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SMART SOLAR AT SCALE:

Meeting the UK's net-zero emissions and clean growth targets

A Report by ResPublica

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EXECUTIVE SUMMARY

The energy sector can play a central role in powering the UK's economic recovery, post-Covid-19. This report makes the case for scaling up the development and implementation of smart solar and battery storage technologies to meet the UK's objectives for both carbon reduction and clean economic growth. We explore the challenges and outline the solutions that can remove the current policy and regulatory barriers to achieve this ambition.

INTRODUCTION

The past decade has witnessed a paradigm shift in the global energy sector. Since the Climate Change Act became law in 2008, the UK has cleaned up its energy mix faster than any other major world economy. Back then, four-fifths of the UK's electricity came from fossil fuels, making it by far the largest contributor to the nation's carbon footprint. Presently, the country gets more than half of its electricity from low-carbon sources, such as solar, wind and nuclear.

The UK's support for renewable energy and decarbonisation is a success story and the Government's pledge to achieve 'net-zero' emissions by 2050 will necessitate further growth in the green economy. In terms of employment levels, the UK's low carbon and renewable energy sector is the second largest in Europe. Prior to the Covid-19 pandemic, the sector was outpacing the wider UK economy with growth five times greater and employment seven times greater than the national average.[1]

The UK Government's Clean Growth Strategy and Industrial Strategy White Paper highlight the role of the low carbon and renewable sector, and the clear potential for scaling up solar and battery storage technology. Trends in the supply and demand for energy are changing. Advances in smart technology will see more people using energy at different times of the day and consumers playing a more active role, in an 'intelligent' grid, selling energy as well as buying. All of this points to a world where the cost of producing electricity will be dramatically lower, and where energy decarbonisation is not only possible but also affordable.

But in order to gain the full social, economic and environmental benefits of investments in this market, we will need to change existing energy regulations, which are no longer fit for purpose and are hindering the advantages and timescale for delivering energy transformation.

CHALLENGES

There are key challenges facing Government in this critical transition moment for UK energy. The cost of energy is chief among these. Uncertainty about short and long-term oil and gas prices can make it harder for suppliers to pass savings through to consumers, and for nations that are heavily dependent on imports of fossil fuels to control costs and plan their economies.

However, the cost of renewable energy is falling rapidly. In most parts of the world today, renewables have become the lowest-cost source of new power generation. Wind and solar PV are set by 2020 to consistently offer a less expensive source of new electricity, without financial assistance, than the least-cost fossil fuel alternative. And the market share will grow from less than a fifth of final energy demand to nearly half in 2050.[2]

In the UK, consumers have been increasingly frustrated by increases in energy bills – rising by 38% between 2007 and 2019. This despite improved energy efficiency, falling consumption and increased competition in the energy market. Unfortunately, the most vulnerable consumers are amongst those paying more, with 10% of all households in England living in fuel poverty.[3] New power sources alongside flexible generation and consumption can make energy affordable for all.

The UK energy system is based on a networked grid of large power stations using mainly non-renewable fuel and providing a minimum 'baseload' of electricity to supply the grid at any given time. This model of energy generation requires a constant source of power. And the conventional view is that while clean generation sources like wind and solar power are great for supplementing the energy mix, their intermittency is a huge issue.

However, the concept that there is a fixed block of given demand insensitive to generating conditions is now under serious reconsideration. Improving 'flexibility' in the system - the extent to which supply and demand can be shifted - challenges the assumptions underlying investment in traditional baseload plants. Increasing renewable capacity and storage on both sides of the meter - including demand response, smart inverters, microgrids and other innovations – allows for the localised and decentralised production of energy. But consumers will have to pay out for traditional baseload power generation for many years, while in many parts of the UK the electricity grid is becoming overloaded, making it more difficult for new clean sources of energy to get access.

SOLUTIONS

While the UK has made significant progress in decarbonising the energy system, this was largely due to wider economic changes and the one-off adoption of the efficient Combined Cycle Gas

Turbine (CCGT) technology to replace coal.[4] Moving forward, services which will store energy at times of low demand and feed energy back into the system when demand is high will help maintain wider system reliability. Industry is now ready to supply these on a commercial basis, thanks to the impact of renewables policies in developing an efficient and innovative industrial and supply base.

Nowhere has this been more apparent than in the solar industry. Between the 21st and 28th June 2018, solar broke the record for weekly output, producing 533 gigawatt hours of power. And for about an hour on Saturday 30th June, solar was the number one source of electricity, with a share of more than 27%. A decade ago, solar contributed almost nothing to UK electricity supplies. Some developers now believe they can build without subsidies by going large-scale, increasing the number and size of solar farms and solar plants.

Battery technology is central to the creation of an entirely different energy landscape, allowing widespread roll-out of solar. Smart solar + storage installations enable storage of on-site generation for later release; storage from the grid if prices are low; aggregation into trading networks to provide capacity on demand; and network management services to ensure the stability of the grid.

The UK has supported development of the supply chain with the creation of significant research expertise. The Faraday Challenge is one such example of significant funding of battery technology development, and there are some signs that Government is ready to shape the energy market in the light of the new potential of storage. This is timely, as our global competitors are also now looking to rapidly scale-up distributed smart renewables, and many successful examples are already underway abroad.

BARRIERS

Despite the potential of solutions like solar + storage, existing energy regulations and legislative frameworks are now actively hindering the advantages and timescale for delivering energy transformation. The main barrier is the lack of flexibility of both electricity generation and demand throughout the system.

This manifests in several ways. The way energy storage is defined in current legislation complicates and reduces the security of investments in it, furthering potential users' lack of confidence in a storage service. There is a lack of clarity, for instance, as to when storage can co-locate with renewables without interfering in existing agreements, which itself is also part of wider issues with transmission access rights.

The structure of network programs also presents problems. Battery storage is currently charged for using the energy network as both a demand customer and a generator, with little distinguishing between connection capacity and capacity rights to use the network. There is no specific market programme for Demand Side Response (DSR). Currently, the main Short-Term Operating Reserve (STOR) service has DSR included within it. The objective of STOR is to provide extra power through generation or reduction in demand at short notice, when needed. Providers are paid to make their facilities available to do this. However, STOR as it stands has an unsuitable structure, with implicit benefits for generators not available to DSR.

Lastly, many consumers are not currently benefitting from being able to measure their usage in half-hour settlements. Instead, companies rely on crude estimations of energy use and infrequent meter readings.

Moving to a more flexible system could, in one scenario, unlock an additional 25% of wind energy that would otherwise have to be taken offline to protect the grid. Whereas our current course could see consumers paying to keep fossil fuel plants at half capacity in case of changes in demand, a flexible future could see solar, battery and demand-reduction assets in every neighbourhood employed to balance the grid, enabling all to participate. Achieving this will require the UK Government to address the regulatory barriers, which are entirely within their gift. Policymakers must now turn their attention to a comprehensive solution.

RECOMMENDATIONS

Smart solar and batteries will play a critical role in delivering cost-effective, low-carbon energy which is secure and accessible to everyone. It will reduce the costs of energy systems, providing next-to-zero baseload costs of electricity. It will ensure advantage for the UK in an area where competition is fierce and of high geopolitical importance. So, a clear decision to continue the path of investment in smart solar can help ensure the country remains globally competitive, particularly now that we have left the EU. To deliver this vision, this report puts forward the following recommendations:

1. The UK Government should continue its trajectory of enabling key investments in smart solar, which has been set by recent energy policy. Some **regulatory changes** will be required to speed-up market adoption and strengthen the UK's competitive position.
2. The National Grid **Capacity Market** should aim to increase storage and Demand Side Response participation, extending the one-year contracts under transitional arrangements for a longer time period.
3. The industry would benefit from the **deployment of large scale, medium to long duration storage**.
4. The Government should **review transmission access rights**, possibly through a Transmission Access Review.
5. With regards to **double charging**, the Access Framework by Ofgem should be modified to develop clearer definitions of capacity rights as distinct from connection capacity.
6. Researchers should produce more analysis on the impacts of moving to **half-hourly settlement.**
7. The Government should consider a common policy for **Demand Side Response**, in order to maximise the flexibility potential of electricity demand.
8. Remove barriers to **smart home balancing** as part of the proposed changes to the Targeted Charging Review.
9. **Water heaters** and **storage heaters** should be prioritised as one of the main solutions to address fuel poverty in communities.
10. Distribution network operators **(DNOs) should become active managers** of their networks through cross-sector reform.
11. The Government should **fund R&D in Electric Vehicle Charge Services** to establish the UK as a leading provider.

1. INTRODUCTION

The Covid-19 pandemic has plunged the global economy into crisis and the UK has been especially hard hit – experiencing the biggest economic contraction in over three centuries. As we start to look towards recovery the focus is on those sectors of the economy that present the best hope for rapid growth. This report makes the case for smart solar and battery storage and the critical role that this technology can play in powering the UK's net-zero emissions and clean growth targets, post-Covid.

The UK was the first major economy to commit to reaching 'net-zero' emissions by 2050. Achieving this ambitious milestone will require significant challenges to be met and overcome. This will include the continued expansion of renewable energy – like wind and solar – but also new developments in carbon capture technologies.

The energy landscape is changing and innovations in green technology have contributed greatly to the UK having already reduced emissions by around 44 per cent since 1990, with new coal-free records being set every week. In many ways, the UK is a leader in the energy field. But if we can realise the scope and scale of the new technological advances - and what they could do if combined in areas like solar and battery storage - the local and national gains would be unprecedented.

We could be on the verge of a carbon-free energy system that delivers an abundant supply of close to zero-cost energy to all our homes and businesses. A system where real time energy data drives the demand and supply of energy through smart enabled premises and decentralised networks; and where neighbouring homes and businesses trade their surplus energy with each other. This is a vision of a highly distributed and widely owned energy infrastructure that enfranchises its customers and delivers clean, reliable energy at ever lower costs.

Yet clean power is still seen as something for the future, not for today. Too many still see green energy as unachievable in the short to medium term, a cost rather than a benefit which could endow consumers with both assets, lower prices and, finally, control over their energy bills.

Unsurprisingly, given the momentum of the current system, consumers have not yet been able to benefit through lower energy prices as much as we would like. The technologies now entering the market have the potential to change that. 'Smart' solar and storage are first among them. By combining the best aspects of existing technologies, these new products are already available and commercially viable.

This report sets out a compelling case and clear recommendations for policymakers to reform the existing energy regulation and legislative framework which are hindering the transformation of energy in the UK, and the dramatic benefits that this can offer to both consumers and businesses.

Specifically, we argue for scaling up the development and implementation of smart solar photovoltaic (PV) and battery storage technologies as part of the UK's energy mix. We argue that the expansion of this sector can make a vital contribution to the Government's objectives for both carbon reduction and rapid economic growth post-Covid. We explore the challenges and outline the solutions that can help remove the current policy and regulatory barriers to achieve this ambition.

