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Our Energy Storage Future

Recommendations for an All-Island Energy Storage Roadmap

December 2019

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ACRONYMS

BESS	Battery Energy Storage System
CRM	Capacity Renumeration Market
CRU	Commission for Regulation of Utilities
DCCAE	Department of Communications, Climate Action and Environment
DS3	Delivering a Secure, Sustainable Electricity System
DSM	Demand Side Management
DSR	Demand Side Response
DSU	Demand Side Unit
ECP	Enduring Connection Policy
ESBN	Electricity Supply Board Networks
FCAS	Frequency Control Ancillary Services
FFR	Fast Frequency Response
ITE	Independent Technical Expert
IWEA	Irish Wind Energy Association
LI	Lithium Ion
MEC	Maximum Export Capacity
PPA	Power purchase agreement
REFIT	Renewable Energy Feed-in Tariff
RES-E	Renewable Energy Share – Electricity
ROC	Renewable Obligation Certificate
RoCoF	Rate of change of frequency
SEM	Single Energy Market
SNSP	System Non-Synchronous Penetration
TES	Tomorrow’s Energy Scenario (EirGrid)
TSO	Transmission System Operator
TUoS	Transmission Use of System
ZC	Zero Carbon

1 Executive Summary

The use of energy storage is critical for the future security, reliability and operation of Ireland's power system. Energy storage technologies are a key enabler to a decarbonised electricity system, and their deployment supports renewable energy policy objectives by providing a multitude of valuable services.

This all-island storage roadmap provides an overview of the role energy storage can have in the safe and reliable operation of a grid with high levels of renewable energy integration and the benefits that energy storage can deliver in terms of consumer savings, reduced carbon emissions, and reduced curtailment of renewable energy.

A robust policy, regulatory and commercial framework is needed to allow the deployment of energy storage in Ireland at the scale required to achieve current renewable policy objectives and our long-term decarbonisation ambitions. However, the current policy framework is unsuitable to deliver the volumes and types of energy storage we will require.

This roadmap outlines the significant barriers and challenges faced by the storage industry and proposes recommendations and possible solutions for policy makers to help alleviate these obstacles, in the short term (2020 to 2023), medium term (2023 to 2025) and long-term (2025 to 2030 and beyond). Under each category, a review of existing policy is carried out, along with policy recommendations, in addition to the key stakeholders involved and relevant timelines for each. Table 1 summarises the roadmap's policy recommendations over each timeframe.

The key policy asks are front loaded towards the short-term priority areas. This is because firstly, the short-term priority areas are still applicable across the medium term and long-term timeframes. Secondly, the policy changes needed for energy storage to effectively play a role in Ireland's energy system in the medium and long term must be considered now so that there is sufficient time for these changes to be implemented for 2030 and beyond.

Table 1: Summary of Policy Recommendations

Category	Key Policy Recommendations	Stakeholders and Timelines
Short-Term Priority Areas (2020 – 2023)		
System Services Procurement	• Develop and implement a comprehensive programme of work to achieve SNSP of > 90% and the removal of fossil fuel system constraints (e.g. Min Gen, RoCoF). • Work with industry to identify and breakdown the existing barriers to achieve DS3+ and ensure continued industry involvement via frameworks such as the DS3 Advisory Council • Model electricity system CO_2 emissions to compare energy market emissions and actual electricity generation emissions to calculate the non-energy market emissions contribution. • Measure and report quarterly on such non-energy market emissions.	Q4 2020 – As per the actions in the Climate Action Plan (CAP), the TSOs will develop the DS3+ programme in order to deliver the system changes needed for 2030. Q1 2021 – Also, as per the CAP, the Regulators will develop the enduring procurement framework for System Services post 2020.

	• Prioritise the procurement and dispatch of sources of System Services from low or zero carbon sources, with the goal of bringing such emissions to zero from System Services and meeting all System Service constraints from zero-carbon sources. • Ensure that sufficient System Services are procured to efficiently integrate the 70% renewable electricity targeted by 2030 and enable SNSP levels of >90%. • Begin the scoping and analysis needed to achieve long-term decarbonisation goals (e.g. 100% RES-E and 100% SNSP).	
Holistic approach to market design and long-term investment frameworks	• Develop a holistic market design so that an appropriate balance of risk and reward to incentivise widescale investment and deployment of energy storage is achieved. This must allow storage technologies to gain access to multiple revenue streams and maximise their potential as a flexible asset	Q1 2020 – CRU and NIAUR to instigate review of market design and regulatory frameworks for energy storage Q4 2020 – Completion of review and implementation of new regulatory framework for energy storage
Grid access and requirements for maximum export capacity	• Perform a review of the grid access and network planning standards to consider the unique characteristics of energy storage (including a review of the requirement for MEC for short-term reserve batteries and other System Service technologies)	Q2 2020 – EirGrid/SONI as TSOs and ESBN/NIEN as DSOs to carry out a review of grid access and network planning standards for energy storage.
FlexTech	• Develop the proposed FlexTech work areas so that the ambitions are more aligned with the key challenges the system will need to overcome to meet national renewable targets. • Consider the commercial arrangements needed to ensure the solutions are implementable, such as market design, contractual frameworks and connection policy. • Ensure that FlexTech is sufficiently prioritised and resourced to deliver the required changes. Each work area should have dedicated resourcing and work plans to deliver on programme ambitions. • Revise the proposed approach to industry engagement with allowance for ongoing bi-later meetings to maximise input from industry, similar to the previous DS3 engagement structure. • Address the current issues such as barriers to sharing of MEC between technologies on the same site under the FlexTech Hybrids workstream.	Q2 2020 – EirGrid/SONI to establish working groups or forums for each FlexTech workstream with industry representation.
Network charges	• Conduct a network charging review to remove the issues of double charging for energy storage and allows for fair and proportional allocation of network charges.	Q1 2020 – CRU to lead network charging review with support from ESBN/EirGrid Q3 2020 – Network charging review changes to be

		implemented by the TSO and DSO.
Connection policy	• Develop an appropriate connection process for flexible system support technologies, such as battery storage, synchronous condensers, flywheels and other technologies, with associated route to market. • Grid Following Funding must be developed in consideration of long-term contracting frameworks for energy storage.	Q4 2019 – ECP-2 Consultation Q1 2020 – CRU decision on ECP-2 framework. Q3 2020 – Opening of ECP-2 batch (subsequent batches to open on an annual basis with final offers issued by the end of the following year) Q2 2021 – Potential implementation of a Grid Following Funding model
Medium-Term Priority Areas (2023-2025)		
System Services procurement	• As per the short-term priority areas, prioritise the procurement and dispatch of sources of System Services from low or zero carbon sources, with the goal of bringing such emissions to zero from System Services and meeting all System Service constraints from zero-carbon sources. • Develop the necessary regulatory framework for the procurement of potential additional System Services such as synthetic inertia or congestion management.	Q4 2020 – EirGrid/SONI to complete technical analysis looking at issues which need to be overcome to manage a real time operational limit of over 90% SNSP by 2030. Q1 2021 – CRU/NIAUR will develop the model for the procurement of System Services post 2020 to facilitate increased penetration of variable renewables on the grid. Q1 2023 – EirGrid/SONI implementation of new DS3 System Services market design.
Network deferral / Short term congestion management	• TSOs to assess system needs for 2030 and develop suitable network support contracts and market signals for the procurement of congestion products or other alternative network solutions • Work with industry to define the likely future market paths, such as asset blending and local energy services, and to identify and provide solutions for the potential issues of these market paths.	Q4 2020 – EirGrid/SONI to complete technical analysis on future system needs and new flexibility products/network solutions

Long-Term Priority Areas (2025 – 2030 and beyond)		
Seasonal Storage and Demand shifting	• Develop dedicated frameworks and incentives to scale up longer duration technologies such as hydrogen electrolysis from renewable generation to enable the decarbonisation of the heat and transport sectors, and provide sources of seasonal storage. • Work with industry, within a dedicated forum or Advisory Body, to define and develop the innovative approaches to seasonal storage, and how they may be implemented. • Develop new market mechanisms, new tariff structures and new System Services relevant to these longer duration storage technologies. • Develop pilot projects for longer duration storage via programmes such as the FlexTech initiative.	Q3 2020 – Establish an all-island working group to address approaches to longer-duration energy storage Stakeholders include: Ireland - Department of Communications, Climate Action and the Environment (DCCAE), Northern Ireland – Department for the Economy, CRU, NIAUR, EirGrid, SONI, NIEN and ESBN, Industry Representatives.

2 Introduction

Energy Storage Ireland is a newly established representative body composed of industry members who are active in the development of the energy storage market in Ireland. Our aim is promote the benefits of energy storage in terms of meeting our future decarbonisation goals and to work with policy makers in facilitating the development of energy storage on the island.

The use of energy storage is critical for the future security, reliability and operation of Ireland’s power system. Energy storage technologies are a key enabler to a decarbonised electricity system, and their deployment supports climate change and energy security goals by providing a multitude of valuable services. Renewable energy generation and energy storage are highly complementary technologies, helping to address the issues arising out of intermittency, especially at very high renewable penetration levels as anticipated under current government targets by 2030 and beyond. The 70% RES-E target by 2030 is referred to as 70by30 hereafter.

However, for storage to realize its full potential, a robust policy, regulatory and commercial framework is needed. The flexibility of storage means that these assets can be simultaneously part of the generation, demand, and network infrastructure, and thus market arrangements need to facilitate access to multiple revenues sources. This creates new challenges for policy makers in bridging what have previously been considered separate, distinct components of the wider electricity market. Appropriate and timely regulatory and market design is therefore essential to allow the deployment of energy storage in Ireland at the scale required to achieve current environmental policy objectives. However, the current policy framework is unsuitable to deliver the volumes and types of energy storage we will require.

The purpose of this all-island energy storage roadmap is twofold; firstly, to clearly demonstrate how energy storage can enable a fully decarbonised electricity system by demonstrating the substantial benefits that energy storage can provide to the island of Ireland. These benefits are quantified using a cost benefit analysis carried out by Baringa.

Secondly, the roadmap provides an overview of the significant barriers and challenges faced by the storage industry and proposes recommendations and possible solutions for policy makers to help alleviate these obstacles.

The roadmap is organised into sections focused on the short, medium and longer-term barriers in policy and market design, and discusses the type of commercial arrangements required to facilitate the deployment of storage technologies at scale within the all-island market.

The following timeframes are considered;

I. Short-term (2020 – 2023),
II. Medium-term (2023 – 2025),
III. Long-term (2025 – 2030 and beyond).

The intended audience of this roadmap are energy regulators, energy policy makers, transmission and distribution system operators and other key figures involved in setting the future policy, regulatory and commercial frameworks necessary to meet Ireland’s renewable energy and climate targets for the future.

3 Mission and Objectives of the Roadmap

Roadmap Objectives:

1. Demonstrate the key role that energy storage can play in supporting Ireland's energy and decarbonisation goals, and quantity the benefits to the Irish consumer.
2. Provide an overview of the existing barriers to storage investment, and identify the most important actions required in the short, medium and long term to successfully develop and deploy energy storage.

3.1 Objective 1:

Energy storage is a key enabler of decarbonisation and provides numerous benefits. The first objective of the Roadmap is to demonstrate this by:

- Looking to how the role of energy storage will develop over the near to long-term timeframes, as the system needs evolve (Section 5);
- Detailing the benefits of energy storage to consumers in Ireland specifically. To achieve this, analysis from Baringa is presented in Section 6 to quantitively show the benefits of using energy storage and demand side response to meet System Service constraints instead of using fossil fuel generation plants. These benefits quantified in the study included system cost savings, emissions reductions, and reduced renewable curtailment;
- Providing worldwide examples of energy storage use cases illustrating the multitude of services and benefits that energy storage can provide (detailed in the Appendix).

3.2 Objective 2:

However, to reap these benefits, a robust policy, regulatory and commercial framework needs to be in place. An ever-changing environment with increasing integration of renewables means that grid codes, policy and market design are constantly evolving. Subsequently, not all policies and standards are currently fit for purpose for the level of energy storage integration needed to meet our goals.

These barriers and challenges are hindering the development of more widespread energy storage in Ireland, and, if not addressed, will prevent consumers from receiving the full potential benefits of these technologies. Therefore, the second objective of this Roadmap is to:

- Provide an overview of the existing barriers to storage investment;
- Identify the most important actions required in the short, medium and long term to successfully develop and deploy energy storage to support Ireland's energy and decarbonisation goals;
- Summarise the policy hurdles preventing the creation of a business case for energy storage, and provide recommendations for the revisions in policy that should be adopted to prevent these.

Each area is discussed within the context of short, medium and long-term requirements (Sections 7, 8, and 9 respectively). Recommended solutions are put forward in each of these sections which will help remove the current and potential future barriers to energy storage development.

An overview of the all-island policy landscape, and the outlook for energy storage in Ireland is provided in the following section.

4 All-Island Policy Landscape

Overview

- EU Renewable Energy Directives
- EU Clean Energy Package
- Ireland's Climate Action Plan
- Northern Ireland Future Renewable Policy
- System operator initiatives such as DS3, EU SysFlex and Flexible Technology Integration Initiative (FlexTech)

4.1 EU Renewable Energy Directives

In 2009, the EU Renewable Energy Directive (2009/28/EC) set out targets for 20% greenhouse gas emissions reductions and 20% renewable energy by 2020. In order to meet the aims of this directive, the Republic of Ireland and Northern Ireland governments set targets of 40% electricity consumption from renewable sources by 2020 (2020 RES-E targets). Northern Ireland has reached its 2020 RES-E target ahead of schedule, while the Republic of Ireland will likely miss its target by a small margin.

Following on from this, under the Paris Climate Agreement, the EU pledged to achieve greenhouse gas emissions reductions of at least 40% by 2030 and in December 2018, a revised EU Renewable Energy Directive 2018/2001 entered into force requiring the EU to source at least 32% of its total energy needs from renewables by 2030.

4.2 Clean Energy Package

In order to deliver on its renewable ambitions, the EU finalised the Clean Energy Package (CEP) regulation in 2019 which sets out the rules and frameworks for member states to manage the energy transition. This regulation is centred around five key pillars; energy security, energy markets, energy efficiency, decarbonisation of the economy and innovation and research.

