ELECTRICITY
ASSOCIATION
OF IRELAND

Our Zero e-Mission Future

Decarbonising the Electricity Sector

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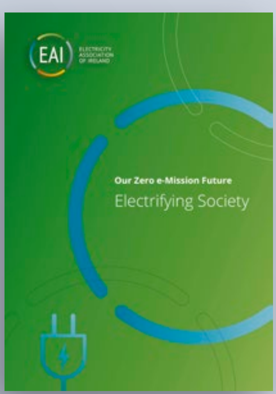
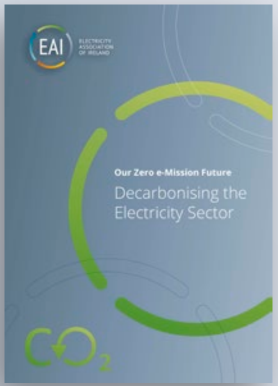
Contents

This report is part of a series of three reports from EAI. They are available at:
Our Zero e-Mission Future – Electricity Association Ireland





Foreword

The Electricity Association of Ireland (EAI) is the representative body for the electricity industry and gas retail sector operating within the Single Electricity Market (SEM) on the island of Ireland.

Our membership comprises utilities that represent over 90% of generation and retail business activities and 100% of distribution within the market. We believe that a decarbonised electricity system will decarbonise society in a cost-effective manner and move transport and heating away from fossil fuels. We are fully committed to leading this vital journey of transition and working with others to accelerate the rate of decarbonisation and electrification.

Electrifying our economy will help build a more comfortable and healthier living environment with less noise, better air quality and increased energy efficiency. We know that the energy transition of society will require genuine support from all stakeholders – from policymakers and regulators to consumers to ensure it happens. Our aim is to provide insights that are authoritative, evidence based and constructive.

In 2020, the Electricity Association of Ireland commissioned the MaREI SFI Research Centre for Energy, Climate and Marine research and innovation to investigate what the all-island electricity system needs to look like in 2030 on the way to fully decarbonised electricity generation. Uniquely they examined a quarter of a million hours of historical weather data to determine the extremes that our future weather-dependant electricity generation system will have to flex to.

The study found that moving to a Zero e-Mission Future post 2030 will require grid flexibility and different technological options, all of which come with implicit uncertainty, but share a requirement for early investment decisions, significant capital commitment and long lead times for construction.

Since the publication of our Zero e-Mission Future[1] in 2020, government ambition has increased significantly and with a little over five years to go to 2030, now is the time to turn our attention to achieving a post-2030 Zero e-Mission Future and ensure that the correct policy signals stimulate appropriate market incentives and the right investments for a cost-effective transition. The EAI has prepared several policy papers to outline the collective view of the electricity sector on achieving our post 2030 zero e-Mission Future.

