2021 Annual Innovation Report

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Foreword

We are delighted to publish this report on the innovation carried out across EirGrid and SONI in 2021 as well as our future ambition.

Both innovation and research are essential in getting us to where we need to be, enabling solutions to realise sustainable energy benefits. Throughout 2021, EirGrid and SONI have strategically innovated to deliver key projects, such as Shaping Our Electricity Future, as well as delivering several smaller individual projects that enhance the way we operate.

We have also refreshed our Innovation and Research Strategy in the last year to outline the necessary support structures, frameworks, and people we need to enhance our innovation and research capability. The strategy complements recent publications from EirGrid and SONI on the Shaping Our Electricity roadmap to 2030, by focusing our collective research and innovative strategies to deliver on Ireland's and Northern Ireland's respective ambitions to 2030, while enabling and supporting the innovation and research in our ecosystem to deliver on longer term net zero carbon commitments.

Collaboration with our partners has been fundamental in delivering on our current innovation programmes. Enhancing these strong relationships, as well as building new ones will be vital as we strive to innovate further with our strategic programmes of work.

As part of this annual innovation reporting process, we seek to consult on our multi-year innovation programmes. This reporting includes both programmes covered by the regulatory price controls as well as proposed new strategic programmes, which will require appropriate regulatory support and funding. The proposed strategic innovation programmes are EirGrid and SONI's view of the crucial areas of innovation that need to be investigated to ensure we can respond effectively to the challenges ahead.

Whilst our ambition to net zero carbon is decades away, it is vital we begin our journey of discovery now. We need to understand the options and solutions which will work best for the Island of Ireland, to ensure we are on the right path to deliver on a cleaner energy future.

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Contents

1.0 Introduction

EirGrid Group is made up of EirGrid plc (the Transmission System Operator for Ireland), SONI Ltd (the Transmission System Operator for Northern Ireland), SEMO (the Single Electricity Market Operator for the Island of Ireland), EirGrid Interconnector DAC and EirGrid Telecoms DAC.

As a group of companies, we operate the electricity transmission grid in Ireland and Northern Ireland. We also plan the future of the grid on the island of Ireland, operate the grid every minute of every day, link with neighbouring grids in countries such as Scotland and Wales (interconnection), and run the wholesale electricity market (where electricity is bought and sold by generators and suppliers). In brief, we make sure that everyone has power when they need it at the most economic price possible.

Recent Government policy in Ireland and in Northern Ireland has set ambitious targets that will further affect how electricity is generated. In Ireland, the Climate Action Plan states that up to 80% of electricity will be generated from renewable energy sources (RES-E) by 2030. In Northern Ireland, the target in the Energy Strategy for Northern Ireland is to meet at least 70% of electricity consumption from a diverse mix of renewable sources by 2030. Also, in the UK, the government is pursuing net zero carbon emissions by 2050. Both targets will require us to break new ground in the amount of RES-E we manage on the electricity system.

The Shaping Our Electricity Future[1] initiative outlines a secure transition to deliver the 2030 renewable ambition. In consultation with governments, regulators, and stakeholders we have used scenario-based analysis across the whole electricity system to identify a roadmap to

[1] https://www.eirgridgroup.com/site-files/library/EirGrid/Shaping_Our_Electricity_Future_Roadmap.pdf
https://www.soni.ltd.uk/media/documents/Shaping_Our_Electricity_Future_Roadmap.pdf

delivery of the renewable ambition in an economic and reliable fashion. Given the relatively short planning horizon to 2030, Shaping Our Electricity Future provides a deliverable, economically feasible, dynamic, and transparent roadmap that delivers system reliability while meeting the renewable ambition. This analysis is on achieving at least 70% RES-E by 2030. However, the future evolution of the power system beyond 2030 is also implicitly considered in delivering the broader EU and UK ambition of net zero carbon emissions in the economy by 2050.

Considering these challenges and ambitions, the purpose of this Annual Innovation Report is to document progress on innovative programmes throughout 2021, as well as our ambition for future developments of programmes and new initiatives to begin. Many of the innovative programmes are directly aimed at delivering on the Shaping Our Electricity Future roadmap and will be critical to its success. A consultation is included through this report to enable us to gather the views of our stakeholders, and ensure the programmes are deemed appropriate by all.

We will also use the final reports issued to the regulatory authorities, with feedback from stakeholders included, as a mechanism to seek approval from the regulatory authorities in Ireland and Northern Ireland to undertake new innovative programmes. These new innovation programmes are our view of the essential initiatives we must begin to investigate now to position us to respond effectively to the challenges ahead.

All responses to consultation questions are requested by the 16th of March at the latest. Please visit https://consult.eirgrid.ie/ or https://consult.soni.ltd.uk/ to respond to the consultation

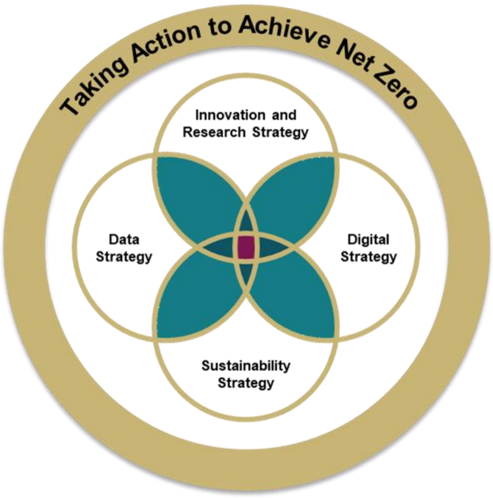
2.0 Strategies Developed to deliver on our Innovation Ambition

Our Strategy 2020-2025 recognises the importance of a number of key facets to deliver on our primary goal, to Lead the island's electricity sector on sustainability and decarbonisation. These include sustainability, innovation and research, data, and digital as key enablers to deliver on this goal.

We recognise the interdependent and synergistic role of data, digital and sustainability alongside innovation and research in delivering on our 2030 ambition and beyond to net carbon zero. Unlocking value from these synergies is key to achieving a sustainable and carbon free future which is why we chose to refresh these strategies in unison.

We will unlock synergies across these strategies by ensuring:

- Digital enables Data
- Digital and Data facilitates Innovation and Research
- Innovation and Research can drive Digital and Data
- Innovation and Research enables us to lead the island's electricity sector on sustainability and decarbonisation



Below is an outline of each of these strategies.

2.1 Digital Strategy

EirGrid and SONI have strong foundations in digital transformation and have made significant steps in driving innovation through transformative digital solutions such as our Energy Management and Market Management platforms. We are continuing to build and enhance our digital capabilities across the Group, leveraging the latest technology to enhance both our employee and customer experiences. The role of our Digital Strategy is to strengthen EirGrid and SONI's capabilities as people-centric digital organisations, committed to only the best digital experiences and enabling the Group to innovate faster.

Our Digital Strategy is about embedding digital in the way EirGrid and SONI think, work, and operate. It will support the transformation of our business by systematically evaluating new relevant technologies, business models and capabilities to identify potential for digital innovation. The strategy will create additional value by increasing efficiency and levels of transparency.

2.2 Data Strategy

As Transmission System Operators and Market System Operator for Ireland and Northern Ireland, EirGrid and SONI already deal in large quantities of data. We process large data flows and manage technically complex data for many aspects of the power system. This is how we operate, plan, and develop the power systems, and how we manage, administer, and settle the electricity markets.

We launched a group-wide Data Strategy in 2021 - it sets out our vision to harness data to drive insights and solve current and future energy challenges. It builds on our digital strategy and identifies how we can improve our use of data to support innovation and data sharing across our ecosystem. It sets out a series of measures to improve how data is governed, managed, and re-used in a secure, efficient, and transparent manner across the organisation.

The strategy also recognises the importance of our data for engaging the public, policy makers and industry. Our aim is to position EirGrid and SONI as the nexus of electricity sector ecosystem by becoming the go-to source of data, insight, and innovation. This will build on the extensive platform of open data which is currently available via our websites and the SmartGrid Dashboard.

In addition, SONI will also be supporting the Utility Regulator on the development of a Digitalisation Strategy for Northern Ireland.

2.3 Innovation & Research Strategy

EirGrid and SONI have a proven track record in the delivery of transformational innovation in support of the energy transition and are currently delivering a portfolio of innovative programmes to achieve our 2030 goals. Our net zero carbon ambition now necessitates enhancing and accelerating our approach to overcome the natural limitations of many established technological, operational and market practices, delivering ever-greater innovation capability and solutions to address whole system challenges.

Our refreshed Innovation and Research Strategy is aimed at enhancing our innovation and research capability. It is designed to help us become more innovative by putting in place the necessary support structures, frameworks, and people to help make this happen.

The strategic innovation programmes identified as part of the strategy are EirGrid and SONI’s view of the crucial areas of innovation that we need to investigate now to ensure we can respond effectively to the challenges ahead. These programmes form our proposal for the reopener mechanism as captured later in this report.

A more comprehensive report on the innovation strategy was published in 2021 and is available on our websites[2].

2.4 Sustainability Strategy

In 2021 we undertook a process to support the development of a Sustainability Strategy for EirGrid and SONI. The objective of this programme of work is to further embed sustainability in support of our primary goal to 'Lead the Island's Sector on Sustainability and Decarbonisation.' It will enable us to build on the strong foundations laid by our previous Corporate Social Responsibility Programme and elevate it to maximise impact by mainstreaming sustainability into decision making and programmes of work in every area of the business.

A key component of this in 2021 involved surveying our internal and external stakeholders through a materiality assessment to inform a decision on what were the material considerations for the Group and material impacts the Group could make from a sustainability perspective. In addition to this we have embarked on a process to evaluate the emissions profile for the Group and set Science Based Targets to ensure the decarbonisation of our own organisation and the broader emissions impacts across Scope 1, 2 and 3 emissions is aligned with the latest climate science. We have submitted these targets to the Science Based Target initiative in October for validation and upon receiving this validation will be in a position to communicate our targets and the broader Sustainability Strategy in 2022.

[2] http://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Innovation-and-Research-Strategy-Report.pdf
https://www.soni.ltd.uk/media/documents/Innovation-and-Research-Strategy-Report.pdf

3.0 Innovation in EirGrid and SONI in 2021

This section of the report sets out innovative projects that EirGrid and SONI have progressed during the 2021 calendar year. For this report, projects have been grouped under four main strategic objectives:

1. Shaping Our Electricity Future
2. Horizon 2020
3. Collaborations
4. Automation

3.1 Consultation Questions

Please visit https://consult.eirgrid.ie/ or https://consult.soni.ltd.uk/ to respond to consultation questions on the projects outlined in this section of the report by the 16th of March 2022.

3.2 Shaping Our Electricity Future

To deliver the 2030 Government ambition, the grid will need to carry more power from energy sources depending on the weather. This power will also need to be carried over longer distances. As a result, we need to make the grid stronger and more flexible.

Through 2021, EirGrid and SONI consulted extensively on four different approaches to decide how best to develop the all-island grid to reach the 2030 energy targets, and the results of this work can be found on the EirGrid and SONI websites[3].

Within this section of the report are a number of key innovative project that have specifically been carried out to assess the feasibility of the different approaches and begin to act upon the output from the consultation, enabling the grid to operate in ways not previously achieved.

[3] https://www.eirgridgroup.com/the-grid/shaping-our-electricity-f/
https://www.soni.ltd.uk/media/documents/Shaping_Our_Electricity_Future_Roadmap.pdf

Hybrid Technology Enablement

Scope:

Hybrid Technology presents an opportunity for both System Operators and private industry in maximising the use of existing network assets, increasing diversity factors, and improving security of supply. This may help to maximise the use of transmission and distribution infrastructure and work towards delivering our 2030 targets and beyond. To aid in delivering our 2030 targets, we have identified several priority areas that focus on breaking down the barriers for Hybrid technology across technical, operational, commercial, regulatory, and market challenges. These priority areas are a key activity under the Operations pillar of EirGrid and SONI's Shaping Our Electricity Future Roadmap. Furthermore, they also form part of the Actions of the Climate Action Plan 2021 and Joint System Operator Multi-year plan. A list of the key priority areas is outlined below.