The CEP is very supportive of energy storage and expects energy storage to play a key role in meeting the legislation's ambitious 32% by 2030 renewables target. The EU acknowledges that these ambitious targets can only be achieved with the widespread deployment of flexibility solutions such as storage. The regulation notes that efforts should be made to ensure a level playing field for all market participants, for example, in terms of the non-discriminatory application of network tariffs for technologies such as energy storage.

4.3 Ireland's Climate Action Plan

In May 2019, Ireland became only the second country in the world to declare a climate and biodiversity emergency. Ireland also endorsed the recommendations of the Report of the Joint Oireachtas Committee on Climate Action - 'Climate Change: A Cross-Party Consensus for Action', published in March 2019[1], that advocated a net zero emissions economy by 2050. Following this in June 2019, the

[1] https://data.oireachtas.ie/ie/oireachtas/committee/dail/32/joint_committee_on_climate_action/reports/2019/2019-03-28_report-climate-change-a-cross-party-consensus-for-action_en.pdf

Republic of Ireland published an ambitious roadmap on climate change policy covering the period to 2050, dubbed the Climate Action Plan[2]. The plan includes a target for 70% of all electricity to be sourced from renewables by 2030 (2030 RES-E target).

The Climate Action Plan includes actions and the relevant steps, with stakeholders and timelines, necessary for delivery. There are a number of welcome steps in the Plan in relation to energy storage, which are summarised in Table 2. (Action 24 in general refers to the steps necessary to "Facilitate very high penetration of variable renewable electricity by 2030 (both SNSP and average) through system services and market arrangements"). There are also a number of grid and DS3 related actions for the CRU, EirGrid and ESB Networks from 2020-2030, including a reference to operating the grid at SNSP levels of over 90%, for which energy storage will be an important facilitator.

Table 2: Climate Action Plan activities related to energy storage

Action 24: Relevant Steps Necessary for Delivery	**Timeline**	**Lead**	**Other Key Stakeholders**
Expansion of the DS3 Qualifier Trial Programme (the trialling of new technologies on the system) into a new programme known as 'Flex Tech Integration Initiative'	Q3 2019	EirGrid	ESBN
Deliver the remaining deliverables under the DS3 Programme to enable 75% of the demand on the system to be met from variable renewable generation (75% System Non-Synchronous Penetration - SNSP)	Q2 2020	EirGrid	CRU
Technical analysis looking at issues which need to be overcome to manage a real time operational limit of over 90% SNSP by 2030	Q4 2020	EirGrid	SONI
Develop the model for the procurement of System Services post 2020 to facilitate increased penetration of variable renewables on the grid. The future design will need to enable Ireland's 2030 RES-E ambitions	Q1 2021	CRU	n/a
Technical and market design, using findings from Flex Tech initiative, for the evolution of System Services to enable renewable electricity targets for 2030	Q4 2021	EirGrid	n/a
Review of policy regulatory framework for electricity storage to facilitate efficient level of electricity storage to meet 2030 70% renewable electricity target	2020/2021	CRU	EirGrid, ESBN
Implementation of new DS3 System Services market design, post-regulatory decision EirGrid	Q1 2023	EirGrid	CRU, ESBN
Implementation of European regulations, including Electricity Balancing Guideline and Clean Energy Package, into programme as appropriate	Q4 2023	CRU	EirGrid, ESBN, DCCAE

[2] Climate Action Plan, https://www.dccae.gov.ie/en-ie/climate-action/topics/climate-action-plan/Pages/climate-action.aspx

4.4 Northern Ireland Future Renewable Policy

In Northern Ireland, the lack of a functioning Assembly means there has been little progress towards a revised renewable energy policy beyond 2020. However, the Department of Energy has been engaging industry bodies on the feasibility of post-2020 renewable targets and has recently commissioned studies to inform a way forward. Following a comprehensive report by leading energy and utilities consultants Baringa, which concludes that it is technically possible and cost neutral for Northern Ireland to use renewable energy to supply 70 per cent of its electricity by 2030[3], the renewable industry is recommending alignment of Northern Ireland 2030 RES-E targets with the Republic of Ireland to facilitate a coordinated policy framework for further renewable development across the all-island market.

It is also worth noting that the UK has set a goal of net-zero greenhouse gas emissions by 2050. It is very likely that Northern Ireland will have its own part to play in contributing to this goal and should set a 70% RES-E target for 2030 accordingly.

4.5 System Operator Initiatives

4.5.1 Delivery a Secure, Sustainable Electricity System (DS3)

The EirGrid and SONI led "Delivering a Secure, Sustainable Electricity System" (DS3) programme has been an extremely successful initiative to date that has enabled Ireland to be a world-leader in the integration of renewable electricity onto the grid.

The DS3 programme has so far successfully delivered the tools, policies and system services needed to allow the current SNSP operational limit to be increased to 65%, an increase from the 50% limit when the programme began in 2011. Further trials to increase SNSP to 70% and 75% are expected in 2020.

Going forward, achieving a 70% renewable electricity target will require the continued development of the DS3 programme as achieving even higher levels of renewable integration will bring significant system challenges that must be addressed.

It is a stated objective of the CAP that the SNSP operational limit be raised to over 90%, or above, by 2030. In order to reach 70by30, many of the other existing operational constraints which limit the penetration of renewable generation on the system will need to be removed. The DS3 programme has so far maintained curtailment at manageable levels of less than 5% but, as the volume of renewables connecting to the system continues to grow, it is certain that without a strong DS3+ programme and further SNSP increases, curtailment levels will increase substantially. For instance, a report commissioned by SEAI 'Managing Curtailment in 2030'[4] estimates that with current system constraints, and no new mitigation measures, curtailment levels could increase to 44%. In this scenario, we would need over 21 GW of installed wind capacity to meet 70% RES-E due to these high curtailment levels.

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[3] Baringa, 70 by 30, A 70% Renewable Electricity Vision for Ireland in 2030, https://www.iwea.com/images/files/70by30-report-final.pdf

[4] 'Managing Curtailment in 2030' Report Presentation recording- https://www.youtube.com/watch?v=XGHk1PfdEfg

If Ireland is to achieve the 70% RES-E target in the most cost-efficient manner, the power system will need to accommodate non-synchronous renewable penetration levels of over 90% at any one time. This will likely mean that, at these times, all system services requirements will need to be met by non-energy zero carbon service providers, such as wind, solar, DSUs, energy storage and synchronous condensers, as there will be no room on the system for fossil fuel generators.

Therefore, a long-term framework that incentivises the development of zero-carbon technologies such as energy storage is needed.

4.5.2 EU-SysFlex

EU-SysFlex[5] is a Horizon 2020 project with a pan-European consortium of TSOs (including EirGrid), DSOs, technology providers and researchers tasked with examining innovative services that will meet the needs of the electrical system with more than 50% of renewable energy. The project began in 2017 and will run to 2021. The project aims to identify the long-term needs as well as the technical scarcities of the future power system. EU-SysFlex is working to incentivise the necessary flexibility and solutions to enhance the market and regulatory framework. The project will ultimately create a long-term roadmap of actions for Europe to facilitate the large-scale integration of new technologies and capabilities. An enhanced system services market is envisioned, in addition to the need for flexibility needed to deal with variable electricity demand and the increasing variability and ramping created by renewable energy sources – two key areas where energy storage will be able to play a role.

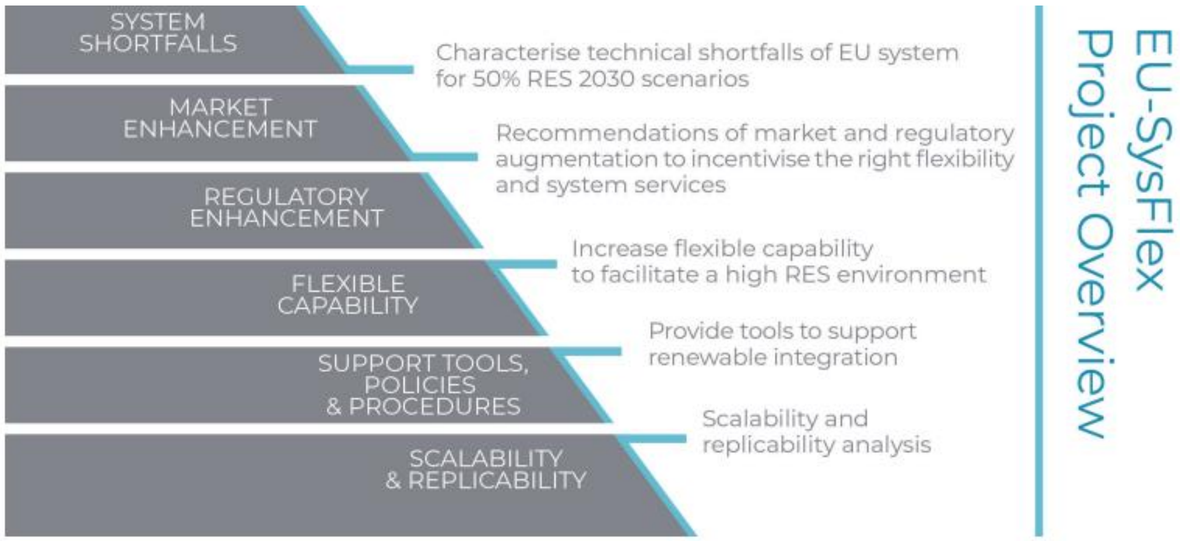


Figure 1: EU-SysFlex Project Overview

[5] Pan-European system with an efficient coordinated use of flexibilities for the integration of a large share of RES https://eu-sysflex.com/

4.5.3 FlexTech

Another welcome initiative being spearheaded by the System Operators is FlexTech. The SOs launched the FlexTech initiative in June 2019 which aims to break down the technical, policy, legal and regulatory barriers to integrating technologies onto the power system which will help meet the 70by30 targets. EirGrid/SONI proposed five working groups in their initial consultation published on 30th September 2019[6], and requested feedback on the overall structure of the initiative and the focus of the working groups. The suggested working groups in the consultation were;

- Renewables/Small Scale Generation (SSG),
- Demand Side Management (DSM)
- Hybrids
- Large Energy Users
- Storage.

The consultation closed in November 2019. Section 7.4 highlights the storage industry's engagement with the FlexTech initiative to date, and provides some recommendations on proposals for alternative working groups to tackle the key policy challenges, future governance structure and programme resourcing.

4.6 System Operator Strategy Updates

The Regulatory Authorities and System Operators have recently updated their respective strategies to highlight decarbonisation as a central element to their strategies in line with government targets:

- The strategic plan of the Commission for Regulation of Utilities (CRU) covering 2019 to 2021 sets out their obligations to deliver sustainable low-carbon solutions with well-regulated markets and networks[7].
- EirGrid highlight decarbonisation as one of their primary goals within their "Strategy 2020-25; Transforming the Power System for Future Generations" [8].
- ESB's Strategy to 2030 (Strategy 2030) sets out their plan to enable the transition to reliable, affordable and low-carbon energy.
- The Corporate Strategy for the Northern Ireland Authority for Utility Regulation (NIAUR) 2019-2024[9] outlines their role in ensuring that their investment best supports government decarbonisation targets and enables a low carbon future.

[6] FlexTech Consultation 2019: http://www.eirgridgroup.com/site-files/library/EirGrid/FlexTech-Consultation_30092019.pdf
[7] CRU Strategic Plan: https://www.cru.ie/document_group/strategic-plan-2019-2021/
[8] EirGrid's Strategy 2020-25, http://www.eirgridgroup.com/about/strategy-2025/
[9] Northern Ireland Corporate Strategy 2019-2024, https://www.uregni.gov.uk/sites/uregni/files/media-files/Corporate%20Strategy%202019-24%20final%20for%20web.pdf

5 Outlook for Storage in Ireland

Storage encompasses a broad range of technologies ranging from chemical, electrical, thermal, electrochemical and mechanical. Each of these technologies has different characteristics and capabilities in terms of speed of response and storage capacity which means they can provide a variety of valuable services to the power system. These attributes will become very important in the medium to longer-term timeframes as the need for longer duration storage becomes more important.

An overview of the how different storage capabilities may be required over time from a range of storage technologies is discussed in the following sections.

5.1 Short Term Outlook

Lithium ion battery energy storage systems (LI BESS) are the most common type of grid-scale batteries at present and are already operational worldwide. They are predominantly used to provide fast acting frequency response and reserve grid services that can replace the need to use fossil fuel generators for these services.

For example, to ensure the stability of the system in case of a sudden disruption to power generation or demand, such as a large generator failing unexpectedly, the TSOs must make sure that there is sufficient reserve back up power on the system at all times. This reserve power must be available at a moment’s notice and currently the TSOs meet the majority of their reserve requirement from fossil fuel generators. This means that out-of-merit fossil fuel generators are often constrained on or run inefficiently just so they are available to provide this immediate reserve back up. LI BESS can replace the need to use fossil fuel generators for reserve and fast frequency response as they are available nearly all the time and can respond to tiny frequency deviations in milliseconds, thus helping to manage system stability. This has benefits in terms of system cost savings, emissions reductions and lower renewable curtailment as will be outlined in Section 6.

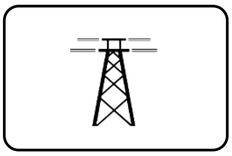
While LI BESS can also provide more energy intensive use cases and are widely deployed internationally in this context with up to 4-hours storage duration, the technology is subject to increased degradation with cycling, and therefore other storage technologies may prove more suitable for such use cases in the medium to longer term.

In the context of the all-island market, the only operational grid-scale battery energy storage system is the Kilroot energy storage array which primarily provides system support services such as frequency response and operating reserves. Further to this, EirGrid/SONI have recently procured 110 MW of fast acting frequency response and reserve products from LI BESS via a competitive DS3 Volume Capped auction held in July 2019. Provision of these services by LI BESS will help reduce curtailment of renewable generation and facilitate increasing operational SNSP levels above 65%. It is expected that the projects which were successful in this process will become operational between 2020/2021.

