Electricity Storage: Pathways to a Net Zero Future

THE ELECTRICITY STORAGE NETWORK™

regen transforming energy

ESN & Regen, June 2020

Introduction

Electricity storage has a vital role to play in enabling a zero carbon electricity system and facilitating the UK's transition to net zero. We are facing two global crises: the current pandemic, and the climate emergency. As we start to recover from the former, we must focus our attention on the latter. Storage can play a role in both, providing jobs and economic benefit whilst enabling the electricity system to become zero carbon.

This paper aims to provide a short primer on storage – the services it provides to the electricity system, how it is a vital part of the net zero transition and how the industry has grown in the last few years. Looking towards the next decade, we explore how the storage industry can prosper, but also what barriers currently stand in the way of its deployment.

With a wide-ranging evidence base, drawn from extensive engagement with members of the Electricity Storage Network and the wider industry, and building on Regen's previous research on storage, this paper offers six key recommendations for government and industry to create a pathway for storage over the crucial next decade.

Recommendations

1. Formally include storage in the electricity licence framework

2. Government should set a clear signal for the trajectory of storage over the next decade

3. Develop a joint government and industry plan for long-duration storage, including revenue mechanisms that would fund such projects beyond the research and development phase

4. Industry and government need to work to increase awareness of the supply chain challenges and the solutions available, working towards a supply chain standard that the industry can adopt

5. Provide business rates relief to storage providers who are key to the transition to net zero

6. Market barriers must be eliminated to fully value the services that storage can provide. Flexibility markets should value carbon and provide transparent reporting on the carbon intensity of all services

Role of storage in the climate emergency

Climate emergency

We are living in a climate emergency. We face increasing warnings from scientists of the need to take urgent action in the next decade. The UK Parliament has declared a climate emergency, along with 67% of local authorities across the UK. In recognition of this increasing urgency, the UK Government has set a target to reach net zero carbon emissions by 2050.

Increased renewables and demand

To address the climate emergency and decarbonise electricity supply, the UK is rapidly increasing the amount of renewable generation on the system, with 45 GW connected, nearly 40% of total capacity.

Simultaneously, decarbonising transport and heat is necessitating electrification of vehicles and heating systems, resulting in increased demand for low carbon electricity.

Greater need for flexibility

Renewables generate electricity in a manner that is fundamentally different to the thermal power stations of the past. With less ability to control when electricity is produced, greater flexibility is needed in the system, both to balance supply and demand and to maintain adequate frequency.

The technologies needed to provide this flexibility already exist: demand-side response, interconnectors, storage, and renewable generation itself. There are multiple types of services that are needed to provide flexibility, from balancing the system to providing inertia.

Many different technologies will need to be called upon and incentivised in different ways to allow the system operators to operate in a net zero world.

The government and regulator recognise the importance of flexibility and have put in place a clear plan for enabling these technologies, including storage, through funding, regulation and policy, and market models.

The growing UK storage industry has risen to this challenge, successfully establishing itself in several markets. With multiple technologies that are able to provide a variety of services, storage has the agility to support the transition to net zero in multiple areas.

Storage

The cost of storage technologies, particularly lithium-ion batteries, has fallen significantly in recent years, and this trend looks set to continue as the electric vehicle market develops. There is research underway to improve storage technologies in the earlier stages of development; government funding for feasibility studies and research and development has enabled technologies beyond pumped hydro and lithium-ion to reach grid scale.

Positive policy developments have also helped the industry to flourish, for example, widening access to electricity markets and reforming planning regulations to enable larger projects.

This paper will explore the barriers that are currently facing storage and how the UK can best enable storage to deploy at the scale needed to support the transition to net zero.

What services can storage provide?

Electricity can be stored using a number of technologies, and then exported to provide a variety of services to the electricity system.

Reserve

reserves | time shifting | back-up supply

The fundamental use for storage is, not surprisingly, storing electricity for use at a later time. As renewable output varies according to weather conditions, storage provides **reserves** for use when demand is high, when supply is low, or at times of system stress.

For individual customers, storage can provide the ability to '**time shift**' energy or to provide **back-up supply** behind-the-meter when an existing connection is lost. This could be done for variety of reasons, but is most often to take advantage of market price fluctuations and avoid peak electricity network charges.

Frequency control

inertia | frequency response

As the amount of renewable generation on the system increases, variability of the frequency of the system also increases. An optimal frequency range is needed to maintain the stability of the grid - an imbalance between demand and generation will affect frequency. Most renewable generation does not currently provide the inertia needed. Overall system inertia decreases and as a result, the frequency can change very quickly and cause instability on the system.

Storage can help address this issue in two ways: by providing **inertia**, either real or synthetic, or **frequency response**. Storage, particularly battery storage, can respond in milliseconds, helping the system deal with rapid changes in frequency.

What is inertia? Generators with a spinning turbine rotate at the same frequency to the grid to provide inertia and keep system frequency stable when demand and supply are imbalanced. Inertia can be provided by a spinning turbine or engine, but counter-intuitively, spinning wind turbines don't provide inertia due to being connected to the grid through an inverter. Storage can provide inertia if it has a rotating turbine, or it can simulate inertia by dynamically controlling the power electronics in its inverters.

What services can storage provide?

Flexibility

constraint management

investment deferral

Grid infrastructure (wires, transformers etc.) requires regular upgrades to handle increases in demand and generation. As the electricity system becomes increasingly decentralised, with generation now connecting to lower voltage networks, existing infrastructure is not able to cope, resulting in constraints.

Expensive, time-consuming infrastructure upgrades may be necessary, but storage can help reduce these costs by supporting the network during periods of constrained generation or high demand, thus alleviating such constraints at a local level. This reduces the amount of new infrastructure needed, or allows upgrades to be deferred to a more appropriate time.

Reserve: co-location with renewables

Storage can provide reserve and time-shifting directly to renewable generating plant, storing excess energy when it is not needed by the grid. As renewable penetration increases, curtailment of renewable plant is also increasing, at times of low demand and high generation, as we are currently experiencing through the lockdown, and as we head into the summer.

Generators are paid by the Electricity System Operator (ESO) to ‘turn down’ at times of high generation and low demand, however these payments may not be commercially viable or even available in future, making co-located storage a more attractive prospect.