Priorities	Proposed Output	Timeline
Scoping of Work Package for trading of Maximum Export Capacity (MEC)	Internal Review	Q1 2022
Issue System Operators recommendations to Regulators on proposed changes to Over Install policy	Recommendation	Q2 2022
Technical assessment of options for trading of MEC behind a single connection point	Technical Analysis	Q4 2022

Future Potential:

If the full benefit of Hybrid technology is to be realised, it will aid in maximising the opportunity for effective use of new and existing technologies to meet the needs of the future power system.

2019/2020 Qualification Trial Process

Scope:

In 2021 we concluded the 2019/2020 trials focussing on Solar, Residential Services, and enhanced communication protocols for new and existing technology.

Rationale:

Facilitating new technologies to provide System Services on the system to increase competitive pressures on the long-term costs of System Service provision to the consumer by expanding the range of Service Providers. This will improve the technical capability of the generation fleet and the system more generally by facilitating capability valuable to the system at high levels of renewable penetration therefore delivering value to consumers and a secure, sustainable power system.

Impact:

Each of the trials has demonstrated valuable learnings to EirGrid and SONI. Firstly, the solar trial has shown solar photovoltaic technology can deliver fast-acting reserves (FFR, POR, SOR and TOR1). In addition, the trials have identified operational complexities associated with solar technology. These primarily relate to the ability to provide reactive power at night, forecasting of response and testing of units to demonstrate capability.

On the residential trials, two participants were successful: Energia and SMS (previously Solo Energy). Both participants implemented a different methodology and range of technologies as part of the trial demonstration of System Services capability. Each trial successfully demonstrated a subset of DS3 system services is possible from the technologies in domestic properties. Each trial delivered an aggregated response for SOR, TOR1 and TOR2. Currently, FFR and a full POR response seem unlikely, unless frequency meters are located onsite with upgrades required in the metering hardware to allow for millisecond monitoring, measurement, and validation. These services could be achieved by allowing more suitable, cost effective frequency meters and metering requirements to be used to avoid a significant negative impact on the cost to manufacture and install the batteries.

To fully understand the capability of residential homes to provide system services, greater research and knowledge is required in the area. As the trial's locations were geographically dispersed participants, they did not assess the impact of residential services providers at scale. Therefore, we need further information to understand the impact and the complex interactions of residential demand side management service providers.

Finally, on the telecommunications trials, two trials took place focussing on alternative forms of communication protocols. Both trial participants brought forward new solution designs that have helped the TSO's look at the possibilities of telecommunications. The learnings and outcomes have identified several operational complexities for the integration of alternative telecommunications protocols. This primarily focuses on security, protocol-based communications, standardised end to end telecommunications, and communications to control centres. The key findings from the trials will help inform the develop a roadmap for telecommunications between the distributed energy resource (DER) and the TSO's in the future. With the help of the trials, the TSO's have developed a clearer understanding of suitable solutions available, and how they could be implemented. These findings will help steer our course towards a more efficient telecommunications network. While security concerns are still a significant challenge for TSO's worldwide, it is fully understood that this work needs to be carried out in collaboration with our security partners and the broader industry to help deliver suitable solutions.

Future Potential:

The Qualification Trial Process (QTP) is a key activity under the Operations pillar of EirGrid and SONI's Shaping Our Electricity Future Roadmap. The Shaping Our Electricity Future Roadmap provides an outline of the key developments from a networks, engagement, operations, and market perspective needed to support a secure transition to meet our 2030 targets.

In designing the next set of trials, to ensure that we can facilitate active participation by industry stakeholders, we released call to industry seeking stakeholder views on the current QTP process and areas the TSOs should focus on. We intend to use the feedback from stakeholders to inform the design of the next set of trails.

75% System Non-Synchronous Penetration (SNSP) Study and Trial

Scope:

There is currently an operational system constraint within our operational policy that limits the operation of the All-Island power system with up to 70% SNSP. One of the DS3 Programme targets is to relax this operational system constraint to 75% SNSP in order to enable more renewable energy to be transferred through the power system. During 2021 extensive studies were carried out to ensure that the All-Island power system can be operated in a secure and reliable manner when increasing SNSP to 75%. Extensive studies were carried out to investigate different aspects of power system security and stability by performing various steady-state and dynamics power system studies and modelling of a number of different power system phenomena.

Whilst moving to 75% SNSP is an innovation in its own right, there are two particularly innovative aspects of this modelling related to:

1. Data mining used to identify a valid set of study snapshots to cover the entire space of different operating conditions based on the power system attributes such as SNSP, imports/exports, demand, the minimum number of large units on, ROCOF and many others.
2. Automation related innovations used to perform bulk studies in parallel, efficient data processing of the study results and modelling tasks/challenges especially with respect to the modelling of Voltage Dip Induced Frequency Delay (VDIFD) phenomenon.

Rationale:

Increasing SNSP is part of the DS3 Programme and will facilitate higher levels of non-synchronous renewable generation on the system. This is just one step in the pathway towards 95% SNSP by 2030, which is required to fulfil government RES-E targets.

Use of data mining and automation related innovations are the key drivers for the study case selection process and efficient processing of both study snapshots and a significant number of the generated simulation results. The developed automations are very powerful for the extraction of the results and performing modelling changes and sensitivity analyses, especially with respect to some phenomena not frequently observed in our power system that requires a number trial and error problem-solving attempts.

Impact:

The timely outputs of the studies ensured that EirGrid and SONI were able to commence the 75% SNSP trial in April 2021. This trial is expected to close in Spring 2022. The benefits start to accrue from the start date of the trial and there have been a significant number of hours where the SNSP has been greater than the previous limit of 70%, thus enabling more renewable generation and reducing curtailment. For a small island network, such high levels of SNSP are rare. Further studies during 2021 benefitted from the data mining and automations developed as part of this study.

Future Potential:

The 75% SNSP trial is nearing completion and a trial analysis has begun. This will assist in decision making on whether and when to change the operational policy and relax the corresponding operational system constraints.

The developed data mining techniques and automation are further used for similar studies targeting relaxation of our operational system constraints in order to enable more renewable energy on to the All-Island power system.

The successful completion of the 75% SNSP trial will enable us to move on to further operational trials, for example reducing the minimum number of units and the inertia floor, all of which are required to further facilitate even higher levels of renewable generation.

Undertake studies to identify the technical and locational requirements considering inertia, reactive power, and short circuit level

Scope:
This study investigates the dynamic and steady state security of the All-Island Power System for different scenarios of deployment of Low Carbon Inertia Solutions (LCIS), for example Synchronous Condensers with/without Flywheels (with STATCOM). This study supports the integration of technologies which can facilitate a reduction in the quantity of carbon intensive conventional generation required on the all-island power system. As part of this study and in conjunction with other studies ongoing in parallel, innovative tools were developed to interface Plexos with LSAT and evaluate the system strength. These tools and methodologies not only enable the LCIS study but also will play a big role in future studies.

Rationale:
To identify needs for LCIS and their placement to provide sufficient kinetic energy (inertia), reactive power support, additional system strength (short circuit contribution) and synchronizing and damping torque to ensure secure and stable operation of the all-island power system with an 85% SNSP in 2026.

Impact:
These studies form the backbone of the procurement of LCIS which paves the path towards the 2030 goal of 95% SNSP. Innovative tools such as Plexos2LSAT, DPS Extension, System Strength Evaluation Tool and the methodologies that bring these together were developed as part of this project. These tools and methodologies bring about a significant improvement in our study capabilities. They allow us to carry out investigations on more realistic/accurate future operation condition of the power system. This helps us to reveal and mitigate bottlenecks, ensuring the continuity of a secure, stable, and reliable power system with ever increasing levels of RES-E. Capacity has now been built which can enhance the delivery of future projects. Using these new automation tools, we can prepare, carry out and extract most important results in an efficient way and quantify some of the most important phenomena moving toward 85% SNSP using different metrics more comprehensively.

Future Potential:
These studies continue into 2022 and the final results will facilitate the delivery of the first LCIS consultation, providing signals for procurement of LCIS. Workshops to stakeholders will be delivered to support the LCIS consultation. Tools and methodologies that have been developed can be used for future projects. Capacity has now been built which can speed up the delivery of future projects.

Minimum Number of 7 Conventional Generation Units On for the All Island Power System

Scope:

This project evaluates security and stability of the future snapshots (2022 and beyond) where operational system constraints related to the minimum number of units are relaxed to enable more renewable energy being transferred through our All-Island power system. The main focus is on relaxing the minimum number of large units on constraints both jurisdictional (five in Ireland and three in Northern Ireland currently) and regional constraints.

In the studies these minimum number of units are relaxed to allow for having the minimum of all-island units set to seven, with SNSP up to up to 85%, a RoCoF (Rate of Change of Frequency) constraint of 1 Hz/s and inertia constraint of 20 GWs. The study focuses on voltage stability and dynamic studies to identify potential insecurities and instabilities when operating with less than 8 large units on.

Rationale:

To enable the efficient and secure operation of the power system, EirGrid and SONI schedule and dispatch units so as to adhere to their respective Operating Security Standards. These standards ensure that the All-Island transmission system is operated in a secure and reliable manner. The focus of this study is on minimum number of conventional units on that is currently set to eight. The TSOs are aiming to relax this particular constraint in order to operate the all island power system with minimum number of seven conventional units by 2022 and beyond. The reduction in synchronous generation on the system leads to reduction in system inertia, reserve and ramping capabilities, system strength, and synchronising torque. Different technical scarcities might arise when operating our system with seven units and increased need for the system requirements in frequency, voltage, rotor angle stability and system strength domains. In order to securely operate the system with a minimum of seven convention units this study must evaluate in detail and identify the technical scarcities of the future all island system (2022 and beyond) and recommend whether the relaxing of this important Operational System Constraint is sustainable.

Impact:

This project is ongoing. Innovative tools such as Plexos2LSAT, DPS Extension Tool were developed as part of this project. In addition, a number of automations have been developed to carry out different modelling changes and efficiently extract useful knowledge from the output results. The developed tools and automations significantly improve study efficiency and enable us to further explore a vast space of study scenarios, fast but comprehensive identification of issues, and efficient identification of potential mitigations.

A formal study outcome is expected in Spring 2022. When complete, the study outcomes will inform whether it is prudent to start an operational trial with a reduced number of minimum units. This will enable higher levels of renewables to be facilitated onto the all-island system, contributing towards the 2030 RES-E targets.

Future Potential:

The studies are ongoing into 2022. When complete, they will inform whether it is prudent to start a trial with a reduced number of minimum units. The developed tool and automations and learning from the study will be informative and re-used in many other studies that explore the impact of the relaxation of our operational system constraints to accommodate more renewable generation to our system.

Control Centre of the Future

Scope:
To develop a vision for, and roadmap to, the Control Centre of the Future that supports the achievement of our renewable integration targets for 2030 and beyond. This was achieved by:

- Considering future demand, generation, and markets to be served and the operational challenges these will bring;
- Assessing the tools and IT infrastructure design needed to support system operations;
- Evaluating upgrades to the current EirGrid and SONI control centres in the context of modern design principles;
- Developing an implementation plan to move towards the Control Centre of the Future; and
- EirGrid and SONI engaged the services of EPRI and DNV to develop this vision and roadmap and was supported in this by a range of EirGrid and SONI subject matter experts.