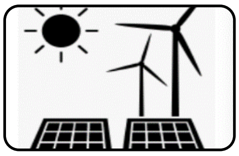
In addition, 371 MW of battery storage projects secured grid connection offers in the first Enduring Connection Policy (ECP) batch which opened in 2018. However, development uncertainties exist for those projects not contracted under the DS3 Volume Capped framework regarding the viability of the Volume Uncapped arrangements and future procurement policy. This uncertainty, and other existing barriers to investment in storage technology are discussed in more detail in Section 7.1.

5.1.1 Current Energy Storage Use Cases

The previous section has focused on the ability of energy storage to provide fast acting frequency response and reserve grid services. However, energy storage can provide numerous benefits in terms of helping system operators maintain security of supply, integrating higher levels of renewable energy onto the network, reducing power sector emissions and in providing savings benefits to the consumer. An outline of these benefits is illustrated in Figure 2. A range of different energy storage technologies, along with example use cases from projects worldwide are discussed in more detail in the Appendix.

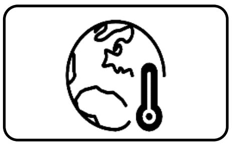


Optimum Operation of the Transmission System
Provision of system services
System adequacy
Prevention of system black events
Grid reinforcement deferral
Network constraint management



Increased Integration of Renewable Energy
Co-location with renewable energy for peak shifting
Reduction of curtailment of renewable generation
Increase operational SNSP levels from 65% to 75% to help meet 2020 RES-E targets

Consumer and Economic Benefits
Increases the competitive dynamic of the ancillary service markets, resulting in reduced consumer prices
Reduces the need for gas 'peaking plants'
Transition from traditional consumer to pro-sumer with micro-scale storage aggregation



Environmental Benefits
Carbon emission abatement by displacing reserve from conventional fossil fuel generation

Figure 2: Benefits of Energy Storage

5.1.2 Battery Safety and Community Engagement

As energy storage systems become more prevalent and are an increasingly important part of our global energy transition it is only natural that communities being introduced to a new technology will have questions. It is very important to address any concerns people may have from a health and safety perspective.

Energy Storage Ireland is developing an information paper on the safety of grid scale battery energy storage systems. This paper will outline some of the most commonly expressed concerns around the safety of lithium ion batteries as well as the design features that mitigate the risks associated with battery energy storage projects. It is expected that this paper will be published in Q1 2020.

Currently, most grid-scale battery-based energy storage systems use rechargeable lithium ion battery technology as other energy storage systems are predominantly at an early development stage. As these other technologies mature and potentially see a take up in the Irish market, Energy Storage

Ireland will continue to monitor developments and will formulate an appropriate position on safety in relation to other types of storage system as needs arise.

Energy Storage Ireland will continue to engage with our members to ensure that safety and best practices are at the forefront of grid-scale battery energy storage developments in Ireland and Northern Ireland.

5.2 Medium Term Outlook

As storage technologies mature it will become more commercially viable to time-shift energy, storing energy at low price/cost periods to be used at high price/cost periods, which allows users to benefit from the change in the price of energy over time. This move to multi-hour energy storage will be required at high levels of RES-E penetration to provide flexibility and to maximise the use of renewable generation assets and facilitate intermittent energy sources to replace existing fossil fuel generators in order to meet the 2030 RES-E targets.

For example, electricity demand tends to have a consistent profile day to day characterised by the lowest demand at night with a gradual ramp up in the morning, with another fairly steep demand rise in the early evening, in line with peoples' activities at home. Generation has to be scheduled to meet this demand profile, with the most generation needed to meet the evening peak. This also tends to be when the most expensive electricity prices are seen as expensive gas or diesel peaking generators are often brought on just for a couple of hours to meet this evening demand. Multi-hour energy storage systems can replace these peaking generators as they can discharge energy over this short evening peak timeframe to help meet demand. Energy storage systems active in this market generally charge when electricity prices are low, which is typically when wind generation is high, and discharge at times of peak demand. This removes the need to turn on expensive fossil fuel peaking plant, lowers costs to consumers and reduces overall power sector emissions. A number of multi-hour battery storage projects were rewarded new-build capacity contracts in the 2019 T-4 all-island Capacity Auction. They are expected to become operational in 2022/23. These battery energy storage systems will reduce the need to bring on expensive fossil fuel peaking generation at times of high electricity demand.

The benefits of multi-hour energy storage as a zero-carbon energy provider are even more relevant in the medium to long-term as Ireland's Climate Action Plan has made two firm commitments: firstly, to shut down the Moneypoint coal-fired power station by 2025; and secondly, to decommission the peat burning plants in the midlands by 2028. The closures of the midlands peat power plants have since been brought forward to 2020 in line with the expiry of their planning permissions.

Longer duration energy storage technologies could also be used to provide a non-wires alternative to network build out to help mitigate peak transmission or distribution network congestion. As the electrification of heat and transport adds additional demand to an already constrained grid, energy storage offers a potentially cheaper network reinforcement solution to network operators for the benefit of all users. For instance, deployment of storage in large demand centres such as Dublin can help avoid network congestion during peak hours and reduce or defer the need for network reinforcement. Behind the meter electricity storage schemes will also have a role to play in managing energy balancing and network congestion, increasing the overall utility of existing grid infrastructure.

5.3 Long Term Outlook

To achieve a decarbonised energy sector a cost-effective means for the long-term storage of large volumes of renewable energy will be required. Technologies such as pumped hydro, compressed air energy storage, liquid air energy storage etc. already offer potential options, but these types of solution require locations with specific geographical characteristics that are not common on the island of Ireland. While solutions of this type do have a role to play, when considering the high capex costs associated with such projects, it seems unlikely they will offer a solution at the scale required to meet longer-term decarbonisation ambitions.

Electrolysis may provide a scalable alternative solution, whereby surplus or dedicated renewable generation is used to produce hydrogen gas, which is then stored and transported, potentially via existing gas infrastructure, as a 'clean' fuel for use in the electricity, heat and transport sectors. Significant research and development is ongoing across the world on the development of a 'hydrogen economy' and it could prove an ideal solution for the all-island Irish market, improving energy sustainability and security, while also facilitating achievement of long-term decarbonisation goals.

5.4 Potential Future Energy Storage Volumes

Table 3 summarises the volumes of energy storage currently procured under existing schemes or in the development pipeline. However, there is much debate and uncertainty regarding the overall volumes that will be required in the future.

Baringa's Zero-Carbon System Services model is used as a guideline (detailed further in Section 6). This model assumes that *at least* 700 MW of fast acting reserves will be required from providers such as battery energy storage and demand side response (DSR) to meet system requirements in 2030, while up to 1,200 MW will be required from longer-term battery storage that will be active in the energy, capacity and System Services markets.

Table 3: Energy Storage Pipeline

Policy	Volumes / Details
Enduring Connection Policy	371 MW DS3 applications processed out of c2000MW of battery storage applications received
DS3 Volume Capped	EirGrid has selected three large scale storage projects (110 MW in total) to deliver Fast Frequency Response and Tertiary Operating Reserve Services via a DS3 competitive procurement process held in July 2019. The contracts were awarded on a fixed term basis for a maximum period of six years.
DS3 Volume Uncapped/Tariff Arrangements	This framework will last until April 2023, with the option to extend at the Contracting Entities' discretion and subject to Regulatory Authority approval. 14 System Services in total are being procured as part of the Qualification System, over 28 lots (14 for EirGrid and 14 for SONI). 12 services were procured in accordance with Phase 1 (May 2018) and Phase 2 (October 2018). The procurement process involves a qualification system which requires interested parties to submit a response to EirGrid/SONI before being considered for the provision of the relevant services. Tenderers have repeated opportunities to apply for Volume Uncapped Contracts, under an iterative gate process. It is intended that specific contracts under this process will be awarded every six months. The 10 MW Kilroot energy storage array is contracted under these arrangements. Further detail on System Services procurement is set out in Section 6.1.
2019 T-4 All-island Capacity Auction	A number of multi-hour battery storage projects were rewarded capacity contracts in the 2019 T-4 all-island Capacity Auction, including 209 MW of pumped hydro storage and 81 MW of Other Storage technologies.

6 Quantifying the Benefits of Energy Storage In Ireland

The 70by30[10] report completed by energy and utilities experts Baringa, and published in October 2018, showed that a 70% RES-E target for the Ireland and Northern Ireland power system could be achieved by 2030 at a net financial benefit to end consumers. The report found that the provision of flexibility on the all-island power system is a vital ingredient to the successful and efficient integration of renewables by 2030.

Further to this Energy Storage Ireland and the Irish Wind Energy Association (IWEA) commissioned Baringa to carry out a cost-benefit analysis assessment investigating the benefits to the power system in procuring all System Services from zero-carbon providers such as battery energy storage, demand side response and synchronous condensers. This assessment leveraged previously completed work carried out as part of the 70by30 analysis.

Currently, the majority of System Services are provided by fossil fuel generators, that are often constrained on or positioned by the TSOs, outside of the market schedule, to meet System Service constraints. These generators receive compensation to cover the additional fuel and carbon costs they need to operate in order to provide these services. This also results in increased CO_2 emissions and the curtailment of renewable generation.

Baringa have modelled scenarios with System Service constraints in place for the years 2021, 2023, 2025, 2027 and 2030, and have then removed these constraints in turn – reflecting provision of reserve and all other System Services from 'non-energy market' zero-carbon sources.

The report titled, *'Store, Respond and Save – Cutting Two Million Tonnes of CO_2'* was published on the 13th December 2019[11].

The following sections outline the results of the analysis in terms of system cost savings, avoided emissions and reduced curtailment.

6.1 System Cost Savings

Baringa examined the costs to the system of meeting all System Service constraints (e.g. reserves, inertia, voltage) which are derived primarily from the fuel and carbon costs of constrained on part-loaded fossil-fuelled plant.

The Baringa modelling results show a potential system cost saving of €57m per annum by 2030 if system reserve constraints are met solely by zero-carbon sources such as battery storage and demand side response. Interestingly, the analysis shows that even sourcing 50% of reserve from zero-carbon resources would provide the same system cost saving of €57m. This is due to the fact that other system constraints are binding and therefore the remaining reserve is sourced from fossil fuel generators that are being brought on to meet additional constraints.

This figure increases to €117m per annum by 2030 when all other constraints (e.g. inertia and voltage) are met by zero-carbon sources, showing that there is a significant benefit from removing these fossil

[10] Baringa "70 by 30 - A 70% Renewable Electricity Vision for Ireland in 2030", https://www.iwea.com/images/files/70by30-report-final.pdf

[11] https://iwea.com/images/files/iwea-baringastorerespondsavereport.pdf

fuel System Service constraints as well. The chart below highlights the system cost savings under these different scenarios.

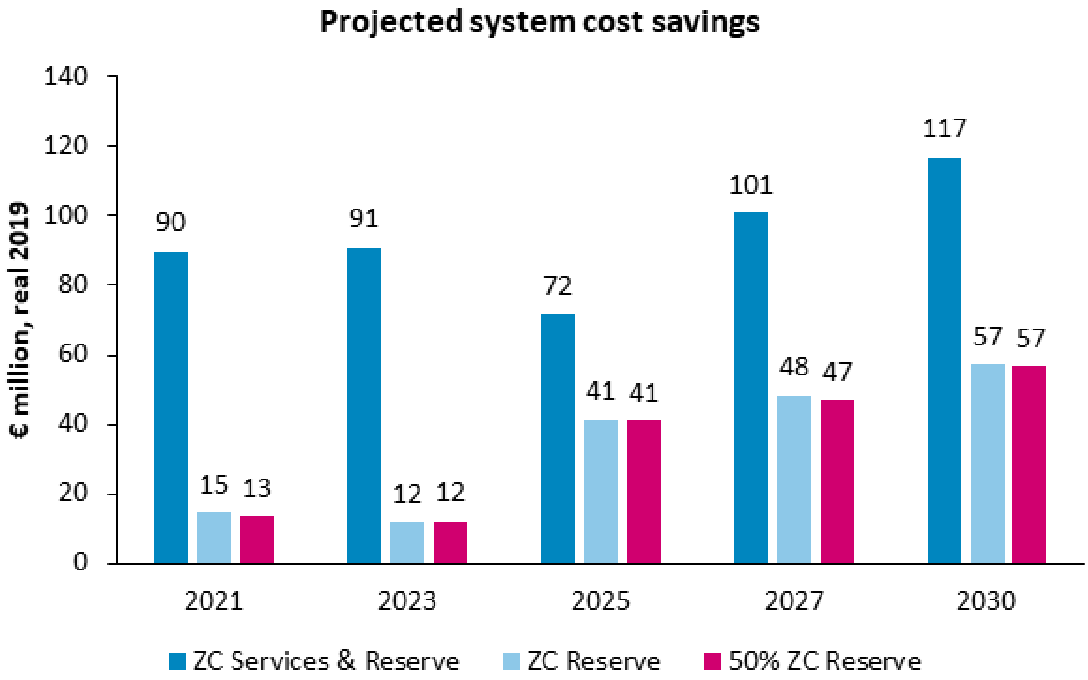


Figure 3: System Cost Savings from Zero-Carbon System Services Provision

6.2 Emissions Reductions

The Baringa analysis also shows that there is a huge benefit from avoided CO_2 emissions from full zero-carbon provision of reserve and other System Service constraints, equating to almost 2 million tonnes of CO_2 avoided per year by 2030. This is due to the fact that fossil fuel generators do not need to be constrained on or run inefficiently to provide these services. To put this in context, Baringa estimate that this would equate to avoiding one third of total power sector emissions in 2030. Even sourcing the reserve services alone from providers such as battery storage would avoid 0.4 million tonnes of CO_2 per annum by 2030. The chart below highlights the annual avoided emissions out to 2030 under the zero-carbon System Services scenario.