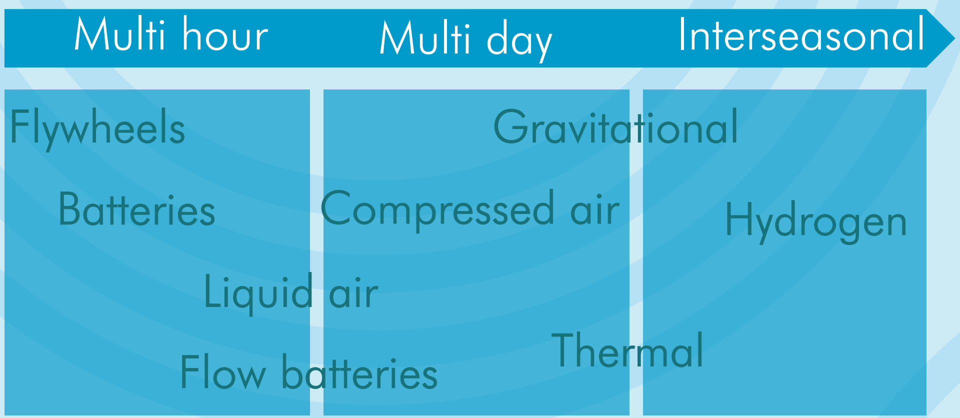
However, storage may be underutilised if it is only used for this purpose and may also need to provide other services in order to make full use of the asset. Currently, there are several co-located storage sites, but most only share a grid-connection with renewable generation, not an operating model.

What services can storage provide?

Long duration and seasonal storage

Currently, many of the services described in this section are either being met with lithium-ion battery storage, with around 0.5 - 2 hour duration, or pumped hydro, lasting several hours. However, the case for longer-duration storage is growing. There is no agreed-upon definition of 'long-duration storage', but splitting storage into broad categories may help focus debate (see below).

Currently, the ESO is not asking for services from storage for a duration beyond a few hours, but the need for longer duration and even seasonal storage may increase as we see high renewable penetration and electrification of heat, for example storing some surplus solar generation in the summer, for use on winter evenings.

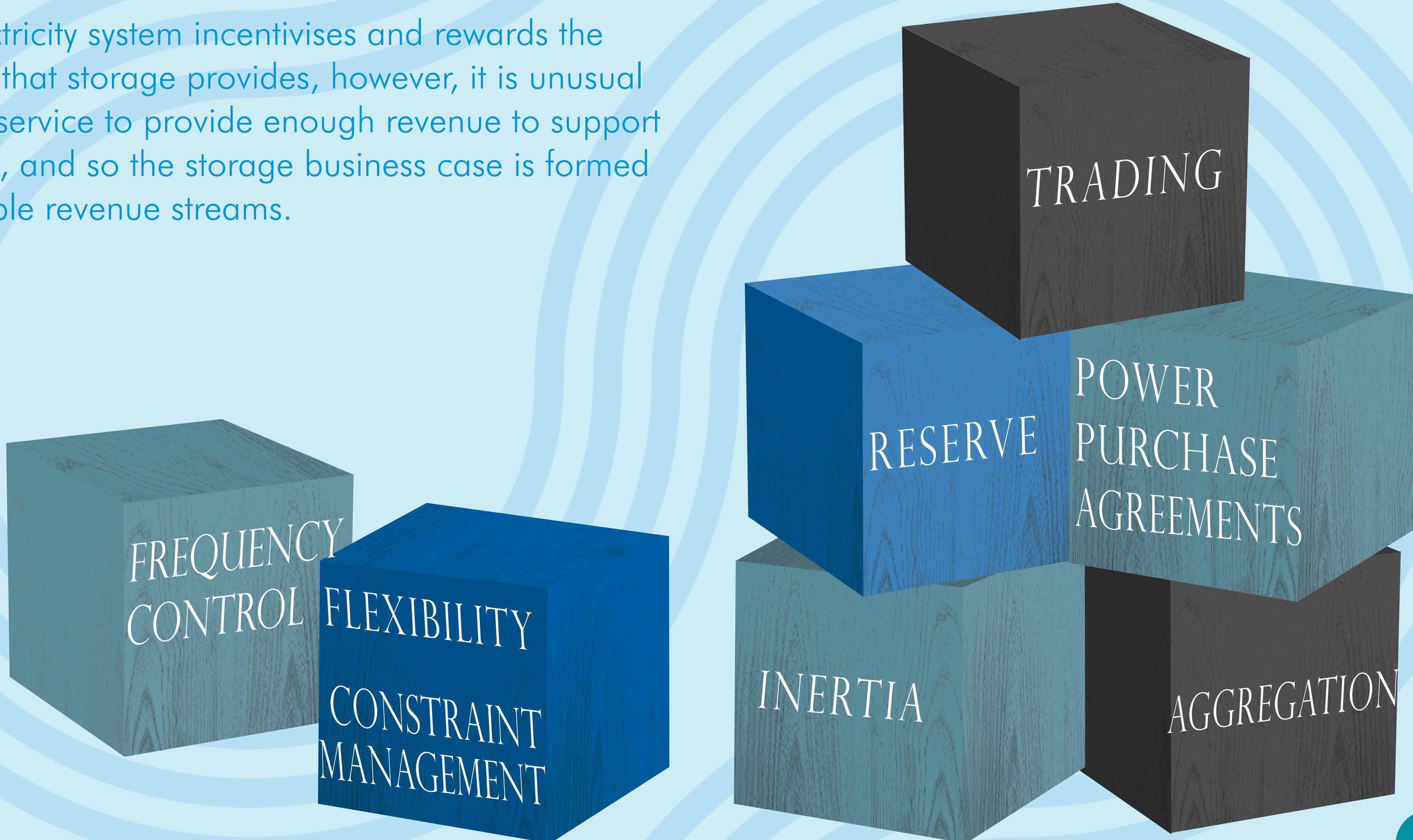


There are multiple options for dealing with these longer-term variations alongside storage: building up interconnection and international collaboration, or developing carbon capture and storage for high carbon, dispatchable generation. Much research and finance is being invested in the latter, with comparatively little going towards storage.

If storage is the most viable option, questions remain about its economic model – it's unlikely to be able to compete on a market basis, and could be in competition with carbon capture and storage technologies, or even shorter-duration storage. An investment model more comparable to network infrastructure would be more appropriate.

The storage revenue stack

The electricity system incentivises and rewards the services that storage provides, however, it is unusual for one service to provide enough revenue to support an asset, and so the storage business case is formed of multiple revenue streams.



The storage revenue stack

Capacity Market: a big driver for storage in past years, with the long-term contracts providing a boost to storage deployment. Opportunities are now dwindling as shorter-duration assets are heavily de-rated, prices diminish and the administrative burden of this complex market outweighs the benefits.

Behind-the-meter (BTM) business models have historically been lucrative for storage, but returns will decrease as peak avoidance charges (Triads and red-band distribution charges) are reduced. Many BTM models now also stack grid services to increase revenues and build a viable business model.