Rationale:
Through judicious planning and innovative design, the Control Centre of the Future will become the core of the continued successful transition to a clean energy future, allowing EirGrid and SONI to continue to provide secure, reliable, high-quality service to customers. The Control Centre of the Future will enable EirGrid and SONI to operate and manage this complex system of renewable resources, energy storage, and shifting demand patterns, safely, economically, sustainably, and reliably.

Impact:
The project delivered a comprehensive assessment of the needs of the Control Centre of the Future and a staged, long term plan for the evolution and development of tools, IT architecture and physical infrastructure.

Future Potential:
The roadmap is an ambitious vision for the future of transmission operations and real-time control. To deliver on this ambition to 2030 and beyond will require enhanced capabilities and resources for project planning, procurement, detailed design, and software implementation and deployment.

EirGrid and SONI are now commencing a more detailed planning phase for the staged delivery of the roadmap over the coming decade.

EirGrid and SONI have also engaged with other TSOs on their control centre development plans through the Global-Power System Transformation consortium. Further information sharing and co-ordination among TSOs will support the achievement of our renewable energy integration targets in Ireland and globally.

Control Centre Tools Implementation

Scope:
Decision Making Tools currently being developed in the Control Centre include:

- Look-Ahead Security Assessment Tool (LSAT): enables Grid Controllers[4] to analyse the stability of the power system in the near future facilitating optimal system operation with higher levels of wind and solar integration.
- Voltage Trajectory Tool (VTT): enables Grid Controllers to assess the impact of varying sources of reactive power across the power system to ensure that local voltage management issues are managed. Enhanced voltage control management capability in the control centre is critical to facilitate increased levels of SNSP[5].
- Ramping Margin Tool (RMT): enables Grid Controllers to accurately schedule and dispatch the Ramping Margin services[6], and manage changing demand and generation profiles, with increased wind and solar integration.

Rationale:
The evolving power system requires new principles and practices of operation, with the resultant requirement for development and implementation of new control centre tools and capabilities. In keeping with the natural flow of DS3 from system performance to system policies to system tools, many of the new tools requirements will be driven by the outputs of other DS3 work streams, especially those in the policy area. The evolving I-SEM design also drives the requirement for new tools.

Impact:
The Look-Ahead Security Assessment Tool went live in the control rooms of Belfast and Dublin in December 2020. The tool is a world first which enables operation of the All Island power system with world leading levels of variable renewable generation in a safe and secure manner while minimising the level of constraint and curtailment of wind and solar. Thus, LSAT is a key contributor in the path towards decarbonisation of the electricity sector. Enhancements to Look Ahead functionality have been developed and tested during 2021 and will be deployed to the control rooms in early 2022.

Voltage management in Ireland and Northern Ireland is becoming more challenging due to the reduction of available reactive power resources (through displacement of conventional plant) and the disperse location of wind farms (with different capability characteristics), combined with increasing installation of HV underground cables. Currently, an active transmission

[4] **Grid Controllers** operate the grid from National Control Centre (NCC) in Dublin and the Castlereagh House Control Centre (CHCC) in Belfast. The grid controllers carry out the intricate task of matching electricity production to customer demand.

[5] **System Non-Synchronous Penetration (SNSP)** is a real-time measure of the percentage of generation that comes from non-synchronous sources, such as wind & interconnector imports, relative to the system demand.

[6] **A Ramping Margin service** is the increased MW output that can be delivered with a good degree of certainty for a given time horizon.

constraint dictates that there must be a minimum of 8 large synchronous machines on-load at all times in the all island system. To accommodate increasing amounts of non-synchronous renewable generation, this constraint must be relaxed. VTT will determine optimal reactive targets for different types of device, delivering voltage trajectory plans secure against contingency events for a near time horizon (typically intra-day and day-ahead). This innovative decision support tool will enable operation with reduced number of conventional plan on-line and, thus, will facilitate increased levels of SNSP in the All Island system. The Voltage Trajectory Tool has been scoped and developed throughout 2021. Agile development, testing and validation are underway in cooperation with vendors and external consultants. Deployment to control rooms is expected in early 2022.

An enduring Ramping Margin Tool went live in the control centres in SONI and EirGrid in October 2021. This tool enables grid controllers to accurately schedule and monitor the ramping margin reserve services, thereby enabling more effective management of changing demand and generation profiles with increased wind and solar integration.

Future Potential:

This DS3 Control Centre Tools project will deliver a suite of Control Centre Tools to enhance the stability analysis, voltage control and frequency management capability of the control centre. This capability enhancement is necessary to increase the levels of instantaneous renewable generation on the system (SNSP). A core objective of the TSO and the DS3 Programme is facilitating levels of SNSP up to 75% to meet public policy. Additional tuning of the tools and development of enhanced capabilities is expected throughout 2022.

Dynamic Power Flow Control

Scope:

The deployment of dynamic power flow control devices will have an important role to play in network congestion management and maximising the existing network capacity. These devices will also assist in minimising the need for network reinforcement projects and mitigating the challenges associated with building new overhead lines or underground cables such as societal acceptance and prolonged outages of key infrastructure.

Rationale:

In our strategy to accommodate 2030 RES-E targets, a range of network, operational and market initiatives will be required to achieve this target. The candidate lines are identified in Shaping Our Electricity Future to manage flows in Ireland around the local 110 kV and 220 kV transmission network.

The candidate lines are as follows:

- Flagford – Sliabh Bawn – Lanesboro 110 kV lines
- Sligo – Srananagh – Corderry 110 kV lines
- Letterkenny – Tievebrack - Binbane 110kV
- Letterkenny – Cathaleen's or Letterkenny – Clogher 110 kV lines
- Killonan – Knockraha 220kV line
- Clashavoon – Knockraha or Cullenagh – Knockraha 220 kV lines

Impact:

Dynamic Power Flow Control devices will be considered as strategic assets. They will be installed on an as-required basis in the most beneficial locations on the Irish transmission network.

Future Potential:

The dynamic power flow control devices will be modular and suitable for installation on 110 kV, and 220 kV circuits. Depending on the location on the network or the nature of the need, the dynamic power flow control installations may be enduring or may facilitate relocation of the installations to other locations as needs change on the network over time, or as other more significant network reinforcements are delivered which address capacity needs in the wider roll out is included in the strategic initiatives later in this report.

Dynamic Line Rating

Scope:
To trial and investigate Dynamic Line Rating (DLR) implementations in Ireland. This includes a trial of 'Direct Measurement' DLR technology which has been committed to on the Lisheen – Thurles 110kV overhead line, consideration of the 'Indirect' DLR technology as well as studies on the wider roll-out of this flexible network solution.

Rationale:
DLR installations enable the usage of real-time thermal loading limits which increase transmission capacity of lines safely without high cost burden or extensive outages. The dynamic ratings are determined from the live environmental conditions, while seasonal static ratings assume conservative limits.

'Direct Measurement' DLR requires the installation of equipment on a line, which measures the local conditions with high confidence which increases the capability to operating beyond static limits. In comparison 'Indirect' DLR generates estimates this from weather data which provides a more conservative increase in line ratings.

DLR offers the potential to facilitate the connection of greater volumes of variable renewable generation with less infrastructure upgrades and provides a medium-term solution for congested lines. The technology also offers the capability to forecast line ratings based on weather forecasting.

Impact:
The Lisheen – Thurles 'Direct Measurement' DLR trial is progressing towards the installation of the technology so testing can begin in 2022.

Future Potential:
Dynamic Line Rating installations increase the capability for variable renewable generators to export power onto the grid without the requirement of building/upgrading network infrastructure. The technology can also ease congestion problems experienced on the grid as well the future potential to use forecast dynamic line ratings within our processes. The wider roll out is included in the strategic initiatives later in this report.

Engagement and Consultation Programme

Scope:

In the development of the Shaping Our Electricity Future (SOEF) roadmap, EirGrid and SONI sought to hear thoughts on our four draft approaches, so that we could agree on an approach to prepare the electricity grid to reach the 2030 renewable targets. The move to clean electricity will affect everyone in Ireland and Northern Ireland – we wanted to work with the public to find the best way of shaping our electricity future.

To do this, we needed to explain the proposed changes that will affect the future of electricity. We outlined the need to add a lot of new sources of clean electricity, and where these are typically located. We then encouraged stakeholders to tell us what they thought, utilising a range of communication channels.

This approach was driven by a wide-ranging public engagement strategy and consultation programme. This 12-month programme included more than 100 external engagement events in Ireland and Northern Ireland during a 13-week consultation period. The programme was delivered in partnership with key stakeholders such as Chambers Ireland, Irish Rural Link, the National Youth Council of Ireland and the MaREI research institute (UCC). Reporting on the consultation and engagement feedback was undertaken independently.

Rationale:

The purpose of this approach was to:

- Activate the interest of the public in the development of the future of the electricity transmission network;
- Support the organisation to accelerate building our engagement capacity;
- Implement innovative partnerships and approach our engagement;
- Introduce strategic long-term external expertise through academic bodies and NGOs;
- Future and pandemic-proofing our engagement;
- Prioritise the accessibility of our engagement systems, respond to stakeholder needs and embed digital tools;
- Firmly establish the stakeholder at the centre of our grid development process;
- Change our processes to prioritise the views of stakeholders;
- Accelerate public acceptance of electricity transmission infrastructure;
- Build trust by introducing participative engagement and co-design processes to our projects; and
- Build trust with our public stakeholders and provide ownership to the public over the process.

Impact:

- Over 500 consultation responses – the highest we have ever received for a non-grid project-specific consultation.
- Over 100 consultation and engagement events held, including:

- A National Youth Assembly, facilitating dialogue with young people on the future of the grid;
- Meetings with 30 local authorities;
- 6 Rural community workshops in partnership with Irish Rural Link;
- 6 Regional Chambers of Commerce workshops in partnership with Chambers Ireland; and
- A 3-day model citizens assembly with 99 electricity consumers.

Future Potential:

- Dissemination of outcome, including webinars and stakeholder briefings;
- Embedding a deliberative dialogue process in our grid development process through community forums; and
- Roll out of regional citizen assemblies where new grid needs are identified.

Fast Frequency Response – Interim Solution

Scope:
The scope of this project is to:

- Complete a study to determine the volume of the Fast Frequency Response (FFR) service required when operating the transmission system with a minimum of 7 sets;
- Implement a process in the control centres to monitor the FFR service using LSAT; and
- Implement a change (as required) to the reserve policy to include an FFR requirement.

Rationale:
The TSOs have procured FFR from diverse service providers since 2018, including conventional generators, interconnectors, aggregated generator and demand response units, wind farms, and battery storage devices. To date (effective 01/10/2021), the TSOs have contracted for a total all-island FFR capability of 1178 MW; it is expected that additional contracted capability, with most being provided by battery storage devices, will be procured up to October 2023 under the current Volume Uncapped commercial arrangements. Despite this, the service is not managed as per other related System Services, such as Primary Operating Reserve (POR). In particular:

- A specific magnitude of required FFR for diverse system conditions has not been defined and the service is not explicitly referenced in our reserve policy;
- There are no processes and control systems in place to monitor and dispatch the provision of the service in real time; and
- The indicative operations schedules – Long-Term Schedule, Real-Time Commitment and Real-Time Dispatch – do not schedule to meet an FFR requirement.

The aim of the FFR Interim Solution project is to address the above. It is a prerequisite for the 7 sets 23 GWs and 20 GWs inertia floor trials that are scheduled to commence in the second quarter of 2022.

Impact:
This project is ongoing. A formal study outcome is expected in the first quarter of 2022, which will inform the other project deliverables.

Future Potential:
A formal study outcome is expected in the first quarter of 2022, which will inform the other project deliverables. The study outputs will define some of the decision points of the process to monitor FFR in the control centres. The study will also inform whether a change to the reserve policy to include an FFR requirement is warranted.

The use of LSAT to monitor FFR in the control centres is an innovative approach. It is intended that this process, once implemented, will help inform future developments relating to the monitoring of reserve services in general.

