ENERGY SYSTEM FLEXIBILITY

Opportunities for investors

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CARBON TRUST

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Energy system flexibility: Opportunities for investors

The Carbon Trust wrote this report based on an impartial analysis of primary and secondary sources, including an expert workshop.

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This report is supported by Lloyds Bank. For the avoidance of doubt, this report expresses independent views of the authors.

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We are a trusted, expert guide to Net Zero, bringing purpose led, vital expertise from the climate change frontline. We have been pioneering decarbonisation for more than 20 years for businesses, governments and organisations around the world.

We draw on the experience of over 300 experts internationally, accelerating progress and providing solutions to this existential crisis. We have supported over 3,000 organisations in 50 countries with their climate action planning, collaborating with 150+ partners in setting science-based targets, and supporting cities across 5 continents on the journey to Net Zero.

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Abbreviations

BEIS	Department for Business, Energy and Industrial Strategy
CAPEX	Capital Expenditure
CCS	Carbon Capture and Storage
DNO	Distribution Network Owner
DSO	Distribution System Operator
DSR	Demand Side Response
ENA	Energy Networks Association
ESG	Environmental, Social and Governance
ESO	Electricity System Operator
EV	Electric Vehicle
GW	Gigawatt
IRR	Internal Rate of Return
MW	Megawatt
OPEX	Operational Expenditure
PPA	Power Purchase Agreement
TES	Thermal Energy Storage
V2G	Vehicle-to-Grid

Executive summary

£16.7bn/yr

Flexibility is the ability to shift the time or location of energy consumption or generation. Flexibility presents a significant opportunity for the finance sector. In Great Britain, flexibility could save £16.7bn/yr. in 2050 compared to a less flexible scenario.

A portfolio of flexibility services will be required and unlocking sufficient finance will be key to meeting deployment targets.

The whole system value that flexibility can deliver in meeting Net Zero is widely recognised, but market design can make the commercial value of flexibility at a project level harder to establish.

From an investor perspective, three key factors influence the decision on whether to finance a project, and at what cost:

1. Certainty and duration of revenue streams– the likelihood that the investment generates sufficient income over its lifetime to pay back the financing whilst generating a suitable risk-adjusted return to its investors
2. Counterparty risk – the credit rating(s) of the counterparty(ies) providing the revenue certainty
3. Proven and scalable technology – technology with proven operational track record which is suitable for deployment at the scale required by full-size commercial projects

Some market barriers to low carbon flexibility remain. The UK Government and Ofgem's Smart Systems and Flexibility Plan recognises that several actions are needed to create long-term price signals for flexibility, fully account for carbon emissions from small scale flexibility assets, and improve access to flexibility markets.

Flexibility services can access finance, but the challenge is accessing finance at the scale and cost required to meet deployment need. This requires a better understanding of how investments which include flexibility can be structured and how public sector investment can be used to leverage private finance.

Evaluating the risk of investing in flexibility should take account of its potentially positive impacts on other co-located assets.

Continued communication between industry, UK Government, Ofgem and the finance sector will be crucial in unlocking finance.

Introduction

International governments have a strong economic incentive to act decisively to avoid runaway climate change. A growing body of research provides evidence that this will minimise the expected cost to society and in particular the risk of catastrophic economic impacts[1]. Avoiding runaway climate change therefore is not only a moral, but also a financial imperative.

The UK Government was the first major economy to set itself the ambitious goal of reaching Net Zero greenhouse gas emissions by 2050. To achieve this, sector specific pathways over time are critical. This needs to include intermediary emission reduction targets providing industry with time horizons better aligned with those applied for commercial planning and decision-making. By share of emissions and opportunities to reduce them, the energy and transport sectors stand out.

Significant success has been achieved in the deployment of renewables. For example, Great Britain is a world leader in offshore wind. With 10.5 GW, it has more installed capacity than any other country in the world. However, the total cost of any grid connected generation source has two components: the direct cost of the installed generation asset and its system integration cost for the electricity grid. Sticking with the example of offshore wind, significant cost reductions have been achieved for its generation which have reduced by more than 50% since 2015[2] and undercut the cost for new gas or nuclear today. However, the integration of a growing share of intermittent renewables, along with increasing electrification of demand, provides increasing challenges to the electricity system of Great Britain. To continue to decarbonise the UK's energy sector in a cost-effective way requires zero carbon flexibility solutions. Unless these are deployed in a timely fashion and at scale, rising system integration costs for renewables will erode the financial benefits for end-users otherwise achieved from generation cost reductions.

The recent Flexibility in Great Britain project from the Carbon Trust and Imperial College states that timely deployment of additional energy system flexibility could reduce the cost of meeting Net Zero by up to £16.7bn/yr. in 2050[3] (see page 7).

Unlocking this value for Great Britain's energy sector requires substantial investment. These investments cannot be borne solely by the energy sector itself; substantial financing by the private sector is needed. In addition, the level of investment required will only be delivered if insufficient or misaligned incentives for flexibility investment are replaced, and the benefits of flexibility are shared fairly amongst investors. Bringing forward private finance will require UK Government and the energy regulator, Ofgem, to create a suitable market and regulatory framework as well as invest alongside the private sector where there are financing gaps other sources are unable to fill. This is expected to lead to a positive overall result for the public.

This report builds on the Carbon Trust's Flexibility in Great Britain project research to provide a summary of the value of low carbon flexibility solutions to the GB energy sector.
It also:

- Discusses the requirements which have to be in place for private sector financing to be viable;
- Identifies barriers which have to be addressed to make such financing more widely available for viable opportunities; and
- Explores how capital costs can be reduced for parties seeking financing.

The report concludes by proposing next steps to take in order for stakeholders to fully capture this opportunity for Great Britain.