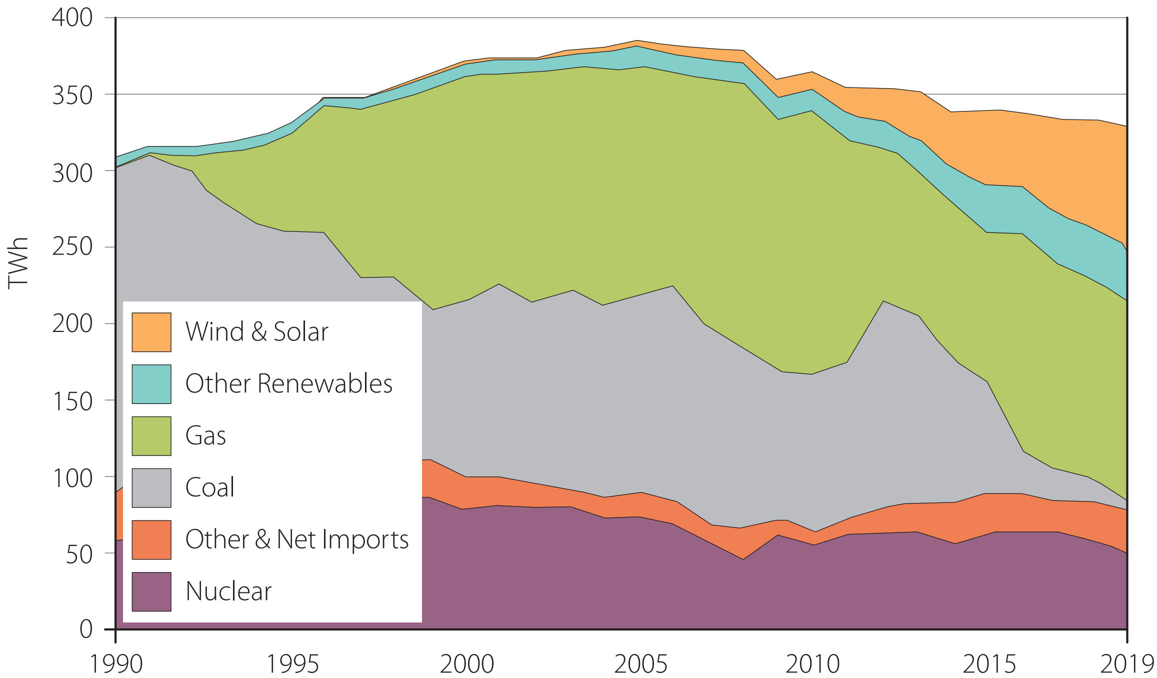
2. BACKGROUND

On the 21st April 2017, the UK's electricity grid ran for a full day without burning coal - the first time this has happened since 1882. In the first half of 2019, the UK extended its record for running without coal-fired electricity, first to one week, then two weeks, then 18 days in a stretch.[5] A growing renewable energy sector is expanding into the gap left by a reduction in the use of fossil fuels.

2.1 NET-ZERO EMISSIONS AND GREEN GROWTH

The past decade has witnessed a paradigm shift in the energy sector. Since the Climate Change Act became law in 2008, the UK has cleaned up its energy mix faster than any other major world economy. Back then four-fifths of the UK's electricity came from fossil fuels, making it by far the largest contributor to the nation's carbon footprint. Presently, the country gets more than half of its electricity from low-carbon sources, such as solar, wind and nuclear.

FIGURE 1: UK ELECTRICITY SUPPLY BY FUEL TYPE (TERAWATT HOURS) 1990 TO 2019



Source: BEIS, 2020[6]

All this means the Government's targets to phase out coal by 2025 and decarbonise the grid by 2030 could be met years ahead of schedule.

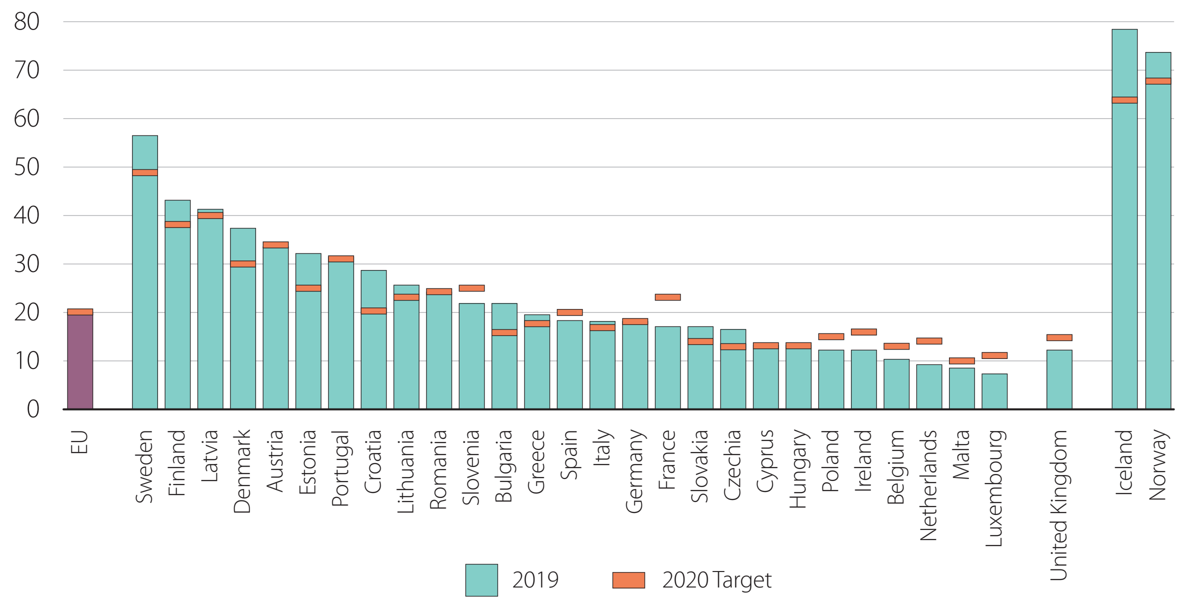
The UK Government's support for renewables has played a large part in this success story, with £2.5 billion of further investment to support low carbon innovation from 2015 to 2021.[7]

Public backing for renewable energy is higher than ever, with 79% of the public in support.[8] And public enthusiasm is likely to increase even more with the full impacts on fuel bills and employment opportunities in a growing low carbon and renewable energy sector.

However, overall investment in clean energy is now the lowest it has been since 2008. The rate of installation for new renewables capacity is slowing, and investments are falling - by 10% in 2016, and 56% in 2017.

Despite the impressive achievements to date, the UK lags many European nations in the proportion of renewable energy which it consumes. From a low base of 1.1% in 2004 to 12.34% in 2019, available data suggests the UK has just about met its 2020 target of consuming 15% energy from renewable sources.

FIGURE 2: SHARE OF ENERGY FROM RENEWABLE SOURCES IN THE EU *(% of gross energy consumption)*



Source: Eurostat, 2020[9]

The UK has now pledged to eradicate its net contribution to climate change by 2050, the first G7 country to legislate for net-zero emissions. The announcement has been widely welcomed by all opposition parties and the business sector alike. The CBI has stated that UK companies are "squarely behind" the commitment, and that firms "are ready to play their part."

> *"Climate leadership can drive UK competitiveness and secure long-term prosperity. This legislation must be followed by a commitment to long-term policies that support decarbonisation across the economy. Some sectors will need clear pathways to enable investment in low-carbon technologies, and* ***it is vital that there is cross-government coordination on the policies and regulation needed to deliver a clean future****."*
> Dame Carolyn Fairbairn, Former Director General of the CBI.

Achieving net-zero will be a formidable challenge. It will mean an end to heating homes with traditional gas boilers, and the phasing out of petrol and diesel vehicles. It will require innovations to decarbonise shipping, aviation and building emissions, as well as new ways of capturing and storing carbon. What is also clear is that the continued and rapid expansion of green energy and zero-emissions technology will be essential. And this will provide real economic opportunities for businesses.

The UK's low carbon and renewable energy sector is in a favourable position. It already has the second largest level of renewable energy employment in Europe, accounting for 224,800 full-time equivalent jobs (2018).[10] Employment in renewable energy increased by twelve per cent over the last few years, compared with average job growth of 1.2% in other sectors. This means that UK renewable energy jobs grew over seven times faster than national average employment growth. A bulletin from the Office of National Statistics in January 2019 confirms that UK low carbon and renewable energy economy as a whole grew 4.9 per cent to £46.7 billion in 2018, from £44.5 billion in 2017 (thus outpacing growth in the wider economy).[11] The Government's offshore wind to target 40GW by 2030 alone will support up to 60,000 jobs[12].

The UK Government's Clean Growth Strategy and Industrial Strategy White Paper highlights the role of the low carbon and renewable sector, and the clear potential for scaling up solar and battery storage technology. But while momentum has been established, some regulatory changes will be needed in order to gain the full societal benefits of investments in this market. As the Independent Review on Energy Costs highlighted,[13] existing energy regulations, which are no longer fit for purpose and are hindering the advantages and timescale for delivering energy transformation, will need to be modified.

2.2 PRIVATE OWNERSHIP, PUBLIC POLICY

Energy policy in the UK has seen huge shifts over the course of the last 40 years.[14] Since the 1970s, the vertically integrated state-run energy monopoly has been transformed into a disaggregated market. The process of liberalisation that took place through the 1980s and early 1990s saw widespread privatisation and 'unbundling' of the UK energy system. The hierarchical energy bureaucracy was replaced with a complex quasi free market involving different agents pursuing different incentives.

The hope of many policymakers at that time was that the state's role would wither away, and market competition would deliver both modernisation and cheaper energy. But the corporate monoliths created after privatisation had too much market power. It took intervention from an empowered regulator to create a competitive environment that could deliver for consumers.

Yet, even while policy focused on designing markets to deliver price competition, demands have grown for the energy system to achieve a broader range of public, social and economic goals. Concerns about climate change have grown in the public consciousness and become a matter of international concern, with the need for decarbonisation becoming both an environmental and commercial necessity. The depletion of North Sea gas has left the UK exposed to the global geopolitics of the oil and gas markets, raising national interests about the security of energy supply.

This position has, since 1993, been formulated as the 'energy trilemma' – of affordable prices, secure supply and sustainable sources.[15] In the past, UK Government would have instructed the Coal or Electricity Board to achieve these goals. Today's policymakers use regulation and the design of economic instruments to tweak margins and incentivise behaviours.