The new PLEXOS-LSAT interface will also be used for other projects, including the low carbon inertia solution and min 7 sets studies.

New Harmonics Policy

Scope:
Conduct a review of existing harmonic allocation policy, international practices, and all harmonic distortion data across the system dating back to 2016, to determine a more appropriate harmonics policy based on data and trends.

Rationale:
The old harmonics policy, in place since 2015, tended to allocate very small allowances for harmonic distortion for new customers. In some instances, this could lead to additional costs to customers, with little overall benefit to the overall system.

Impact:
The impact of this innovation is that harmonics allocation is far simpler, and customers get more allocation, lessening the need to install unnecessary filtering, although filters may still be required in some circumstances. Therefore, there is a savings on EirGrid and SONI effort spent on harmonics analysis, and less time spent engaging in back-and-forth with customer queries on harmonics allocations. From the customer side, the financial risk of requiring a filter is lessened, and similarly, less time should be required engaging on this issue with EirGrid and SONI.

Future Potential:
This was a one-off piece of work, and so there will be no further developments at this point. The policy should be reviewed in five years, and harmonics data across the system should continue to be amassed and analysed.

3.3 Horizon 2020: EU Sys-Flex

Scope:
The EU-SysFlex Project is an EU Horizon 2020 funded project addressing system operation and flexibility solutions for integrating 50% renewables in Europe by 2030. The project, led by EirGrid and SONI, has several dimensions being delivered by 34 cross sectoral consortium partners including TSOs, DSOs, technology providers, research, and academic institutes as well as consultancy sector across 15 European countries.

In summary, the project scope consists of:

- Characterising the technical scarcities in the EU power system for ambitious RES-E scenarios aligned with EU and national renewable targets;
- Identification of mitigations options to address the identified scarcities as well as financial and economic analysis of the simulated results to assess the value of the system services required; and
- Market enhancements required to incentivise investment in the identified system services.

In tandem, the consortium is conducting seven demonstration project and qualification trials across Ireland, France, Portugal, Estonia, Italy, Germany, and Finland exploring flexibility capability of technology to provide services to grid.

- In addition, the project is assessing operator protocols and tools required to operator in a high RES-E scenario as well are data management and data exchange aspects.

For more information please see www.EU-SysFlex.com

Rationale:
The rationale for participating in EU-SysFlex is to enhance our collaboration with other sectoral participants in addressing system wide challenges as well as sharing knowledge to enhance our understanding and ability to solve future challenges. From a technical perspective, participation has funded the technical analysis and studies associated with future operations aspect of 'Shaping our Electricity Future'.

Impact:
The four year ground breaking project, co-ordinated by EirGrid and SONI, has identified the needs of the future power system by charactering the technical scarcities of the future power system with a high share of renewables across three synchronous areas of Ireland and Northern Ireland, Continental Europe and the Nordics. Through financial and economic analysis of the simulated results, the project team have identified associated financial gaps and market enhancements required to incentivise investment in system services. From an Ireland and Northern Ireland perspective, this work has directly fed into 'Shaping our Electricity Future' and our plans to meet our renewable ambition of 70% renewables and 95% SNSP.

In 2021, EU-SysFlex submitted 16 major deliverables to the EU Commission, most notably EirGrid and SONI led report on ‘Mitigation of the technical scarcities associated with high levels of renewables on the European power system, D2.6)’ as well as ‘Development of EU-SysFlex operator protocol, (D4.7)’

Future Potential:

The project team are currently in the process of finalising the project outcome, which will culminate in the publication of a ‘Flexibility for Europe’ roadmap. The intent of this roadmap is to provide a clear vision for development and deployment of system services needed by TSOs to support the integration of RES-E to meet EU renewable targets. The results and outcome of can be found on the projects website at www.EU-SysFlex.com.

3.4 Collaborations

Collaboration with other industry experts is imperative in delivering on our innovative ambition. The collaborative projects identified in this section of the report enable all parties to benefit from the shared responsibility, with each party able to deliver on their key strengths. In addition to delivering these projects, the collaborative approach further enhances our relationships with our partners and strengthens EirGrid and SONI's breadth of knowledge and capability.

EirGrid and SONI are always open for new opportunities to collaborate further with our established partners, and forge new relationships with partners we do not currently operate with.

Our Energy Future - Friends of the Earth

Introduction and Rationale

This project encompasses agreements for collaborative efforts that complement the work undertaken by the Renewables Grid Initiative, EirGrid and SONI, and Friends of the Earth. It takes account of the "European Grid Declaration on Transparency and Public Participation". This project aims to implement common ambitions through collaboration to support the continuous and ecologically sound development of the grid infrastructure which is needed for a successful energy transition.

The Renewables Grid Initiative (RGI) is a unique collaboration of NGOs and TSOs from across Europe engaging in an 'energy transition ecosystem-of-actors'. RGI promotes fair, transparent, sustainable grid development to enable the growth of renewables to achieve full decarbonisation in line with the Paris Agreement. As part of its strategy, RGI initiates innovative approaches to enable a sensitive grid development. This includes that RGI actively instigates and facilitates cooperation between TSOs and NGOs to jointly work on better processes at local, regional, and national level.

RGI will liaise between partners and act as the facilitator and mediator between EirGrid and SONI, and Friends of the Earth, thus ensuring a constructive and respectful exchange. RGI will also contribute to further detailing out the project concept throughout the project and take a lead on logistical and contractual aspects of the project. Given RGI's experience in leading similar projects in other national contexts (Germany and Italy), RGI will secure the exchange with colleagues from other projects where relevant, as well as itself acting as a general sparring partner for both parties. Furthermore, RGI will secure dissemination of project results with a European audience where appropriate. Independent of this, Friends of the Earth has the right to use and publish intermediate and final results at their own discretion.

Friends of the Earth seeks to ensure that everyone, particularly marginalised and disadvantaged groups who might be affected by policy, are considered and included in the conversation. It strives to expand and diversify civic engagement by creating spaces for everybody to participate and be included in activism and political change.

Friends of the Earth brings its specific knowledge on sustainable development, community participation and social justice to inclusive dialogue regarding the implications of the energy transition and the role of necessary grid development projects.

Friends of the Earth will contribute to the increased accessibility, quality, and effectiveness of the energy transition through capacity building and assistance provided by EirGrid and SONI.

EirGrid and SONI's aim is to develop a cohesive approach to Public Engagement that reflects and is framed by the energy transition – and by the urgent context of climate action. They do not expect to always be able to deliver the specific technical solution that the public want. Where they cannot, they will ensure that they explain why. EirGrid and SONI always pursue an approach of continuous improvement in everything they do. They aim to build trust by clearly detailing their goals and limitations – and they then seek to reach an agreed response.

Recognising the value of creating a dialogue with the wider society, and in line with other partnerships and initiatives, EirGrid and SONI intend to engage a broad range of stakeholders in in-depth, meaningful discussions about the future and the role of the grid.

Impact:

- In December 2021, the partnership was publicly announced. This is a major milestone in the sense that it is a first for EirGrid and SONI and reflects an evolution in our approach to public engagement; and
- Two-day in-person workshop on programme development.

Future Potential:

Outreach shall include:

- Engagement with grassroot organisations, opening dialogue on their position on Ireland's energy future;
- Engagement with nature-based organisations, opening dialogue on infrastructure and renewables and their benefits and challenges from a nature, societal and system operation perspective;
- Workshops and webinars on the energy transition;
- Production of accessible information for communities and advocacy tools;
- National conference on the Irish Energy Future;
- Support and organise participation in Government organised social dialogue on climate action; and
- International learning exchange.

Commenced Rollout of Community Forums on Grid Development Projects

Scope:
2021 saw the establishment of Community Forums across several EirGrid projects for Ireland. The following forums were established in 2021:

- Clashavoon Dunmamway 110kV Overhead Line
- Celtic Interconnector
- Laois Kilkenny Reinforcement Project
- Kildare Meath Grid Upgrade
- North Connacht 110kV Underground Cable

The role of the forums is to ensure that local people take part in the project as much as possible and that they take ownership of the project. Members of the Community Forums are made up of representatives of local community groups, local County Councillors and Chamber of Commerce.

Each forum is independently chaired by a local NGO such as Irish Rural Link and Development Perspectives.

Each Forum is unique with core group working principles and a term of reference. The Forums focus will differ depending on what step the project is at. For example:

- The Kildare Meath Grid Upgrade Community Forum's main focus at present is the route of the project;
- The Celtic Interconnector Community Forum is commencing the development of a community benefit strategy for the Community Benefit Scheme; and
- The Laois Kilkenny Community Forum designed and opened a round of Community Benefit funding.

As each forum is only recently established, capacity building has also been a focus, encouraging a sense of ownership and empowerment ensuring that community forum members gain greater control over the future development of their area, through the Community Benefit Scheme.

To date all meetings have taken place virtually however it is hoped that as Covid-19 restrictions allow Community Forums will meet in person.

Rationale:
The purpose of a community forum is to:

- Provide a level of ownership and empowerment to local communities and stakeholders on the project;
- Represent the views of their organisation or community in relation to the project and its proposals;
- Consider the project and provide guidance on local needs and priorities;

- Assist in the resolution of local issues resulting from the project in a timely manner;
- Support the project team in identifying local sources of information and analysis, strategies, and proposals;
- Provide feedback at key stages in the delivery of the project;
- Facilitate a 'local voice' and communicate information to local stakeholders; and
- Support the overall efficient delivery of the project.

Impact:

- 5 community forums have been regularly meeting throughout 2021 with an average of between 10 – 15 members at each forum;
- The community forums have enabled EirGrid to build relationships and trust within Communities. We have been harnessing local knowledge and views, to assist decision making and ensuring maximum impact of the community benefit in the area. This has been evident in Clashavoon Dunmanway project where the forum contributed to the scoping study of the area and the design of the fund, and most notably on Laois Kilkenny, the first community Forum to endorse and sign off on a scoping study for their community. The scoping study sets out the cross-community challenges and poses recommendations by identifying projects and organisations that will benefit the community;
- We have been able to foster a sense of project ownership within communities by ensuring the community forums are involved in drafting the scoping study and thus the fund design and guidelines;
- The community forums have enabled EirGrid to develop robust two-way communication systems to collate and disseminate key project information and updates, this is most evident on Kildare Meath forum with the main focus of this community forum on the ongoing consultation and route options;
- We are building on local expertise and knowledge in developing partnerships and opportunities for collaboration, for example The Celtic Community Forum is working with relevant partners and recently the Local Development Company, SECAD, attended a forum meeting to present on LEADER funding available for the area. These partnerships will ensure a coordinated and enhanced approach to the community benefit strategy, ensuring community groups can draw on a wide range of supports available; and
- Clashavoon Dunmanway €600,000 community benefit scheme: A total of 36 projects from Dunmanway, Aghinagh, Carrigadrohid, Kilmurry, Rusheen, Macroom, Tirelton, Kilmichael and Coppeen West were successful in the application process. The successful projects include the development of community and sports facilities, funding for youth facilities, along with heritage, older persons, and enterprise initiatives. There was incredible interest to the fund with an ask of over 2.4 million and the level of collaboration was very evident across communities. The fund was allocated in a fair and transparent manner and shared by communities along the full length of the transmission line and by a range of different groups and organisations.

Future Potential:
Journal article sharing learnings over a number of years.

EPRI Project on Weak Grid Analysis

Scope:

As part of EirGrid's partnership with EPRI there has been ongoing collaboration on a weak grid analysis project. Phase 1 of the project used EPRI's Grid Strength Assessment Tool (GSAT) to carry out a case study on the Irish power system, across several scenarios, for weak grid issues.

The goal of Phase 2 of this project is to investigate the capability of newly developed inverter models to assess dynamic stability of Irish network compared to existing state of the art root mean square (RMS) dynamic models.