Overview of the Flexibility in Great Britain project

The Flexibility in Great Britain report was published by Carbon Trust and Imperial College Consultants in May 2021. The project sought to understand the value of flexibility in delivering a cost-effective, Net Zero 2050 energy system and assess the 'deployment readiness' of a range of flexibility technologies, identifying current barriers to deployment of flexibility which may impact Britain's ability to deliver flexibility at the rate required to meet decarbonisation targets.

The value of flexibility was determined through whole systems modelling, using Imperial College's Integrated Whole Energy Systems (IWES) model. IWES includes the power sector, along with the heat, transport and hydrogen sectors which enabled the modelling to highlight how flexibility in one part of the energy system has impacts in another.

Heat pumps

Hydrogen boilers

Hybrid heating

The system modelling considered three pathways to 2050 each dominated by a different heating solution: heat pumps, hydrogen boilers or hybrid heat pumps (a heat pump coupled with a small gas boiler to provide additional heat on the few days when the heat pump can't meet demand). Each pathway was modelled first with a low deployment of flexibility technologies and then a high deployment of flexibility technologies.

The flexibility technologies included:

- Demand side response (DSR)
- Smart charging and vehicle-to-grid (V2G)
- Battery storage
- Thermal storage
- Pumped hydro
- Interconnection
- The flexible production and storage of hydrogen
- Dispatchable power generation (e.g. gas and biomass power stations and turbines)

Comparing the whole system cost of the low and high flexibility modelling results found that investing in a portfolio of flexibility technologies is a no-regrets decision as it delivers material net savings of between £9.6bn/yr. and £16.7bn/yr. across the three Net Zero pathways analysed and supports a cost-effective decarbonisation of the energy system. The savings predominantly come from avoidance of gas generation (Capex and Opex), reduced reliance on carbon negative technologies (although significant carbon capture and storage (CCS) is still required), and reduced network reinforcement.

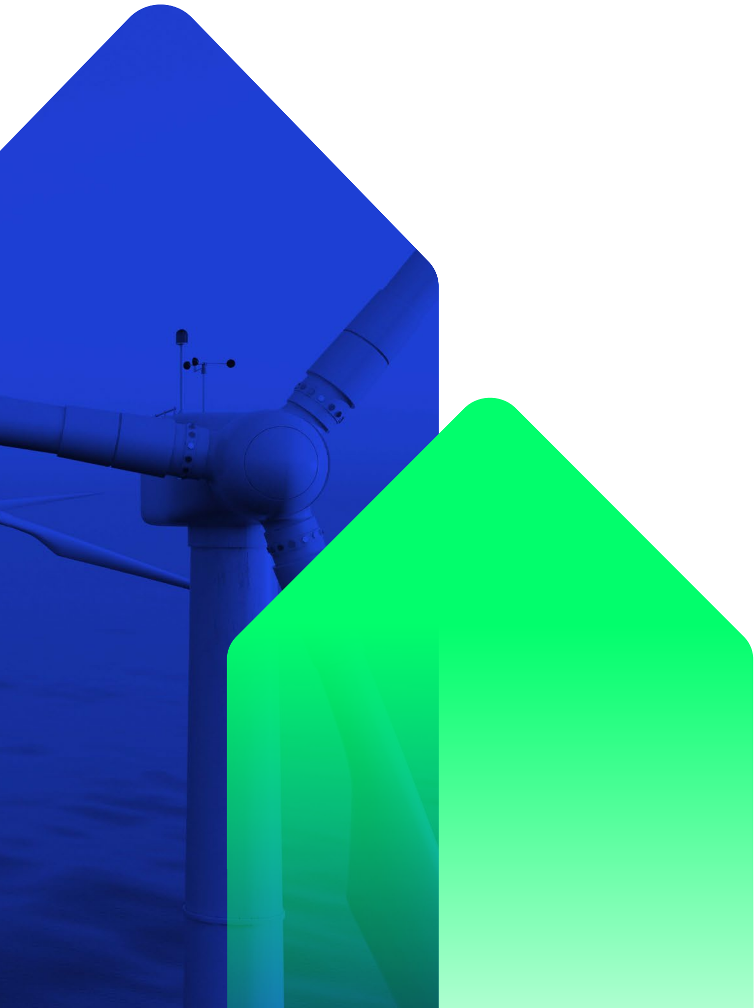
Delivering this value requires action now. The 'deployment readiness' assessment of different flexibility types, concluded that in order to deliver a flexible energy system by 2050, flexibility should be integrated now into enabling infrastructure, such as electric vehicle charge points and thermal storage in heating systems. This requires investment and the development of attractive propositions for both energy consumers and the finance sector.

Method

This report focuses on identifying the challenges and barriers to financing flexibility services and identifying actions which could increase the availability of finance for flexibility services and/or reduce the cost of finance.

Information was gathered via a survey and workshop with both finance and energy sector stakeholders. The survey sought to understand the level of awareness of different forms of flexibility amongst stakeholders and gather views on the types of finance currently available to different forms of flexibility, as well as the barriers to accessing more, and lower cost, finance. More detail on the survey is provided in the Annex. The workshop built on these themes, focusing particularly on barriers related to deployment of DSR services and thermal storage.

Finance sector stakeholders included banks, pension funds, infrastructure fund managers and broader energy sector investors. From the energy sector, participants included network owners and operators, energy suppliers and generators.



Key themes

A portfolio of flexibility services is crucial to delivering a cost-effective Net Zero transition.

Smart

refers to the ability of a device to respond in real time to communication signals, using digital technologies, to deliver a service.

Flexibility

is the ability to shift in time or location the consumption or generation of energy.

A smart and flexible system

is one which uses smart technologies to provide flexibility to the system, to balance supply and demand and manage constraints on the network[4]

Flexibility can be provided by storing energy (as chemical, mechanical or thermal energy), changing the time at which energy is used, using flexible forms of generation (such as hydrogen turbines), and interconnection with neighbouring markets. The Annex to this report provides an overview of key flexibility technologies that could be deployed in Great Britain to deliver a more cost-effective transition to Net Zero.