1 Our Zero e-Mission Future – EA Ireland

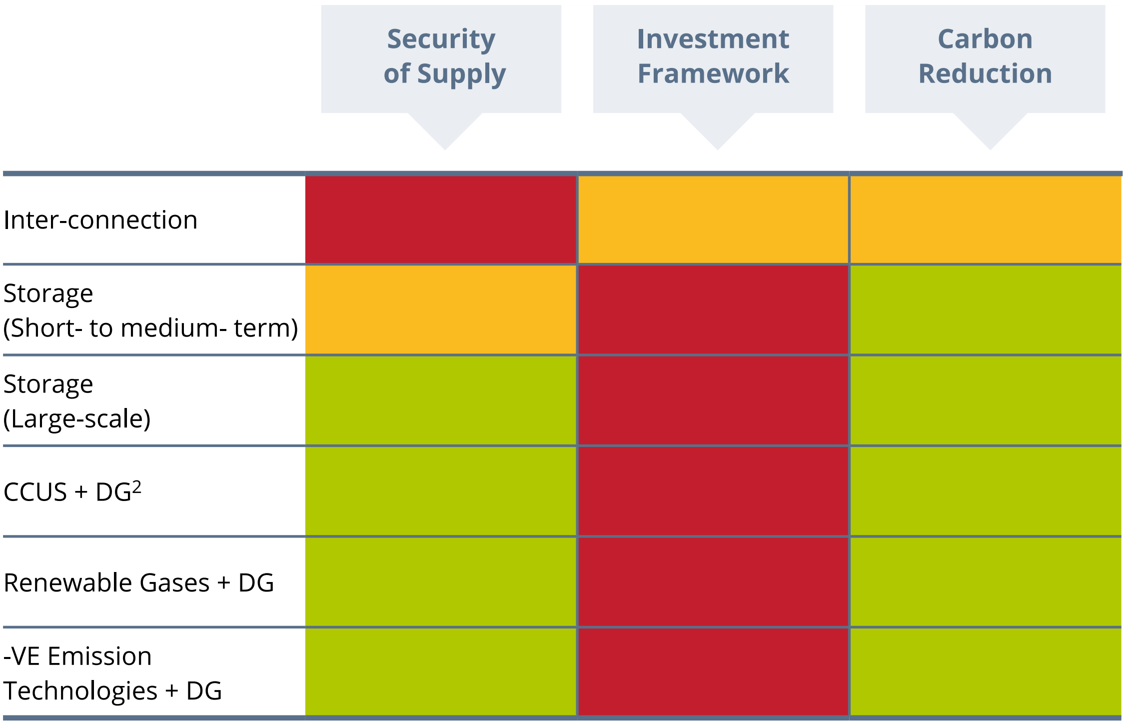
Executive Summary

The objective of this paper "Decarbonising the Electricity Sector" is to identify the actions we should take to ensure that we achieve a cost-effective transition to a decarbonised electricity sector.

The EAI is neutral in its approach to technology, and while there are a number of technology choices that offer further decarbonisation potential, it is not yet clear which option (or mix) is most appropriate for the all-island system.

What is clear is that the electricity sector will have to decarbonise in advance of society decarbonising and that the potential technology options all have implicit uncertainty. They share a requirement for significant capital commitment, long lead times for construction, decades-long operational lifetime and a need for investment decisions to be made well in advance of 2030.

As part of the EAI's contribution to the dialogue on the future pathways for the power system, the following report card on the maturity of post 2030 technologies in an Irish context are provided to assist in the development of policy that support the sector meeting its decarbonisation targets.



2 DG – Dispatchable Generation

The EAI makes the following policy recommendations with more detailed recommendations contained within the paper.

Early and significant investment in grid infrastructure

To remove constraints.

Plan for a steady stream of projects and auctions

Supported by policy and Government.

Accelerate the electrification of new loads,

Particularly in switching from high-carbon fossil fuel to maximise the benefit of renewable generation for emissions reduction.

Support renewables following smart electrification

To allow new loads to offset fossil fuel use and provide balancing services to the Grid.

Complete a cost benefit analysis of potential decarbonisation technology options

That fully cost the value of security of supply and carbon reduction to identify which technologies are best suited to the all-island power system.

Develop the required policy to support Investment in, and development of required decarbonisation technologies

Such as multi annual large-scale energy storage projects.

Assess the role of the State and State Agencies in the context of Procuring, operating, licensing and market participation of the technologies of the future.

Examine options to decarbonise dispatchable generation beyond 2030 to ensure investment and action in a timely manner.