Inertia has only recently been recognised as a remunerated service, rather than just a by-product of electricity generation; in 2020, the ESO launched what it believes to be the first market in the world to reward inertia. This is an opportunity for storage providers to add to the revenue stack, either with a spinning turbine or producing synthetic inertia. However, the results of the first auction were opaque and contracts were not won by storage. The second round of this tender may prove more fruitful.

Frequency response markets have been the core driver behind storage industry growth since 2016. **Firm Frequency Response** and **Enhanced Frequency Response** markets precipitated the first wave of storage projects, beyond pumped hydro. However, these markets became saturated in subsequent years, driving down the price.

Dynamic frequency markets: many have argued for an increase in frequency response capabilities on the system, in order to deal with increasingly fluctuating frequency. The ESO addressed these concerns with a new suite of frequency response products which will respond to continuous frequency changes and bring 100s of MWs of additional flexible capacity to the system. This will eventually replace the Firm Frequency Response market.

The storage revenue stack

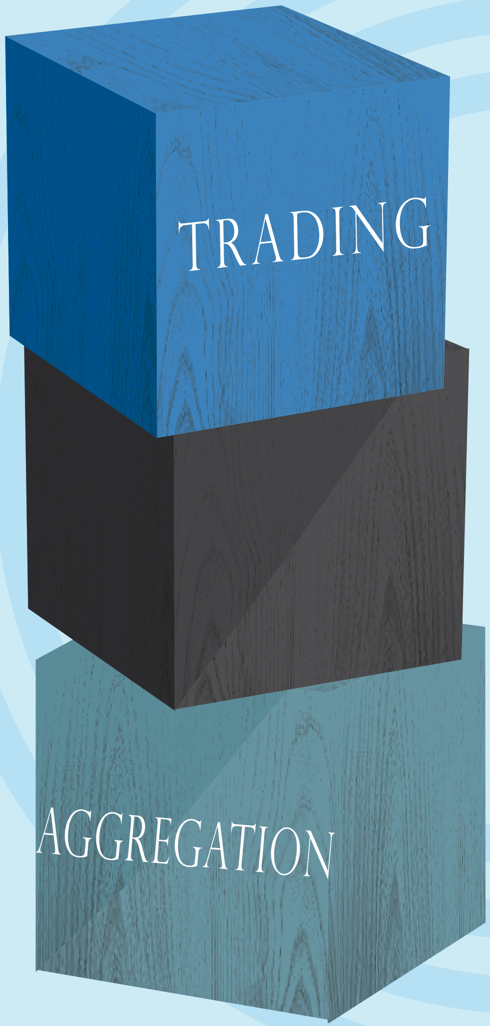
Local flexibility markets: Flexibility at a local level is becoming increasingly necessary as the UK electricity network decentralises. All Distribution Network Operators (DNOs) are now running auctions to procure flexibility locally, and this is seen as a crucial innovation in the net zero transition, strongly supported by BEIS and Ofgem.

Several auctions have been run over the last few years, but are currently managing demand constraints only, thus contracts are typically low-value and short-term due to a predominant aim to manage peak demand and outages. Additional value could be unlocked by using these markets to address generation constraints. For now, these auctions seem to favour existing fossil fuel assets and demand-side response from some larger energy consumers, although there is little data available to scrutinise the contracts awarded.

Constraint Management Pathfinder: National Grid ESO are looking at procuring services that can provide flexible resources to address localised constraints at the transmission level. This is an opportunity for storage to help with national congestion issues, by providing flexibility at known constrained areas, such as the Scotland-England border.

Recently, **Power Purchase Agreements** have started to be a serious prospect for storage. The contract lengths are long enough to provide stability, and floor prices are being offered to give a guaranteed income. However, this inevitably entails giving up some value, so accepting a PPA is often a toss up between a higher risk, but possibly higher revenues, or a secure, longer term contract of lower value.

The storage revenue stack



Trading: The settlement markets are inherently volatile – National Grid ESO uses these markets to balance the system close to real-time, and prices fluctuate according to the variation between spikes in demand and generation. Storage is well placed to respond quickly and help the ESO to balance the system. Its quick response times and agility also means it is well placed to take advantage of these price spikes. As access to these markets (slowly) opens up to storage, trading is becoming an increasingly viable revenue stream.

Net Imbalance Volume (NIV) chasing: Assets of a certain capacity (MW) which don't have to notify the ESO of their imbalance position before gate closure, can try to anticipate what actions the ESO will take and predict the imbalance price. After gate closure, assets then put themselves intentionally out of balance in order to take advantage of high or low system prices. The values of this can be abnormally high, but often fleeting. This does allow assets that can't get official Balancing Mechanism access to participate in the system and provide value to the ESO, but if the practice increases, it may create uncertainty as the ESO balances the system.

An emerging business model in recent years, **aggregation** has now become a prominent industry, using data science techniques to trade multiple assets into many of the ancillary service markets and in wholesale and Balancing Mechanism markets. Aggregation provides an opportunity for much smaller units, which are otherwise unable to enter due to their small size, to participate in markets and provide services to the grid.

Cost of storage

Battery storage costs, which have already fallen significantly, are predicted to fall further, thanks to the upscaling of manufacturing capacity and increased competition, as well as improved energy density, battery life and other efficiencies. IRENA's 2017 market survey[1] has projected a potential cost reduction of 54-61% by 2030 across a range of battery storage technologies.