The exact portfolio of technologies deployed will depend on wider decisions in the energy system, but what is certain is that delivering a smart and flexible energy system will require a combination of these technologies.

The whole system value that flexibility can deliver in meeting Net Zero is widely recognised, but market design can make the commercial value of flexibility at a project level harder to establish.

The UK Government's recent Net Zero Strategy[5] recognises that flexibility will 'underpin' the transition to a Net Zero energy system and its Smart Systems and Flexibility Plan[6] published in July 2021 also recognised the urgent need to invest in flexibility now in order to deliver a more cost effective, low carbon energy system in the future.

From a systems perspective, investing in flexibility is a no-regret option as a portfolio of flexibility technologies is expected to deliver value regardless of the wider system change. Flexibility delivers value to the system through reducing the required investment in generation and network capacity to meet a given demand. Therefore, investment in flexibility needs to happen now in order to capture these savings; Great Britain won't realise the full value of flexibility if it is retrofitted after investing extensively in wider low carbon infrastructure.

However, feedback from stakeholders indicates that, from a project perspective, the value of flexibility is often either not well understood, difficult to assess or its value isn't yet fully recompensed through markets for flexibility services.

From an investor perspective, three key factors influence the decision on whether to finance a project, and at what cost:

1. **Certainty and duration of revenue streams -** the likelihood that the investment generates sufficient income over its lifetime to pay back the financing whilst generating a suitable risk-adjusted return to its investors
2. **Counterparty risk -** the credit rating(s) of the counterparty(ies) providing the revenue certainty
3. **Proven and scalable technology -** technology with proven operational track record which is suitable for deployment at the scale required by full-size commercial projects

Flexibility assets can increasingly generate revenue through a number of different markets, either as an individual asset or via an aggregator. The number of revenue streams open to a given asset will depend on the asset type and location but broadly includes wholesale market price arbitrage, providing system services directly to the transmission and distribution network operators, participating in the balancing mechanism or contributing to longer term security of supply through the capacity market.

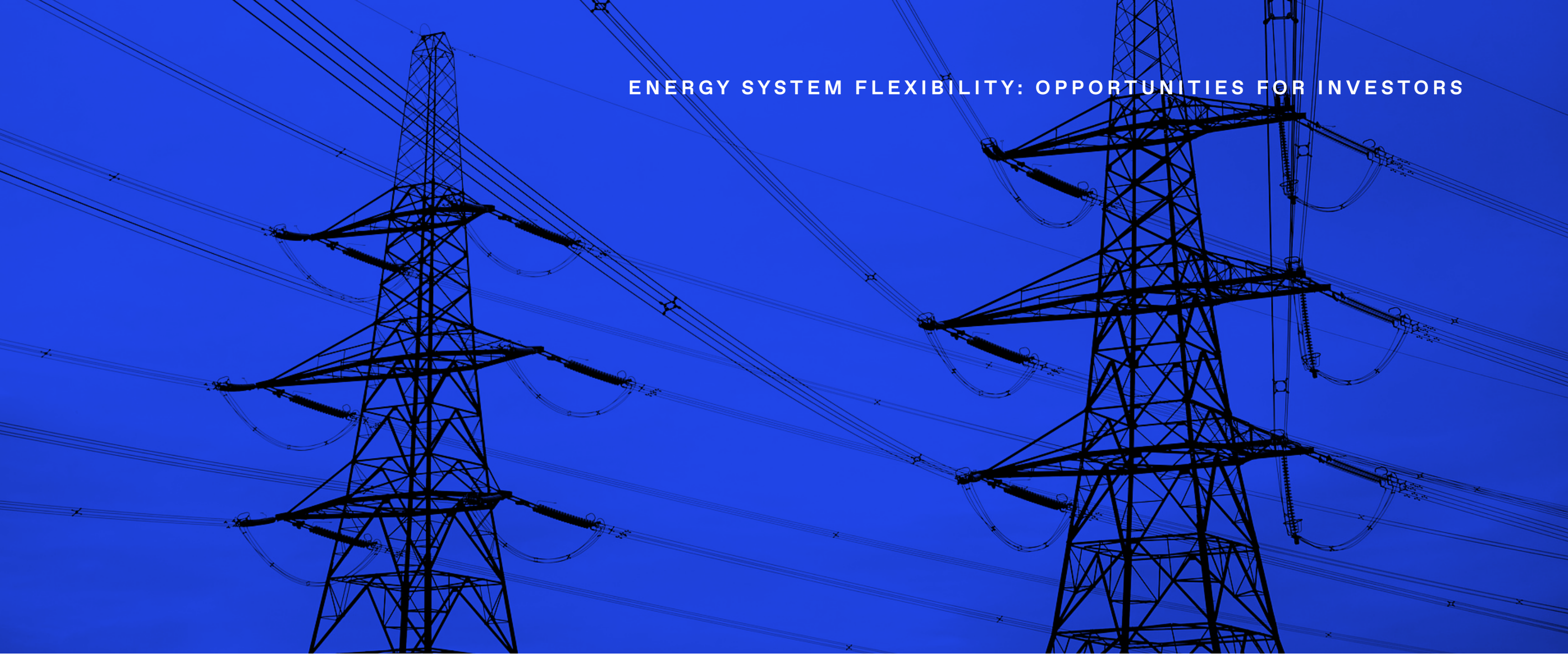
A more recent (although much less frequent) addition includes the provision of corporate power purchase agreements (PPAs) either as a replacement to government backed subsidies or to complement projects partially covered by subsidy regimes. A high-level summary of these revenue sources is provided in the table below.