In recent years, Government departments, DECC and then BEIS, have looked to market mechanisms that can develop an industrial base for renewables as well as a self-sustaining energy market that does not require cross-subsidy. The recent Energy White Paper[16] presents evidence from the 2017 Smart Systems and Flexibility Plan[17] and promises a new Smart Systems Plan in spring 2021, which will include a new framework for monitoring flexibility across electricity markets.

One of the most successful mechanisms has been the 'Contracts for Difference' awarded to low-carbon generators. These guarantee providers, competing in an auction, an agreed 'strike price' for their power which may be higher than the market price, reflecting the cost of their investment in renewables.

Despite ownership moving (mostly) to the private sector, energy remains an issue of high political salience. And since the energy sector is very closely bound to the institutional structure, relationships and pricing mechanisms created by the state, policymakers can effect rapid change in a way not possible in other areas of the economy. With effective tools but multiple goals to choose from, including the 'trilemma' and questions of industrial policy, which priorities should policymakers pursue, and how?

2.3 NEW PARADIGMS REQUIRE NEW DIRECTIONS

Today, we see changing trends in the demand for energy, in the way it is generated and consumed, as well as who provides it. These changes call for a reappraisal of our energy markets. That means engaging in the complex web of rules and incentives that govern the behaviour of a vast range of actors, from consumers to energy providers.

Changes in living patterns and economic activity are seeing population centres expand, with consequent demands on infrastructure. Advances in technology will see more people using energy at different times of day, for example to charge electric vehicles. At the same time, the possibility of making the grid 'intelligent' could mean that consumers play much more of an active role, selling energy as well as buying.

We could see a world where automated trading platforms are always choosing the lowest price, creating a rational consumer by, ironically, taking them out of the loop. We could see an extension of the sharing economy to new levels, with people offering up not just their assets but their willingness to change energy-using behaviour. These are just some of the possibilities when information can be shared and used upstream, instead of crudely adjusting production to fit demand.

Taken together, these trends point to a world where the cost of producing electricity could soon be much lower. It will also be a world where energy decarbonisation is not only possible but affordable. And the transformation will be diverse, pluralistic, and encompass private, public and community bodies.

Correspondingly, the way we regulate energy needs to change too, embracing both new technology and new participants. The picture is of a radically different future, but the forces of inertia are strong, and we could easily follow the path of stagnation. The pent-up demand for a transformational scaling up of renewables is there. But it will take a dedicated commitment to reform for policymakers to escape the 'tyranny of the trilemma.'

3. CHALLENGES

There are a number of key challenges facing Government in this critical transition moment for UK energy. These include how the nation can maintain:

- Secure provision of low-cost, clean energy generation
- Affordability of energy for all consumers
- Effective grid balance of fluctuating supply and demand.

By tackling these challenges together and intervening to allow the market to operate more efficiently, policymakers can achieve objectives to meet net-zero emissions, lower fuel bills and grow the domestic energy sector.

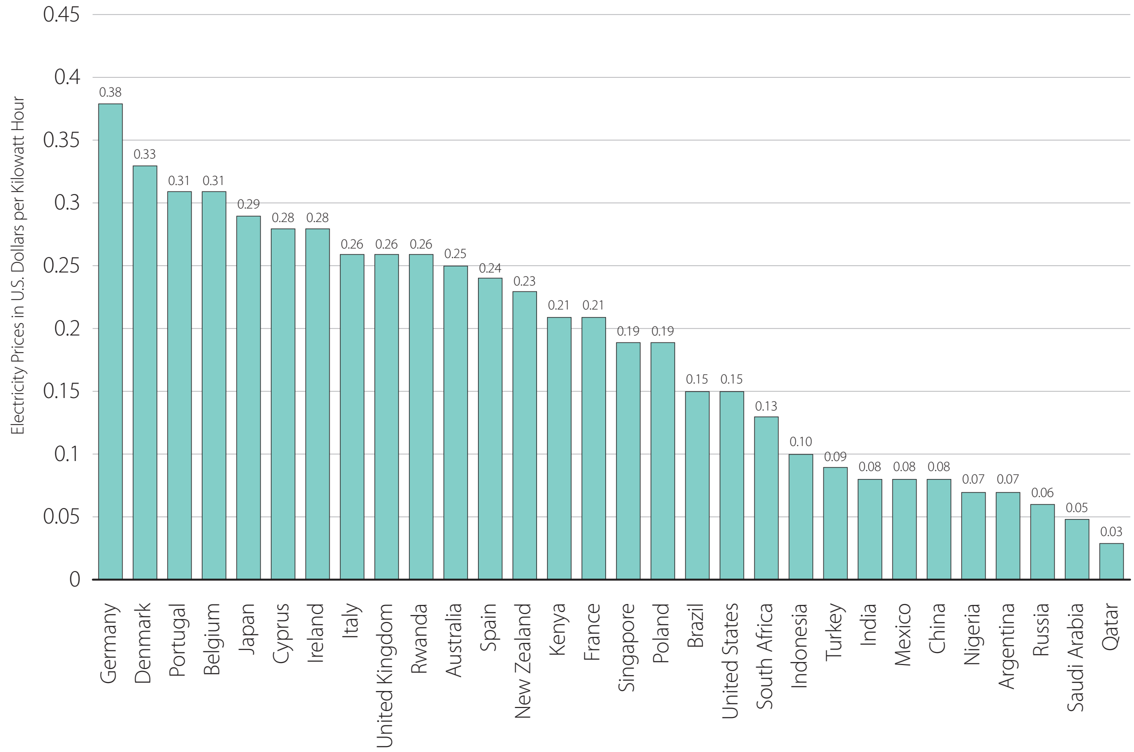
3.1 CHALLENGE 1: THE COST OF ENERGY

Energy prices and costs in the UK, and indeed globally, are highly volatile. Fluctuations in wholesale energy prices – particularly oil and gas – occur in response to over-supply and under-demand, resulting from increased competition in markets (e.g. from renewables) and energy-efficiencies, as well as the impact of recession and economic downturn.

Uncertainty about short and long-term oil and gas prices can make it harder for suppliers to pass savings through to consumers, and for nations that are heavily dependent on imports of fossil fuels, to control costs and plan their economies.

The cost of electricity in the UK is currently amongst the highest in the developed world.

FIGURE 3: GLOBAL ELECTRICITY PRICES IN 2018 BY SELECT COUNTRY *(U.S. dollars per kilowatt hour)*



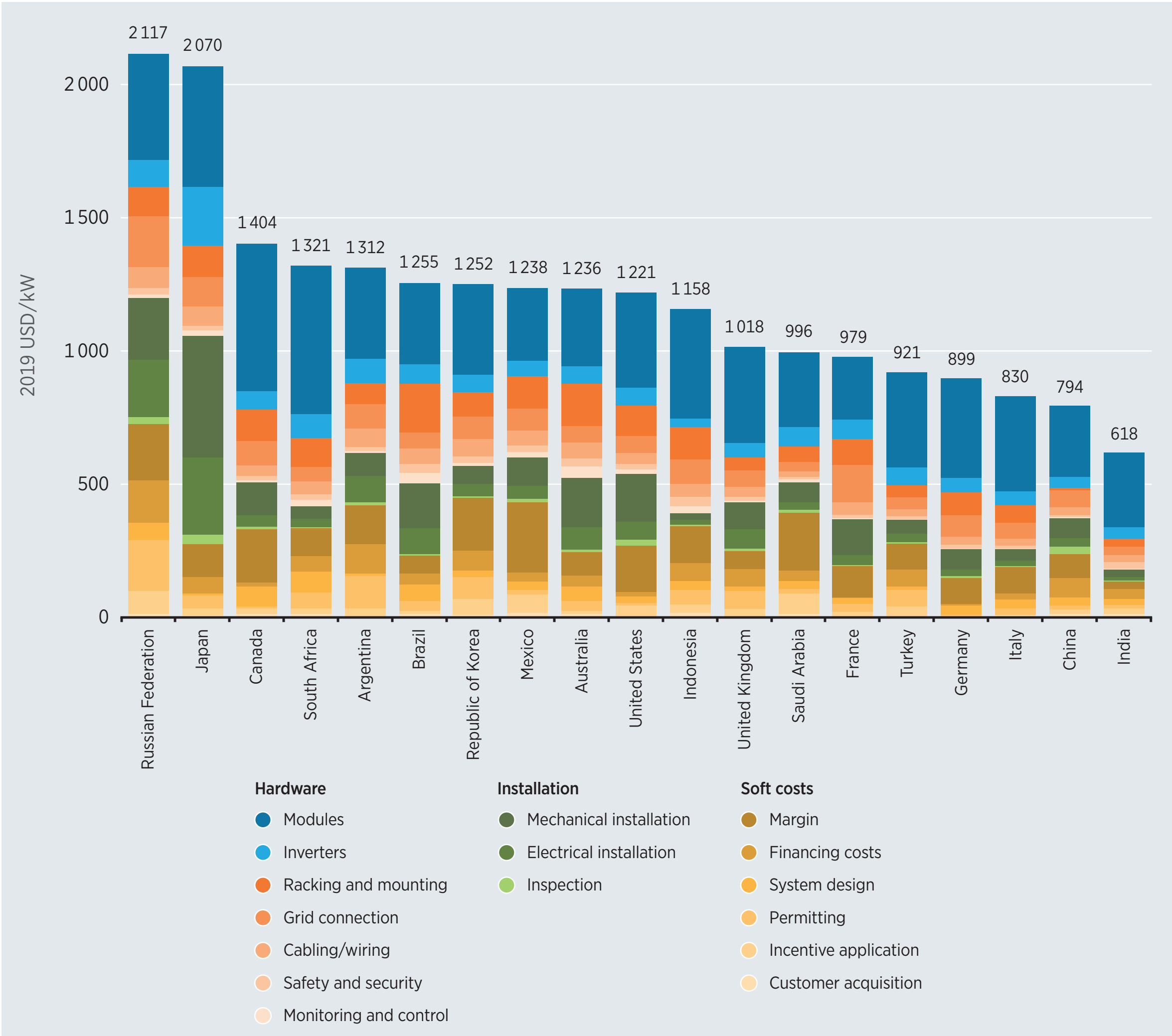
Source: Statista, 2020[18]

The cost of renewable energy is, however, falling rapidly. In most parts of the world today, renewables have become the lowest-cost source of new power generation. This will be true in a growing number of countries as capacity is increased. The global weighted-average of the newer solar and wind power technologies have all fallen between 2010 and 2018, within the range of fossil fuel-fired power generation costs.[19]

Wind and solar PV are set to consistently offer a less expensive source of new electricity than the least-cost fossil fuel alternative, without financial assistance. And these cost reductions are set to continue beyond 2020. IRENA's latest analysis of the world's pathway to a sustainable energy sector therefore sees an increase in electrification, with the share growing from less than a fifth of final energy demand to nearly half in 2050.[20]

Between 2010 and 2019, utility-scale solar PV has seen a dramatic decline in average installation costs of 79%.