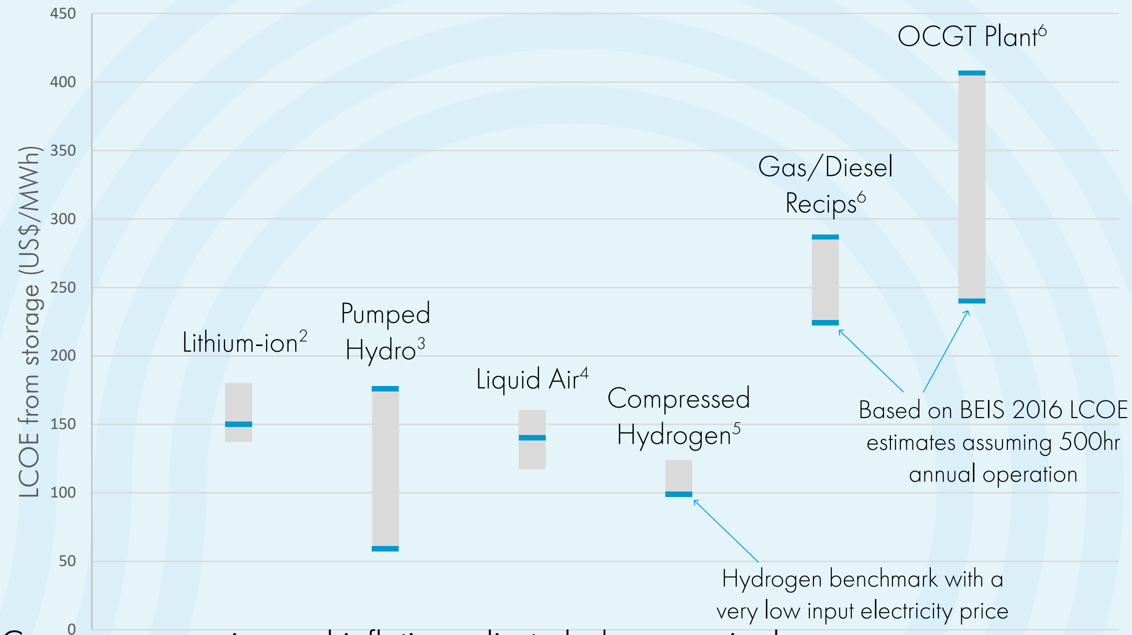
A big question, however, is when static battery storage solutions will reach the milestone of being able to outcompete fossil fuel peaking plant solutions.

Finding like-for-like comparisons across technologies is very difficult, but the latest LCOE headline figure from BloombergNEF of $150/MWh suggests that batteries could already be energy cost competitive with gas or diesel reciprocating engines, and a lot less expensive than OCGT plants.

Of course, a lot depends on the project, and in a UK context the key cost factors are still economies of scale, and the ability to achieve synergies in grid costs, land utilisation and existing energy infrastructure.

Inter-seasonal electricity storage raises a whole new set of questions, but here again the industry is beginning to look seriously at solutions such as compressed hydrogen and liquid air.

Illustrative LCOE benchmarks for selected technologies



Currency conversion and inflation adjusted where required

Indicative only – sources of data, assumptions, utilisation rates and timescales vary

Sources

1 Electricity storage and renewables: costs and markets to 2030 IRENA Oct 2017

2 BNEF 2020 (based on a 4 hour duration asset)

3 IRENA Cost Analysis Series, 2012

4 Highview Power, 2019

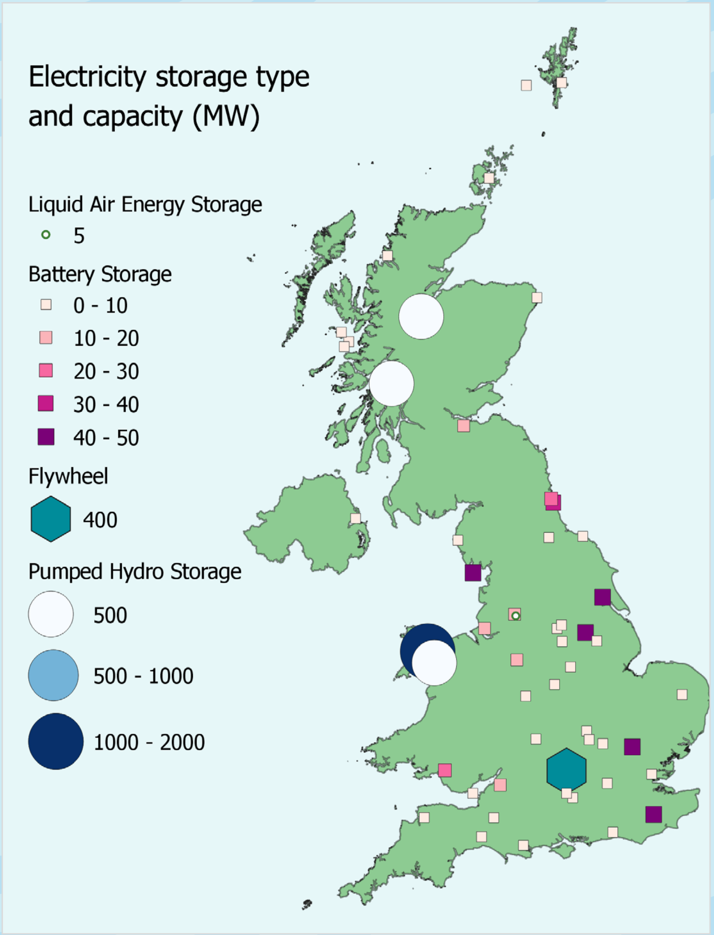
5 The promise of seasonal storage, DNV GL, 2020

6 Electricity Generation Costs, BEIS, 2016

Storage technologies in the UK

Pumped hydropower is based on a closed-loop system of reservoirs at high and low elevation. The water is pumped to an upper reservoir, converting electrical energy into stored potential energy, and is then released into the lower reservoir through turbines in order to generate electricity in times of need. Ffestiniog power station was the first major pumped storage system in the UK, commissioned in 1963.

Liquid air energy storage is based on the compressing and liquifying of air, which is then stored in highly insulated high-pressure tanks. To recapture the energy, the liquid air is heated under pressure to create a high-pressure gas which can be released through a turbine to generate electricity. With duration of several hours, and its ability to provide inertia, this technology is gaining traction in the UK.