However, whilst there are a range of revenue streams available to most flexibility services, the long-term revenue profile for flexibility assets is often highly uncertain as the revenue streams are secured via the wholesale energy market, half hourly balancing mechanism, or through short to medium term contracts with network operators or government. Stacking multiple income streams is often necessary to build a viable business case, but this can be difficult to achieve as a result of contract conditions with the procurer of each service[7]. In addition, flexibility markets are still maturing; both the Energy System Operator (ESO) and Distribution Network Operators (DNOs) are trialling new flexibility services and updating their procurement methods to meet system needs.

Feedback from the survey and workshop for this report indicated that this revenue uncertainty remains a barrier to investment. However, it was highlighted by workshop participants that significant progress has been made for some forms of flexibility, with energy sector representatives highlighting the progress made in raising finance for battery assets (albeit whilst noting that battery financing from a senior debt perspective is still in its infancy). This is partly as a result of an increase in project scale, rapid reductions in capital costs and widening access to different flexibility and balancing markets, but also as a result of extensive communication between the energy and finance sectors to fully understand the revenue streams these assets can access, their risk profile and how these risks can be mitigated through asset management. The increased appetite for investment in large scale battery storage assets is evidenced by the fact that two dedicated UK-based energy storage funds launched by investment groups have by now been listed on the stock market[8]. However, the principal route to financing these assets is via equity with relatively low levels of senior debt.

Key revenue sources for flexibility

Revenue source	What is it?	Who can participate?	How do flexibility services participate?	Where to find out more
Price arbitrage	Generating an income through buying energy when prices are low and selling when they are high	Typically, battery storage owners/operators	Through buying and selling energy to the wholesale market	-
Transmission level system services	A range of services procured by the System Operator, National Grid ESO to maintain system stability and security	Depends on the service provided	Through procurement processes led by National Grid ESO	National Grid ESO[9]
Distribution network system services	A range of services procured by the DNOs to manage peak demand and constraints caused by faults	Depends on the service provided	Through procurement processes arranged by the DNO – several use the Piclo Flex platform as a marketplace	ENA[10]
Balancing mechanism	A tool used to balance supply and demand in daily half-hourly trading periods. It is an ad-hoc market with no forward commitments	Applies to any business with flexible power that can provide a response within the timeframe. Minimum size is 1MW, but smaller assets can participate via an aggregator	Registered flexibility assets provide their bids/ offers directly to National Grid ESO or via an aggregator to participate in each half hour of the Balancing Mechanism	National Grid ESO Elexon
Capacity market	Market mechanism offering a payment for reliable sources of electricity to ensure there is sufficient generation or load management in the system to cope with network stress	It is a technology agnostic mechanism open to: • New and existing generators • Interconnectors • Energy storage • DSR	Capacity Market Contracts are issued via an auction, typically 1 or 4 years ahead of capacity need	BEIS[11]
Corporate PPAs	Contract typically between an end demand user and a generation and/or storage asset The corporate typically pays a fixed or a floor price per kWh generated or exported. This acts as a hedge against volatile energy prices	For flexibility assets, corporate PPAs are typically applied to battery storage projects (either standalone or co-located with a renewable generator)	Corporate PPAs are agreed bilaterally. Storage PPAs are increasingly attractive to end users who want to match their demand with low carbon energy in real time	-



UK Government and network operators recognise that barriers to participating in systems services markets need to be removed, and that the market must send clearer long-term investment signals to signal when and where flexibility will be needed. In the Energy Networks Association's (ENA) Open Networks programme, network operators are taking steps to increase the transparency of the market for procurement of flexibility services with standardised contracts, clear timescales, and clarity on interactions between services[12]. In addition, the UK Government's Alternative Energy Markets programme is exploring how network and energy market price signals can be adapted to encourage cost-effective decarbonisation. Their first report on Energy Price Signals is expected to be completed in February 2022. Effective engagement from both the finance and energy sectors with both programmes will increase the likelihood that the changes made to the energy and flexibility markets will bring forward a larger pipeline of investable flexibility projects.

This section has focused on revenue streams available to flexibility services through the energy market. However, revenue generation is just one part of the value of flexibility assets.

The assessment of the value of flexibility within a project needs to include its ability to mitigate the risk of future cost increases, not just its ability to generate revenue.

The availability and cost of finance for a given project is based on an investor's assessment of the attractiveness of associated income streams and their degree of uncertainty over the investment life cycle. However, only considering income streams from the provision of flexibility services to Britain's energy system may underestimate the full value of flexible assets by ignoring available additional income of the asset if managed in combination with a local source of demand for flexibility services.

Incorporating flexibility from the start of projects (or including the space and enabling infrastructure to rapidly add additional flexibility) can reduce upfront costs and mitigate the impact of future risks associated with network costs and energy price volatility.

For example, flexibility services which form part of a wider asset investment, such as enabling DSR at a new industrial site or storage assets co-located with renewable energy[13], can deliver upfront capital cost savings such as reducing the cost of connecting to the local grid, because they reduce the capacity required or enable a more flexible connection to be approved[14]. They can also mitigate the impact of future risks, such as switching from a fixed to a time-of use energy tariff, by enabling an energy user to vary when they import electricity from the grid and thereby minimise their energy bills.

Flexibility can also help energy users and generators manage regulatory changes. Ofgem is currently considering the role that network charges will play in ensuring efficient network usage in the future and, the Smart Systems and Flexibility Plan states that Ofgem will improve price signals for flexible network usage through network charging reform. In addition, UK Government is planning a review of business rates to support building decarbonisation.

Considering flexibility as part of a wider project investment can help demonstrate the value of flexibility to the co-located asset and should be considered as a single project.

Flexibility services have the opportunity to access finance, but the challenge is accessing finance at the scale and on terms that complement equity investors' respective Internal Rates of Return (IRRs). This requires a better understanding of how investments which include flexibility can be structured to secure private finance.