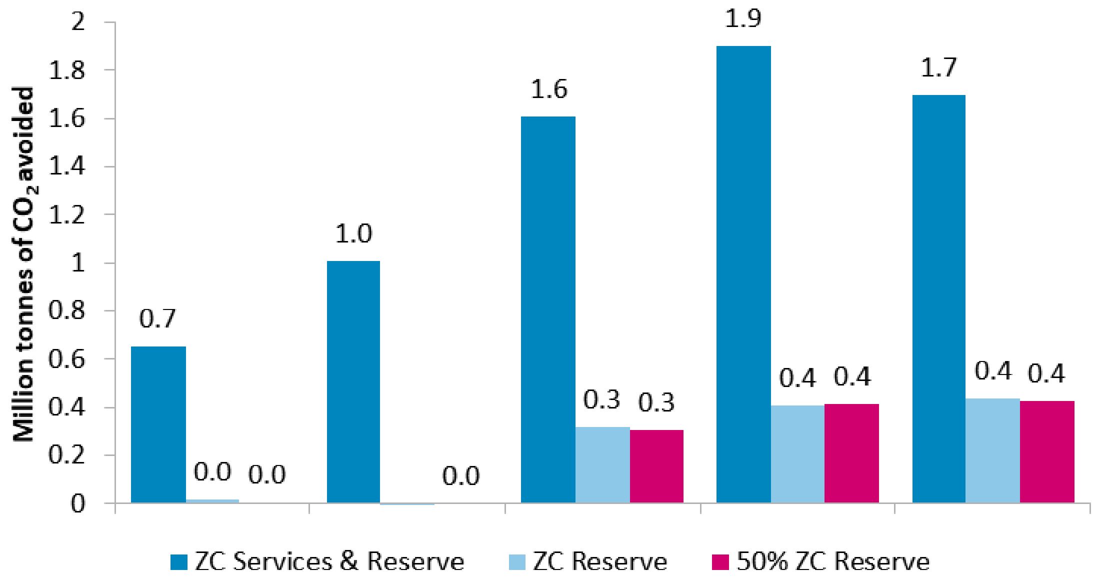


Figure 4: Annual avoided SEM CO_2 emissions from zero-carbon System Services

6.3 Benefits for Renewable Curtailment

Baringa's Zero-Carbon System Services analysis has also analysed the potential benefits for renewable curtailment in a 70% RES-E scenario where all System Service constraints are met using zero-carbon service providers. Baringa's analysis assumes several existing system constraints have already been alleviated, an operational SNSP limit above 90% and approximately 2000 MW of interconnector export capacity by 2030, as per the 70by30 report analysis. In the Zero-Carbon System Services study, Baringa estimate a reduction in curtailment from around 8% to 4% in 2030, when meeting all system constraints using zero-carbon providers. This allows for more capacity on the system for wind generation, removes the need to constrain on fossil fuel generation and reduces electricity generation production costs in the SEM.

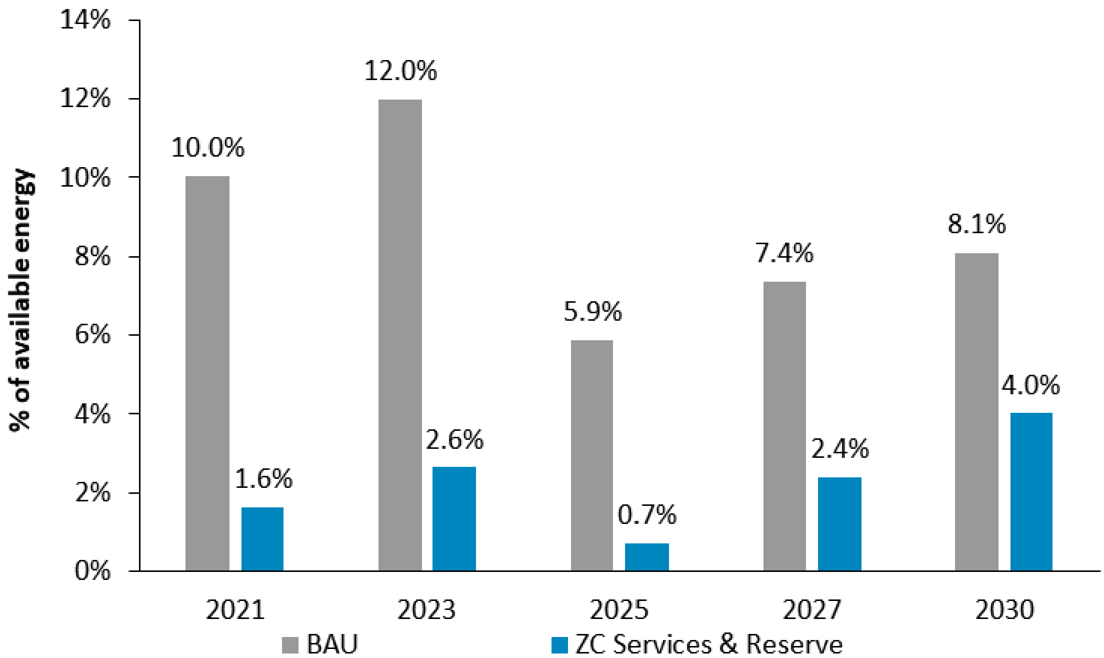


Figure 5: Projected renewable curtailment levels under a zero-carbon System Services scenario

7 Short-Term Priority Areas

7.1 System Services Procurement

7.1.1 Summary of Existing Policy

As noted earlier, great progress has been made in recent times with the implementation of the DS3 programme which has facilitated increasing levels of renewable generation on the system. The implementation of a DS3 System Services Procurement Framework has improved the capability and flexibility of providers and has increased the volumes of System Services available to the TSOs. Since May 2018, System Services have been procured under the Regulated/Tariff arrangements with procurement gates scheduled to run every six months where new providers can enter, and existing providers can adjust their contracted volumes.

However, the framework for the DS3 Regulated Tariff arrangements is only set to run until 2023 with no certainty for providers or new build investments beyond this. Two extensions of 18 months each to the arrangements are possible but these are subject to regulatory approval. There is also potential tariff volatility if System Services expenditure is projected to exceed the €235 million cap set by the Regulatory Authorities.

In addition, the current contractual structure for the Regulated Tariff arrangements may be unsuitable for new investment as projects first have to build and test before they can receive a contract. This includes the reserve services, as well as services such as reactive power, inertia etc. The TSOs have stated that amending this would require a large-scale change to the current procurement framework. It would be beneficial to consider this, if not for the short term then at least for any post 2023 framework.

In September 2019, a DS3 Volume Capped fixed contract auction process was carried out that resulted in 110 MW of new build battery storage being procured to provide a sub-set of System Services (i.e. fast-acting, short-term reserve products). Providers procured under this process will rely on the six-year contract terms and revenue certainty guaranteed under these arrangements for investability. It is clear that 110 MW of fixed auction-based contracts will not provide sufficient reserves as more will be needed from zero-carbon providers to displace fossil fuel generators.

However, there is no visibility or certainty on further Volume Capped auctions and no route to market exists for new-build units providing other types of System Services- e.g. reactive power, inertia.

The SEM Committee's DS3 High Level Design Principles Paper (SEM-14-108)[12] specifically sought to allow for new-build devices:

> *"In arriving at its decision on system services, the SEM Committee has been conscious of each of these key demands. Accordingly, the SEM Committee has built a decision framework which it believes achieves the following:*
>
> *…*
>
> *Provide **certainty to new providers** of system services that the defined procurement framework delivers a mechanism against which significant investments can be financed;*
>
> *…*

[12] https://www.semcommittee.com/publication/sem-14-108-ds3-system-services-decision-paper

Ensure that Article 16 of Directive 2009/EC/28 is being effectively implemented (duty to minimise curtailment of renewable electricity);

Provide assurance to consumers that savings in the cost of wholesale electricity, which can be delivered through higher levels of renewables on the electricity system, can be harnessed for the benefit of consumers;"

and, under the Allocation of Contracts section:

*"117) The SEM Committee has decided that **long term contracts** will be made available for new investment in system services. This section sets out various aspects of the SEM Committee's decision with regard to contractual arrangements."*

*"118) The SEM Committee has also decided that to provide a level of investor certainty for new projects take or pay contracts should be made available where **capital investment** is required. Take or pay contracts will not be available for existing capability."*

*"119) Additionally, the SEM committee acknowledge that any new investment may require **a lead-in period**, therefore contracts should be made available taking into account the potential lead-in period."*

These principles have not been fully delivered for all System Service providers.

7.1.2 Policy Recommendations

Baringa's Zero-Carbon System Services study has shown the benefits of moving to a model where all System Service constraints are met by zero-carbon 'non-energy market' providers such as battery storage by 2030.

To unlock these benefits, the system will require at least 700 MW of fast frequency response and operating reserve from zero-carbon sources to match the largest single infeed (which will be the Celtic Interconnector when it comes online). Baringa's 70by30 report has also projected up to 1200MW of longer duration 2-hour battery storage will be required by 2030. This battery storage will be active in the System Services, capacity and energy market and can provide longer-acting System Services such as replacement reserve.

The focus should be on minimizing conventional units being dispatched on or positioned by the TSOs for System Services provision and so mechanisms must be put in place to incentivize new units to connect and provide these services at zero-carbon emissions and at a cheaper cost to the consumer. Going forward, System Services policy should be to prioritise the procurement and dispatch of sources of System Services from low or zero carbon sources, with the goal of bringing such emissions to zero from System Services and meeting all system operational constraints from zero-carbon sources.

An example of the existing categories of System Services, together with potential future volume requirements and zero-carbon sources of these services is given in Figure 6.

Reserve	700 - 1,200 MW of Reserves – 500 ms to 1 hour (BESS, DSM, RES)
Inertia	20,000 MWs of Inertia (Synchronous Condensers)
Reactive power	± 3,600 Mvar of Reactive Power (STATCOMs, RES, BESS)
Ramping	1,500 MW – 1 hour, 3,000 MW – 3 hour, 4,000 MW – 8 hour (Long-duration storage, pumped hydro, DSM)

Figure 6: Zero-Carbon System Service providers and potential capacities required in a 2030 70% RES-E power system

As can be seen, energy storage is capable of providing the majority of the existing System Services. Given the lead times for projects to progress through the planning and connection processes and secure a route to market, it is imperative that long-term frameworks that provide contract certainty, and are investable, are implemented as soon as possible in order to deliver these volumes by 2030.

A number of recommendations for the CRU, NIAUR, EirGrid and SONI relating to the procurement of System Services are summarised below:

- Develop and implement a comprehensive programme of work to achieve SNSP of >90% and the removal of fossil fuel system constraints (e.g. Min Gen, RoCoF).
- Work with industry to identify and breakdown the existing barriers to achieve DS3+ and ensure continued industry involvement via frameworks such as the DS3 Advisory Council
- Model electricity system CO_2 emissions to compare energy market emissions and actual electricity generation emissions to calculate the non-energy market emissions contribution.
- Measure and report quarterly on such non-energy market emissions.
- Prioritise the procurement and dispatch of sources of System Services from low or zero carbon sources, with the goal of bringing such emissions to zero from System Services and meeting all System Service constraints from zero-carbon sources.
- Ensure that sufficient System Services (Figure 6) are procured to efficiently integrate the 70% renewable electricity targeted by 2030 and enable SNSP levels of 90%+.
- Begin the scoping and analysis needed to achieve long-term decarbonisation goals (e.g. 100% RES-E and 100% SNSP).

In relation to asset testing and securing of contracts, the procurement arrangements should also allow projects to secure contracts in advance of build and testing. A coordinated approach to testing, prequalification and procurement across revenue streams may minimise administrative costs for industry participants e.g. where there is duplicate testing, prequalification and procurement requirements for different revenue streams – e.g. for CRM, DS3 and DSO services.

If a coordinated approach is taken, then the Independent Technical Expert (ITE) model deployed by National Grid ESO in the UK may be a possible way to implement this for testing. Under this regime, the witnessing and certification of testing is conducted by a qualified and independent third party. Within the Irish context, a third party could potentially certify the coordinated testing for all services. The benefits would be lower overall costs and swifter delivery for new investment.

7.1.3 Key Stakeholders

- CRU and NIAUR will develop and decide on the enduring procurement framework for System Services. They will also decide on the expenditure cap for System Services and the allowed System Operator spend on the DS3+ programme.
- EirGrid/SONI will develop the DS3+ programme of work and the system requirements needed to meet 2030 targets, this includes potential new System Services and testing requirements for service providers.

7.1.4 Timelines

- Q4 2020 – As per the actions in the Climate Action Plan, the TSOs will develop the DS3+ programme in order to deliver the system changes needed for 2030.
- Q1 2021 – Also, as per the CAP, the Regulators will develop the enduring procurement framework for System Services post 2020.

7.2 Holistic Approach to Market Design and Long-Term Investment Frameworks

7.2.1 Summary of Existing Policy

The energy storage market is developing, with different services and use cases continuing to evolve. As can be expected with new technologies entering a settled industry, the regulatory framework is struggling to keep pace with the changes these new technologies bring. Policy and regulation are trying to catch up with the pace of development as the plunging costs of storage technologies mean they are aiming to enter more and more markets.

The flexibility of battery storage means that assets are simultaneously part of the generation, demand and grid infrastructure, creating a challenge for policy makers who are now having to bridge previously separate aspects of the market. Due to the diverse services that can be offered by storage technologies, there is an opportunity to maximise the benefits of these assets, for both consumers and investors, by developing frameworks that allow energy storage to enter these various markets.

However, this leaves energy storage uniquely exposed to a wide range of policy challenges. For example, an energy storage project could be participating in all of the following activities; behind the meter price arbitrage, System Services market, wholesale energy markets, the capacity market and as a network asset on both the generation and demand side.

Investment in new technologies is always challenging due to uncertain revenue sources and the potential revenue volatility within a new and emerging market. In this regard, stable predictable revenue sources, similar in principle to the support offered historically to other renewable technologies via the Renewable Energy Feed in Tariff (REFIT) or Northern Ireland’s Renewable

Obligation Certificates (ROCs) mechanisms, helps significantly to increase investor confidence in new technologies.