Rationale:

Phase 1 has provided the ability to quickly assess areas on the Irish grid where inverter-based resources (IBRs) are likely to experience stability issues due to the weak grid conditions. The GSAT toolset can efficiently determine Short Circuit Ratio & Critical Clearing Time on the system at high SNSP levels.

Phase 2 looks to build on from Phase 1 using the results to define a study area which can be used to test the ability of improved inverter models to assess dynamic stability relative to existing models. As the networks tends towards 100% SNSP it is vital that network models reflect the expected behaviour as accurately as possible. Also, it is intended to create an operational metric for high SNSP situations suitable for on-line implementation in Control Centre environment.

Impact:

The Phase1 study has finalised with the publication of a final report in late 2020. Phase 2 of the Weak Grid project has kicked off this year and is currently under development.

Future Potential:

As the capability of the system to handle increasingly higher SNSP levels grows, it is necessary that weak grid and instability issues can be simulated and detected with accuracy. Toolsets designed to handle scenarios proximal to 100% IBR penetration are necessary to ensure the reliable and secure transmission of power at these operation levels.

EPRI P173a & P40.024

Scope:
EirGrid and SONI have entered a multi-year membership arrangement with EPRI and are participating in two base research projects P173A: System Planning Methods, Tools and Analytics with Emerging Technologies and P40.024: Advanced Power Flow Control, HVDC Planning, and Contingency Analysis Methods and Tools.

Rationale:
P173A considers the need for advancement in terms of tools, methodologies, and analytics, primarily in transmission planning and protection, as we transition from legacy transmission into a high IBR system with distributed energy resources (DER).

This project targets the need for improved IBR models & tools to enable planners to accurately simulate and assess power systems with high IBR penetration levels, as well the refining and verifying aggregated DER models. Investigation into how this scenario impacts legacy protection schemes is also considered to enable protection engineers to conduct relay setting.

P40.024 similarly considers the challenges and opportunities that exist as the power system is transitioning. This project considers established & new HVDC technologies in planning, as well as frameworks on how advanced transmission technologies and energy storage can be considered in evaluating and designing cost-effective solutions for transmission reinforcement, alongside more conventional infrastructure solutions. Also included is Machine Learning methods to screen critical power flow cases out of large datasets to accelerate studies.

Impact:
The 2021 phase of P173A and P40.024 are set to close out at the end of the year, the majority of research material will be of great value to EirGrid and SONI. EirGrid and SONI have had particularly significant involvement in the development of the k-means clustering Machine Learning power flow screening solution for critical case detection.

Future Potential:
EirGrid and SONI's involvement in both projects will continue as the 2022 phase of P173a and P40.024 progress, to increase understanding/availability of the capabilities of new technologies, tools, and methods.

Developing Real Time Contingency Analysis and Network Optimization Control Centre Tools and Capabilities

Scope:
The main objective of this project is to develop and validate open-source software tools that will enable Transmission System Operators to capitalise on network flexibility introduced with the use of innovative Power Flow Control (PFC) technology.

The project is led by the power technology firm Smart Wire Grid Europe ('Smart Wires') in partnership with EirGrid and SONI and the research and development consortium Electric Power Research Institute (EPRI). The project has direct visibility of the Sustainable Energy Authority of Ireland (SEAI) as it is partially financed under the Development & Demonstration Funding Programme 2019.

This two-year project was kicked off in 2021.

Rationale:
In the context of decarbonisation and ongoing transformation of power systems towards net-zero, network capacity and flexibility have been identified as key challenge to the integration of high levels of energy coming from renewable sources such as wind or solar. This brings substantial challenges to the secure operation of the power system.

A key challenge is managing grid congestion in a cost-effective and efficient manner and this can be difficult as development of new transmission assets are normally faced with concerns from the general public.

An emerging solution is the use of Dynamic Power Flow Control (PFC) technology, referenced earlier in this report. This technology assists in dynamically controlling power flows on the system to alleviate overloads and mitigate congestion. It is anticipated that the co-ordinated control of multiple PFC devices strategically located throughout the power system will maximise use of existing infrastructure, aid in the management of network congestion and contribute to the integration of increased levels of renewable generation in real time.

To maximise the benefits offered by this technology, new tools are required to support real time operation and day-ahead operational planning. Such control and scheduling capabilities are not currently available in any control room in the world and the open source outcomes of this project will aim to bridge that gap.

Impact:
The use of Power Flow Control (PFC) devices on the transmission system is key to delivering on the 2030 targets.

Integrating a large number of power flow control devices into a power system can provide significant benefits in terms of controlling power flow on grids, minimising congestion, and deferring investment in new transmission assets. To get the maximum benefit offered by these devices power flow analysis tools are required to support real time operation and day ahead operational planning processes.

The development of software tools and expertise to allow co-ordinated control of PFC devices will enable the control centres to optimise the use of this technology to maximise the amount of renewable energy that can be transported on the grid.

The main operational benefits derived from this project are:

- Enhanced Situational Awareness; and
- Device Optimization Decision Support Tool.

Future Potential:

The outcomes of this project will support enhanced operation of the all-island power system and will develop understanding of how to operate and manage the transmission systems with high levels of dynamic network control devices. The project will also develop expertise within EirGrid and SONI in a high growth area for power systems worldwide and will apply international class energy R&D. This will be carried out through close collaboration with Smart Wire Grid Europe, industry experts as well as through the demonstration of software tools which will be used to enhance situational awareness.

The proposed demonstration of optimally dispatched network assets will lay the groundwork to move the all-island power system toward more resilient and efficient operation. This project has the potential to improve the efficiency of the grid through supporting a reduction in generation constraints, transmission outage management, enhancing reliability and decreasing the costs of connecting renewable and demand customers.

A paper describing the objective and preliminary results of this project has been submitted and accepted for presentation at the CIGRE Paris session 2022.

3.5 Automation

Automating key processes in EirGrid and SONI is increasingly important and has the potential for significant efficiencies in how we operate. This will enable more in-depth studies and faster turnaround times. Delivering on these efficiencies is vital for EirGrid and SONI as we operate in an increasingly challenging environment with a more complex grid. This work links closely with the Digital and Data strategies outlined earlier in this report.

Geographic Map Creation and Data Visualisation Framework

Scope

The new tool for generating transmission system maps will provide more consistent and detailed maps of the system, while also making the mapping process more efficient for the yearly maps that are required to be provided by EirGrid and SONI.

Rationale

Transmission system maps are put together each year to show upcoming projects / changes planned for the transmission system in the coming years. This was previously done using MS Visio. A new method was required to make the process more efficient as numerous maps have to be generated each year and this is quite time consuming when manually doing this using Visio. A number of different mapping tools were looked at and scored against each other on aspects such as mapping functionality, pricing, and ease of use. In the end, through in-depth comparison and analysis, Tableau was decided as the software to use for these maps.

Impact

Company time and resources are saved due to the increased speed of making maps as Tableau is quicker than manually editing a map using shapes in MS Visio. More detailed maps of a better quality overall will be generated in the future.

Future Potential

As further familiarisation with the mapping tool develops, more intricate maps can hopefully be generated depending on the need. More importantly, develop scripts and methods of automation to further improve the speed and design of the maps themselves.

Automation of N-1 and N-1-1 Study

Scope:

To automate the demand opportunities study using Python coding to reduce the repetitive tasks done manually using PSS/E software and improve the time and efficiency in performing the study.

Rationale:

The demand opportunities study is an important study in the Ten-Year Transmission Forecast Statement (TYTFS). This study reflects the amount of demand opportunities available at the defined areas on the all-Island power system. Performing this study manually in PSS/E takes more time and involves lot of repetitive works. Therefore, the study was automated using Python coding along with PSS/E, NADA and LAMDA tools to perform the N-1 and N-1-1 analysis for calculating the increased demand in the all-Island transmission system.

Impact:

Reduced time taken for completing the study compared to doing it manually, increased productivity and avoids human errors. This tool gives more accurate results compared to doing it manually as it involves LAMDA for performing the N-1 and N-1-1 analysis.

Future Potential:

This automated tool can be used for future TYTFS analyses and for other documents which involves N-1 and N-1-1 type of studies. Potentials can be extended for using this for other RMS software tools such as Digsilent PowerFactory.

Generator portfolio optimization based on system constraints using OPF

Scope:
In several projects a new innovative scenario-based methodology was employed to determine the optimal connection locations for new generation sources. This methodology was implemented as a module in the LAMDA scenario planning programme used in EirGrid and SONI.

The technique used a 2-step process where first unconstrained schedules (schedules that don't consider grid constraints) are applied to the system. These are typically 8760-hour schedules (a full year). Following this Optimal Power Flow (OPF) techniques allow the automatic rescheduling of generation so that grid constraints are eliminated or minimized. By looking at the difference in how individual generators are scheduled between the grid unconstrained and grid constrained cases, it is possible to determine which generation portfolios are consistently being used more in the grid by the OPF (and therefore are in good locations, as they cause less grid violations), versus those that are consistently being dispatched down (and are therefore in bad locations, as they need to be dispatched down to avoid grid violations).

As such the technique allows a fair comparison between generation locations based on generators capability to provide power without resulting in adverse violations in a highly efficient fashion. Some examples of where this was used was:

1. Security of Supply studies: It was used to show promising locations for new generation;
2. Wind portfolio optimisation in Shaping Our Electricity Future: It was used to aid in the choosing of an allowable 600 of 800 MW of non-RESS market generation (all RESS market wind generation was assumed to have been built); and
3. Optimal connection locations for offshore wind: It was used here to determine preferable locations of connection to the mainland grid for offshore grid assets.

Rationale:
Increasingly EirGrid and SONI are faced with complex decisions to make regarding the locations of new generation. Traditionally this work has been done in a very slow manner manually, and often drawing on very limited cases as a result. This is severely limiting in terms of the conclusions that can be drawn. The outlined approach is a clear, scientific, and efficient technique that makes extensive use of automation to highlight deficiencies in the grid, and propose satisfactory solutions, based on massive amounts of data creation and parsing,

Impact:
This formed a key set of results across 3 critical projects as previously outlined in the company. This methodology is readily applicable again for future analyses across the company.

Future Potential:

The company is increasingly having to make complex decisions on optimal locations for generation into future. Similarly, most system wide analyses in the company need to look at the how best that generation can be used to supply the necessary power to the grid while minimizing the impacts on the grid. This tool is a valuable tool in all such future analysis.

Migration of Adequacy Studies for GCS from AdCal to PLEXOS Software

Scope:
To migrate the Generation Capacity Statement (GCS) adequacy studies to PLEXOS software using a Monte Carlo probability approach. This should also be incorporated in the software for the capacity market auctions.

Rationale:
Currently, adequacy studies for the Generation Capacity Statement are carried out using a convolution probability approach with the purpose-built AdCal software. This methodology has limitations, particularly for capacity with restricted run-hours, etc. A new approach has been developed by the ERAA team (European Resource Adequacy Assessment) at ENTSO-E, using Monte Carlo probability to assess adequacy with PLEXOS software. EirGrid and SONI have been heavily involved in this innovative development from its inception. It is now proposed to investigate migrating the GCS studies using this methodology to PLEXOS, in conjunction with agreement from the regulatory authorities.

With this new approach, we can enhance our modelling capabilities to more accurately capture the benefits and limitations of new sources of capacity, e.g. batteries, demand side units and intermittent renewable sources of generation. Fundamentally, AdCal was not designed for this level of detail, and so it was required to innovate to model these energy-limited technologies more accurately. Similar to ENTSO-E studies, we can avail of 35+ years of climate data and up to 20 or more forced outage patterns to give a wide spread of varied modelling scenarios.