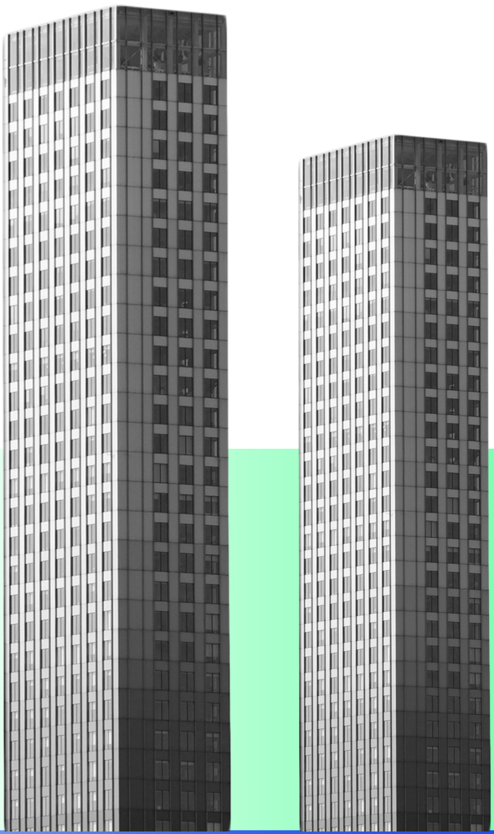
Scaling up flexibility requires the creation of a 'virtuous circle' – increasing the scale of projects to reduce costs, which then brings forward an even larger pipeline of projects.

The responses gathered from engagement with the energy and finance sector highlighted a number of ways to make investing in flexibility services at scale more attractive, either by improving returns or by mitigating risks.

Improving returns:

Aggregate opportunities to increase the attractiveness to finance providers of investing in small scale technologies

The transaction cost associated with investing in individual small scale flexibility projects is high relative to their potential return, making them less attractive to investors. All finance sector survey responses to the questions on domestic DSR stated that aggregating opportunities can be a more attractive proposition for investors and lower overall costs.



Price in the cost of carbon across all forms of flexibility

Gas engines are a common form of flexibility but assets under 20MW are exempt from the UK Emissions Trading Scheme (UK ETS) meaning they don't have to buy allowances for the emissions they create. This distorts the markets and could potentially block investment in low carbon flexibility – for example 615MW of small (<20MW) gas assets received a capacity market contract in the last T-1 auction[15], compared to 327MW of DSR and 114MW of battery storage. This exemption is being reviewed by the UK Government in 2022 and increasingly procurers of flexibility are publishing data on the carbon impact of their flexibility services (e.g. National Grid ESO now publish carbon intensity data for balancing services[16]) which will help monitor the uptake and impact of low carbon forms of flexibility.

Mitigating risks:

Increase confidence by creating long-term signals as to the value of flexibility

As mentioned above, contracts for flexibility service are often short term, partly because requirements for flexibility change, but also to encourage competition in an emerging market. Long-term predictable price signals in combination with viable income levels minimise the risk of either over or under deployment of flexibility solutions in the evolving market environment. Lack of such long-term predictability of markets increases risk levels to investors thereby making investments less attractive and increasing the likelihood of under deployment of flexibility solutions, which in turn results in increased system costs.

In our survey, for almost all forms of flexibility (excluding interconnectors which have a regulated income governed by Ofgem's Cap and Floor regime[17]), a majority of finance sector respondents stated that the lack of long-term predictability of revenue streams was a significant barrier to financing.

Create stable revenue streams for flexibility assets by encouraging private investment through Corporate PPAs

In a corporate PPA a corporate typically pays a fixed or a floor price per kWh exported from a flexibility asset. For example, corporate PPAs for battery storage are increasingly being seen in the market. For a corporate, a PPA can act as a hedge against volatile energy prices, as well as demonstrating their Environmental, Social and Governance (ESG) credentials. It also provides a more stable revenue stream for the flexibility asset owner. Typical bankable corporate PPAs will have a robust counterparty (investment grade), tenor of contract matching/exceeding the debt and a fixed price element upon which to "anchor" the debt.

Develop novel financial structures

If the risk of investment remains too high for some forms of debt financing, blended finance structures (using government-backed funding to leverage private investment) could bridge the investment gap and may open up new sources of finance and reduce overall cost. For example, investment from government on a 'first loss' basis, or using public sector funding during higher-risk phases of a project (as has historically happened with offshore wind) could reduce the risk to other investors. With earlier stage opportunities, government has successfully attracted private sector co-investment through a combination of de-risking external market environments, guaranteeing some investment-related risks, and by offering early exit options.

Deliver enabling investment

Domestic DSR requires smart meters. V2G and smart charging require a charging network. Investing in these forms of enabling infrastructure is crucial to many forms of flexibility. From a financing perspective, the smart meter rollout is an example of where a clear requirement for installation (from government) and the ability to invest at scale (in wide scale rollout programme) has delivered bankable opportunities for the private sector to raise finance. For future infrastructure needs, the UK Government can continue to play an important role alongside the private sector by providing local governments with the expertise needed to identify and bring forward green infrastructure projects, and by using public funding to invest in higher risk projects through financial structures which reduce the risk to the private sector.[18]

This is part of the remit of the newly formed UK Investment Bank (UKIB) who will provide finance to tackle climate change and support regional and local economic growth.

Invest in early stage innovation

In the survey results from both the finance and energy sector, the majority of respondents highlighted that a lack of technical maturity was a barrier to deployment for V2G charging infrastructure, and hydrogen solutions including production (electrolysis), storage and use in turbines/engines. These forms of flexibility have not been delivered at scale in the UK before. Demonstrating the technical maturity of technologies like these will require innovation grant funding or investment.