Post-2030 Technologies

Table 1: Increased All-Island Climate Ambition

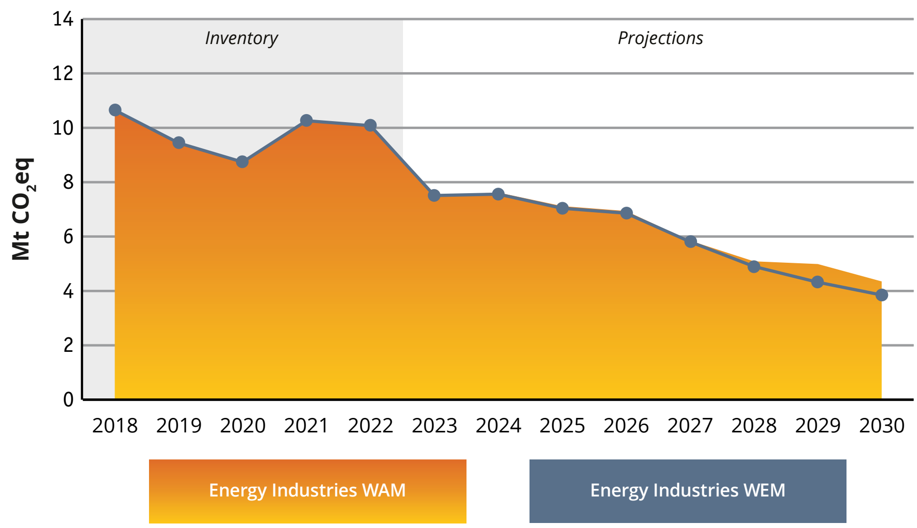
	MaREI All-Island Base Scenario 2030	All-Island Ambition (CAP ambition 2030 + Energy Strategy NI)	Difference
AI Demand	53.7 TWh	55.2 TWh [3]	+ 1.5TWh
CO_2	6.3 Mt CO_2eq	3 Mt CO_2eq	-3.3 Mt CO_2eq
Res Target	72%	80% {80% (ROI) 80%(NI) [4]}	+8%
Wind (On & Offshore)	11.634 GW	14 GW (5+9) [5]	+2.366 GW
Solar	3.317 GW	8 GW (1.5GW [6])	+4.683 GW
Gas	5.204 GW	7.2 GW (2GW new)	2 GW
Batteries	1.1 GW	0.903 [7]	-0.197 GW
Interconnection	2.2 GW		
DSU Capacity	0.75 GW	0.896 GW [8]	+.146 GW
Smart Movable Load	20%	20-30%	+0-10%
SNSP limit	95%	95-100%	+0-5%
VRE Curtailment	7%	7%	0%
EVs	1,000,000		0%
Heat Pumps	750,000		0%
Hydrogen		Green Hydrogen ion Production	
		Zero Emission gas fired generation from biomethane and hydrogen commencing by 2030	

Since the publication of our Zero e-Mission Future report in 2020 Government ambition has increased significantly (see table above).

3 EirGrid All-Island GCS 2022-2031 p64
4 Climate Change (Northern Ireland) Act 2022.
5 DECC Climate Action Plan 2023
6 EirGrid All-Island GCS 2022-2031 p50
7 EirGrid All-Island GCS 2022-2031 p49
8 EirGrid All-Island GCS 2022-2031 p48

In 2023, overall emissions from the Energy Industries sector declined by 21.6 % due to a reduction in fossil fuel usage and an increase in net imports from interconnectors[9]. Projections by the EPA[10] of greenhouse gas emissions indicate that emissions from the Energy Industries sector are to decrease by between 57 and 62 per cent over the period 2022 to 2030 to between 3.9 and 4.43Mt CO_2eq, which will not meet the 3Mt CO_2eq. 2030 target.

Figure 1: GHG Emission Projections to 2030 from the Energy Industries – EPA[11]



There are a number of technology choices that offer further decarbonisation potential and while it is not yet clear which option (or mix) is most appropriate for the all-island system, the decarbonisation of the electricity sector will have to happen in advance of Society decarbonising.

What is clear is that the technology options all have implicit uncertainty, they share a requirement for significant capital commitment, long lead times for construction, decades-long operational lifetime and a need for investment decisions to be made well in advance of 2030.

The EAI is neutral in its approach to technology in line with the recommendations of the Climate Advisory council in 2020[12] which stated:

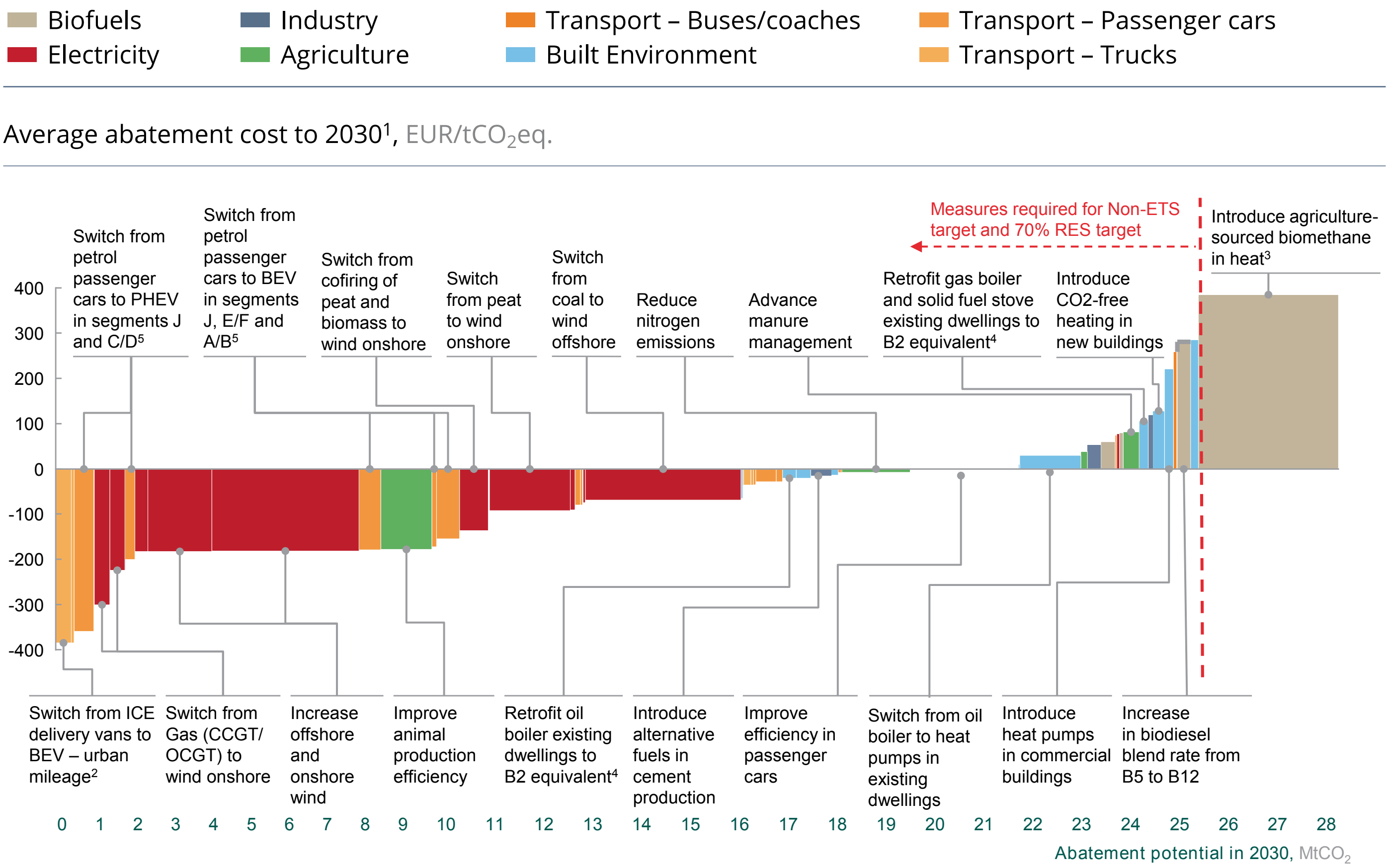
"A technology-neutral approach would avoid policy bias against alternative, cost-effective mitigation options, particularly in the context of deep decarbonisation and growing electricity demand, for example biomethane coupled with carbon capture and storage."

Determining what is a cost-effective approach has been supported previously by developing Marginal abatement curves[13] such as the curve below developed by the then DCCAE in 2019.

9 EPA GHG Projections Report-2022-2050
10 EPA GHG energy
11 EPA GHG-Projections-Report-2022-2050
12 Climate Change Advisory Council Annual report 2020
13 DCCAE 2019 Ireland's 2019-2030 Marginal abatement Cost Curve

Post 2030 Technologies (continued)

Figure 2: Ireland's 2019-2030 Marginal Abatement Curve, DCCAE (2019)



Note: The horizontal axis shows the abatement potential of the technology switches. The vertical axis displays the average abatement cost as EUR/tCO_2 for each switch. The CO_2 price of the EU ETS is included in the cost of measures for industry and power and heat

1 Measures considered exclude LULUCF and biofuels use in energy/heat production. MACC does not include cost of enabling infrastructure (e.g., EV charging network, transmission and distribution upgrade). Agriculture measures are based on Teagasc Greenhouse Gas Working Group report "An Analysis of Abatement Potential of Greenhouse Gas Emissions in Irish Agriculture 2021-2030"; Total abatement includes abatement for growth in the analysed sectors