Initial assessments for the transition to PLEXOS have previously been carried out, and this successful trial gave confidence in employing the strategy to deal with the current, urgent security of supply (SOS) requirements. Following on from GCS2021-2030, a large amount of security of supply scenarios were carried out in PLEXOS to aid in the development of a strategy to address the adequacy issues highlighted in the GCS2021 report.

As PLEXOS is commercially available and widely used, it will make our studies more transparent. This project will likely take a number of years, and it will be necessary to carry out the GCS studies using both formats for these overlap years – to demonstrate that the new methodology is equivalent to the old. The feasibility and results will need to be assessed and discussed amongst experts from across the company, and engagement with regulatory authorities will be required, particularly if methodology changes are needed. This body of work will also lay the foundations for a future project to coordinate adequacy assessment and market requirements into an overall capacity requirement process.

Impact:
By moving to an ERAA-type methodology, we will be adhering to the EU/ACER-approved methodology. This is an important step when seeking State-Aid clearance for our capacity market.

Future Potential:

With more renewable energy coming onstream over the next decades, it is vital to model appropriately its contribution to overall adequacy.

PLEXOS is a growing, commercial software tool, e.g. recent developments incorporate the modelling of a Hydrogen market (using RES that would otherwise be dumped/dispatched down).

Forms basis for a more extensive process to coordinate adequacy assessment into an overall capacity requirement process with further integration with capacity market modelling.

3.6 TSO / DSO Joint Work Programmes

The ongoing TSO / DSO joint work programmes provide significant opportunities for innovation in the coming years. In 2021, this has mostly focussed on knowledge sharing between ESB Networks, NIE Networks, EirGrid and SONI. The knowledge sharing initiatives completed during 2021 are listed below:

1. TSO to share Control Centre of the Future progress / findings. DSO to share its future tools analysis as relates to provision of data / support to TSO;
2. TSO to present to DSO on Look Ahead Stability Assessment Tool;
3. TSO to present to DSO on Voltage Trajectory Tool;
4. DSO to document impacts of fast response battery storage on distribution systems and workshop findings with TSO to develop common understanding and agree next steps;
5. Workshop on streamlining telecommunications for distributed connected resources; and
6. Ongoing sharing of innovation as it relates to the Network and the Control Centre.

Future Potential

In October 2021, a consultation on a Multi-Year Plan for joint TSO-DSO projects between EirGrid and ESB Networks was published. This report can be found on our website[7], and details many projects that will require innovation. A comparable plan is currently being revised for the joint TSO-DSO projects between SONI and NIE Networks.

3.7 Multi-Year Innovation Plan

Shaping our Electricity Future has outlined a roadmap of innovation required by EirGrid and SONI to deliver on our future ambition. This is captured both in the future potential of the projects throughout this report, as well as the new initiatives identified in the Shaping our Electricity Future Roadmap[8].

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[7] https://www.eirgridgroup.com/site-files/library/EirGrid/DSO-TSO-Joint-Incentive-Multi-Year-Plan-Consultation-Paper.pdf

[8] https://www.eirgridgroup.com/site-files/library/EirGrid/Shaping_Our_Electricity_Future_Roadmap.pdf
https://www.soni.ltd.uk/media/documents/Shaping_Our_Electricity_Future_Roadmap.pdf

Proposed New Strategic Innovation Programmes

This section of the report documents two additional programmes of work not covered under the current price control. These are both critical programmes that EirGrid and SONI believe we need to progress now in order to position ourselves to achieve our future ambition effectively. As such, EirGrid and SONI are proposing that the uncertainty mechanism outlined in the price control is utilised to secure additional funding for these two projects.

4.1 Consultation Questions

Please visit https://consult.eirgrid.ie/ or https://consult.soni.ltd.uk/ to respond to consultation questions on the projects outlined in this section of the report by the 16th of March 2022.

4.2 Hydrogen Strategy

Introduction & Context

Hydrogen is enjoying a period of renewed attention in Europe and around the world. Yet, hydrogen currently represents a modest fraction of the global and EU energy mix and is still largely produced from fossil fuels – notably natural gas and coal – resulting in the release of 70 to 100 million tonnes of CO2 annually in the EU. For hydrogen to contribute to climate neutrality its production needs to expand to a much larger scale, become fully decarbonised and find a cost-effective place in the electricity system.

Ireland and Northern Ireland have one of the best wind resources in Europe which can provide enough energy to meet our local needs as well as potential for export. However, with increasing levels of renewable electricity we would expect to see increasing levels of constraint and curtailment. The production of hydrogen through electrolysis is an area that provides significant opportunity. The synergies of reducing renewable energy curtailment, providing alternative energy sources for transport and possibly heat, as well as decarbonising the gas network all point to hydrogen as being a real opportunity for the integration of energy systems. In order for Ireland and Northern Ireland to address the challenges associated with decarbonising our entire energy system, it is essential that we examine the role that Green Hydrogen can play. Green hydrogen is hydrogen that is generated entirely by renewable energy such as solar and wind. A coordinated strategy will ensure that this continues to be an important area of research focus, enabling increased capacity to be developed and maintained to support the decarbonisation of our energy future.

Ireland's Climate Action Plan 2021 (CAP21) established an ambitious framework for growth in renewable electricity, with an 80% target for renewables for 2030, including an increased target of up to 5 Gigawatts of offshore wind energy. Ireland's 2030 target is to reduce emissions by 51% as against 2018. The 2050 target is to reach net zero. In CAP21, Green hydrogen has been identified as having the potential to support decarbonisation across several sectors, and in particular in high-temperature heat for industry and in electricity generation. Northern Ireland has launched an ambitious new energy strategy in 2022 - The Path to Net Zero Energy strategy, that includes plans to place hydrogen as a key energy source for the future. Hydrogen production is already underway on the island of Ireland that will significantly increase the amount of hydrogen produced over the next five years. There are many companies that are examining the potential for large-scale hydrogen in Ireland and Northern Ireland and showing interest in installing electrolysers. In order to develop a Green hydrogen roadmap for the all-island power system, a clear strategy needs to be developed by EirGrid and SONI, considering potential electrolyser location for green hydrogen production over the years and their impact on the all-island power system. With the right planning system and a strong electricity grid we can deliver the 2030 electricity targets in the Ireland Climate Action Plan and Northern Ireland Energy Strategy and furthermore ensure we are on the correct pathway to net carbon zero emissions by 2050.

Progress to Date

EirGrid and SONI have been building up our knowledge base by actively participating in the following ongoing Hydrogen initiatives:

- CIGRE C1.48 - Role of green hydrogen in energy transition: opportunities and challenges from technical and economic perspectives. This working group commenced in 2021; and
- HyLIGHT – This is an all-island research project, with academia, industry, and state bodies to look at the islands green hydrogen transition. This research project commenced in 2021.

Identification of Need

The Climate Action and Low Carbon Development (Amendment) Bill 2021 will support Ireland's transition to Net Zero and achieve a climate neutral economy by no later than 2050. Huge reductions are required in most sectors and It is universally accepted that electricity has a critical role to play in tackling climate change. The EirGrid and SONI corporate strategies are shaped by climate change and the need for a secure transition of the electricity sector to low-carbon, renewable energy.

Ireland's Climate Action Plan 2021 renewables target intended to meet up to 80% of electricity demand from renewable power by 2030, to reduce emissions by 51% as against 2018 and, the 2050 target is to reach net-zero. To meet the required level of emissions reduction by

2030, Government will carry out a work programme to identify a route to deliver 1-3 TWh of zero-emissions gas (including green hydrogen) by 2030.

Northern Ireland has launched an ambitious new energy strategy that includes plans to place hydrogen as a key energy source for the future. Energy Strategy - Path to Net Zero Energy - Action Plan published January 2022, follows the publication of The Path to Net Zero Energy, which outlined a roadmap to deliver a 56 per cent reduction in our energy-related emissions by 2030 and a pathway to deliver the 2050 vision of net-zero carbon and affordable energy. As part of the plan, a greater focus on hydrogen as a renewable energy source and Northern Ireland is ambitious to become the world leader in the new hydrogen economy by playing to its strengths.

Green hydrogen will play an important role in the decarbonisation of the economy. Our future energy needs will be met increasingly by renewable electricity; however, some energy end uses are hard to electrify via the grid or with batteries, especially in transport but also in other sectors. In many sectors, direct electrification is, and will remain, technologically challenging or uneconomical, even at very high CO2 prices.

Hydrogen represents a possible overall solution for long-term, carbon-free seasonal storage. While batteries, super-capacitors and compressed air can also support balancing, they lack either the power capacity or the storage timespan needed to address seasonal imbalances. As we transition towards net zero emissions, these secondary fuel requirements will need to be reviewed and hydrogen could play a key role.

Finally EirGrid and SONI have been approached by a large number of developers seeking to connect electrolysers to the transmission system in the next several years and we need to be ready for these installations.

Option Appraisal

Option 1: Act as an observer in the Industry

Expectation: This would involve EirGrid and SONI gathering knowledge through various industry fora such as participating in the different hydrogen initiatives in the industry, summarise the current hydrogen industry progress.

Option 2: Internal competency development with adding new resources which can bring a new set of skills (e.g. Hydrogen/ electrolyser)

Expectation: This would involve new resources being retained to specifically build knowledge and experience of power-to-X technologies, energy markets, such as power and ancillary service markets, new modelling tools, simulation schemes for P2X projects.

Option 3: Hire an external consultant or consultancy to perform the study, drive the direction, identify the needs and way forward.

Expectation: Hiring an external consultancy service who have significant experience in the green hydrogen area to deliver a clear vision considering the different aspects like electrolysis for hydrogen production, location, and impact on the all-island power system. This would ensure we have a readiness plan for when electrolysers seek to connect to the all-island power system e.g. Grid Code changes, Trading & Settlement Code changes, etc.

Option 4: Funding/ Collaborate for a Hydrogen research project with the research and academic institutes

Expectation: Funding/ Collaboration with research and academic institutions to design a clear vision, roadmap, and plan for the Green hydrogen Power system integration strategy for Ireland and Northern Ireland.

Delivery of Preferred Approach

Considering below four different delivery options,

- Option 1: Act as an observer in the Industry
- Option 2: Internal competency development with adding new resources which can bring a new set of skills (e.g. Hydrogen/ electrolyser)
- Option 3: Hire an external consultant or consultancy to perform the study, drive the direction, identify the needs and way forward.
- Option 4: Funding/ Collaborate for a Hydrogen research project with the University and Research Institute

Option 3 is the most suitable approach for delivery. Hiring a consultancy service can deliver a clear road map considering the techno-economic aspect of green hydrogen integration into the all-island power network. Selecting an expert service who has significant experience in this area can deliver a clear vision considering the different aspects like electrolysis for hydrogen production, location, and Impact on the all island power system. This will ensure we have a readiness plan in place for the wide scale deployment of electrolysers.

Proposed initiative

This initiative will examine the role of hydrogen in the all-island energy system as a whole and specifically its potential to enable deep energy system sector integration. The interaction of hydrogen with the all-island power systems stems from: the electricity required to produce hydrogen; and hydrogen-to-power applications, where hydrogen is used to produce electricity. In this initiative, we concentrate on the different aspect like electrolysis for hydrogen production, location, and impact on the all-island power system. This is to ensure a readiness plan is in place for hydrogen.

Electrolysers location and their impact

The location of electrolysers can be next to a generation site, next to a consumption site, or in any generic point of the meshed power grid.

The use of hydrogen as a fuel source for gas fired power stations has the potential to increase RES-E on the all-island power system. From a system operations point of view, provided there is no material change in the operation of the gas fired power stations due to the use of hydrogen, this development could be advantageous. Where material changes to the operation of the gas fired power stations are needed, the Technology Enablement workstream in the Operations Pathway to 2030 Program will support the development, testing and integration of new technologies onto the all-island power system. The use of hydrogen as a localised source of energy storage at wind and solar farm sites has potential benefits for both dispatch down and system security.