In Ireland, the Capacity Renumeration Market (CRM) provides such a revenue source by offering 10-year support contracts to new-build projects. However, the capacity market on its own is insufficient to support new energy storage investment due to the de-rating methodology implemented for this technology. De-rating assumes a reliability factor for different technologies and CRM participants can only earn capacity revenues for their de-rated MWs. For recent CRM auctions, penal de-rating factors have been applied to storage that have reduced potential capacity revenues, particularly for shorter duration energy storage projects.

While there may be technical justification for the de-rating approach implemented for the capacity market, the issue for storage is compounded by the fact that there are limited opportunities for these technologies to participate simultaneously in the DS3 Volume Capped arrangements and the capacity market. The DS3 Volume Capped arrangements have a 97% availability requirement with strong financial penalties if providers do not meet their availability obligations. This means that these providers are mainly ring-fenced for fast-acting System Service provision. The Volume Capped process is the only source of securing a fixed price, long-term contract with revenue certainty to underpin storage investments. While this process does provide system benefits, and the auction has resulted in 110 MW of new-build service provision, there is no certainty on further Volume Capped procurement routes. Furthermore, this process as it is currently designed, limits the revenue stacking opportunities for new investment and reduces the benefits storage can provide to consumers through their use in multiple markets. The DS3 Regulated Tariff arrangements are then the only potential revenue stream underpinning investment in storage but these arrangements, in their current form, with potential tariff volatility and a framework that may end in 2023, are unsuitable to deliver bankable projects.

7.2.2 Policy Recommendations

Market design and coordination of markets and incentives are crucial policy areas for storage assets and must be approached in a holistic manner in order to derive maximum benefit from these technologies. A siloed approach where specific policy challenges are tackled in isolation, without a view to their wider implications, can have unintended consequences for the viability of energy storage projects.

The current commercial arrangements in the all-island market do not provide investors with an appropriate balance of risk and reward to incentivise the widescale investment in storage technology that is required. A holistic approach that considers the ability of energy storage to participate in multiple markets, while providing long-term stability to underpin investment, needs to be adopted.

The history of wind generation in the all-island market demonstrates that delivery of large-scale private investment in new technologies requires stable and predictable revenue streams. The financial conditions created by the REFIT and ROC mechanisms helped provide a financial environment that facilitated significant private sector investment in wind generation. To ensure continued investment in renewable generation, and to deliver on long-term renewable policy objectives, substantial investment in storage technologies is now needed. This requires development of policies, regulation and contractual frameworks that deliver long term, predictable revenue streams that will drive financial investment in this sector.

While long-term stable revenue streams are essential to ensure delivery of optimal storage solutions, careful coordination of obligations across different contracts and market arrangements is also required. Given the diverse range of potential services that can be offered by storage systems, the overall utility of systems is optimised via a flexible approach to contractual arrangements, incentivizing provision of those services beneficial to the system at any point in time via appropriate price signals, and avoiding imposition of penalties for non-provision of other contracted services when they are not required.

Creating the conditions required to stimulate widespread investment in storage is challenging and requires the reassessment of current approaches to long-term contracting and electricity market design. However, this presents a unique and exciting opportunity for policy makers within the all-island market to take a leading role in assisting the global transition to a zero-carbon electricity sector.

This can be achieved by appropriate balancing of risk between system operators and storage service providers by requiring system operators to decide, in advance, the type of services they require from a suite of potential contracted services. At times when no services are required the unit should then be 'free' to perform price arbitrage functions in the energy market, lowering wholesale electricity prices, to the benefit of consumers. Such 'revenue stacking' of services will lower investment risk and ensure systems are optimally designed, delivering multi-functional, cost effective solutions to the system operator.

7.2.3 Key Stakeholders

- The Regulators, CRU and NIAUR, to lead the review of the market design and regulatory frameworks for energy storage, with support from the System Operators, EirGrid, SONI, ESBN and NIEN.

7.2.4 Timelines

- Q1 2020 – CRU and NIAUR to instigate review of market design and regulatory frameworks for energy storage
- Q4 2020 – Completion of review and implementation of new regulatory framework for energy storage

7.3 Grid Access and Requirements for Maximum Export Capacity (MEC)

7.3.1 Summary of Current Policy

The DS3 Volume Capped procurement process has incentivised the provision of fast frequency response and operating reserves from battery storage, which require a maximum 20 minutes of export potential. These fast-acting reserve services are also where the most value and revenue potential are for batteries in the short term so projects in development now are incentivised for shorter discharge durations. This means that battery storage units may have a relatively high maximum export capacity (MEC) compared to their MWh energy duration.

At present, battery storage is subject to the same rules for grid access and the associated network planning standards as any other generation unit based on their MEC. MEC for units which can export for a maximum of 20 minutes is well within overload capabilities for grid infrastructure. This approach is not fit-for-purpose and will lead to wasteful network development and unnecessary development costs unless the process for allocating MEC is reviewed.

7.3.2 Policy Recommendation

A review of grid access and network planning standards is warranted to consider the unique characteristics of energy storage. This process must be flexible to avoid unnecessary network development or excessive costs to developers where possible. A review of the requirement for MEC for short-term reserve batteries and other system service technologies should also be carried out by the TSOs/DSOs.

7.3.3 Stakeholders

- EirGrid/SONI as TSOs and ESBN/NIEN as DSOs are responsible for grid access and network planning standards.

7.3.4 Timelines

- Q2 2020 – SOs to carry out a review of grid access and network planning standards for energy storage.

7.4 FlexTech

7.4.1 Summary of Existing Policy

As outlined in section 3.5.3, the FlexTech initiative aims to remove barriers to further renewable integration across a range of work areas, including energy storage.

A FlexTech industry forum was held in June 2019 where the SOs presented their high-level work plan and sought initial industry input. Following this, in September 2019 a SO FlexTech consultation paper with proposed priority work areas for each of the workstreams was published. The proposed priority areas for storage are:

- Investigate a mechanism for identification of, and appropriate treatment of, various modes of operation,
- Review of Grid Code/ Distribution Code for Storage,
- Strategic consideration to be given to the prioritisation of grid access, and
- System Operator Task force to assess impacts of fast response services on Distribution Systems.

It is also proposed that FlexTech industry forums will be held twice per year and that there will be one consultation each year to inform the SOs' annual work plan.

7.4.2 Policy Recommendations

The establishment of FlexTech and its high-level aims to remove barriers to the integration of technologies such as energy storage are welcome, however, it is apparent from the SOs' consultation that the proposed work areas are unambitious and do not go far enough to address the key challenges the system will need to overcome to meet national renewable targets. As well as technical considerations, the initiative should also consider the commercial arrangements needed to ensure the solutions are implementable, such as market design, contractual frameworks and connection policy.

The SOs' concerns in the paper are focused on the controllability and predictability of storage technologies. While this is understandable from a System Operator perspective, the flexibility of storage technologies to provide multiple benefits whether through the capacity, energy or System Services markets should not be overlooked and we would caution against approaches that may constrain these assets from providing this inherent flexibility.

FlexTech should be focused on the opportunities and benefits to be gained from the deployment of new flexible technologies such as storage and how we can overcome barriers to their integration. While understanding potential issues is important, and one of the proposed priorities is to assess impacts of fast frequency response on the distribution system, we would propose that this should go further in seeking to address solutions if needed.

Furthermore, FlexTech needs to be sufficiently prioritised and resourced to deliver the required changes. Each work area should have dedicated resourcing and work plans to deliver on programme ambitions.

The proposed governance structure, with bi-annual forums and one consultation, is also concerning as it minimises the input of industry into the strategic direction of the initiative, as well as the ongoing development and progression of the individual work areas.

It is important that FlexTech allows for industry engagement that can leverage industry expertise and input. There is a need for continuous industry involvement in the FlexTech process and the inclusion of ongoing bi-lateral meetings with associations as representatives of industry. These bilateral meetings could be used to set strategic objectives and priority work areas for FlexTech in more detail than could be discussed at a large industry forum. Specific workstreams such as energy storage should have their own working group forum or elected industry board to engage with the SOs on an ongoing basis. This type of structure has worked well with the DS3 programme where the DS3 advisory council has allowed ongoing industry input and engagement on project progression.

The possibility of one overall system operator, regulatory and elected industry board to strategically map out the development of FlexTech would also be a welcome consideration. This would enable a mechanism to monitor and track progress against strategic goals.

In addition, there are also a number of regulatory barriers to co-locating energy storage with renewable energy generation projects, such as dynamic sharing of MEC between units using the same grid connection. There are a number of cases in the UK where batteries have been added to existing wind or solar farms. In order to maintain Renewable Obligations (RO) or feed-in tariff (FIT) subsidies received for the wind or solar generation, submetering arrangements must be agreed with the regulator (Ofgem). Ofgem published guidance on this type of co-location in 2017[13] giving much welcome clarity on regulatory requirements for co-location and this has reduced the level of risk perceived by investors and lenders. A hybrids workstream has been established under the FlexTech initiative where existing issues such as barriers to sharing of MEC between technologies on the same site should be addressed.

[13] https://www.ofgem.gov.uk/publications-and-updates/guidance-generators-co-location-electricity-storage-facilities-renewable-generation-supported-under-renewables-obligation-or-feed-tariff-schemes

7.4.3 Stakeholders

- The SOs – EirGrid, SONI, ESBN and NIEN are leading the design and progression of the FlexTech initiative.

7.4.4 Timelines

- Q2 2020 – SOs to establish working groups or forums for each FlexTech workstream with industry representation.
- Q2 2020 – SOs to ensure FlexTech is adequately resourced and dedicated work programmes set under their respective price reviews for the upcoming five year period

7.5 Network Charges

7.5.1 Summary of Existing Policy

This section on network charging is specific to the Republic of Ireland as the existing EirGrid/ESBN charging regime poses a significant barrier to energy storage. EirGrid charge a Transmission Use of System (TUoS) charge to generation and demand customers based on the Maximum Export Capacity (MEC) and Maximum Import Capacity (MIC), respectively, to recover the cost of operating and maintaining the network. The Trading and Settlement Code includes a 'Battery Storage Unit' classification; however, such units may only be registered as a 'Generator Unit'[14] and so would be subject to both generation and demand charges for the energy stored i.e. battery storage is treated as both a generator and demand customer even though they are not the final consumers of the stored energy. For distribution connected projects, in addition to the TUoS charges, projects are also liable to pay Distribution Use of System (DUoS) charges.

As Battery Energy Storage Systems have both an MEC and MIC they will be 'double charged' TUoS for both their export and import capacity. This 'double charging' is disproportionate to Battery Energy Storage Systems and for a similar issue in Great Britain, Ofgem (the GB regulator) has initiated a number of consultations, to reform charges for use of network that apply to Battery Energy Storage Systems and remove 'double charging' amongst a broad suite of objectives.

7.5.2 Policy Recommendations

The CRU's information paper[15] on the application of the PSO Levy to commercial energy storage systems is a welcomed clarification which helps improve certainty on the business case for battery energy storage projects. The CRU's information paper recognises that storage should not be classified as the final demand customer for the electricity that is stored and then later reinjected into the grid. Guidance was received from DCCAE on this matter regarding the facilitation of batteries and other storage providers into the market as key enablers for the delivery of renewable electricity both for Ireland's 2020 RES targets and 2030 RES-E goals, in line with Ireland's first National Energy and Climate Plan.

The EU's Clean Energy Package under Regulation (EU) 2019/943 on the internal market for electricity[16] contains provisions for the non-discriminatory treatment of technologies, such as storage, as regards

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[14] Trading and Settlement Code Part B, Clause B.7.2.7

[15] CRU Information Paper, Application of the PSO Levy to Commercial Storage, Reference: CRU/19/034

[16] Regulation (EU) 2019/943 on the internal market for electricity https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32019R0943&from=EN

network charging. Specifically, section 39 of L158/60 of the Regulation - *"provide for a level playing field between all market participants, network tariffs should be applied in a way which does not positively or negatively discriminate between production connected at the distribution level and production connected at the transmission level. Network tariffs should not discriminate against energy storage, and should not create disincentives for participation in demand response or represent an obstacle to improving energy efficiency."*

A network charging review is required that removes the issues of double charging for energy storage and allows for fair and proportional allocation of network charges. A charging review is being carried out in Britain at the moment, which seeks to address a similar double charging issue for energy storage, and the learnings from this process should be considered in the Irish context. A similar approach to that taken for PSO Levy charging, i.e. network charging on import only based on the import required for serving house loads, would be a more appropriate approach for a BESS and remove the impact of '*double charging*'.

It is also important that a *holistic* approach to reforming use of system charging is adopted i.e. aligning explicitly with policy objectives rather than tackling specific elements in isolation. The distributed energy revolution is systemic and requires a fundamental, holistic approach as the potential impact on behind the meter storage has been noted. A charging framework is needed that supports investment in battery storage over the longer term, recognizing its unique characteristics and the benefits of the resilience it provides on the system.

The commercial landscape for behind-the-meter storage also warrants careful consideration by policy makers, offering an opportunity to maximise the utility of existing network infrastructure and grid connections. This is particularly relevant for increasing the flexibility of demand sites by facilitating the stacking of revenue streams across services. However, more certainty on the future development of network charging policy is required to provide reassurance to this sector of the market, specifically regarding how network charges will be levied on storage in future.

The Climate Action Plan has set out an action for the CRU to lead a review of the policy regulatory framework for electricity storage in 2020 to facilitate efficient level of electricity storage to meet the 2030 70% renewable electricity target. This should incorporate a review of current network charging arrangements for storage.

7.5.3 Stakeholders

- The CRU will lead the review of the regulatory framework for storage and is responsible for instigating the network charging review. The recent consultation process in GB which resulted in a resolution of this 'double-charging' issue should also be referenced.
- The TSO and DSO have supporting roles in this regulatory framework review and in designing and implementing network charging arrangements.