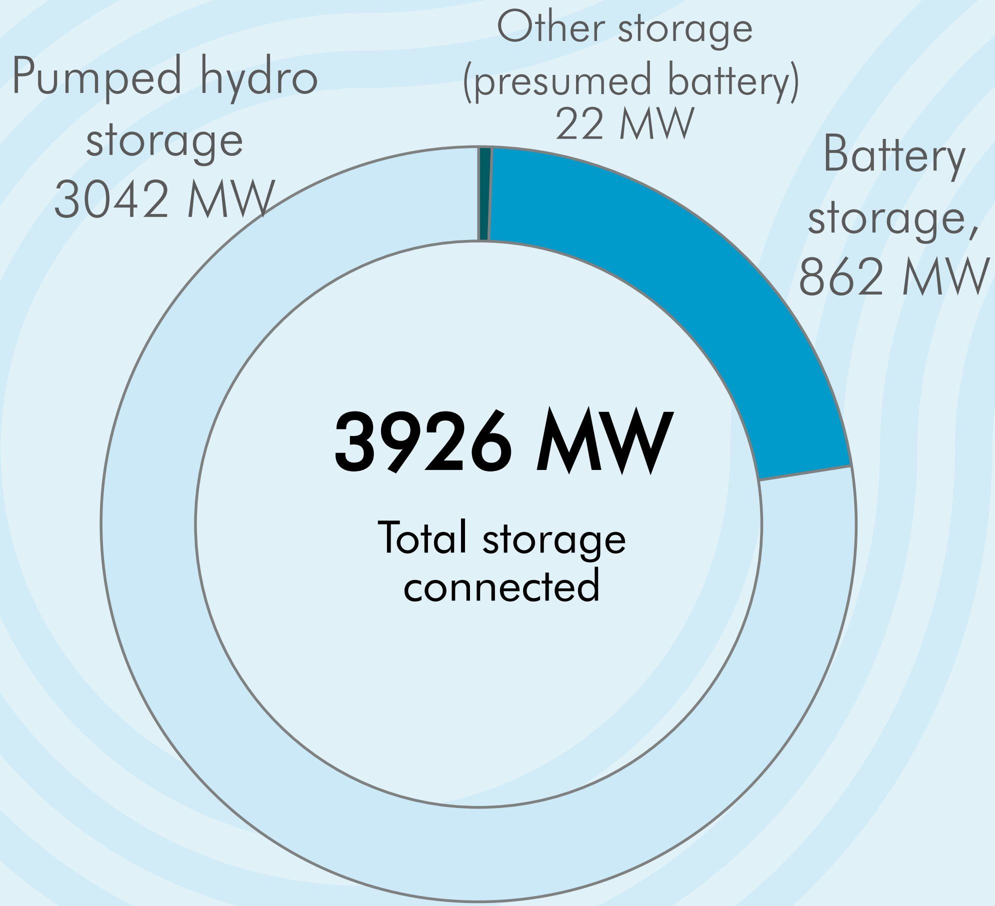


Data from the Renewable Energy Planning Database (BEIS)

Battery storage is an electrochemical storage technology with a large range of different chemistries; lithium-ion, lead-acid, magnesium, nickel, metal-air, sodium-based and flow batteries, among others. Lithium-ion is currently the most common, with costs falling considerably in the last few years. This trend is expected to continue with the increased uptake of electric vehicles. Vanadium flow batteries are also connecting to the grid at a smaller scale, and there is significant development in other types of battery storage in the UK.

Flywheels store electricity as kinetic energy in the form of a rotating mass in the centre of the flywheel, held in a vacuum. When energy is required from the device, the flywheel can be used to rotate a generator, delivering electricity back to the system, usually over a period of a few minutes. One of the largest storage systems in the UK is a 400 MW flywheel used for a research purposes, however, it is only able to provide power for a matter of seconds.

Deployment of electricity storage



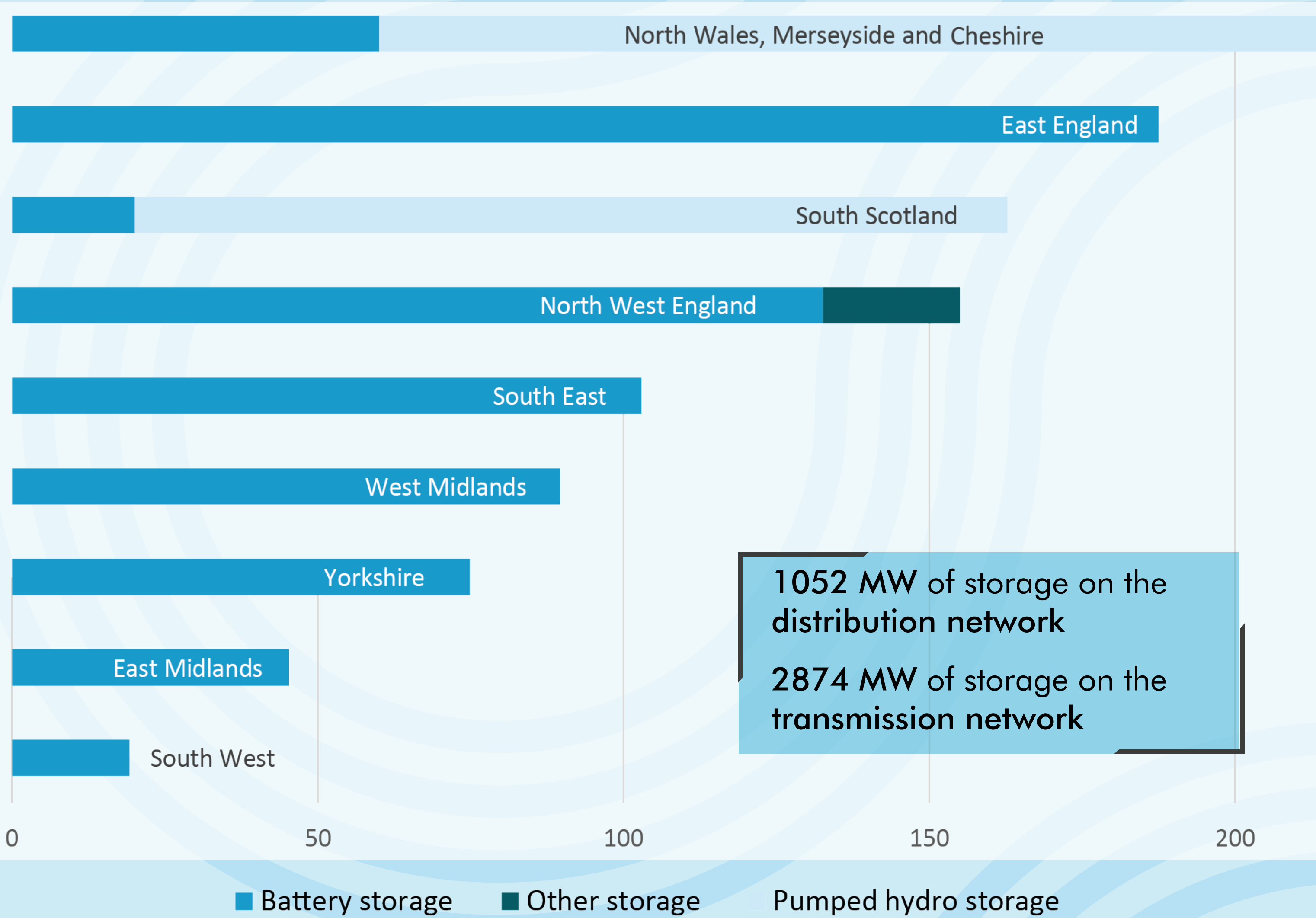
Data on storage has historically been difficult to obtain. The release of System Wide Resource Registers (SWRR) by all DNOs has been a vital step in transparency for the industry and has allowed us to make an accurate measure of connected storage in the UK using publicly available data. There are still some limitations to the above data; only sites above 1 MW are represented, and behind-the-meter sites are not included, which presents a challenge for system operation and for general analysis and projection of capacity growth.