2 The switch to electric light commercial vehicles bring early TCO parity due to low weight vehicles doing long journeys

3 Biogas/biomethane abatement lever could displace emissions in both industry, buildings and power

4 B2 BER insulation equivalent: includes wall, roof and window insulation, excludes boiler upgrade

5 Vehicle classes include: A/B – mini, small cars; C/D – medium, large cars; E/F – executive, luxury cars; J – sport utility cars (including offroad vehicles)

More recent analysis by EirGrid also looked at potential pathways to post-2030[14] using the pan European model "Plexos" to align with the increased ambition of government policies and targets outlined above. Their analysis looked at:

- Renewables such as solar, onshore and offshore wind.
- Energy storage through pumped hydro, short-medium duration batteries and long-duration energy storage (LDES).
- Flexible thermal generation technology operating on natural gas, hydrogen and biomethane.
- Carbon capture and storage.
- Electricity interconnection between Ireland and Northern Ireland with Great Britain and continental Europe.
- Dispatchable gas generators capable of running wholly on hydrogen.

These technologies echo a recent government report[15] that stated that a balanced portfolio of long duration storage, interconnection, demand side and renewable ready gas turbines will be needed. The development of decarbonisation solutions will also be against a backdrop of change as back-up generation transforms from a 'high capacity – high volume' situation (fit for gas generators) to a 'high capacity – low volume' situation, which can also increasingly be managed by new carbon-free approaches[16].

Mindful of the fact that between one-third and half of the cumulative emissions reductions in the IEA's net zero scenarios stem from technologies that are in development but not yet commercially available today, a recent report by Google[17] on advanced Clean Electricity Technologies, has focused on five technologies that they believe could play a critical role in grid decarbonisation by 2030 and beyond. The chosen technologies were based on the criteria of:

- forecasted pricing,
- potential for cost declines,
- global scalability, and
- environmental considerations.

They believe these technologies demonstrate the clearest path to meeting the criteria above and overlap with findings from other leading researchers.

14 EirGrid Tomorrow's Energy Scenarios
15 DECC Energy Security in Ireland to 2030
16 EEA/ACER Flexibility solutions to support a decarbonised and secure EU electricity system Report 09/2023
17 Google The Corporate Role in Accelerating Advanced Clean Electricity Technologies, September 2023

Table 2: Technology Portfolio Google is Assessing to Achieve 24/7 Carbon Free Energy (CFE) Goal

Firm generation resources			Clean peaker resources	
1 Next-generation geothermal	2 Carbon capture and storage	3 Advanced nuclear	4 Hydrogen	5 Long-duration energy storage

As part of the EAI's contribution to the dialogue on the future pathways for the power system, the following report cards on the maturity of post 2030 technologies in an Irish context are provided to assist in the development of policy that support the sector meeting its decarbonisation targets.

Further Interconnection

Security of Supply	Red	▸ Important that Ireland can export excess renewable energy and import power in scarcity scenarios. ▸ No Security of supply provided at times of stress. ▸ May be a net importer until 2040s.
Investment Framework	Amber	▸ Need to prevent negative interaction with incentives for demand side participation customer bills and investment in SEM. ▸ Reduces the business case for indigenous generation. ▸ Transparent and effective trading platform needed for multiple interconnectors to improve price formation. ▸ Requires a robust positive CBA informed by power system modelling (to include cost of Dispatch down and potential loop flows) to determine future interconnection need, cost, timeline and impact on SEM investment.
Carbon Reduction	Amber	▸ Can facilitate low carbon electricity supply if carbon Intensity can be verified. ▸ Can lead to dispatch down of renewables during times on importation.

Short- to Medium-Duration Storage

Security of Supply	(red)	▶ Positive contribution to security of supply but only over short periods.
Investment Market Signals	(amber)	▶ Cannot dispatch batteries as part of the energy system therefore Investment signals for storage not present. (Larger-scale battery installations (20 to 190 MWh) are providing short term grid balancing services). ▶ Locational signals important, firm access policy needs to evolve to determine when firm access can be established in high constraint areas to reduce dispatch down. ▶ A review of tariffs required. ▶ No Incentive for on-site and hybrid connections.
Carbon	(green)	▶ Reduces the need for peaker generation plants.