FIGURE 4: TOTAL INSTALLED COSTS OF UTILITY-SCALE SOLAR PV BY COMPONENT AND COUNTRY



Source: IRENA, 2020[21]

This has combined with a sustained fall in the average levelised cost of electricity (LCOE), from solar PV, of 82%, from USD 0.378 to USD 0.068/kWh. In the UK the LCOE was higher, at around USD 0.187/kWh in 2019, a 60% drop since 2010.

FIGURE 5: UTILITY-SCALE SOLAR PV WEIGHTED-AVERAGE LCOE TRENDS IN SELECTED COUNTRIES, 2010–2018

Source: IRENA, 2020[22]

In an increasing number of countries, the price impacts of renewables on electricity bills are now beginning to be felt by consumers. For example, prices for electricity in Germany regularly dip below zero, meaning that customers are being paid to consume power.[23] As this develops, the perception that 'renewables put up prices' can be expected to diminish over time. "Green energy is, increasingly, cheap energy."[24]

CASE STUDY: NEGATIVE WIND PRICES, GERMANY

The German electricity grid has, on several recent occasions, moved into negative prices for renewables, which is to say that buyers are paid to use power by sellers, an inversion of the usual state of affairs. This is usually due to high renewables output on windy days and low demand. The produced electricity cannot be taken offline, and so must be used up to keep the power grid stable, so consumers are paid to do so.

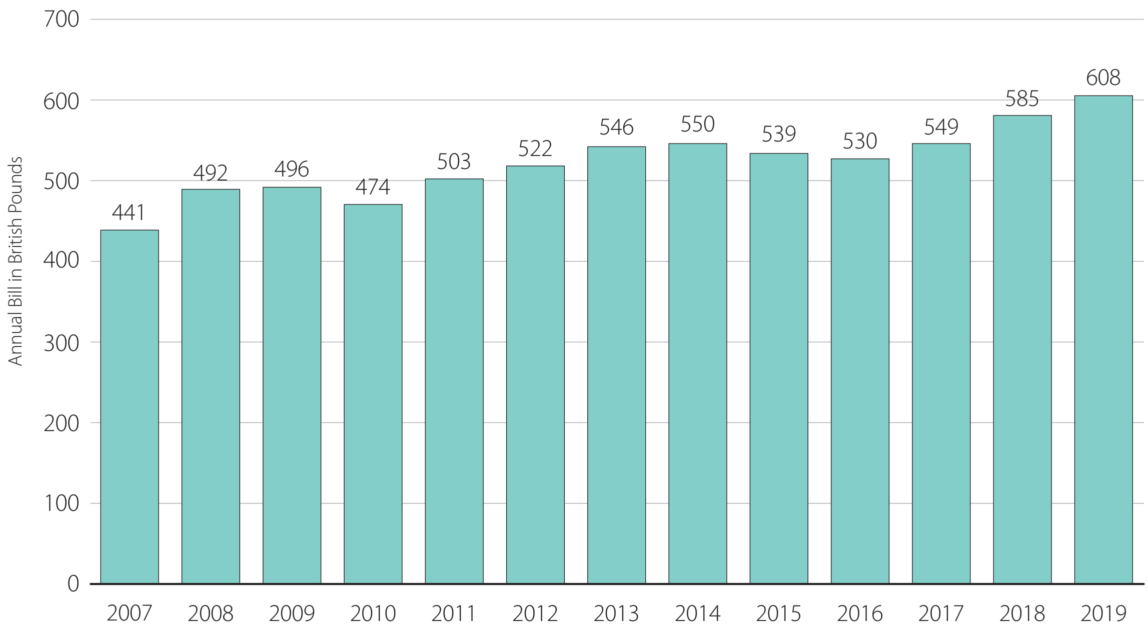
The negative prices are good for buyers and incentivise them to change their demand as conditions change. They also incentivise producers to take generation offline in periods of excess production, to reduce risk to the grid from oversupply.

However, they also signal that there is an opportunity for buyers who could store the cheap electricity and release it at a different time, when prices are higher. This supply could be absorbed if and when storage providers enter the market.[25]

3.2 CHALLENGE 2: ENERGY PRICE INCREASES

In the UK, consumers have been increasingly frustrated by increases in energy prices. According to the Government's figures, 30% of consumers are concerned about paying their electricity bills.[26] Ofgem points to the fact that despite losing consumers to competitors since 2012, the six largest suppliers have maintained a healthy combined profit margin of between 3.9% and 4.5%.[27] Price differences between variable tariffs and fixed tariffs have widened over this period. This suggests suppliers can offer low-price fixed tariffs to attract active consumers, who are motivated to switch, to cover direct costs; but rely on the higher prices charged to less active consumers to cover operating costs and maintain profits.

FIGURE 6: ANNUAL DOMESTIC ENERGY BILLS



Source: BEIS, 2020[28]

Domestic energy bills increased between 2007 and 2019 by 38%, from £441 to £608 per year. Yet higher energy efficiency has brought about reductions in overall consumption. In fact, over the period between 2006 and 2016 average annual electricity consumption decreased from 4.9 MWh to 3.9 MWh. The increase in retail prices has meant that despite the fall in consumption, bills are overall higher than before.

Unfortunately, the most vulnerable consumers are those paying more and more for electricity bills. Households living in 'fuel poverty' are in significantly greater need than ten years ago. 'Fuel poor' consumers are defined as having energy costs that are above the national median level and a residual income, after fuel costs, that are below the official poverty line. In 2015, more than 2.5 million households lived in fuel poverty in England – the equivalent of 10% of all households.[29]

The amount by which a consumer's energy needs would need to be reduced, not to be fuel poor, was 39% higher in 2015 than in 2005 (in real terms). Over the same period, the average energy bill increased by 27%. This means that people in fuel poverty were either less able than the average consumer to reduce their energy needs, or they consumed less than their energy needs. The aggregate fuel poverty gap for England is at £884 million.

In 2019 the Government introduced price caps as a way to ensure customers on default tariffs do not pay excessively for not switching retailers. From April 2021, the price cap will increase by £96 to £1,138 for 11 million customers on default tariffs. The 2020 White Paper states that automatic switching to lower tariffs will be tested. It is not clear whether this will include Time of Use tariffs (as 'lower tariffs' could also be those at a lower average £/kWh cost for retailers).

Capping prices is only one of the many ways to avoid vulnerable consumers paying 'too much' for their energy bills. Other examples include increasing incentives on energy efficiency, strengthening and supporting the Home Energy Conservation Act and enhancing the level of support for local councils' fuel poverty initiatives, for instance to increase energy efficiency measures. New power sources must also go alongside flexible generation and consumption to avoid price increases.

A large part of the market has the potential for convergence with disruptive smart energy technologies, and subsidy-free renewables are attracting investors in Great Britain. However, recent policies have not favoured further investment, with perceptions of instability and uncertainty over profitable rates of return. Analysis by the UK Energy Research Centre (UKERC) suggests that the cost of integrating these sources of power remains relatively modest (between £5 to £10 per MWh), but could increase substantially if the grid fails to adapt.[30]

So, at this juncture, a change in policies is needed.[31] For instance, Aurora Energy Research estimates that today the gap between solar costs (£650 per kW) and returns (£461 per kW) is around 29%. This gap could, in principle, be bridged by Power Purchase Agreements (PPAs). Power Purchase Agreements consist of a 'free solar' proposition in which there are two parties: one business generates solar energy, and the other business purchases solar energy. These agreements offer companies long term financial, accounting and environmental benefits. But to date, a comprehensive policy roadmap does not exist to chart the path towards mass energy-independence, renewables at scale and grid-wide transformation.

3.3 CHALLENGE 3: THE BALANCE BETWEEN 'BASELOAD' AND 'FLEXIBILITY'

The UK energy system is based on a networked electricity grid of large power stations using mainly non-renewable fuel. These include coal fired plants, which are set to be phased out by 2025, but also oil, gas, biomass, hydro and nuclear sources. Power plants need high capacity to provide a minimum 'baseload' of electricity to supply the grid at any given time. Therefore, they will often operate every hour of every day, all year round.

Since demand for electricity fluctuates vastly throughout a day, the grid also requires the use of 'peaking power' to meet spikes in demand, although baseload levels may often exceed the minimum required demand.

The conventional wisdom is that the baseload model of energy generation requires a constant source of power. And while clean generation sources like wind and solar power are great for supplementing the energy mix, their intermittency is a huge issue. In this scenario we will always need the 24/7 baseload generation powered by nuclear or fossil fuel (or, where available, biomass or geothermal) generators as the basis of a safe, reliable and affordable electricity supply.

This model requires stand-by plants to run for only a few days a year when demand is higher, which has become less and less cost-effective, as the investment that such plants represent is sitting idle, when it could be employed elsewhere. Also, increasing output at times of peak demand makes electricity prices more volatile. Electricity price spikes occur frequently when demand is very high. In such circumstances, electricity prices in wholesale markets could fluctuate from less than 3 pence per kWh to as much as 22 pence per kWh on several days of the year.

The need for baseload to ensure reliable electricity is often considered the main reason to delay the shift from fossil fuel generation to renewable sources such as wind and solar. But there are numerous examples of 'reliable' baseload power failing which create significant price increases. In 2017, electricity prices in the Alberta province, Canada, rose to the £585/MWh cap, compared with a 30-day average of about £14. This happened when in the middle of the afternoon two coal plants tripped offline. If Alberta had installed significant solar PV generation, the price rises could have been avoided completely.

Traditionally, balancing demand and supply has occurred via expansion of the capacity base to deal with aggregate increases in energy demand. However, baseload generation is set to play a less significant role in the future. The concept that there is a fixed block of given demand insensitive to generating conditions is now under serious reconsideration. Improving 'flexibility' in the system, i.e. the extent to which supply and demand can be shifted, challenges the assumptions underlying investment in traditional baseload plants.

'Baseload' refers to an old paradigm where energy is centralised and output is constant, where energy flows in one direction from producer to consumer, and where customers have no control. Designing grids around a constant but inflexible supply makes less sense with the potential for ever increasing renewable generation and storage. The variable output of renewables is more valuable, not less - 'dynamic' rather than 'intermittent.'

Increasing renewable capacity and storage on both sides of the meter - including demand response, smart inverters, microgrids and other innovations – allows for the localised and decentralised production of baseload energy.