Sources: National Grid Transmission Entry Capacity Register, all DNO SWRRs, BEIS Renewable Energy Planning Database

Significant operational storage not connected to the network:

Flywheel - 400 MW
Liquid air energy storage - 5 MW

Deployment of electricity storage



1052 MW of storage on the **distribution network**

2874 MW of storage on the **transmission network**

We need as much accurate, publicly available data as possible to aid the UK's transition to net zero. Improvements could include better locational and technology-specific data. For example, batteries are one category, but we know this includes multiple types, including some vanadium flow installations.

Sources: National Grid Transmission Entry Capacity Register, all DNO SWRRs, BEIS Renewable Energy Planning Database

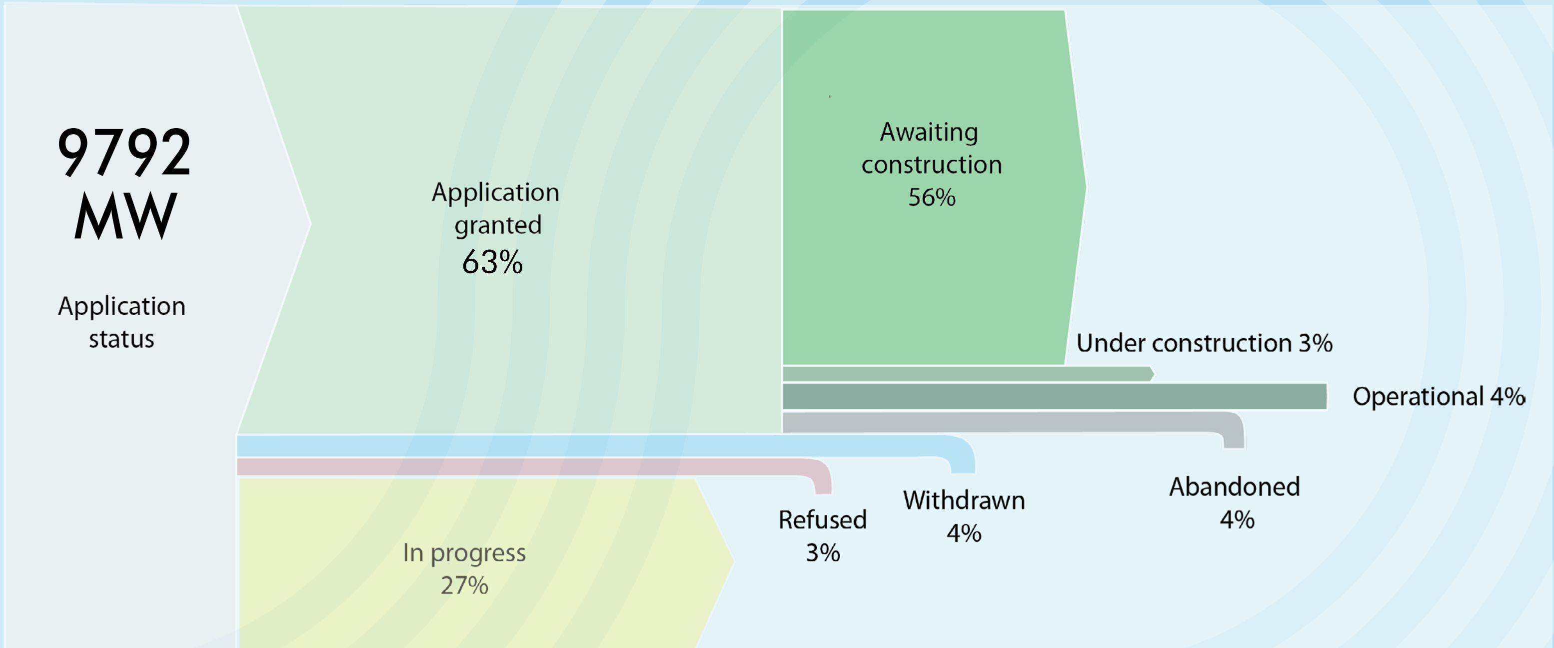
Pipeline of UK storage projects

There are a number of policy, regulatory and market barriers that are preventing storage from deploying at the rate required to enable a net zero system.

Storage project planning applications (2012 onwards)

Analysing the Renewable Energy Planning Database, we can begin to understand how well storage projects are progressing.

We can see there is a high level of ambition and confidence in the near-term future of storage, with 311 applications totalling almost 10 GW capacity submitted across the UK. 63% have had their planning application granted, with very few being refused.



However, of the number with a granted application, we can see a large amount are still to be constructed; only 4% are operational and 3% are under construction. This suggests that several projects are still putting together their business case, and there may be a number of factors inhibiting their progress to construction and operation.

Note: data from projects without complete planning history available in the REPD (28 projects, totalling 157 MW) are excluded due to lack of planning data

Projections to 2035

The level of storage needed in a zero carbon system will depend on a variety of factors: operating renewable capacity, operating dispatchable generation, the growth in capacity of other flexible technologies (demand-side response and interconnectors) and the level of network infrastructure upgrades. The chart shows a range of projections through to 2035.

3.9 GW Current levels

7 GW BEIS - Baseline policies

BEIS' projections use different economic scenarios to understand how much storage might be expected to be built under current policies. These figures are based on current build rates and government policies.

10 - 12 GW Regen (2030)

13 GW BEIS - High price

14.9 GW FES - Two Degrees

National Grid's widely-used Future Energy Scenarios look more deeply into the energy system and these projections are based on the changing shape of demand and supply.

18.3 GW FES - Community Renewables

Regen's analysis of the projects in the pipeline likely to succeed indicates the UK is currently on track to meet the FES 2019 Community Renewables scenario*, as long as the right market conditions exist which allow them to deploy.