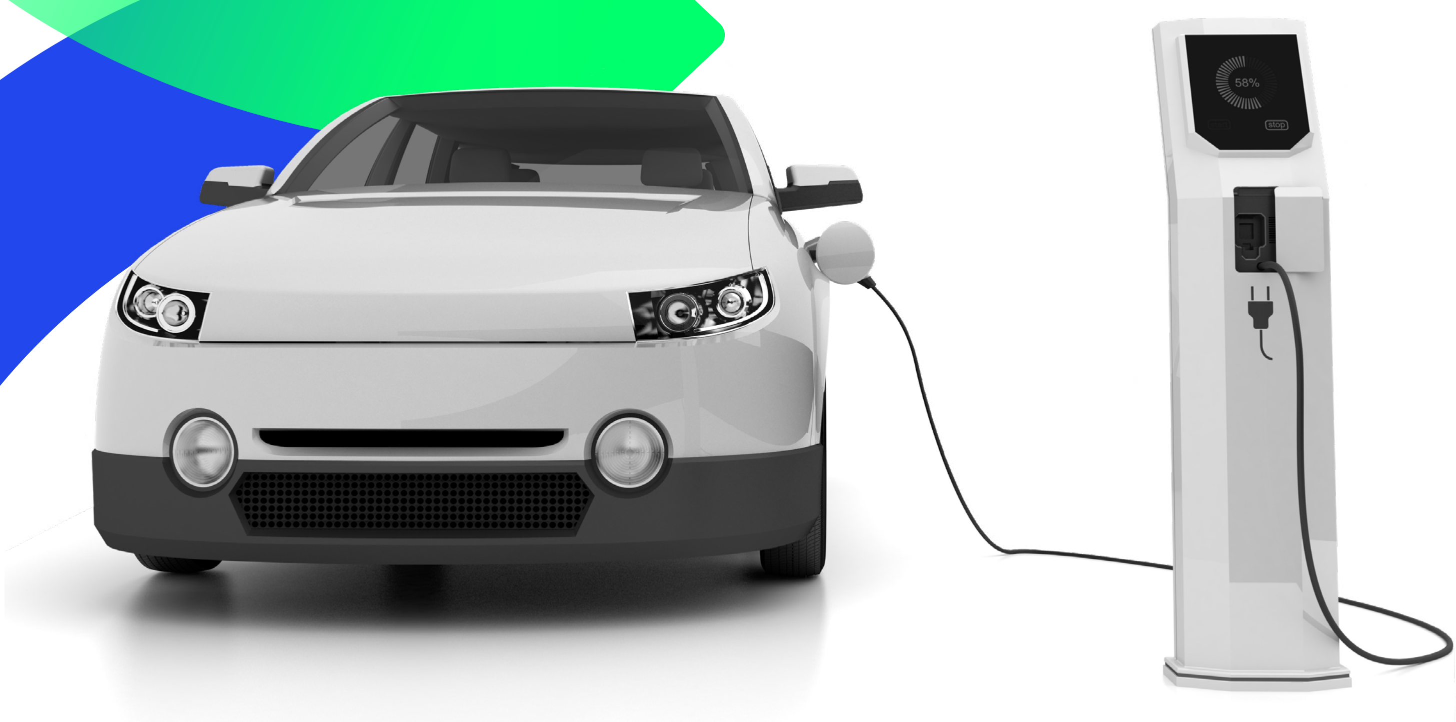
One example of how UK Government support for innovation has delivered a more flexible energy sector is the development of Piclo. Piclo developed and operate Piclo Flex, a platform which acts as a marketplace for flexibility between network operators and flexibility providers.

Established in 2013 Piclo benefited from UK Government grant funding to develop and trial their Flexibility Marketplace platform, launching commercially in 2018. In December 2020, Piclo successfully raised £4.7m of equity investment from both public and private sources to expand their operations.[19]

Investment in such early-stage solutions will generally be equity-based financing due to the associated risk levels for later stage, project-type opportunities, public-private partnerships can help accelerate the availability of less costly, debt-based financing. While examples for such partnerships may still be limited for flexibility solutions, they have been successfully realised in more established markets such as for offshore wind.

Continued dialogue between the energy and finance sectors is crucial in understanding different perspectives and financing needs

The last few years has seen the finance market open up to some types of flexibility. Large scale battery projects are starting to attract debt financing, and investment in wider infrastructure projects such as charging networks are picking up pace. This has been achieved through energy and finance sector engagement to fully understand the assets and how they are used. This dialogue needs to continue and be applied to the full suite of flexibility solutions.



Next steps

Investing in flexibility is an urgent need if we are to decarbonise the power sector by 2035 and reach Net Zero by 2050.

As highlighted in the UK Government and Ofgem's recent Smart Systems and Flexibility Plan, a smart and flexible energy system is crucial if the UK is to reach Net Zero by 2050. Flexibility reduces the need for additional investment in network capacity and back up generation. Therefore, to capture these cost savings, the time to invest in flexibility is now, not after investments in network and generation capacity have been delivered.

Sustained leadership by finance sector professionals will be required to communicate flexibility-related opportunities available to the industry and to support their realisation.

To raise awareness within the financial sector of flexibility-related opportunities as well as to act on them will require both a communication effort and leadership from the financial sector.

Communication will be a continual challenge and necessity to ensure flexibility is fully understood, aiding its adoption. Realising this opportunity will require stakeholders from the finance sector, industry, and UK Government to work together to ensure the value of flexibility is recognised and rewarded at a project level, and that appropriate financing sources are readily available. The earlier industry stakeholders are able to realise investments aligned with these goals, the greater the available savings will be in reaching Net Zero. The Carbon Trust and Imperial College's own analysis indicate that this could be up to £16.7bn/year in 2050.

The Carbon Trust will continue to work with the energy and finance sectors to accelerate the deployment of flexibility services. If you would like to join us in tackling the challenges of financing flexibility, please contact one of our experts.