CASE STUDY: CORNWALL LOCAL ENERGY MARKET

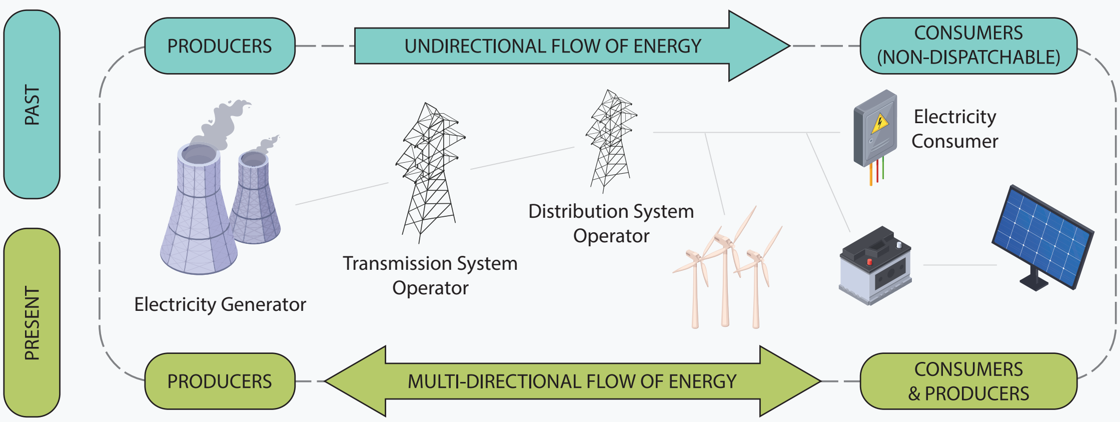
The energy grid in Cornwall is heavily constrained, an issue which is increasingly affecting other parts of the UK as it pursues its legally binding renewable energy and carbon targets.

The issue in Cornwall is exacerbated due to the excellent renewable energy sources available (Cornwall is one of the sunniest and windiest regions of the UK) and the amount of renewable energy installed. There is simply too much generation and not enough network to accommodate the export of energy. The grid is becoming overloaded, making it more difficult for new, clean sources of energy to get access.

Traditional network reinforcement would require huge investment and take a long time to complete. So, in search of another solution, Centrica, in partnership with the local authority, Western Power Distribution, the National Grid and Exeter University, has begun to trail a smarter, more flexible local energy system. It is built around a virtual local energy market where homes, businesses and renewable generators can make money by being more flexible about how they generate and use energy.

New technology is being installed into homes and businesses hooked up to a local network. This is a marketplace platform for the network to request, and the market to provide flexible demand, generation and storage to help optimise capacity on the local grid. When there is too much renewable generation, consumers will be incentivised to use it or store it for later. If there is too much demand and not enough generation, consumers can save money by using less or make money by selling their surplus energy back to the market.

All of this happens automatically using smart technology.



The challenge of getting priorities right between baseload and flexibility has significant implications for system balancing, utilities pricing and future grid development. Issues of flexibility have not featured strongly in energy policies predominantly focused on estimating and reducing total average annual demand per capita. But increasing awareness of the greenhouse effects of fossil fuel generation has created political pressure.

Policies designed around the trilemma no longer reflect the reality of plummeting solar energy costs per unit compared with the high costs of conventional Combined Cycle Gas Turbine (CCGT) infrastructure. Renewables can, and do, contribute to baseload reliability. In the US, during the winter of 2014, wind power provided 13% of demand when extreme cold conditions associated with a polar vortex meant that all energy generation systems suffered outages.[32]

The UK has introduced legal incentives so that System Operators prioritise renewables over other forms of generation. But regulations are failing to keep up with developments in the market, including the trajectory of falling costs and increasingly high adoption of battery EVs. As a result, investment is being directed towards CCGT generation and infrastructure that will end up being underutilised, and cost consumers for many years to come.

Security of supply – 'keeping the lights on' – is central to the classical and well-worn narrative. This insecurity and fear, that demand will exceed supply, is one of the critical points of the energy trilemma. It is, however, becoming what many commentators are now referring to as a key energy fable.[33] Baseload power is becoming an increasingly expensive way of ensuring reliability. Inflexible power plants are not the solution. Instead, flexible systems and services which will help maintain reliability are the way forward.

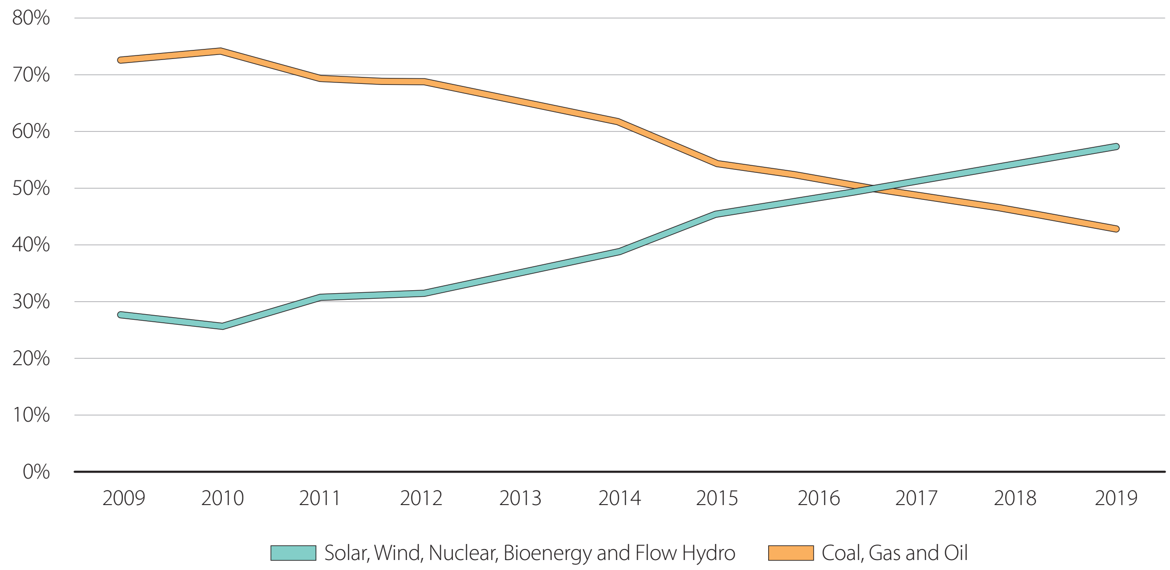
4. SOLUTIONS: TURNING TO SMART RENEWABLES

The current state of the energy market points toward the key factors that will enable a different approach to net-zero emissions and green growth.

4.1 DECARBONISATION HAS SUCCEEDED – WITH A LARGE DOSE OF LUCK

The decarbonisation of the system is one of the standout energy successes of the UK over the last couple of decades. UK emissions in 2016 were 42% lower than in 1990.[34] Using yearly electricity generation data, the figure below shows that low-carbon sources overtook fossil fuel generation for the first time ever in 2017, a pattern that has continued in the years since.

FIGURE 7: ELECTRICITY GENERATION IN THE UK BY ENERGY SOURCE



Source: Digest of United Kingdom Energy Statistics 2020[35]

Successive pro-environment government policies have certainly played their part. Subsidy policies have driven greater diversity in generators and facilitated the gradual introduction of renewables from a standing start.

However, just as important has been the shift toward a service-led economy. In parallel with the decline of manufacturing and heavy industries, between 1990 and 2016 industrial electricity consumption fell from 38.7m tonnes of oil to 23.7m tonnes.[36] At the same time, decarbonisation has been led by the rapid shift from coal to gas, enabled by the development of efficient Combined-Cycle Gas Turbines that can rapidly start-up to respond to demand.

Both deindustrialisation and the substitution of coal for gas were one-time events that cannot be repeated. Despite their impact and much progress on decarbonisation, the UK still has a long way to go if it is to meet its net-zero emissions target or legally mandated target to cut the 1990 levels of emissions by 57 per cent by 2032. Low-carbon energy would need to reach roughly three-quarters of UK power generation for this goal to be achieved.

4.2 INDUSTRY IS NOW READY FOR AN UNSUBSIDISED MARKET

Attention to additional solutions is essential if the UK is to meet its decarbonisation commitments. Both international partners and voters are increasingly concerned about the environment and want to see continued progress.

While beneficial conditions got the UK to this point, commercially viable renewable products are now ready for the market to take over. This is because the real impact of pro-renewables policies has not been in the total percentage of electricity supplied, but rather the development of an efficient and innovative industrial and supply base.

Nowhere has this been more apparent than in the Solar PV and smart solar industry, where generous Feed-In Tariffs created a boom in solar installation. Rapid withdrawal of this grant has led to a fall in new solar installations but also some consolidation. The commodification of parts and services has meant that a significant diversity of suppliers remain, with commercially viable, cost-effective systems.

Between the 21st and 28th June 2018, solar broke the record for weekly output, producing 533 gigawatt hours of power. During that period, solar generated more than 75GWh on five of the seven days, another record. In a first, solar output also hit more than 8GW for eight consecutive days. And for about an hour on Saturday 30th June, solar was the number one source of electricity, with a share of more than 27%. The record for peak solar generation was 9.42GW, set on 14 May 2018 up just 1.6% on May 2017.

These records were achieved during 2018's heatwave and they are largely symbolic, but the milestones demonstrate how far the technology has come. A decade ago, solar contributed almost nothing to UK electricity supplies. The growth in household installations of solar panels is likely to slow, due to subsidy cuts, but adoption of solar by businesses, as a cost saving measure, could be transformative.

CASE STUDY: ADOPTION OF SOLAR BY BIG BUSINESS

Tech giant Amazon is to install solar panels at its UK fulfilment centres and has **pledged to use only renewable energy sources across all its sites** and buildings in the UK.

Amazon expects the panels to generate the equivalent amount of electricity required to power over 4,500 homes, which will cut the company's carbon footprint by 6,000 tonnes of carbon dioxide per year.

This is part of Amazon's global mission to green its operations, to put its scale and inventive culture to work on sustainability for the good of the environment, but also to help keep business costs low and pass along savings to customers.

Importantly, some developers believe they can build without subsidies, by going large-scale -- increasing the number and size of solar farms and solar plants, on land and on water.

CASE STUDY: LIGHTSOURCE BP

In March 2016, Lightsource Renewable Energy successfully completed and connected **Europe's largest floating solar farm.** The 6.3MW installation sits on the surface of the Queen Elizabeth the Second reservoir just outside of London, connected directly into Thames Water's private network.

The solar farm supplies green, renewable solar electricity to the utility company via a Power Purchase Agreement (PPA), satisfying around 20% of the plant's energy needs. With a surface area of 57,000m2, the solar array covers less than 10% of the reservoir but can generate 5.8 million kilowatt hours in one year, enough to power 1,800 homes.

Improved technology will also help scale-up the sector. Hive Energy estimates that their Kent solar farm will have 14% more capacity than originally conceived, due to technical innovations. The Cleve Hill scheme could have a capacity of 400MW compared to 72.2MW in a solar farm in Wales, which is currently the UK's largest.