7.5.4 Timelines

- Q1 2020 – CRU to lead network charging review with support from ESBN/EirGrid
- Q3 2020 – Network charging review changes to be implemented by ESBN/EirGrid

7.6 Connection Policy

7.6.1 Summary of Current Policy

A robust and efficient connection process is essential for delivering the renewable capacity and flexible technologies needed for achieving national renewable energy targets and reaching our decarbonisation goals. In Ireland, grid connections are processed in batches via the CRU's Enduring Connection Policy (ECP) framework. The CRU's (ECP) Stage 1 decision[17] in March 2018 contained a specific DS3 capacity carve out for flexible technologies to support the 2020 RES-E target. The technologies under this DS3 carve out materialised as either battery storage or hybrid projects that were then able to enter the DS3 Volume Capped auctions and compete for fixed term contracts to supply highly available fast acting reserve services to the grid.

The CRU is currently developing the policy for ECP Stage 2. The consultation was delivered towards the end of November 2019, with a final decision expected in Q1 2020. Going forward, it is proposed that ECP batches will be processed on an annual basis with 50 connection offers given out under each batch. Projects applying for a grid connection via ECP must have planning permission secured and, for projects such as battery storage, prioritisation will be based on the date of planning grant.

The CRU is also seeking views on the potential of moving to a grid following funding model in subsequent years whereby connection offers will only be issued to projects that have secured planning and a route to market e.g. RESS auction or corporate PPA.

7.6.2 Policy Recommendation

In Ireland, while the CRU's proposal to process annual batches with at least 50 offers is welcome, consideration is needed for a connection process, whether through ECP or separately, for potential system support technologies such as battery storage, synchronous condensers, flywheels and other technologies, that will be essential in providing flexible services to help manage the grid with high penetration levels of variable renewable generation. It is imperative that connection policy is approached with a view to system needs and the relevant commercial frameworks that exist for such technologies. As noted, there are limited routes to market for battery storage outside of the DS3 Volume Capped process. Projects that have sunk time and resources into securing a grid connection via ECP may be left stranded without a viable alternative to develop.

A Grid Following Funding model would, in principle, allow for more efficient use of System Operator and developer resources but consideration must be given as to the viable routes to market for energy storage and how these projects can secure a route to market. Outside of the Volume Capped process, for which there is no certainty of future auctions, there are limited routes for storage to secure a route to market and provide 'proof' of funding to gain a grid connection. This is in contrast to the upcoming RESS auctions where successful projects can easily display this proof and secure grid access. The CRU is seeking views on Grid Following Funding as part of the ECP-2 consultation. As outlined in Section 7.2, a policy framework that allows energy storage to secure a route to market via long-term contracting is essential to the success of Grid Following Funding for these technologies.

In Northern Ireland, the connection process works differently as there is no batch process and connections are processed on a case by case basis. As per their licences, the SOs, SONI and NIEN, have

[17] ECP-1 Decision - https://www.cru.ie/wp-content/uploads/2017/04/CRU18058-ECP-1-decision-FINAL-27.03.2018.pdf

90 days to process an application and make a connection offer to the applicant. However, the issue in Northern Ireland at present is a lack of grid capacity for new projects seeking to connect to the system. Substantial network investment is needed to free up grid capacity to allow more renewable generation and energy storage projects to connect in an efficient and cost-effective manner. It is important to note that this need for network investment is relevant on an all-island basis as significant volumes of renewable generation, and energy storage, will need to connect to the system going forward, in line with long-term renewable policy objectives.

7.6.3 Stakeholders

- The CRU will develop and decide on the ECP framework, including any potential Grid Following Funding model.
- ESBN and EirGrid will play a supporting role in processing the necessary connection applications and providing connection offers.
- NIAUR and CRU must support the need for network development and grid reinforcement in their revenue allowances for the System Operators.

7.6.4 Timelines

- Q4 2019 – ECP-2 Consultation.
- Q1 2020 – CRU decision on ECP-2 framework.
- Q1-Q2 2020 – CRU and NIAUR decisions on future System Operator revenue allowances
- Q3 2020 – Opening of ECP-2 batch (subsequent batches to open on an annual basis with final offers issued by the end of the following year).
- Q2 2021 – Potential implementation of a Grid Following Funding model.

8 Medium-Term Priority Areas

8.1 System Services

8.1.1 Summary of Existing Policy

The continued growth of renewable generation into the mid 2020's will see more non-synchronous power electronic based generating units connected to the transmission and distribution networks. At the same time, there will be a decline in fossil fuel generating stations as older units are decommissioned and the levels of synchronous inertia and minimum generation needed on the system decrease in line with long-term DS3 objectives.

At SNSP levels of 90% and above, this will likely mean that, at these times, all System Services requirements will need to be met by non-energy zero carbon service providers, such as wind, solar, DSUs, energy storage and synchronous condensers, as there will be no room on the system for fossil fuel generators.

This will mean that the volumes of services, particularly fast acting reserves, will need to increase from providers such as energy storage to replace the services that have traditionally been provided by fossil fuel generators as we move to a 70% RES-E system (see Figure 6 projected System Service volumes).

Furthermore, there may be additional services that will be required by 2030 to meet system needs such as synthetic inertia or congestion management. For example, synthetic inertia can provide a fast-acting response to help manage system frequency in real-time while congestion management provides a signal for energy provision in locations or at times of constraint. In addition, the future development of System Services may see the need for location specific signals for existing services such as reactive power or reserves. Energy storage can be a potential provider of these services, therefore System Operator analysis on system requirements and a regulatory framework that provides stable signals for investment are needed.

8.1.2 Policy Recommendations

The System Operators are currently carrying out analysis on future system needs via initiatives such as EU SysFlex and DS3. This analysis will likely form the basis for future investment scenarios for technologies such as energy storage. As noted, the current DS3 Regulated Tariff framework is due to finish in 2023. To ensure the required volumes of services from zero-carbon providers such as energy storage are delivered, clear market signals highlighting the System Service needs and requirements for 2030, as well as long-term investment frameworks, should be implemented to allow for continued development in this area.

It is important that these frameworks are planned in advance and allow for project delivery in line with system development and SNSP increases.

8.1.3 Key Stakeholders

- EirGrid/SONI will develop the future system needs analysis, including potential new System Service requirements, and implement the DS3 System Services market design.
- CRU and NIAUR will develop the commercial and regulatory frameworks to deliver these services.

8.1.4 Timelines

- Q4 2020 – EirGrid/SONI to complete technical analysis looking at issues which need to be overcome to manage a real time operational limit of over 90% SNSP by 2030.
- Q1 2021 – CRU/NIAUR will develop the model for the procurement of System Services post 2020 to facilitate increased penetration of variable renewables on the grid.
- Q1 2023 – EirGrid/SONI implementation of new DS3 System Services market design.

8.2 Network Deferral / Short Term Congestion Management

8.2.1 Summary of Existing Policy

The traditional approach taken by the System Operators to network congestion is circuit uprating and/or grid reinforcement projects. However, this may not always be technically or economically viable while planning approval or public acceptance can be difficult to achieve and can become a time-consuming process. Therefore, the deployment of energy storage technologies can be used instead to alleviate network congestion, and this approach is particularly suitable in situations and locations with demand side issues such as urban areas with short peak demand spikes.

8.2.2 Policy Recommendations

An approach for the medium term is the use of energy storage as an alternative network solution in helping to manage congestion at peak times and allowing for higher levels of SNSP and RES-E on the system. Storage can locate close to demand centres and be used to help meet peak demand over short-term durations. Using energy storage in this manner can maximise existing circuit ratings and defer line uprates and/or grid reinforcement projects. This approach can relieve congestion on both the demand and generation side. An existing UK example of storage as an alternative network solution is shown in the Appendix and examples can be taken from countries such as the UK and Australia where potential network solutions are tendered out to third parties to seek the least cost outcome.

It should be noted that in the medium term, battery technology is not yet capable of handling long periods of constraint or curtailment on the generation side of the network due to their relatively shorter discharge durations and cycling capacities. Longer duration storage would be better equipped to handle this and recommendations are outlined in the next section on long-term priorities.

Energy storage can form part of the solution in congestion management with clear benefits added in the deferral of network reinforcement and the possibility to maximise existing circuit ratings and grid infrastructure. However, in the absence of clear market signals and incentives, the business cases for developers to invest in the necessary storage solutions become more difficult. The shift from short term to medium term storage needs to be adopted with suitable market products such as a congestion products or locational signals for existing products like reactive power support. These solutions would require long-term network support contracts to be developed by transmission and distribution network operators, which in turn requires wider policy initiatives and a robust regulatory framework.

Furthermore, as the use cases and revenue opportunities for storage start to increase, these should be potential to blend storage assets with other technologies such as demand side response to provide enhanced network flexibility. This brings the benefit of combining the best characteristics of each asset – for instance, batteries can provide cost-effective quick response, but other demand side solutions can complement this through offering longer duration response, thus maximising grid flexibility.

8.2.3 Key Stakeholders

- EirGrid/SONI will develop the future system needs analysis for network congestion management for both constraints on the demand and generation side, including the potential for flexible technologies as a network solution.
- CRU and NIAUR will develop the commercial and regulatory frameworks, including appropriate incentives and market signals, in conjunction with the System Operators to allow flexible providers such as energy storage to access these new markets.

8.2.4 Timelines

- Q4 2020 – EirGrid/SONI to complete technical analysis of likely congestion management services and other products needed for 2030.
- Q1 2021 – CRU/NIAUR will develop the model for the procurement of these congestion management services and other new products.
- Q1 2023 – EirGrid/SONI implementation of new market design, including congestion products and signals for alternative network solutions.

9 Long-Term Priority Areas

9.1 Demand Shifting

9.1.1 Summary of Current Policy

If we are to achieve our RES-E ambitions and decarbonisation goals for 2030 and beyond then this will require shifting energy demand from other sectors such as heat and transport into electricity and developing means for seasonal long-term energy storage.

Achieving 70% RES-E will necessitate installing higher volumes of renewable generation than can be met by demand/exports at any one time. For instance, Ireland's Climate Action Plan has set out targets of 8.2 GW of onshore and 3.5 GW of offshore wind in order to reach 70by30. These volumes will be in excess of all-island peak demand which is projected to reach between 6-7GW by 2030.[18] This means that, on high wind days, excess renewable generation would have to be curtailed for 'energy balancing' reasons i.e. where generation exceeds demand, unless mechanisms are found for converting this excess generation into long-term storage that can be used at times of low renewable generation, or to meet demand in other energy sectors.

IWEA has carried out analysis on potential curtailment of wind generation for 'energy balancing' reasons out to 2030. If we assume that the Clean Energy Package regulation means that priority dispatch remains for existing wind generation and that this relates to market-based curtailment for energy balancing reasons, then new renewable generation will be curtailed first when there is excess wind on the system. The graph below shows the increase in this energy balancing curtailment for excess wind generation as the renewable volumes on the system increase out to 2030. Average curtailment, including both existing and new renewable generation, is projected to reach up to 8% by 2030.

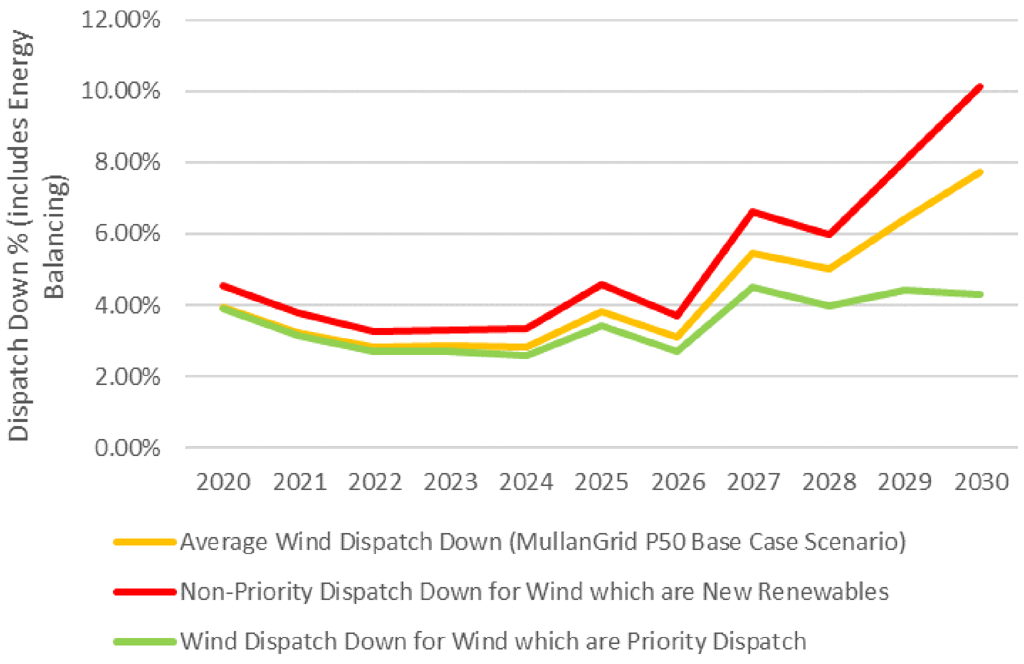

Figure 7: IWEA analysis on excess wind curtailment by 2030

[18] EirGrid Generation Capacity Statement 2019-2028: http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Group-All-Island-Generation-Capacity-Statement-2019-2028.pdf

Additional interconnection, beyond the development of Celtic and Greenlink, can help with this problem by exporting excess renewable generation on high wind days but this is uncertain and can potentially have the opposite effect, even increasing curtailment, as interconnectors flows are a function of market outcomes and can vary depending on pan-European price signals. Furthermore, as neighbouring power systems increase their own renewable sector development and move to full decarbonisation, the benefits of interconnection for renewable curtailment in Ireland may diminish over time.

As well as this, the storage technologies we have highlighted in the short to medium term sections are generally shorter duration technologies that can provide a multitude of valuable services, as we have outlined, but are less suitable to longer-term demand shifting that will be needed for a net-zero emissions future.

Therefore, the ideal solution is to develop and incentivise longer-term storage technologies that can store excess renewable generation, or can be used in conjunction with dedicated renewable generators, for use in electricity, transport and heat. For example, renewable generation could be used to produce hydrogen gas via electrolysis, which can then be stored and transported via the existing gas network and used for electricity at times of high wind, or in other sectors such as heat or transport. Hydrogen electrolysis is a process that splits water into hydrogen and oxygen using electricity, and can be generated by zero-carbon sources, like wind or solar PV.

