smart network	4.2	Bring energy management into core business model
Forecast increase in the price of carbon	4.2	Bring energy management into core business model
Brand reputation	4	Ambitious carbon reduction targets for impact
Acceleration of technology innovation	4	Collaboration
Commitments from government	3.6	Collaboration
One team, i.e. RE100	3.6	Collaboration
DSR and ANM	3	Bring energy management into core business model
Total ≥ 3	11	
Threat	**Score**	**Strategy**
Complex energy markets and legislation	4.6	Collaboration with RE100/technical experts
Matching demand and supply	4.4	Mixed portfolio of energy procurement
Government relying on business	4	Leverage scale
UK infrastructure—centralised	3.6	?
Total ≥ 3	4	

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