CASE STUDY: CLAY HILL SOLAR FARM, BEDFORDSHIRE

Clay Hill Farm is a 10MW installation developed by Anesco, with 6MW of on-site battery storage. It is also **the first commercial solar installation to be entirely subsidy-free**, opening in September 2017. It has achieved this through optimising both its supply chain and its use of revenue streams.

Anesco worked with BYD, a Chinese firm, to deliver solar panels, and new electrical inverters from Huawei to maximise the solar yield. The site was also able to piggyback on an existing grid connection from an adjacent solar site, reducing capital costs. The batteries will be able to supply grid balancing services to National Grid's Enhanced Frequency Response and Capacity Market tenders, providing further revenue.

The subsidy-free nature of the development clearly benefits from the optimisations delivered. At the same time, the use of different policy mechanism revenue streams demonstrates the importance of aligning these with the abilities of the technology.[37]

4.3 THE KEY ENABLER: BATTERY STORAGE

The technology allowing widespread roll-out of solar installations is battery storage. In smart solar installations, this enables storage of on-site generation for later release; storage from the grid if prices are low; aggregation into trading networks to provide capacity on demand; and network management services to ensure the stability of the grid.

Global battery prices have fallen even as prices of the component lithium carbonate rose between 24% and 55%, and the cost of cobalt doubled. Battery prices have continued to fall from $273/kWh in 2016 to $209/kWh at the beginning of 2018. Research by Aurora forecasts that the cost of batteries will decrease further from 2018 to 2025 by a significant percentage (between 19% and 25%).

The UK has supported development of the supply chain with the creation of significant research expertise. The Faraday Challenge is one such example of significant funding of battery technology development. The Challenge has been developed by the UK Government via its Industrial Strategy Challenge Fund, which aims to focus innovation on 'missions' to develop solutions to specific challenges. It is an overall £246 million investment, with a first phase investment of £45 million in the Faraday Institute for battery research, to develop 'safe, cost effective, durable, lighter weight, high performing and recyclable batteries.'[38]

This investment is timely, as our global competitors are also now looking to rapidly scale-up distributed smart renewables, and many successful examples are already underway abroad.

CASE STUDY: REPLACING GAS PLANTS WITH SOLAR + STORAGE, CALIFORNIA

In California's Ventura County, two older gas plants are being retired.[39] The local utility, Southern California Edison, was approved by the state to build replacement peaker plants at a total capital cost of $299m, but citizen campaigns have opposed these on environmental grounds. The California Independent System Operator found that storage alternatives were viable but would cost $805m over 30 years.

However, later analysis by the Clean Coalition using up-to-date costs found the true figure for solar + storage was actually $267m - less than the cost of gas plants. This was because the cost of storage had declined over 50% in 4 years. Furthermore, combining storage and solar created efficiencies that reduced overall cost and qualified the project for tax credits.

As a result, the California Energy Commission recommended that the request to build new gas plants be rejected. This demonstrates the significant difference that assessing the unique combination of solar and storage together makes in identifying investments.

Across the wider renewables sector, over the last 15 years the UK has made a substantial investment in energy and low-carbon technology research, development and demonstration (RD&D). For example, the UK Research Council's Energy Programme invested £839 million between 2003 and 2011, and another £625 million was invested between 2012 and 2018.

Making battery storage a reality requires adapting the existing rules in the energy market, and the UK government has actively engaged in doing so. As a result, battery investment is increasingly a viable proposition for energy investors. In particular, four recent decisions have sent positive signals about the role of batteries.

First, in March 2017, BEIS began consultation on removal of 'double charging' and other barriers. In July 2017, National Grid announced a consultation into the future of 'balancing' services to even out the load across the electricity grid. On 24 July 2017, Ofgem opened a Capacity Market consultation to reduce the de-rating of storage, which reduces payments for batteries that supply for short duration; and on 13 September 2017, Renewables Obligations certificates were specifically granted for solar paired with batteries, recognising the uniqueness of the technology.

Additional measures to treat battery storage appropriately could unlock the market further.

5. BARRIERS TO ADOPTION

There are key regulatory and commercial barriers to scaling smart, distributed renewable technology, such as 'smart solar.' Existing energy regulations and legislation are no longer fit for purpose and are hindering the advantages and timescale for delivering energy transformation. These barriers have inhibited consumers and the grid from realising potential net gains. Government must follow through and further explore policy and regulation as proposed by BEIS' July 2017 Smart and Flexible Energy Plan and the Clean Growth Strategy.

As discussed, the main over-arching barrier is the lack of flexibility of the electricity generation and demand systems. At present, extra capacity when electricity demand is high is provided by conventional gas and coal generators. Energy storage technologies and demand-side response could significantly enhance system flexibility, but the lack of appropriate market signals has so far suppressed their deployment. To a large extent, the current structure is unable to provide these signals.

Studies suggest that in the current inflexible system, with 30GW of variable renewables and inflexible nuclear generation, up to 25% of wind energy may need to be curtailed.[40] This is due to the increased need for fossil fuel generation to take its place running below full capacity, in order to respond quickly to balance out changes in supply and demand and ensure a smooth continuous flow of electricity. National Grid currently facilitates and provides these 'ancillary services.' Flexible balancing technologies using storage can potentially support system balancing by supplying these services more efficiently than conventional technologies.

Moreover, the value of the technical potential of the flexibility market was estimated to be around £8 billion per year by the National Infrastructure Commission. This includes flexible technologies, such as: flexible generation, interconnection and flexible network technologies, demand-side response and energy storage. Specific barriers include how energy storage is defined in current legislation, capacity market rules, storage co-location with renewables, double charging and other third-party charges for use of batteries, dynamic pricing, Demand Side Response and half-hourly settlements.

5.1 DEFINITION OF ENERGY STORAGE AND CAPACITY MARKET RULES

Regulations such as relatively short contracts and restrictions on stacking of revenues complicate and reduce security of investments in energy storage. For instance, the UK's Electricity Market Reform policy aims to deliver low carbon energy and reliable supplies. A key mechanism this uses is the creation of a Capacity Market that "provides a regular retainer payment to reliable forms of capacity (both demand and supply side), in return for such capacity being available when the system is tight."[41]

The Capacity Market is technology neutral, and therefore accepts capacity from generation, Demand Side Response and interconnectors to other countries. However, a special Turndown Demand Side Response only auction was also run in March 2017, only available to those promising to reduce consumption.

The payments for promised capacity are awarded through yearly auctions covering delivery up to 4 years in the future. The participation requirements are: providing at least 500kW of capacity (directly or via an aggregator), delivering capacity 4 hours after being notified, providing capacity for at least 4 hours and being available to deliver the capacity at any time during the operational year. The service is funded by paying winners of the auction a set yearly payment.

The Capacity Market services provide the National Grid with an extra level of security when a 'stress event' is likely to occur and available generation will not meet forecast demand. This is expected to be a rare occurrence, and the service **has only been used twice in its first year of operation between 1st October 2016 and 30th September 2017.**

While this policy specifically includes Demand Side Response and storage as a measure for meeting the mechanism's aims, it has been criticised for restricting participation, arbitrarily limiting contract lengths and offering only uncertainty about storage capacity during transitional arrangements.[42] The Capacity Market implicitly favours fossil fuel generation through only offering one-year storage contracts, compared with the up to 15-year terms available for generator contracts.

The 2016 Capacity Market auction offers an example of the limited support to Demand Side Response. Of the overall 52,425MW of capacity awarded in the auction, only 1,410 MWs (2.69%) was for Demand Side Response. This compares to 44,464MW (84.81%) being awarded to existing generators. This is similar to the outcome of previous auctions and has drawn criticism, as the mechanism is not obviously achieving the desired outcome of prompting creation of new generation and demand reduction capacity. It is instead helping to subsidise existing generators.

The perceived lack of government support and permission for long-term storage contracts and uncertainty in the new market is furthering potential users' lack of confidence in a storage service, confidence which is essential for necessary investment and uptake.

A fairer, better incentivised system is needed that will decrease investors' uncertainly and boost the uptake of storage technologies. This would see the Capacity Market explicitly aiming to increase storage and Demand Side Response participation, extending the one-year contracts under transitional arrangements for a longer time period. There is an opportunity for BEIS to consider contract duration as part of their review of Capacity Market rules.

5.2 BARRIERS TO STORAGE CO-LOCATION WITH RENEWABLES

Energy storage located on-site at renewables projects is a key market for future energy storage deployment. There are a number of key design parameters which define network access and charging arrangements. The rights for network access may vary in applying for entry onto the network (i.e., by generators or storage exporting onto the system) or for exit from the network (i.e., by demand, or storage that is importing). The same rights vary depending on which users the requirement to hold rights applies to (for example, depending on whether there are different arrangements for different sizes of generator or consumers).

There is a lack of clarity about when storage can co-locate with renewables without interfering in existing Contracts for Difference, Renewables Obligations and Feed in Tariffs. **The Government should review transmission access rights, possibly through a Transmission Access Review**, which looks at how generators access the long-distance electricity transmission network.

This review would focus on accelerating connections as a key enabler in meeting our renewables and carbon targets. The last Transmission Access Review considered a range of options, including market-based mechanisms for allocation of rights (e.g. auctions and secondary trading) alongside variants on the 'Connect and Manage' scheme. Concerns about the ability of the network to handle additional power from new electricity generators had prevented them connecting in the past. Connect and Manage involves generators being able to connect before wider reinforcement works are completed, waiting only for enabling works to be complete.

At the time, Ofgem considered that a market-based approach could be beneficial and encouraged industry to bring forward modification proposals (this was prior to Ofgem having the ability to launch Significant Code Reviews itself). Market-based approaches could involve technical enablers such as blockchain, big data and the Internet of Things. However, the industry process got bogged down – arguably as a result of the vested interests of incumbent generators – and consequently Ofgem recommended to Government that it used its powers to step in and develop a solution.

Government, which was heavily focused on renewables deployment at the time, decided to introduce Connect and Manage. In contrast to the previous 'invest and connect' approaches, this enabled user connection ahead of completion of wider reinforcement work. This was enabled through a derogation from the usual standards enforced to keep supply stable, with generators agreeing to limit their production when the network was at full capacity. The resulting constraint costs from underutilised generating sites is socialised (i.e., spread) across consumers.

Moving beyond this accommodation will need a new focus on accelerating connections, and full clarity on when storage can co-locate with renewables without interfering in existing Contracts for Difference, Renewables Obligations and Feed in Tariffs.

5.3 DOUBLE CHARGING AND OTHER THIRD-PARTY CHARGES FOR USE OF BATTERIES

Battery storage is currently charged for using the energy network as both a demand customer and a generator. This means that battery storage is charged network costs both when drawing power from and discharging power back to the system.

The speed and extent of the electricity system transition has not been reflected in changes to the access framework. Users' rights and charges are a relatively opaque area in energy markets regulations. Definitions are often unclear and subject to different interpretations. Significant differences exist across transmission and distribution, generation and demand.