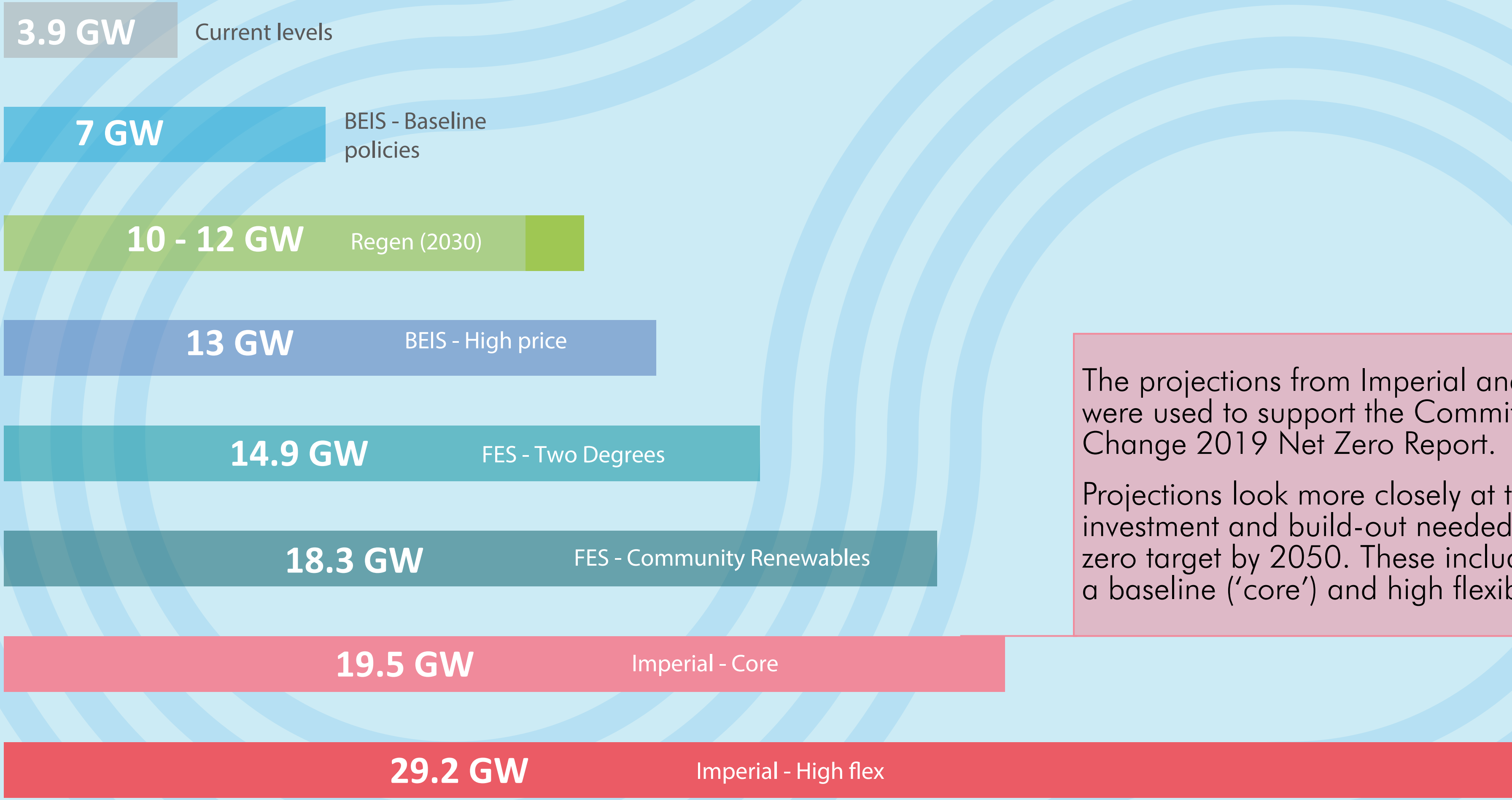
19.5 GW Imperial - Core

on next page

29.2 GW Imperial - High flex

*Based on total 'accepted-to-connect' projects in SWRR and TEC registers, and the percentage of planning applications in the REPD that make it to 'operational' or 'under construction'

Projections to 2035



The projections from Imperial and Vivid Economics were used to support the Committee on Climate Change 2019 Net Zero Report.

Projections look more closely at the amount of investment and build-out needed to meet a net zero target by 2050. These include scenarios with a baseline ('core') and high flexibility variants.

[Annex L, Updated energy and emissions projections: 2018 (BEIS)]

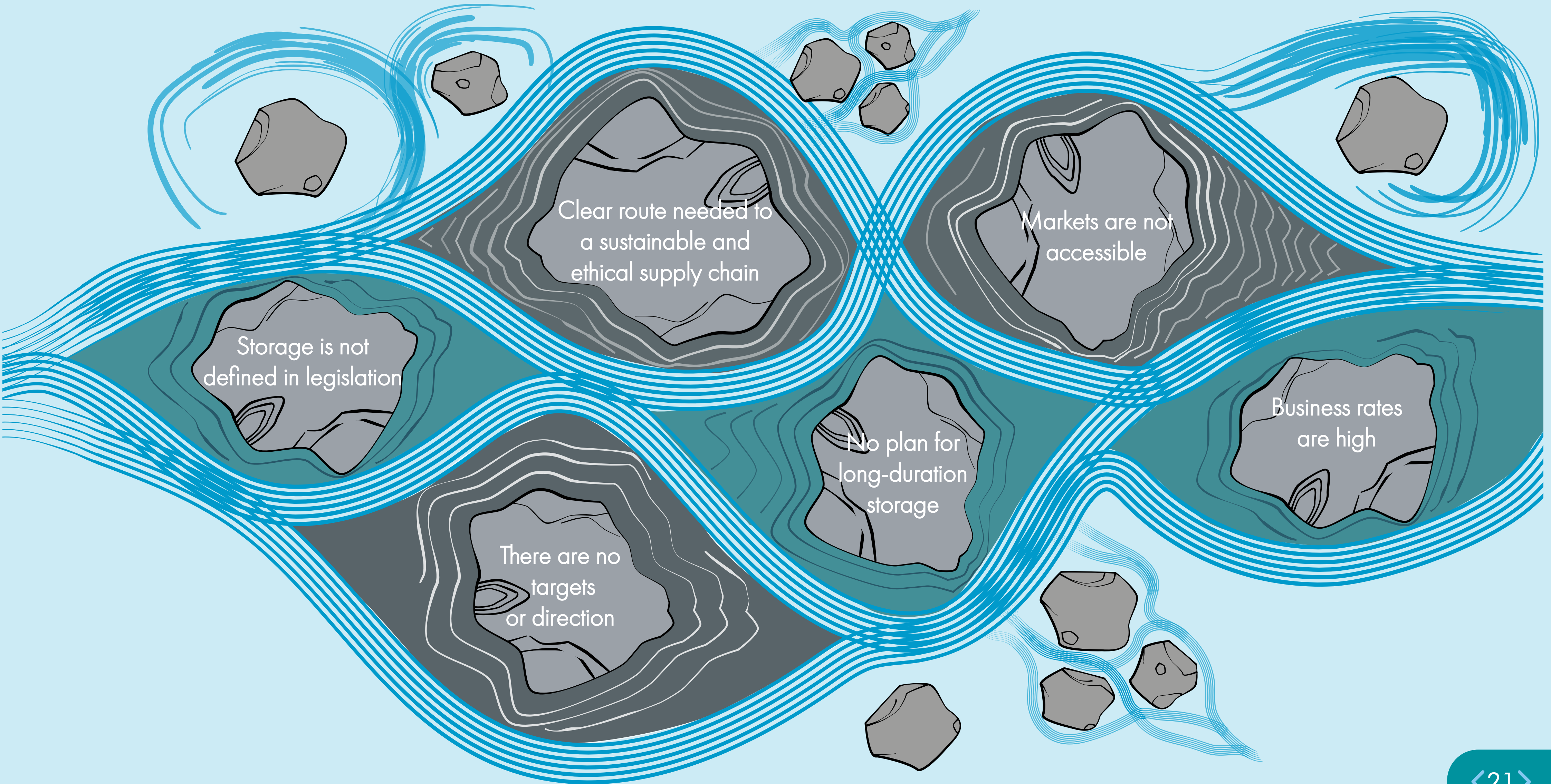
[Energy Storage: The Next Wave, Regen, 2017]