9.1.2 Policy Recommendations

Longer duration storage technologies, such as hydrogen electrolysis or power to synthetic gas from renewable generation, are still at an early development stage and require dedicated frameworks and incentives to scale up and become commercially viable. For instance, over 95% of hydrogen production today is fossil-fuel based. Only around 4% of global hydrogen supply is produced via electrolysis from renewable generation, with the large capital costs of this technology being the main barrier at present[19].

In order to be economically viable, these technologies require low cost renewable generation and high full load hours, otherwise the costs and inefficiencies of the electrolysers or conversion equipment are too high to sustain. Therefore, it is unlikely that excess renewable generation alone can make these projects viable and a form of sector coupling, with dedicated renewable generation powering electrolysers or power to gas technologies, will need to be added.

Delivering seasonal storage solutions in the long term will require developing innovative approaches, detailed planning and will need policy makers support. A recommended first step would be the establishment of a dedicated forum or advisory body that seeks to define and develop approaches to removing barriers to longer-duration storage. This body could be composed of government policy makers, Regulators, System Operators and industry representatives.

One of the group's first activities would be to coordinate the development of pilot projects that look at the potential opportunities of seasonal storage technologies in the Irish market and the barriers that need to be overcome for their further development. Innovation trialling and research & development into longer-duration energy storage will require financial support from policy makers

[19] WindEurope Report 'Wind to X' https://windeurope.org/policy/position-papers/wind-to-x/

and early investment is needed to drive cost reductions via economies of scale and efficiency improvements that will increase the scaling up possibilities of these technologies.

For example, pilot projects for hydrogen electrolysis or synthetic gas from renewable generation could be progressed via the SOs' FlexTech initiative or other innovation mechanisms with the support of industry.

In the longer term, government support and regulation via price signals such as new market mechanisms, new tariff structures and new System Services will be required to unlock the potential of longer duration energy storage technologies and to increase their commercial viability. High carbon prices and carbon policies will also play an important role in the energy transition and the potential longer-term uptake of these technologies as the relative costs of fossil fuel generation increase.

9.1.3 Stakeholders

Potential members of an all-island seasonal storage advisory body:

- Ireland - Department of Communications, Climate Action and the Environment (DCCAE).
- Northern Ireland – Department for the Economy.
- CRU and NIAUR
- EirGrid and SONI
- ESBN and NIEN
- Industry Representatives

9.1.4 Timelines

- Q3 2020 – Establish an all-island working group to address approaches to longer-duration energy storage.

10 Conclusion

The key recommendations outlined in this Roadmap are summarised in Table 4. The key policy asks are front loaded towards the short-term priority areas. This is because firstly, the short-term priority areas are still applicable across the medium term and long-term timeframes. Secondly, the policy changes for energy storage to effectively play a role in Ireland's energy system in the medium and long term must be considered now so that efficient time is allocated to defining the likely policy gaps, addressing them and allowing sufficient time for these changes to be implemented to reach our 70by30 targets and longer-term decarbonisation goals.

Energy Storage Ireland is looking forward to working collaboratively with the relevant stakeholders to help bridge these gaps to enable greater integration of energy storage in our electricity system.

Table 4: Summary of Policy Recommendations

Category	Key Policy Recommendations	Stakeholders and Timelines
	Short-Term Priority Areas (2020 – 2023)	
System Services Procurement	• Develop and implement a comprehensive programme of work to achieve SNSP of > 90% and the removal of fossil fuel system constraints (e.g. Min Gen, RoCoF). • Work with industry to identify and breakdown the existing barriers to achieve DS3+ and ensure continued industry involvement via frameworks such as the DS3 Advisory Council • Model electricity system CO_2 emissions to compare energy market emissions and actual electricity generation emissions to calculate the non-energy market emissions contribution. • Measure and report quarterly on such non-energy market emissions. • Prioritise the procurement and dispatch of sources of System Services from low or zero carbon sources, with the goal of bringing such emissions to zero from System Services and meeting all System Service constraints from zero-carbon sources. • Ensure that sufficient System Services are procured to efficiently integrate the 70% renewable electricity targeted by 2030 and enable SNSP levels of >90%. • Begin the scoping and analysis needed to achieve long-term decarbonisation goals (e.g. 100% RES-E and 100% SNSP).	Q4 2020 – As per the actions in the Climate Action Plan (CAP), the TSOs will develop the DS3+ programme in order to deliver the system changes needed for 2030. Q1 2021 – Also, as per the CAP, the Regulators will develop the enduring procurement framework for System Services post 2020.
Holistic approach to market design and long-term investment frameworks	• Develop a holistic market design so that an appropriate balance of risk and reward to incentivise widescale investment and deployment of energy storage is achieved. This must allow storage technologies to gain access to multiple revenue streams and maximise their potential as a flexible asset	Q1 2020 – CRU and NIAUR to instigate review of market design and regulatory frameworks for energy storage Q4 2020 – Completion of review and implementation

		of new regulatory framework for energy storage
Grid access and requirements for maximum export capacity	• Perform a review of the grid access and network planning standards to consider the unique characteristics of energy storage (including a review of the requirement for MEC for short-term reserve batteries and other System Service technologies)	Q2 2020 – EirGrid/SONI as TSOs and ESBN/NIEN as DSOs to carry out a review of grid access and network planning standards for energy storage.
FlexTech	• Develop the proposed FlexTech work areas so that the ambitions are more aligned with the key challenges the system will need to overcome to meet national renewable targets. • Consider the commercial arrangements needed to ensure the solutions are implementable, such as market design, contractual frameworks and connection policy. • Ensure that FlexTech is sufficiently prioritised and resourced to deliver the required changes. Each work area should have dedicated resourcing and work plans to deliver on programme ambitions. • Revise the proposed approach to industry engagement with allowance for ongoing bi-later meetings to maximise input from industry, similar to the previous DS3 engagement structure. • Address the current issues such as barriers to sharing of MEC between technologies on the same site under the FlexTech Hybrids workstream.	Q2 2020 – EirGrid/SONI to establish working groups or forums for each FlexTech workstream with industry representation.
Network charges	• Conduct a network charging review to remove the issues of double charging for energy storage and allows for fair and proportional allocation of network charges.	Q1 2020 – CRU to lead network charging review with support from ESBN/EirGrid Q3 2020 – Network charging review changes to be implemented by the TSO and DSO.
Connection policy	• Develop an appropriate connection process for flexible system support technologies, such as battery storage, synchronous condensers, flywheels and other technologies, with associated route to market. • Grid Following Funding must be developed in consideration of long-term contracting frameworks for energy storage.	Q4 2019 – ECP-2 Consultation Q1 2020 – CRU decision on ECP-2 framework. Q3 2020 – Opening of ECP-2 batch (subsequent batches to open on an annual basis with final offers issued by the end of the following year) Q2 2021 – Potential implementation of a Grid Following Funding model

Medium-Term Priority Areas (2023-2025)		
System Services procurement	• As per the short-term priority areas, prioritise the procurement and dispatch of sources of System Services from low or zero carbon sources, with the goal of bringing such emissions to zero from System Services and meeting all System Service constraints from zero-carbon sources. • Develop the necessary regulatory framework for the procurement of potential additional System Services such as synthetic inertia or congestion management.	Q4 2020 – EirGrid/SONI to complete technical analysis looking at issues which need to be overcome to manage a real time operational limit of over 90% SNSP by 2030. Q1 2021 – CRU/NIAUR will develop the model for the procurement of System Services post 2020 to facilitate increased penetration of variable renewables on the grid. Q1 2023 – EirGrid/SONI implementation of new DS3 System Services market design.
Network deferral / Short term congestion management	• TSOs to assess system needs for 2030 and develop suitable network support contracts and market signals for the procurement of congestion products or other alternative network solutions • Work with industry to define the likely future market paths, such as asset blending and local energy services, and to identify and provide solutions for the potential issues of these market paths.	Q4 2020 – EirGrid/SONI to complete technical analysis on future system needs and new flexibility products/network solutions
Long-Term Priority Areas (2025 – 2030 and beyond)		
Seasonal Storage and Demand shifting	• Develop dedicated frameworks and incentives to scale up longer duration technologies such as hydrogen electrolysis from renewable generation to enable the decarbonisation of the heat and transport sectors, and provide sources of seasonal storage. • Work with industry, within a dedicated forum or Advisory Body, to define and develop the innovative approaches to seasonal storage, and how they may be implemented. • Develop new market mechanisms, new tariff structures and new System Services relevant to these longer duration storage technologies.	Q3 2020 – Establish an all-island working group to address approaches to longer-duration energy storage Stakeholders include: Ireland - Department of Communications, Climate

	• Develop pilot projects for longer duration storage via programmes such as the FlexTech initiative.	Action and the Environment (DCCAE), Northern Ireland – Department for the Economy, CRU, NIAUR, EirGrid, SONI, NIEN and ESBN, Industry Representatives.

11 Appendix I: Energy Storage Case Studies

This section provides several case studies to highlight the proven benefits that energy storage plays in the safe, and reliable operation of the grid. Examples using lithium ion, vanadium redox flow batteries and hydrogen are given.

11.1 Lithium Ion Battery Storage

Lithium ion battery energy storage systems consist of large numbers of lithium ion cells, similar to phone or lap top batteries, only slightly larger, connected together and operated as a single coordinated large electricity storage facility via a Battery Management System. They can be housed in containers or a building, depending on the intended scale and function of the storage system. They are currently the most common form of grid-scale battery energy storage.

11.1.1 Lithium Ion Storage Costs

As the penetration of electric vehicles continues to rise and lithium ion battery production sees efficiency gains and greater economies of scale, the production costs for battery packs as the core component of battery storage systems will continue to decline. In a publication issued in March 2019, Bloomberg New Energy Finance expect the price of an average battery pack to be around \$94/kWh by 2024 and \$62/kWh by 2030[20]. Today's average battery price is \$176/kWh. The graph below highlights the steep decline in lithium ion battery pack prices since 2010 and further projected decreases out to 2030.

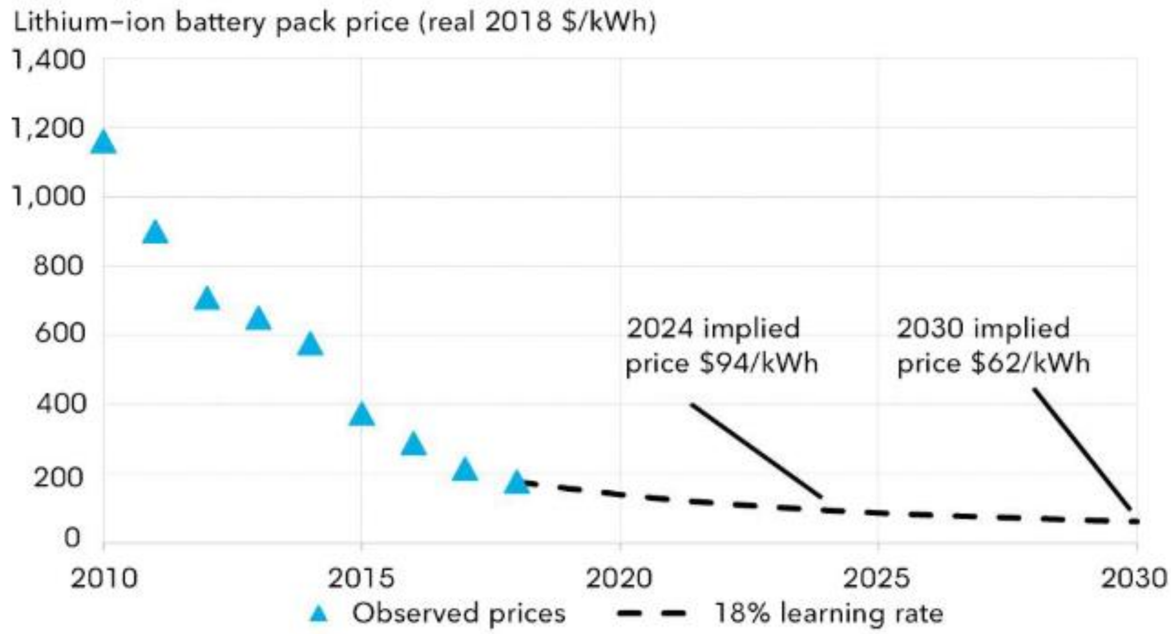

Figure 8: Lithium ion battery prices 2010 – 2030 (Source: Bloomberg NEF)

The battery pack typically accounts for 50% of the entire cost of the battery storage system. Other components of the battery storage system (such as power conversion systems, energy management systems, balance of system etc) will also experience price reductions, but not as the same rate as the decline in battery pack costs. Significant battery manufacturing capacity is also being built within

[20] https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/

Europe (Tesla and Northvolt) which will likely drive further cost decreases, although these are not expected to be at their full capacity prior to 2030.

11.1.2 Lithium Ion Storage Case Studies

Lithium Ion Storage Case Studies

- System Security and Services (Australia)
- Storage as Peaking Capacity (United States)
- Enabling Increased Renewables Integration (French Overseas Territories)
- Transition to Fully Merchant Project (United Kingdom)
- Displacing Reserve from Conventional Generation (Northern Ireland)
- Micro-Scale Storage Aggregation (Germany)
- Using Storage for Grid Reinforcement Deferral (United Kingdom)

11.1.3 System Security and Services (Australia)

Project	**Hornsdale Power Reserve (HPR)**
Operator	Neoen (French renewable energy developer)
Location	South Australia (BESS shares the same 275 kV connection point as the 316 MW Hornsdale windfarm)
Project Ratings	100 MW/129 MWh
Operational Date	2017
Key Services Provided	HPR is contracted by the South Australian government to provide reserve capacity amounting to $4M per annum (€2.48M), for a 10-year term. This accounts for 70 MW/10MWh of the battery. The remaining 30 MW/129 MWh capacity is available for market participation. The facility's merchant activities, i.e. the sale of ancillary grid services, Frequency Control Ancillary Services (FCAS) and arbitrage generated a further $24M (€15.2M) in revenue. **System security:** HPR participates in the System Integrity Protection Scheme and plays an integral role in protecting the locally sited Heywood interconnector from tripping if multiple generators fail. This reduces the risk of separation of South Australia from the National Electricity Market. Such services are deployed to prevent massive black out events, like the one experienced in September 2016. **System services:** The HPR facility provides a premium Contingency (FCAS) service (6 sec, 60 sec and 5 min services) through its Fast Frequency Response ability. HPR also provides a Regulation FCAS service (Lower and Raise regulation). HPR is the first FCAS regulation provider using another technology than conventional synchronous generation and has been shown to respond faster and more accurately than conventional generation [21].