Hydrogen physical destination can be: Hydrogen consumed on its production site, Hydrogen transported to final consumer/storage, Hydrogen injected in a pipeline system gas grid; destination has also a commercial dimension: sold to final user, sold to a trader, sold on a commodity market.

Use cases configurations are the viable configuration of electricity source, electrolysers location and Hydrogen destination. The most relevant options are briefly discussed below, from the perspective of their impact on electricity grids.

On-site production & use

Until today, Hydrogen has long been a feedstock of oil refinery and petrochemical processes, with production on same site mainly through Steam Reforming of methane (SMR), a process integrated with the refining ones; this is labelled black (or grey) Hydrogen, with high CO2 emissions and no requirement for logistics. There is little trading nor transport of Hydrogen, therefore it is not a market commodity and regulation deals only about safety.

There is limited heavy industrial applications of these type in Ireland and Northern Ireland, therefore we consider that this use is very limited.

Off-grid electrolysers

Large and remote RES plants can convert their generation into Hydrogen and transport it (via ships or pipelines) to consumption areas, as an alternative to building new power lines, thus avoiding the impact on electric grids; in Ireland and Northern Ireland, the most relevant case is with off-shore wind farms. The viability of off-grid electrolysers depends on the economic comparison), but also on the destination of Hydrogen:

- Best business case is when Hydrogen can directly reach the final Hydrogen users;
- Intermediate business case is when Hydrogen reaches an entry point of a Hydrogen grid/storage system; and
- Worst business case, from a developer business case model due to losses in the conversion, is if Hydrogen is reconverted to electricity upon reaching a meshed electricity grid.

Only the latter case impacts on the electricity grid, in terms of new Gas-to-Power plants, but they will probably be a minority of cases, because reconversion means a loss of energetic efficiency.

Grid connected electrolysers

From previous considerations, it is likely that the majority of electrolysers will be of grid-connected type, even if located next to Hydrogen consumption centre or next to RES generation plant, both for higher flexibility of their operation (not constrained by local generation or local consumption patterns) and for the possibility to add revenue streams additional to selling Hydrogen (power grid services, H2 market arbitrage, system services, etc.).

Therefore, when this technology will be deployed and upscaled to the GW level, the electrolysers will have a significant impact on the power grid, deserving proper consideration in scenario building, modelling, grid planning as well as grid operation.

Assessment of projects and geographical specifies

The analysis of location options and use cases shows that, especially in the first stage of development, power-to-hydrogen projects must be assessed with an end-to-end approach, in economic terms, energetic terms, decarbonisation effect and cost-effectiveness vs other alternative solutions. Focusing only on a piece of the supply chain (for example one electrolyser plant per se) falls short of providing conclusion on its system impact and viability. Supporting or even incentivising a stand-alone part of the supply chain would be short-sighted and potentially far from optimal choice.

Each project and each geography/industrial configuration need a specific analysis, taking in due consideration RES characteristics, transport & storage options (existing/prospected infrastructures), Hydrogen destination features, as well as externalities (positive and negative) on adjacent sectors. This assessment, coupled with applicable energy policies in place, determines some areas as export-oriented, some as import-oriented, other areas as local cluster-oriented ("Hydrogen Valleys"), others as not suitable for Hydrogen ecosystem.

To summarise, the pre-determined conclusion cannot be made on the viability as well as the impact on the all island grid until the use case has been analysed in its entire framework and boundary conditions.

Impact of Power to Hydrogen on the All-Island power system

Modern electrolysers technology supports fast reaction time and ramping making it a possible candidate for fast frequency control while simultaneously working on a seasonal cycle. Scaling up electrolyser's plants from a few MWs to hundreds of MWs may require (depending on their location along the supply chain) a dedicated connection to high voltage transmission grid. Grid code compliance at plant level will be one of the key aspects to address. Provision of new flexible system services, such as congestion management or frequency response, is another aspect that needs to be examined as potential source of revenue stream for the plant owners while deferring or substituting investment in grid expansion.

Impact on Grid Operation

- Grid-connected electrolysers shall impact as an extra active load;
- Connection issues: location, capacity, grid reinforcements;
- Additional electric load to be managed (for the quota of power not generated on site), with consumption profile depending on the use case;
- Dynamic characteristics, interacting with the wider electric system, to be modelled and included in stability simulations, control & protection schemes;
- Possibility to provide system services: frequency and voltage support, demand response, flexibility provider, to be utilised by the Grid Operator according to the efficiency and cost-effectiveness compared to other flexibility means/services, mid and long-term storage, seasonal reserve, cross-sector energy balancing, to be utilised by the System Operator according to the efficiency and cost-effectiveness compared to other options, both within the electric system (hydro pumps, mechanical storage, compressed air, etc.) or in the surrounding energy sectors (heat & cool, thermal storage, water desalination, multi-fuels engines, etc.);
- Planning and scheduling of electrolysers asset for optimal dispatch of grid-connected hydrogen electrolysis systems operating under dynamic conditions; and
- Power to Hydrogen projects (end-to-end approach), shall impact on System Operation. For demand-driven Power to Hydrogen investments, the availability of a correspondent amount of RES, or at least the coordination of their growth with Power to Hydrogen time plans may be an issue, especially if the additionality principle is strictly applied.

Impact on Grid Planning
The challenges in grid operation and in system operation are dramatically reflected also in the grid planning and system development exercises.

Indeed, in the planning stage the complexity of a sector-integrated system is multiplied by the large uncertainty of most of its fundamental variables: RES capacity development and its intermittent generation pattern, load development between contrasting energy efficiency actions and electrification of other sectors, power-to hydrogen and – more broadly - Power-to-Product projects, impact on natural gas system, etc.. In particular, power-to-hydrogen represent one of the most impacting trend, due to its size and to the correspondent impact on natural gas system (H2 might substitute a quota or even all the natural gas flowing in today's pipes and users' devices).

This requires on one side the updating of scenario building framework, on the other side an important advancement in methodologies, modelling tools, simulation schemes for traditional grid planning, for adequacy resource assessment, and for resilience analysis. The first conceptual step is to identify if P2X initiatives must be included in the perimeter of energy projects to be assessed and how: external input to be forecasted or system resource to be planned in coordination with power & gas grids projects, in Transmission Development Plan for Ireland and Northern Ireland, Ten-Year Network Development Plan by ENTSO-E and Project of Common Interest process. In particular, the new planning paradigm under development, shall be substantially enlarged to include Power-to-Product.

EirGrid and SONI will also be required to work more closely with the Gas Transmission System Operators to ensure a whole system approach is adapted.

Impact on Market
The most important operational cost factors of hydrogen produced by electrolysers are electricity price and, load factor. For analysing operational cost different operational modes like spot operation mode, baseload operation mode, market-based operation mode, or any dedicated operation mode considering the offshore wind potential of Ireland, market suitability and time frame of development must be analysed and predicted when a hydrogen market and infrastructures will be in place.

Benefits
Ireland has committed to tackling climate change by reducing emissions to net zero by 2050. Overcoming this challenge will require a monumental shift throughout society, but solutions based on existing technologies are already available. Renewables such as wind and solar are the primary tools we have to decarbonise our power system. However, the variability of renewables doesn't pair well with our need for on-demand energy. A complementary technology is therefore required to act as a buffer between human demand and the energy

provided by nature. Green hydrogen is the leading candidate for addressing this, thereby unlocking the widespread adoption of renewables.

Northern Ireland is uniquely positioned in the United Kingdom (UK) and Europe to become a leader in hydrogen deployment and technology. Abundant, and in many cases untapped, onshore, and offshore renewable resources, modern gas and electricity networks, interconnection to both Ireland and Great Britain, a relatively small geographic area, availability of salt cavern storage, and an internationally recognised track record of engineering and manufacturing innovation give Northern Ireland a competitive edge to become the world leader in the new hydrogen economy.

Hydrogen is found in water and is the most plentiful element in the world – it is an energy intensive gas that can be used for transport, heat and power – whilst only emitting oxygen and water. It is for this reason that hydrogen is being considered as a legitimate option to make a significant contribution to decarbonising energy.

Hydrogen as a fuel is a reality in countries like the United States, Russia, China, France, and Germany. Ireland and Northern Ireland's ambitions on hydrogen are clearly articulated and a pathway to exploit the potential mapped out, the development of a hydrogen economy would provide real benefits in decarbonisation and energy security but also in economic growth, jobs and innovation for the region.

Risks & Mitigations

Considering different proposed options as below,

- Option 1: Act as an observer in the Industry
- Option 2: Internal competency development with adding new resources which can bring a new set of skills (e.g. Hydrogen/ electrolyser)
- Option 3: Hire an external consultant or consultancy to perform the study, drive the direction, identify the needs and way forward.
- Option 4: Funding/ Collaborate for a Hydrogen research project with the University and Research Institute

A detailed risks and potential mitigation analysis have been carried out and presented in Table- 1.2

Table 1.2: Potential risks and mitigation

Option	Risk	Probability	Impact	Mitigation
Option 1	There is a risk that we gain knowledge, however we do not have the required resources to	High	High	Connection of electrolysers are not allowed until such time that resources are available, to prevent

Option	Risk	Probability	Impact	Mitigation
	ensure we have fully thought through the integration of hydrogen with a readiness plan in place			uncoordinated installation of hundreds of MWs of electrolysers.
Option 2	There are challenges in identifying the appropriate skills in the recruitment for additional staff. Hydrogen is a new area for Ireland and Northern Ireland. It will take time to onboard new resources and for them to develop the appropriate capabilities.	Medium	Medium	We have experience in recruitment for targeted skill sets and will work with hiring managers to ensure we get the most effective people. The development of the strategy and readiness plan would need to be deferred until the appropriate resources are recruited, onboarded and their capability developed.
Option 3	The selected vendor cannot deliver the project within the expected times and costs	Low	High	EirGrid and SONI have significant experience in service procurement from the leading reputed consultancy organisation. EirGrid and SONI are obliged to procure these services through a public tendering exercise and has frameworks in place for the delivery of this type of service. EirGrid and SONI will create a realistic and achievable project plan that includes the time need to complete the project milestones. EirGrid and SONI will validate consultants' skills, experiences, references, and subject capability before selection.
Option 4	There is a risk that the research institutes may not have the appropriate research resources in place to commence this immediately. Furthermore, the resources are typically aligned with a PhD qualification. These timelines would not be aligned	High	High	Connection of electrolysers are not allowed until such time that resources are available, to prevent uncoordinated installation of hundreds of MWs of electrolysers

Option	Risk	Probability	Impact	Mitigation
	with electrolyser developers' expectations.			

4.3 Flexible Network Strategy

Introduction & Context

The Flexible Network Strategy is focused on the investigation and utilisation of flexible network technologies to maximise the use of the transmission grid while minimising the requirement for new network build and includes the facilitation of trials to accelerate the widespread integration of suitable flexible network technology.

Two immediate technologies have been identified in Shaping our Electricity Future. These are Dynamic Line Ratings (DLR) and Distributed Power Flow Controllers (DPFC) and are crucial for Ireland and Northern Ireland to achieve their respective 2030 climate action targets.

- There is a limit to the power which can flow through transmission circuits and this is based on a static rating, which changes based on the season. Generally, the colder it is the more power which can be allowed to flow. DLR installations enable the usage of real-time thermal loading limits determined from the live environmental conditions. Research shows that on average you can achieve 30% more capacity along circuits; and
- Power along circuits generally flows along the path of least resistance and this can cause congestion in certain parts of the network. DPFC allows for control over power flows along circuits to be exerted.