[National Grid Future Energy Scenarios 2019]

[Accelerated Electrification and the GB Electricity System, 2019]. Vivid Economics and Imperial College for the Committee on Climate Change

Barriers to storage

There are a number of policy, regulatory and market barriers that are preventing storage from deploying at the rate required to enable a net zero system



Barriers to storage

Legally, storage is in a state of limbo – by default, it is treated as generation, and the same rules and regulations apply. This has resulted in adverse effects, such as storage being 'double charged' for both import and export, and planning officers treating storage in the same way as generation, despite its radically different planning impacts.

Many of these issues have been addressed by BEIS as part of their Smart Systems and Flexibility Plan, and they have committed to legally define storage as a subset of generation in both the Electricity Act and the electricity generation licence. However, despite committing to this in 2017, there has been little progress.

Many in the industry are pushing for storage to have a licence of its own, with separate rules, codes and guidance specifically for storage. This comes with advantages – creating specific new rules for storage could lead to new markets and increased deployment into services that benefit the system and aid decarbonisation. It also comes with challenges – creating a new legal framework will take time and require significant effort from the sector. Without a decision either way, storage is still stuck in limbo. **Storage must be included in the electricity licence framework.**

The UK is lacking a long-term vision for storage. Whilst we know that the UK Government supports storage and its contribution to the net zero transition, it's unclear about the longer-term plan – how much storage will we need, what services do we need it to provide, what technologies do we need to develop? While general support from policy makers gives investors confidence, a clearer, longer-term plan would increase that confidence and give the whole industry a steer on where to target research and deployment of storage. **Government should set a clear signal for the trajectory for storage over the next decade.**

Barriers to storage

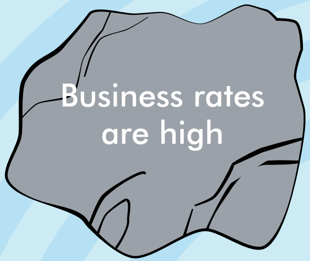
True long-duration storage is still in its infancy in terms of deployment. There are many research projects underway to develop technologies that can provide stored electricity, at a useful capacity, for long periods of time. However, none of these technologies are yet deployed to provide services to the system – at present, there is very little in the revenue stack that would reward such long duration. Many of these projects have high CapEx costs, and it's very difficult to get the investment needed with no realistic prospect of revenue.

Without a long-term plan for the types of storage we need to support the net zero transition, the long-duration storage sector will not develop beyond the research phase. **Government and industry must develop a joint plan for long-duration storage, including revenue mechanisms that would fund such projects beyond the research and development phase.**

As we transition to a net zero, sustainable future, we must ensure that the vital industries we are building to tackle climate change are also sustainable. The minerals used to create vital components in batteries – lithium, cobalt, nickel – are a finite resource and produced within the existing extractive industry model that suffers from environmental and human rights abuses.

There are a multitude of opportunities to address supply chain issues and the storage industry is embracing and developing these solutions, including building up the recycling industry, taking forward second-life projects, researching alternative battery chemistries, and scrutinising their supply chains. **Industry and government need to work to increase awareness of supply chain challenges, working towards a supply chain standard that the industry can adopt.**

Barriers to storage



Business rates make up a significant proportion of the business model for storage, particularly for behind-the-meter assets. The ESN is working with the Valuation Office Agency to improve the current calculation for business rates, but at present the calculation is over-generalised and doesn't take into account the wide variation between assets.

Those using a behind-the-meter business model are penalised with high rates for reducing their impact on the grid and supporting the net zero transition.

The government should provide business rates relief to storage providers who are key to the transition to net zero.

Storage provides a wide range of services to the electricity system and the net zero transition. In order to provide these services and secure the revenues needed to build a viable asset, storage providers must be able to access markets.

The electricity system has traditionally been set up to facilitate large, incumbent providers accessing the system. As we decarbonise, large numbers of smaller assets are connecting, and while the system is adapting to control and balance these smaller units, there are still barriers to accessing some markets and to competing with incumbent providers. The ESN is working with National Grid ESO to improve market access, pushing for a level playing field in control room decision-making and automation, lowered barriers to participation in auctions, and targeted support.

However, non-fossil fuel assets are still struggling to compete on this uneven playing field. **Market barriers must be eliminated to fully value the services that storage can provide. Flexibility markets should value carbon and provide transparent reporting on the carbon intensity of all services.**

Recommendations

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ESN membership

MEMBER
THE ELECTRICITY STORAGE NETWORK

The ESN was established in 2008 as the UK industry group dedicated to electricity storage. The Network includes a broad range of electricity storage technologies and members, such as electricity storage manufacturers and suppliers, project developers, users, electricity network operators, consultants, academic institutions, and research organisations.

The ESN is managed by Regen.

Contact our membership co-ordinator Ella Prior:
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or our policy lead, Madeleine Greenhalgh:
mgreenhalgh@regen.co.uk

Have influence

Have a stronger voice with BEIS, Ofgem, Treasury and key players, and shape the policy agenda around issues affecting the deployment of electricity storage and the role flexibility plays in the overall system.

Raise your profile

Increase your representation in the media and raise the profile of storage and its role in the system. Access our targeted networking opportunities through our exclusive events.

Stay informed

Attend our dedicated ESN-only events and working groups addressing the latest key issues for the sector, and receive our timely member newsletters and policy updates.

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Written and produced by the ESN and Regen, June 2020

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