For example, the Transmission Entry Capacity rules grant an 'option' to a generator to access the transmission system up to a maximum level for a given year. Payment of the Transmission Use of System fees annually, up to the cap granted, confers the right to use that capacity. The removal of these payments would eliminate the double charging barrier for storage since it would no longer be considered a source of demand and therefore chargeable.

With regards to distribution, under the status quo the Electricity Act 1989 grants parties the right to request a connection to the grid to meet requirements for electricity under reasonable terms. Under the current connection processes, an application will specify the maximum power to be conveyed, and may include reasonable terms, with scope to agree different levels of firmness.

However, this arrangement contains little explicit consideration of the notion of 'capacity rights' over time as distinct from the capacity (size) of the connection, other than some obligations relating more to supply or reliability. Distribution Network Operators, who run the regional networks, have limited ability to recover capacity that is unused and allocate it to others. Stand-alone battery storage has to pay to the distribution network residual demand charges, paying for unused capacity which is not needed when the batteries are not needed.

Changes to this arrangement could include only levying charges on energy storage as generation for network residual charges (charges that are intended to recover the cost of running the grid and distributing power), while also removing transmission and distribution residual demand charges for standalone energy storage or storage co-located with generation assets.

5.4 DYNAMIC PRICING

The roll-out of smart meters across all 26 million GB households will facilitate the enrolment of many consumers to new Time of Use (ToU) tariffs in the settlement process. The settlement process allows for charging suppliers for the difference between how much energy they purchase and how much their customers actually use. Since smart meters can record and transmit electricity consumption information for every half hour, suppliers can use this information for settlement instead of monthly readings. Hence, suppliers will have a much more accurate picture of consumption and demand and can match this with the volumes of electricity that they purchase faster and more accurately. This could reduce costs and allows them to charge consumers on a 'Time of Use tariff'(ToU), varying charges by the cost of electricity during the time it is used. The national-level integration of dynamic tariffs such as ToU tariffs has the potential to bring about significant reductions in prices, expand demand for renewables and limit carbon emission from dirty power plants.

ToU tariffs consist of consumers being subjected to different prices for electricity based on a division of the day into time bands. Instead of a single flat rate for energy use, time-of-use rates are higher when electric demand is higher. Typically, two rate periods are applied:

I. During peak periods electricity rates are higher; and
II. Off-peak tariffs are generally lower than the peak rate.

This means when consumers use energy it is just as important as how much they use. ToU rate rewards customers using power at night with lower rates. However, rates during the day (on-peak) and the peak demand rate are usually higher.

ToU tariffs have the potential to stimulate customers to shift demand from peak to off-peak periods or simply to reduce peak demand, in both cases reducing system costs and improving system efficiency. However, there will be variations in the ability of different customers to take advantage of ToU tariffs, depending on their current pattern of electricity usage and their willingness or capacity to respond. Understanding the scale and nature of these variations will be important both to the design of effective ToU tariffs and to considerations of how consumer interests may be protected as such tariffs become available.

There are different possible types of ToU tariffs. Static ToU uses prices and periods (e.g. £X/kWh for 07:00 – 16:00) established in advance, while dynamic ToU adapts to conditions in the market. An example of a dynamic ToU tariff is real-time pricing where domestic tariffs are indexed to the prevailing wholesale price for a specified product, such as electricity for delivery the next day. Critical peak tariffs involve introducing different prices for a limited number of pre-specified peak consumption periods during the year. Critical peak pricing imposes higher prices for consumption during these periods, while critical peak rebates provide compensation for reduced consumption during these periods.

ToU tariffs, unlike other price-based Demand Side Response programmes, provide consumers with certainty about the price of consumption at different periods of the day. This is a significant advantage, considering loss-aversion of most residential electricity users. The great majority of consumers have always paid flat rates, and loss-aversion amongst the general British population may stifle demand for ToU tariffs. Research undertaken by Ofgem found that "consumers focus too much on potential losses (e.g. higher prices, problems during the switching process) than potential gains" when considering whether to switch energy tariffs.[43]

ToU tariffs offer significant potential benefits to the system by enabling responsive electricity demand and reducing peaks. For example, they could reduce the need for new generation and network capacity. In principle, the introduction of smart meters will also enable households to be settled on a half-hourly basis. Therefore, widespread availability of dynamic tariffs should be encouraged by regulators.

There are a number of benefits that are independent of the smart tariff structure, such as potentially greater consumer satisfaction with a more transparent, accurate settlement process using actual consumption. Also, switching should be easier and faster when more granular settlement processes have been established.

PREVIOUS EXPERIENCE WITH TIME OF USE TARIFFS

In the UK, about 5.5 million customers make use of multi-rate energy tariffs. Economy 7 is the most significant example of these Time of Use programmes, with cheaper tariffs in the night, so that customers using electrically charged thermal storage heaters can meet their space heating demand from off-peak electricity. Electrical storage heating was particularly successful in the UK as a complement to the nuclear power programme from the 1960s, with the requirement for nuclear generators to operate continuously giving rise to low baseload and off-peak prices. In the UK, evidence on the conservation effects of the 3 million consumers using Time of Use Economy 7 tariffs is not published.

PREVIOUS EXPERIENCE WITH TIME OF USE TARIFFS *(continued)*

Some of the conservation effects are intimately related to the performance of electric storage heating, which for some of these consumers is automated. As part of the Low Carbon London trial, the low rate was available between 5pm and 8pm. The headline data shows a clear difference in demand between the trial (Dynamic Time of Use Tariff) and Control (Static Tariff) groups. The Trial group used 3.2% less electricity on average. There appears to be a shift in energy demand in the trial group to take advantage of the low rate.

Whilst this trial is showing a significant reduction in demand (around 4.2%) and the data is scaled to give equivalent use for each group, the difference shown cannot be purely attributed to the effect of the Time of Use tariff because there might be inherent selection biases in the Trial group, as this group is made up of people who actively signed up for a trial, whereas the control group are just normal users who did not.[44]

Time of Use tariffs were also trialled in Ireland as part of one of the most statistically robust studies to date. In this study, overall demand could be shown to reduce by 2.5% after the introduction of the new tariffs. Peak consumption was reduced by 8.8% for specifically designed price bands. Higher reductions could be achieved through provision of additional information to participants, such as energy monitors and statements. These were found to be more effective at changing use patterns than setting more extreme price differentials between peak and off-peak tariffs, to which demand appeared highly inelastic.[45]

In France, Time of Use tariffs were combined with weather inputs, with days differentiated based on price signals for peak and off-peak hours. It was estimated that for a typical household with a 1 kW average load, the Tempo tariff brought about a reduction in consumption in the region of between 15% and 45%, with customers saving 10% on average on their electricity bills.[46]

In Norway, the programmes which were undertaken with a view to postpone the expansion of grid capacity brought about energy savings of around 15%, along with 10% reduction in peak demand in the Oslo area.[47]

The Brattle Group conducted a review of international studies on Time of Use tariffs and dynamic pricing. Out of the 163 reviewed studies, the peak reduction levels range from next to 0 to almost 60%. It found that the peak to off-peak price ratio plays a vital role in explaining variation across

PREVIOUS EXPERIENCE WITH TIME OF USE TARIFFS *(continued)*

different countries. For instance, with a peak to off-peak price ratio of 5:1, pricing-only trials obtained a 13.8% peak reduction, whereas a peak to off-peak price ratio of 10:1 pushed peak reduction to almost 16%.

The introduction of enabling technologies (e.g. as smart thermostats) meant that the peak reduction could be as high as 21% to 27%. Findings with the 5:1 price ratio are comparable to those from the 2005 California Statewide Pricing Pilot, which was characterised by a critical peak pricing rate with a price ratio of 7:1 and yielded a 13% peak reduction.[48]

5.5 DEMAND SIDE RESPONSE

One of the solutions being used to help overcome these issues is Demand Side Response (DSR). DSR is a solution that aims to match energy demand with available supply. Historically DSR has been used in the electricity market as a balancing mechanism to temporarily reduce energy usage of large electricity users, such as steel producers. For example, during periods of high demand, controls are applied to reduce usage of non-essential energy by organisations during such periods. DSR offers many benefits, including reducing the need for peak electricity generation plants, reducing infrastructure costs and enabling greater usage of intermittent renewable generation sources.[49]

The UK is currently identified as having the most advanced DSR market in Europe, and this market is steadily increasing in size. While the exact amount of UK DSR usage is hard to obtain, the National Grid's (the UK system operator) Short Term Operating Reserve (STOR) programme offers an indication. The latest reports on this programme show that the amount of Generator DSR in the UK is difficult to quantify due to a lack of published figures. The closest estimate can be obtained from a 2015 National Grid report on fuel usage by the STOR programme participants. The report outlined that participants had 3,444 MW of reserve generation and demand reduction capacity.[50]

There is no specific market programme for DSR in the UK, and DSR is instead contained within the UK's Transmission Operator (National Grid) current electricity balancing services. Currently the main balancing services used for DSR is the STOR. This service provides a means to provide DSR, yet its current structure provides a number of barriers to its usage.

To provide this service, the National Grid runs a tendering process 3 times per year to procure reserve power from companies that can meet its requirements: providing at least 3MW of generation or demand reduction; delivering full capacity within 240 minutes of notification; providing capacity for at least 2 hours; and supplying 3860 hours availability a year during a morning and afternoon window. The service is funded through paying providers an availability and utilisation price (£/MW/h). Yet these conditions pose a number of barriers for DSR:

- **3MW Minimum Capacity** – For generators providing capacity onto the grid, this amount is easy to achieve and provided at a consistent rate. For demand reduction this minimum is achievable through aggregation of many sites. However, as the contracted capacity is fixed per contract with penalties for under provision and no additional revenue for over provisioning, aggregated sites using demand reduction are at a disadvantage compared to export generators in the STOR programme. This disadvantage results from demand reduction contracts having higher uncertainty of actual reduction given a site's natural demand variances, therefore requiring the provision of more capacity than stated to ensure the minimum capacity is capable of being met. For example, a 5MW contract may require contracting 6MW of aggregated sites if an organisation is to ensure at least 5MW of capacity, even though the aggregator will only get availability and utilisation payments for the contractually-prescribed 5MW.

- **240 Minute Notification Before Event** – While the STOR programme states that providers have up to 240 minutes to respond with full capacity, the manner by which the contracts are tendered favours shorter response times, notably contracts that have a sub-20 minute response time. Further, 98.4% of STOR contracts have been awarded for sub-20 minute response providers.[51] This shortened response time favours fast response DSR, like backup generators or turndown of motors and appliances. However, this requirement disadvantages DSR that is reliant on pre-loading. More DSR could be made available if sufficient notification was allowed to enable pre-loading of cooling or heating systems, to cover the event period.