The aim of this proposal is to:

- Over the next 18 months to fully investigate and scope out what is required for the wide scale roll out of these technologies to support the respective 2030 objectives. This detailed scope, once completed, will then be provided to the Regulatory Authorities to seek the required resources to start the wider scale deployment of same.
- To support the detailed scope, we will produce a cost benefit analysis for the implementation of the Flexible Network Strategy.
- To support the scope, we will develop a roll-out strategy & identification of candidate circuits for the integration of flexible network technologies in Ireland and Northern Ireland.
- Lead New Trials & Support Existing Trials:
  - Progress with a demonstration project in Ireland for DLR in 2022, in conjunction with ESB Networks.
  - Investigate a demonstration project in Northern Ireland for DLR, in conjunction with NIE Networks.

    - Progress DPFC demonstration project & investigations for both Ireland and Northern Ireland.
    - Trial to develop optimal operation of multiple DLR applications and DPFC devices for both Ireland and Northern Ireland.
- To support the detail scope to develop a readiness plan to support a pathway for DLR/DPFC to successfully become business as usual technologies. This includes items such as integrating the devices to control room tools, communications with devices, cyber security, etc.

Progress to Date

DLR and DPFC were both highlighted in the Shaping our Electricity Future (SOEF) Technical Report as solutions to network congestion issues found in weaker areas of the grid and areas with increased generation and limited transmission capacity.

A set of both DLR and DPFC installations were included in SOEF Roadmap as candidate reinforcements across both jurisdictions to support the achievement of our RES-E targets. These technologies were also key solutions within the "Technology Led Approach" in the SOEF Technical Report. DPFC was noted as having value in meshed transmission network to route power away from congested network while DLR was considered to have value in boosting transmission capacity and both in effect were considered to also reduce the dispatch-down of renewable generation.

Following the SOEF reports, the Flexible Network Strategy is a requirement to provide a platform for the implementation of these solutions.

Identification of Need

Flexible network technologies such as DLR & DPFC maximise the utilisation of existing assets, thus limiting network congestion. This may allow for the deferment of infrastructure developments for which delivery may be challenging and also support reduced dispatch down for variable renewable (VRES) generation.

Both maximising usage of existing assets and enabling fuller output of VRES generation will be valuable in to reach our 2030 RES-E targets.

Option Appraisal

There are four options considered, with the context of our 2030 objectives:

1. Do Nothing
2. Build Significantly More Grid Infrastructure, in addition to that identified by SOEF
3. Trialling of Flexible Network Technology
4. Detailed scoping and development of a readiness plan for widescale deployment of Flexible Network Strategy

Option 1: Do Nothing

- With VRES generation progressively increasing as we head to 2030, curtailment and network congestion is anticipated to increase- constraint costs would be likely to increase.

Option 2: Build Significantly More Grid Infrastructure, in addition to that identified by SOEF

- SOEF proposes a large number of new grid infrastructure projects and this is supplemented with flexible network technologies. In the SOEF technical report it was highlighted that significant challenges exist to deliver large scale reinforcements by 2030 reactively (i.e. over and above that proposed in SOEF) which pose a risk for achieving our RES-E targets.

Option 3: Trialling of Flexible Network Technology

Reduce scope of FNS to focus on trialling DLR and DPFC technology:

- This would involve progressing with existing trials and seeking to commence trials of both technologies in both Ireland and Northern Ireland.
- This option would not look at developing a full readiness plan. This will mean we are at significant risk of these devices not being ready to be deployed at a wide scale to help us achieve our 2030 targets.

Option 4: Detailed scoping and development of a readiness plan for widescale deployment of Flexible Network Strategy (Preferred Option)

- Over the next 18 months to fully investigate and scope out what is required for the wide scale roll out of these technologies to support the respective 2030 objectives. This detailed scope, once completed, will then be provided to the Regulatory Authorities to seek the required resources to start the wider scale deployment of same.
- This would involve progressing with existing trials and seeking to commence trials of both technologies in both Ireland and Northern Ireland.
- The full scoping would lead to a readiness plan being developed which would result in the benefit of reducing grid constraint costs relative to anticipated outcome from the "Do Nothing" and "Trialling of Flexible Network Technology" options. It would also support us in meeting our respective 2030 targets

Proposed initiative

The proposed initiative is to carry out a detailed scoping for the full implementation of the Flexible Network Strategy. This is to build and expand on the initial analysis that has been carried out in SOEF and ultimately have a readiness plan for the wider scale deployment of DLR and DPFC integrated onto the system and part of our "technology toolbox".

- The benefit of applying these technologies, in terms of savings in transmission constraints, needs to be defined.

- Working collaboratively with the business requirements and proposed operational model, develop a suite of functional / non-functional IT requirements for the implementation of the Flexible Network Technology Strategy.
- Develop the architectural design of the IT end-to-end system to support the integration of the devices/ technologies and enable the appropriate monitoring, control, and optimisation of the use of the technologies in line with the business requirements.
- Develop options for the data exchange between flexible network technology field devices and the operational IT systems and consider from a security / networking / hardware/ telecom perspective.
- Develop options and plan for integration into operational IT systems within the control room environment inclusive of integration into existing systems (EMS) and investigation into new/ enhanced functionality required to optimise operation of the devices (inclusive of consideration of cyber security, networking, data, interfaces and integration). This may include the requirement to procure new applications/ solutions.
- Develop cost / time / effort profile for integration of these technologies to the operational IT systems in line with the projected rollout of devices/ technologies.
- Develop impact assessment and cost /time /effort profile for downstream systems/ applications changes as a consequence of changes to the operation of the power system.
- The cost benefit analysis and the modelling of DLR/DPFC integration will need to be validated through peer reviewed assessments by an independent consultant, leading to a higher confidence understanding of the value these technologies will provide.
- The development of a readiness plan for the wide scale deployment of flexible network technologies and for these to become business as usual solutions.
- Identification of candidate circuits and determination of the requirements for successful integration into control systems.
- Analysis on the co-optimisation of DLR and DPFC to maximise utilisation of existing transmission assets & review of existing DPFC implementations.
- Accelerate adoption and implementation of flexible technologies to business as usual usage.
- Continuously carry out Flexible Network technology horizon scans, report learnings from other TSOs and collaboration with research hubs, to capture emerging technologies such as DLR, DPFC, Virtual Power Lines etc; and
- Extensive engagement and partnership with the Transmission Asset Owners (ESB Networks and NIE Networks) in both Ireland and Northern Ireland.

Delivery of Preferred Approach

The preferred option is option 4. This section outlines the plan to deliver on the Flexible Network Strategy, details of this are set out below:

Cost Benefit Analysis

- Define the benefit:

    - Technical analysis to estimate the cost benefit of the use of flexible network technologies (DLR and DPFC) in terms of transmission constraints.
- Costing of control centre integration requirements
    - Cost estimate for Information Technology (IT) and control centre requirements associated with wide scale roll out of DLR and DPFC on the system. Includes requirements for integration with control centre tools such as the Energy Management System (EMS) to enable grid control operators to monitor and control the technologies, the Market Management System (MMS) to ensure these technologies are included in scheduling and dispatch to maximise their benefits and in Lookahead Security Assessment Tool (LSAT) to ensure dynamic stability of operating the power system with these devices and requirement for additional control centre/operational training and resources.
- Maintenance life cycle costs:
    - Develop TSO/TAO agreement on use of DLR and DPFC technologies on the transmission system.

<u>Develop Readiness Plan for DLR and DPFC</u>

- Determine processes for the Identification of candidate circuits:
    - Identification of candidate network locations may come based on internal analysis and network needs.
    - Consider if new installation or scaling/re-deployment of existing installation is required.
- Define capital approval process - how candidate circuits are brought through the Framework for Grid Development:
    - Candidate locations to be brought through the Framework for Grid Development Gateways.
- Define control centre integration requirements:
    - Define IT and control centre integration requirements to incorporate DLR and DPFC.
    - Set up IT workstreams to deliver on requirements.
- Engagement with the Transmission Asset Owners in Ireland and Northern Ireland.

<u>Live Demonstrations/Trials</u>

- Progress initial demonstration project of direct measurement DLR technology in conjunction with a transmission connected windfarm customer in Ireland in 2022.
- Investigate and progress DPFC demonstration project targeted for completion in Ireland in 2024/2025.
- Investigate trials for both DLR and DPFC in Northern Ireland, in conjunction with NIE Networks; and
- Trial to develop capability to operate the system with multiple DPFC devices and to optimise device settings to optimise system power flows:

- The initial DPFC demonstration project will allow for confidence to be built in the technology. As the technology becomes more mature, a live trial should be facilitated involving two or more interacting DPFC devices. It is likely that a new control centre tool may be required to facilitate this, to provide the control centre operator with advice on optimal settings for DPFC devices.

It is also important to note that the TAOs in Ireland and Northern Ireland also need to be appropriately resources to enable this vision for the wide scale deployment of flexible network technologies.

Benefits

Flexible network technologies, such as Dynamic Line Ratings and Distributed Power Flow Controllers, provide a means to reduce network congestion, act as an alternative to challenging network builds/uprate, provide operational flexibility, maximise utilisation of existing network assets, enable greater output from RES generation hubs and create potential economic/reliability benefits.

As power system generation moves towards greater volumes of VRES and progression continues to be made towards out 2030 targets and beyond, the anticipated value gained from flexible network technologies will continue to increase.

Risks & Mitigations

Risk	Probability	Impact	Mitigation
There is a risk of control centre integration and not realising the potential benefits of investments in flexible devices	Low	Medium	Defining control centre integration requirements and managing the required workstream is a key deliverable included in the project delivery plan
There is a risk of increasing grid constraint costs by not carrying out the Flexible Network Strategy	Medium	High	The development of the Flexible Network Strategy is targeted at addressing the risk of climbing constraints costs
EirGrid and SONI cannot secure the appropriate expertise to manage	Low	Medium	We have experience in recruitment for targeted skill sets and will work with hiring managers to ensure we get the most effective people.

the delivery of this initiative			
Costs of implementation of strategy are more significant than expected	Low	Low	Tasks within the strategy can be prioritised, to ensure maximum value output is delivered
The procurement exercise takes longer than expected leading to delays and additional costs for the project.	Low	Low	We will create a realistic and achievable project plan that includes the time needed to complete the procurement exercise.
The expected benefits from the changes are not achieved leading to wasted investment.	Low	Medium	Initial estimates for the definition of the benefit use cautious inputs, to limit overly optimistic expectations

Innovation Regulation Sandbox

As identified in our innovation & research strategy[1], EirGrid and SONI are conscious that current frameworks provide strictly defined process for new technologies. As we are now in a world of transformative change, these frameworks may unduly prevent innovation. Our Shaping Our Electricity Future roadmap[2] outlines a number of technologies which are crucial to us achieving at least 70% RES-E by 2030.

There are some mechanisms such as the Qualification Trial Process (QTP) for new System Service technologies, however EirGrid and SONI believe that there is a potential for customers to solve problems and that there is a need for an Innovation Trials Sandbox; facilitating innovation trials or bring to market new technologies, products, services, or business models. This proposal aims to secure mechanisms to eliminate barriers to trials of new technologies, products, and services in support of innovators, assess lower technology readiness level (TRL) solutions and quantify benefits so that we learn more about these before their wider deployment.

As EirGrid and SONI are regulated businesses, we would need to explore this concept with the regulatory authorities and will do so based on feedback received as part of this consultation.

5.1 Consultation Question

Please visit https://consult.eirgrid.ie/ or https://consult.soni.ltd.uk/ to respond to consultation questions on this section of the report by the 16th of March 2022.

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[1] https://www.eirgridgroup.com/site-files/library/EirGrid/EirGrid-Innovation-and-Research-Strategy-Report.pdf
[2] https://www.eirgridgroup.com/site-files/library/EirGrid/Shaping_Our_Electricity_Future_Roadmap.pdf

Consultation

Please visit https://consult.eirgrid.ie/ or https://consult.soni.ltd.uk/ to respond to consultation questions on the projects outlined in this section of the report by the 16th of March 2022.