[21] https://arena.gov.au/assets/2019/02/hornsdale-power-reserve.pdf

	Consumer benefits: Under certain conditions, the market operator calls for 35 MW of FCAS Regulation to be sourced from within South Australia. This can lead to high prices due to the limited number of FCAS providers. The introduction of the HPR has greatly increased the competitive dynamic of the FCAS markets. It is estimated that South Australia's regulation costs declined by $40M for the first year compared with the previous year by removing the domination that the gas generators had in controlling the prices in the FCAS market. The HPR stores power from the Hornsdale Wind Farm when demand is low and dispatches when demand is high, reducing the need for expensive gas 'peaking plants'. This places downward pressure on power prices for South Australian consumers.

11.1.4 Storage as Peaking Capacity (United States)

Project	**Multiple Utility Scale Projects**
Operator	Southern California Edison (Utility)
Location	California, United States
Project Ratings	Multiple projects, the largest project will be 100 MW / 400 MWh Li-Ion battery (Long Beach project)
Operational Date	Q4 2020
Key Services Provided	Most storage projects in the US to date provide ancillary services and solar peak shifting, but there is growing interest in using batteries to replace gas peaker plants. In Q1 2019, the utility provider Southern California Edison selected several energy storage projects to supply local capacity needs, instead of a natural gas peaker plant that faced strong local opposition. The project will run under a 20-year resource adequacy contract and will also participate in the California Independent System Operator (CAISO) market providing ancillary services and trading.

11.1.5 Enabling Increased Renewables Integration (French Overseas Territories)

Project	**Sainte Rose Wind Farm and Battery Storage**
Operator	Valorem (French energy group)
Location	Guadeloupe
Project Ratings	5.3 MWh Li-Ion BESS co-located with the 16 MW Sainte Rose Wind Farm
Operational Date	Q1 2019
Key Services Provided	The government of the French islands of Réunion and Guadeloupe are supporting the roll-out of hybrid renewables and battery storage systems through ongoing tenders and pilot projects to help them meet their

	ambitious renewable energy targets and manage system stability on their island systems Under local regulations, the project must submit a day-ahead generation forecast and is only compensated for the electricity produced by the wind turbines if generation remains within certain tolerances of the forecast. The storage system is used to compensate for fluctuations in the wind resource and align actual generation with the day-ahead forecast to avoid loss of revenue and curtailment.

11.1.6 Transition to Fully Merchant Project (UK)

Project	**Breach Farm Battery Storage**
Operator	Anesco
Location	Derbyshire, United Kingdom
Project Ratings	10 MW
Operational Date	2018
Key Services Provided	The first wave of UK grid-scale storage systems relied on revenues from 10-year Capacity Market contracts and 2 to 4-year frequency response contracts. Increased competition and regulatory changes have eroded the value of these revenue streams, and projects are increasingly turning to the Balancing Mechanism and wholesale trading as the primary sources of revenue. In 2018, the Breach Farm battery storage project became the first battery to participate in the Balancing Mechanism via a virtual power plant run by the aggregator Limejump. The Balancing Mechanism is used to balance electricity supply and demand close to real time. For each half-hourly period, National Grid can accept offers from participants to increase or decrease generation or consumption and resolve imbalances. Projects currently participate via an aggregator due to the requirement for a supply license, however, it is anticipated that balancing services will be opened out to all flexibility providers in the near future.

11.1.7 Displacing Reserve from Conventional Generation (Northern Ireland)

Project	Kilroot Energy Storage Array
Operator	AES (and research project partners with project partners, Innovate UK and Queens University Belfast)
Location	Kilroot, Northern Ireland
Project Ratings	10 MW/5 MWh
Operational Date	Q1 2016
Key Services Provided	The motivation behind the Kilroot energy storage array was to demonstrate the viability of battery energy storage to provide system support services such as frequency response/operating reserve services, without requiring the need for additional subsidies. This would then reduce the requirement for partially loaded conventional thermal generators to provide the same services. Queens University Belfast have undertaken research into the role of BESS in supporting power system operation, using real-time operational data from the Kilroot project. This research work resulted in a report, 'Batteries: Beyond the Spin'[22], authored with Everoze and AES, which produced several key findings as follows: **System Stability:** 360 MW of batteries could prove the same amount of power after 0.1 seconds as the inertial response of 3000 MW of conventional, synchronous generators. The report concluded that TSO system stability requirements in the Island of Ireland could theoretically be met and exceeded via the use of battery energy storage technology. **Cost savings:** When compared to System Services provided by conventional generators, large-scale deployment of battery energy storage technology could incur savings to the consumer in the Island of Ireland of €19M in 2019/20. **Carbon abatement:** This would equate to an estimated annual CO_2 savings of approximately 1.4 million tonnes could be achieved through the more efficient operation of conventional generators.

[22] https://everoze.com/everoze-launches-batteries-beyond-the-spin-report-on-digital-inertia/

11.1.8 Micro-Scale Storage Aggregation (Germany)

Project	Aggregated co-located residential solar and storage systems
Operator	Energy storage system developers and energy services providers, such as Sonnen
Location	Throughout Germany, generous subsidy packages saw the solar industry grow rapidly with 1.5 million solar systems installed. Approximately 120,000 households and small businesses installed behind the meter storage systems with their solar assets.
Project Ratings	Varied
Operational Date	Q4 2018
Key Services Provided	The proliferation of micro-scale storage systems across Germany has resulted in the aggregation of these batteries to offer grid scale services. Since the end of 2018, Germany's largest grid operator TenneT allows these aggregated batteries to participate in the local balancing market, in packages of 1 MW up to 100 MW through the Primary Control Reserve market. These systems deployed at the distribution level in energy constrained areas bring benefits in minimising constraints and curtailment of renewable assets on the grid system. Further benefits include supporting the management of the grid through flexible charging, and revenue generation for the homeowner.

11.1.9 Using Storage for Grid Reinforcement Deferral

Project	Smarter Network Storage (SNS) Facility
Operator	UK Power Networks and funded in part by Ofgem under the Low Carbon Network Fund scheme.
Location	Leighton Buzzard, Bedfordshire, England
Project Ratings	6 MW/10 MWh Lithium Nickel Manganese Cobalt Oxide ion technology
Operational Date	2014 (UK's first grid-scale battery storage facility)
Key Services Provided	This project trial explored multi-purpose uses of battery storage from both technical and commercial perspectives, but the main driver for the battery storage at this site was to defer traditional network reinforcement in order to maintain demand security compliance and alleviate capacity constraints at Leighton Buzzard. **Grid reinforcement deferral:** The construction of the 6 MW/10 MWh battery storage system at the substation allowed the conventional upgrade of a building an additional 33kV 34.5 MVA sub-transmission line and additional 38 MVA transformer in the substation to be deferred.

	Network constraint management: The battery was used to conduct peak shaving, ensuring that the battery was discharging electricity to cover increased demand during peak hours to alleviate stress on the electricity grid, and then charge during times of low demand, while also serving as a useful asset to support the transmission network at off-peak times. **System Services:** In 2017, aggregator Limejump won a contract to manage the battery as part of their virtual power plant and to provide dynamic frequency response services. A condition of the agreement with the distribution network operation was that the battery must be available to support UKPN's local grid during winter peak hours of 5-7pm in the town of Leighton Buzzard between October and March. These services were delivered by Limejump during evening peaks free of charge as part of the deal, while the aggregator was able to earn revenues from the site for the rest of the year. **Trial of several revenue streams**: The SNS project also provided an insight into the ability to monetise the value of storage. A Short-Term Operating Reserve (STOR) contract with the National Grid showed that simply using storage for STOR was economically unviable as the cost of providing and maintaining the project was higher than the financial income. A second trial was that of frequency response, and findings confirmed the high value that National Grid has for maintaining a stable network frequency and that providing a Fast Frequency Response (FFR) generated a profit. In early 2019, UKPN placed the facility on the market following completion of the SNS trial and Ofgem's decision that network operators can no longer conduct energy generation, including from energy storage.

11.2 Flow Battery Storage Case Studies

Flow batteries are an electro-chemical technology that are essentially mechanical in nature. While the principles of energy storage used are similar to lithium ion, flow batteries use different electrolytes and cell design. Flow batteries operate by pumping liquid electrolytes through battery cells changing its valence (electrical charge) to either store or release electrical energy. The electrolytes do not degrade with increasing charge / discharge cycles. Due to the mechanical nature of the technology, energy capacity can be increased via the volume of electrolyte easily and relatively cheaply.

While Lithium ion batteries have dominated commercial and grid-scale applications to date, their short-duration (typical maximum duration of up to 4 hours) and much higher degradation rate may mean flow batteries become the technology of choice for energy intensive applications. Flow batteries are typically able to discharge at rated power up to 10 hours, and while currently more expensive than Li-Ion BESS, they are the subject of increasing interest for energy focused applications such as peak demand charge avoidance, or energy arbitrage activities. System costs depend on the type of electrolyte and cell technology used. Costs are expected to decrease over time as extensive further development is ongoing on this technology.

Vanadium redox flow batteries offer numerous advantages: they have a long service life, almost unlimited charging cycles and can be fully discharged without any problems. Thanks to the modular design, the battery capacity can be expanded as required and requires hardly any maintenance. Large-scale storage systems are especially suitable for use as district storage systems or for industrial or commercial applications.

Flow Battery Storage Case Studies

- Vanadium Redox Flow Battery (United Kingdom)
- Vanadium Redox Flow Battery (Japan)
- Smart Power Flow Project (Germany)
- Sodium Sulphur Flow Battery

11.2.1 Vanadium Redox Flow Battery (United Kingdom)

Project	**Anglian Water Flow Battery**
Operator	Anglian Water (UK water utility)
Location	Anglian Water treatment works plant, Norfolk, United Kingdom
Project Ratings	60 kW/300 kWh vanadium redox flow battery co-located with 450 kWp photovoltaic system
Operational Date	2018
Key Services Provided	The battery can provide at least 5 hours of energy storage and can react to real-time energy trading opportunities. It will provide real-time balancing services to facilitate wholesale energy price arbitrage. The behind-the-meter system will participate in the Balancing Mechanism and stack demand-side value streams via an aggregator. In total, the project is expected to reduce site electricity costs by 50% by 2040.

11.2.2 Vanadium Redox Flow Battery (Japan)

Operator	**Hokkaido Electric Power Company (HEPCO) and Sumitomo Electric Industries Ltd**
Location	Abira-chou, Hokkaido, Japan
Project Ratings	15 MW (maximum output power of 30 MW) /60 MWh Vandium redox flow battery
Operational Date	Q4 2015
Key Services Provided	The battery system is operated by the load dispatching centre of HEPCO to mitigate issues such as frequency regulation, and over generation from renewable energy sources. Initial performance testing confirmed that the discharge operation can be maintained for more than 4 hours at rated output power. Flow battery cells can also output for a short duration at double the rated output power of the battery which is useful for short term frequency control. The step response time for the battery, defined as the time for active power at the point of connection to reach 98% of the output command value, was measured at 47ms. The ramp rate of the system, defined as the average rate of active power variation per unit of time between 10% and 90% of the set point value, was calculated to be 200MW/s.

11.2.3 Sodium Sulphur Flow Battery

Operator	**Consortium of Mitsubishi Electric and NGK Insulators**
Location	Kyushu Electric Buzen Substation in Fukuoka Prefecture, Japan
Project Ratings	50 MW/300 MWh Sodium Sulphur (NaS)
Operational Date	2016
Key Services Provided	The system, which is part of a pilot project to balance supply and demand via high-capacity energy-storage systems offers energy-storage capabilities similar to those of pumped hydro facilities while helping to improve the balance of supply and demand when renewable energy sources are used. The system smooths variations in frequency and power flow caused by renewable generation and it allows the System Operator to better coordinate the use of multiple generation sources. The SCADA system installed as part of the battery control matches supply with variable demand on a grid with three dispatchable energy sources (thermal, pumped hydro and battery storage) and one non-dispatchable (intermittent) energy source (solar PV). As demand varies through the day, the battery system manoeuvres to meet increased load and short-term generation variabilities from solar

	PV. This reduces the need for the continuous ramping up and down of thermal generators.

11.3 Hydrogen Gas Energy Storage

Hydrogen Gas Energy Storage

- Wind to Gas storage (Germany)

11.3.1 Wind to Gas Storage (Germany)

Utilising gas to store energy is gaining traction in many parts of the world as the decarbonisation of not just the electricity sector as well as the heat and transport sectors is required to meet our climate targets. A project by Uniper in Falkenhagen, Germany is the world's first demonstration plant for storing wind energy in the natural gas grid.

Project	Wind to Gas Storage
Operator	Uniper
Location	Falkenhagen, Germany
Project Ratings	Plant produces up to 1,400 m^3 of synthetic methane a day, corresponding to approximately 14.5 MWh
Operational Date	2013 - producing green hydrogen 2018 - producing green methane gas
Key Services Provided	Excess wind energy is used to power an electrolysis process when it is not economical to export to the grid due to the fluctuations in demand and energy prices. The electrolysis generates hydrogen gas, which is fed into the natural gas system by ONTRAS Gastranport (the equivalent of Gas Networks Ireland). Using this method, 2 GWh of green hydrogen was fed into the gas network in 2014 alone. However, there are limits in Germany as to how much hydrogen can be injected into the existing natural gas infrastructure. In 2018, the project was expanded to convert this hydrogen from renewable sources into synthetic natural gas. This gas can then be used in the existing natural gas infrastructure without restrictions and can be utilised in other energy sectors. Learnings from this project will be used to inform future developments of these promising technologies.