- **2 Hour Event Duration** – A key barrier to STOR DSR usage is the requirement to be able to provide the agreed capacity for a minimum of 2 hours. While this is not an issue for generators, it does present significant issues for sites using turndown-only approaches. This is because a majority of turndown approaches rely on system inertia (e.g. turning off HVAC) to cover the event period. Experience by a UK Demand Response Aggregator shows that this reduction can only last roughly one hour before impacting users. In theory, the National Grid's 2-hour requirement could be aggregated by having two sites cover one hour each. However, this then requires splitting the availability payment and reducing the economic case for participation. This issue expressly impacts medium sized sites, as organisations that are likely to only provide turndown options and offer less system inertia to cover the event duration given their smaller sizes.

- **Set Operating Windows** – There are typically two 5-hour STOR operating windows per day that cover the morning and afternoon system peaks for the whole year. This is not an issue for export generators, as they are organisations that can provide their capacity when called on. However, for DSR sites with varying demand levels, a requirement for set operating windows will restrict the organisation to only committing to a capacity level that represents its lowest average demand across the operating windows. Additionally, this commitment normally needs to be for the whole year, which causes further issues given seasonal and weekend demand variances. These restrictions make it difficult for businesses of any size that are closed during parts of the windows and/or during the weekends.

- **Tendered Auction Process For Capacity** – The tendering process only allows bidding for capacity up to two years in the future. For DSR aggregators this means that they can only guarantee to clients a maximum of two years' service. While it's likely that the aggregator will continue to win future capacity, it is not guaranteed, and therefore is restricted in the length of contracts it can provide clients. This limited period can discourage clients from investing the necessary effort to enable their business for DSR. This impact can be higher on medium sized businesses, due to lower demand reduction levels requiring a longer return period on initial setup costs.

Each of the STOR participation conditions pose barriers for DSR usage and illustrates how the STOR programme suits generator-based providers, as organisations that are able to more easily meet the conditions. This highlights the overall problem with the STOR programme being presented as a catch-all for many different types of generation and demand reduction services.

While DSR services are possible through aggregation, participating in the STOR market requires more effort from aggregators than is required by the energy generators. The aggregation effort is further increased by the number of companies that are included to meet the conditions: it is easier to enable and control 3-4 large businesses for DSR than 10-20 medium businesses. This makes the STOR programme less than ideal for DSR usage, particularly if trying to expand DSR usage to medium or smaller sized businesses.

Each of the above market features illustrates how unclear government policies discourage investments in DSR and how current market rules favour generator-based services and restrict 'turndown' solutions. There are a number of key barriers for DSR uptake, in particular current rules around Minimum Capacity, notification and duration of DSR events, operation windows and auction processes.

Addressing these will be essential if the country is to avoid an inflexible future with wasted investment in legacy technologies and plants sitting idle for much of the year. Therefore, the Government should consider a common policy for Demand Side Response in order to maximise the flexibility potential of electricity demand. A common GB policy would encourage uptake from residential end-users with significant implications for grid balancing and cost reduction.

5.6 HALF HOURLY SETTLEMENTS

Electricity smart meters should remove the need for 'profiling' – guessing the consumption patterns of consumers to estimate cost - as they can provide accurate half-hourly meter readings. Currently the electricity meters of domestic consumers and small businesses record electricity consumption over longer periods, with meter readings taken one to two times a year. But electricity supply is settled on a half-hourly basis, so estimates are made for the electricity consumption of each household for each half hour of the day.

Hence, without half-hourly settlements, there will be no opportunity to access energy trading platforms, as there is no means to bid and offer power that differs by the time it is used. For consumers, half-hourly data increases the information available on how much electricity is being used. This enables them to use energy trading platforms to automatically find the cheapest power, or to otherwise change their usage and supplies in real time. It may also suit those consumers who can avoid times of the day when electricity is expensive and more carbon intensive to generate.

6. RECOMMENDATIONS

Smart solar and batteries will play a critical role in delivering cost-effective low-carbon energy which is secure and accessible to everyone. Evidence shows that investors are ready to commit large capital investment in solar PV and batteries, taking advantage of diminishing costs and high returns.

From a social welfare perspective, financially backing incentives and research in this area is a win-win proposition. Smart solar will reduce the costs of energy systems, providing next-to-zero baseload costs of electricity. It will ensure competitive advantage for the UK in an area where competition is fierce and of high geopolitical importance. Hence, from a policy perspective, the decision to continue the path of investment in smart solar is one that can ensure the country remains globally competitive, particularly as we have now left the EU.

In order to deliver this vision, this report puts forward the following recommendations:

1. The UK Government should continue on the path of enabling investments in smart solar, that has been set by recent energy policy. Some **regulatory changes** will be required in order to speed market adoption and strengthen the UK's competitive position. The overall approach of regulatory changes should be to increase the market opportunities for flexible technical solutions. This involves ensuring that incumbent network companies play a full role in the transition to a more flexible system, whilst opportunities are created for new entrants in the electricity market.
2. The National Grid **Capacity Market** should aim to increase storage and Demand Side Response participation, extending the one-year contracts under transitional arrangements for a longer time

period. This will decrease investors' uncertainly and boost the uptake of storage technologies. BEIS should consider contract duration as part of their review of Capacity Market rules.

3. Ofgem should consider developing market rules for the **deployment of large scale, medium to long duration storage**. Long duration (>4hrs), large scale storage (LLES) may help to manage two problems. First, increasing penetration of inflexible generation is likely to carry significant system balancing cost on a large scale and over long periods of time. Second, increasing electrification of heat is likely to shift the large swings in seasonal demand from the gas to electricity system.
4. The Government should **review transmission access rights**, possibly through a Transmission Access Review. This would focus on accelerating connections as a key enabler in meeting our renewables and carbon targets, as connections can be a key barrier.
5. With regards to **double charging**, the Access Framework by Ofgem should be modified to develop more clear definitions of capacity rights as distinct from connection capacity. This way, battery storage would not be charged for network costs both when drawing power from and discharging power back to the system. In practice, changes to the Electricity Act 1989 will need to include the definition of storage as a subset of generation asset class, and not as end consumers of energy.
6. Researchers will need to analyse the financial effects of the significant reform of the **pricing settlement**. Ofgem in 2020 put forward a proposal for the Market-wide Half-hourly Settlement reform. Moving to **half-hourly settlement** will enable suppliers to know how much their customers consume every half hour, enabling dynamic pricing. Consumers would benefit from a reform of the pricing settlement. A reduction in the amount of consumption at peak times should reduce the need for investment in new generation and network capacity and hence billpayer cost. However, the impacts on different types of consumers need to be understood.
7. The Government should also consider a common policy for **Demand Side Response** in order to maximise the flexibility potential of electricity demand. Demand Side Response to date has been mainly an operational decision in the hands of National Grid, relying mostly on the flexibility of small industrial and large commercial end-users. However, a common GB policy would encourage uptake from residential end-users with significant implications for grid balancing and cost reduction. The policy should re-consider the current rules of the game of Demand Side Response (in terms of 3MW minimum capacity, 240-minute notification before event, 2-hour event duration and set operating windows and tendered auction process for capacity) as they significantly prevent participation from smaller energy users.
8. Remove barriers to **smart home balancing**, as part of the proposed changes to the Targeted Charging Review. Groups of network users should not benefit disproportionately from network cost recovery (as is currently the case) and storage should not pay the demand residual element of network charges. In order to facilitate the transition to smart home balancing, Ofgem should implement changes on flexible connections, possibly using financial incentives to encourage distribution network operators to reduce costs for consumers who respond flexibly to balancing needs.

9. **Water heaters** and **storage heaters** are examples of solutions which should be widely adopted in homes and social housing as one of the main solutions to address fuel poverty in communities. This would require more proactive communications from Government on smart storage, and strong incentives for local and community organisations.

10. The Government should establish markets in local flexibility services to manage local network constraints, and this can only happen if distribution network operators **(DNOs) become active managers** of their networks through cross-sector reform.

11. The Government should **fund R&D in Electric Vehicle Charge Services** to establish the UK as a leading provider of charge control services, that maximises the benefit for users and energy industry stakeholders. Development of a successful bi-directional ('V2G') service is expected to have significant consequential benefits for facilitating the ongoing growth of renewable generation, and for realising the wider benefits of the burgeoning electric vehicle market. Electric vehicle charging is set to bring dramatic changes for the built environment and infrastructure systems, especially for energy networks. This could be highly detrimental for the power system if badly managed, or bring strong environmental, security and cost benefits if vehicle charging is controlled for optimum benefit to all parties.

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The UK has some of the highest levels of wealth concentration in the developed world. It has an economy where most mature markets are dominated by a small number of players and the barriers to entry are far too high. It is not an exaggeration to suggest that in many areas, from energy to banking to groceries, the UK has a monopolistic rentier rather than a market economy – a system in which certain individuals or small groups gain market dominance and excessive returns through anti-competitive practices. This conspires against innovation and is detrimental to the small and emergent businesses that generate growth and spread prosperity. Added to this, our education system, by specialising too early and often in the wrong areas, fails to produce students with fully rounded skill-sets. We are simply not equipping our future workforce with the means to safeguard our, and their, economic future. This is one reason why the real value of wages in proportion to growth in GDP continues to stagnate or fall. Our long-term productivity dilemma is a function of market capture and the effective de-skilling of the population.

We believe that shared prosperity cannot be achieved by simply tweaking the market. Britain needs significant demand and supply-side transformation, with new visionary institutions re-ordering our economy. We need long-term solutions that give power over wealth and assets, not simply handouts, to ordinary people. Central to this process of economic empowerment is an ethical, practical and adaptable education that gives people the skills to build their own businesses, or develop their own talents, rather than a conveyor belt to a service industry of low wage and less return.

New financial institutions to promote small business lending are required, and this involves smaller, more specialised and decentralised banks that can deliver advice as well as capital. We wish to explore ways in which all financial transactions can be linked to a wider social purpose and profit, which itself needs a transformation of the legal framework within which economic transactions take place. We believe that the future lies in the shaping of a genuinely social market which would be in consequence a genuinely free and open market. Internalising externalities and creating a level economic playing field in terms of tax paid and monopolies recognised and challenged, remains beyond the scope of contemporary governments to deliver. Such a vision requires new concepts. The viable transformative solutions lie beyond the purview of the current visions of both left and right in the UK.

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This report examines the current regulatory and legislative framework that governs the UK's energy system, with a focus on renewable sources of energy and the issues that arise from the status quo on power generation and distribution.

It makes the case for scaling up the development and implementation of smart solar and battery storage technologies to meet the UK's objectives for both carbon reduction and clean economic growth.

We explore the challenges and outline the solutions that can remove the current policy and regulatory barriers to achieve this ambition.

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