Annex

A. Summary of flexibility solutions

The tables in this section provide a summary of energy flexibility solutions, and an assessment of how each asset or service provides flexibility to the system. It details the deployment required by 2030 and 2050 based on analysis undertaken as part of the Flexibility in Great Britain report which examined three heating pathways to 2050 – a system dominated by heat pumps (electric heating), hydrogen boilers or hybrid heating (a heat pump with a back-up gas boiler). The tables also summarise key deployment challenges for each flexibility solution.

Demand side response

	Domestic DSR	Non-domestic DSR
Energy system value and business case for flexibility	Demand side response (DSR) shifts the time of use of domestic and non-domestic energy with little to no impact on overall use for an end user. DSR can reduce peak demand on the electricity system, coordinating the time at which smart appliances are used and electricity consumed. DSR can move demand by a few hours within a day, rather than between days, and can reduce the need for: • Network upgrades to remove capacity bottlenecks; • Alternative flexibility solutions such as electricity storage assets - which may be more costly to install and/or operate; • Fossil fuel demand - If DSR is used during times of system stress with low renewable output and high demand, DSR could reduce fossil fuel demand.	
Deployment 2030	0.2 GW – 1.2GW (growing from a base of limited capacity in 2021).	Up to 3GW (electric heating scenario)
Deployment 2050	6 GW (hybrid/hydrogen heating scenario) – 12.4 GW (electric heating scenario)	3.4 GW (hydrogen heating scenario) – 11.4 GW (hybrid/electric heating scenario)
Current status and barriers to deployment	For smart appliances, the financial propositions to energy customers today are too weak to attract significant attention from suppliers, original equipment manufacturers (OEMs) and consumers. As tariffs and price signals evolve, the proposition is expected to improve. However, customer concerns around autonomy, cyber security and privacy could act as a disruption to smart appliance uptake. Unlocking this market will require significant consumer engagement to develop attractive propositions for residential demand customers and overcome concerns.	Non-domestic DSR is a more established market than Domestic DSR but there is still significant potential for growth. This will require sufficient financial incentive for demand users to participate as well as clear protocols for protecting primary business operations and managing cybersecurity risks. As price signals evolve, it is likely the value from engaging in flexibility will change, increasing the uptake across businesses. UK Government have commissioned work to provide an evidence-based menu of options for price signals, expected in February 2022. Like the domestic sector, a strong customer proposition and attractive returns will be necessary to expand non-domestic DSR.

Transport flexibility

	Smart charging and Vehicle-to-Grid (V2G)
Energy system value and business case for flexibility	Smart charging electric vehicles is a form of demand side response, shifting time of electricity use. Smart charge points are enabled with the ability to respond automatically to remote signals.[20] Through coordinating the time at which vehicles are charged with times of high renewable generation, investment in generation capacity and electricity storage is reduced, peak load on the networks can be reduced, reducing investment needs in network reinforcement. Electric V2G capabilities can also provide system services when connected to a charge point, acting as a form of electricity storage. Utilising these capabilities can reduce required investments in transmission and distribution networks, and generation capacity.
Deployment 2030	2 GW – 3 GW In line with the ban on sales of new internal combustion engine vehicles from 2030, most growth in EVs is expected after 2030.
Deployment 2050	35 GW – 48 GW
Current status and barriers to deployment	Uptake of electric vehicles is increasing alongside charging infrastructure, although there are significant regional differences. Stakeholder acceptance issues, such as range anxiety and access to appropriate charging points, will be a key factor in the rate of increase of electric vehicles. Delivering charging infrastructure which can operate flexibly through smart charging and V2G is crucial and the regulatory framework is being developed to enable the energy system to make use of flexibility. Large scale enabling investments such as electric vehicle charging will require collaboration between national and local government and the finance sector to identify, develop and finance suitable projects.

Thermal flexibility

	Thermal flexibility
Energy system value and business case for flexibility	Thermal energy storage (TES) associated with electric heating systems (heat pumps) can decouple the timing of demand for electricity from demand for heat. Decoupling can reduce peak demand resulting in reduced investment required in generation and network capacity; this is particularly valuable during times with high demand and low renewable generation. Investment into TES assets can also reduce the size of heat pump required for given demand profiles, reducing upfront investment required. Similarly, investing in hybrid heating solutions can significantly reduce electricity demand during periods of system stress and reduce the size of heat pump required.
Deployment 2030	Maintain current capacity
Deployment 2050	800 – 900 GWh
Current status and barriers to deployment	For district heat networks with TES installed and supplied by heat pumps, weak price signals for engaging with flexibility and providing grid services to date are problematic. There is a lack of long-term price signals to incentivise developers to unlock flexibility through upgrading storage assets. Although funding mechanisms exist already to support District Heat Network development, there is no funding dedicated to TES which provides flexibility services.

Electricity storage

	Electricity storage
Energy system value and business case for flexibility	Electricity storage can charge up when surplus generation is available making best use of renewable generation and reducing need for investment in fossil-fuelled back up generation. Depending on location of storage assets on the network, it can reduce network investment required at transmission and distribution level to meet peak demand.
Deployment 2030	5 GW (hydrogen/hybrid heating scenario) – 18GW (electric heating scenario)
Deployment 2050	5 GW (hydrogen heating scenario) – 83GW (electric heating scenario)
Current status and barriers to deployment	The financial performance of battery assets today is generally good through price arbitrage, the ancillary services market, capacity market and DSO services. There is a competitive market landscape, with 16GW of storage assets in the pipeline. There are potential resource availability constraints for battery materials which may be problematic to the supply chain and affect the pace of future deployment.

Interconnectors

	Interconnectors
Energy system value and business case for flexibility	Interconnectors are a key source of flexibility, connecting electricity systems of neighbouring countries to reduce demand or supply imbalances. Interconnectors can be a source of long duration electricity imports during times of system stress. Interconnectors improve the utilisation of existing generation and can reduce renewable energy curtailment and can make more effective use storage assets across borders.
Deployment 2030	14.5 GW (2025)[21]
Deployment 2050	18 GW[22]
Current status and barriers to deployment	Interconnectors have significant strategic implications for multiple countries with long lead times and most projects experiencing delays. Interconnectors are high-cost investments and most recent interconnector projects have been governed by Ofgem's Cap and Floor regime which provides a base regulated income and makes the asset class bankable. Increasing levels of interconnection is seen as a crucial means of enabling integration of renewable energy across Europe. However, without the appropriate frameworks in place to enable flexibility services, greater interconnection could result in system operability challenges. UK Government and Ofgem's Smart Systems and Flexibility Plan notes that even with the current level of interconnection, individual interconnectors are among the largest capacity assets on the electricity system and can cause large system swings in demand/supply.[23]

Hydrogen electrolysers and storage

	Hydrogen electrolysers and storage
Energy system value and business case for flexibility	Electrolysis can make best use of surplus generation. Green hydrogen production can provide flexibility to shift production to best match resource availability with system operational needs and market factors. Storing energy as a gaseous vector which can be stored for weeks or months, such as hydrogen, enables inter-seasonal storage where energy generated during the summer (when demand is low) can be stored for winter.
Deployment 2030 (electrolysers)	1 GW
Deployment 2050 (electrolysers)	1 GW (electric/hybrid heating scenario with high flexibility) – 19 GW (hydrogen heating scenario with high flexibility) 9 GW (electric/hybrid heating scenario with low flexibility) – 35 GW (hydrogen heating scenario with low flexibility)
Current status and barriers to deployment	Developing both the supply and demand of hydrogen simultaneously is a key challenge for the sector. The UK Government is developing hydrogen business models expected in 2022, as well as investing in developing the demand for hydrogen (green or otherwise). However, green hydrogen is expected to be more expensive than blue in the short-to-medium term. For hydrogen storage assets, high upfront capital costs and long lead times, as well as lack of revenue certainty and market signals, leads long duration storage assets to be seen as volatile and uncertain with no long-term visibility on revenue. This topic was the subject of a UK Government consultation over summer 2021.[24]

B. Overview of survey structure and responses

Separate surveys were issued to key stakeholders in both the energy and finance sectors ahead of a workshop held on 13 October 2021, attended by 30 representatives from the finance and energy sectors.

Complete survey responses were received from 10 finance sector representatives and 12 energy sector respondents.

The survey sought first to assess respondents' level of awareness of ten different forms of flexibility:

Domestic Demand Side Response (DSR)	Industrial and Commercial DSR	Smart charging & V2G infrastructure	Thermal energy storage (e.g. hot water tanks)	Electrical energy storage (e.g. battery storage)
Green hydrogen production (electrolysers)	International interconnection	Hydrogen fuelled turbines or engines	Natural gas fuelled turbines or engines	Hydrogen storage

Those respondents who had experience of a given technology were then asked whether they thought each of the following factors were a significant barrier, or not to financing the technology:

- Transaction cost (relative to project size)
- Technical Maturity
- Market demand for service/technology
- Long-term predictability of revenue streams including counterparty risk
- Overall profitability
- Regulatory requirements

Respondents were given the opportunity to provide additional commentary against these points.

Given the relatively small number of respondents we have not presented the quantitative results in this report but have highlighted where there was a clear majority agreement across the responses received, particularly where these findings were reinforced by the workshop discussions.

Endnotes

1 Dietz, S., Bowen, A., Dixon, C. et al. (2016). 'Climate value at risk' of global financial assets, Nature Climate Change, 676-679

2 In the first Contract for Difference (CfD) allocation round, the strike price for offshore wind built in 2017-1 was £119.89/MWh (2012 prices). By the third allocation round this had dropped to £39-£41/MWh (2012 prices) for projects delivered in 2023/24 or 2024/25. Source: UK Government. Allocation Round 1 Results and Allocation Round 3 Results.

3 The Carbon Trust (2021). Flexibility in Great Britain

4 BEIS (2021). Smart Systems and Flexibility Plan

5 HM Gov (2021). Net Zero Strategy: Build Back Greener

6 BEIS (2021). Smart Systems and Flexibility Plan

7 Aurora/UKPN (2020). Flexibility Hub – Local Flexibility Markets Analysis

8 Gore Street Energy Storage Fund and Gresham House Energy Storage Fund

9 National Grid ESO. Future of Balancing Services

10 Energy Networks Association. Flexibility Services

11 BEIS. Capacity Market

12 ENA. Open Networks

13 For renewable generators with a contract for difference contract, UK Government have acknowledged that the rules on co-location of storage have historically been restrictive. In November 2021, LCCC published new guidance allowing co-located storage to import electricity from the grid as well as export, provided that the generation asset and storage asset were separately metered.

14 Flexible connections are often a quicker means of connecting new assets to the electricity grid, but they place restrictions on when and how much energy can be imported/exported to the grid. On site storage can help manage these constraints.

15 National Grid ESO. Capacity Auction Results for T-1 CY2021-2022

16 National Grid ESO. Carbon Intensity

17 Ofgem (2021). Cap and Floor Regime Handbook

18 UKIB (2021). What we offer

19 UK Tech (2021). Mott MacDonald Ventures pumps in £4.7M funding in London cleantech Piclo

20 BEIS (2021). Electric Vehicle Smart Charging

21 Ofgem (2021). Interconnectors

22 CCC (2020). The Sixth Carbon Budget – The UK's pathway to Net Zero, Balanced Net Zero Pathway

23 BEIS (2021). Smart Systems and Flexibility Plan

24 BEIS (2021). Large scale long duration electricity storage

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