Carbon Capture and Storage + Dispatchable Generation

Security of Supply	(green)	▶ Will in tandem with dispatchable generation contribute to security of supply.
Investment Market Signals	(red)	▶ There is currently no existing business case for point source CCUS power generating sites. ▶ CAP 2023 sets an action to conduct a feasibility assessment on CCS in 2023 to announce a policy position in 2024. CCS is mentioned in terms of construction materials and point source capture at industrial and energy production sites as a third carbon budget measure beyond 2030.
Carbon Reduction	(green)	▶ Modelling by the European Commission shows that the EU will need to capture, use or store 300-640Mt of carbon dioxide every year by 2050 to meet climate neutrality goals. Ireland's share of this target is 5-10Mt. ▶ RED III[18] indicates that any future renewable electricity production from biomass sources (i.e., biomethane) needs to include BECCS (bioenergy with carbon capture and storage).

18 Renewable Energy Directive III

Post 2030 Technologies (continued)

Negative Emission Technologies + Dispatchable Generation

Security of Supply	(green)	▸ Will in tandem with dispatchable generation contribute to Security of supply.
Investment Market Signals	(red)	▸ There is currently no existing business case for point source CCUS power generating sites. ▸ European or national indemnity scheme required. ▸ Wholesale market to incentivise investment. ▸ Suits baseload plant not a 100 hr/yr plant. ▸ Policy and regulatory framework required.
Carbon Reduction	(green)	▸ Negative emissions could particularly help offset emissions from hard-to-abate sectors. ▸ 88 of the 90 scenarios in the IPCC SR1.5 report which have at least a 50% chance staying below 1.5 °C warming in 2100 rely on net negative emissions.

Renewable Gases (Hydrogen, biomethane) + Dispatchable Generation

Security of Supply	(green)	▸ Will in tandem with dispatchable generation contribute to security of supply. The Hydrogen Strategy commits to developing a roadmap to bring net-zero dispatchable power solutions to market by 2030 to support the delivery of a near net-zero power system by 2035.
Investment Framework	(red)	▸ Business models for delivery of renewable gas facilities are needed. ▸ MaREI's EirWind project estimates that hydrogen production costs of less than €150/MWh are possible in an integrated production system which couples a 500MW wind farm to a large-scale hydrogen production facility. The additional delivery costs result in a final cost to customers of €240-€270/MWh of hydrogen. ▸ No government targets for electrolysis, hydrogen powered generators, or hydrogen storage.
Carbon Reduction	(green)	▸ Pathway for thermal generation fleet to achieve zero carbon operation using hydrogen or hydrogen derivates such as ammonia or e-fuels.

The Impact of Weather Patterns on Technology Choice

As set out in "Our Zero e-Mission Future"[19] report, weather will have a significant impact on the type of technology Ireland will chose to provide Security of Supply and decarbonise the Irish electricity system.

Extended periods with low outside temperature as well as low production of wind and solar energy or "kalte Dunkelflaute" (German for "cold dark doldrums") are frequently seen, e.g. in Germany from 16 to 26 January 2017, with up to 90% of the generation coming from dispatchable power generators at peak demand. With higher electrification of final demand and high penetration of renewables in the power market, the "kalte Dunkelflaute" becomes an important security of supply test for an evolving energy system. Marei conducted an analysis of these weather patterns with over 250,000 hours of weather data (30 years) to examine how the all-island System operates in extremes.

Cradden et al examined the prolonged cold spells which were experienced across the island of Ireland in the winters of 2009–10 and 2010–11. This research found that while electricity demand was relatively high at these times, wind generation capacity factors were low, there was a high degree of variation within individual seasonal results, and they found that the most useful aspect was to identify the more unusual extreme events in a given season[20]. Typical extreme weather events are listed below and while these occurrences are infrequent, they profoundly impact the design of a robust and reliable electricity system, not only for the all-island system but for the wider north western European region as they tend to impact a wider geographic region which has knock on consequences for flows on interconnectors.

Table 3: Extreme Weather Events Based on Historical Data – Royal Society 2024

Stress events	Description	Frequency
Summer wind drought – frequent	One full day of very low wind speed in summer.	One or two per year
Summer wind drought – infrequent	Up to four weeks of very low wind speed in summer.	Once every 10 years
Winter wind drought	Up to a week of very low wind speed in winter.	Every few years

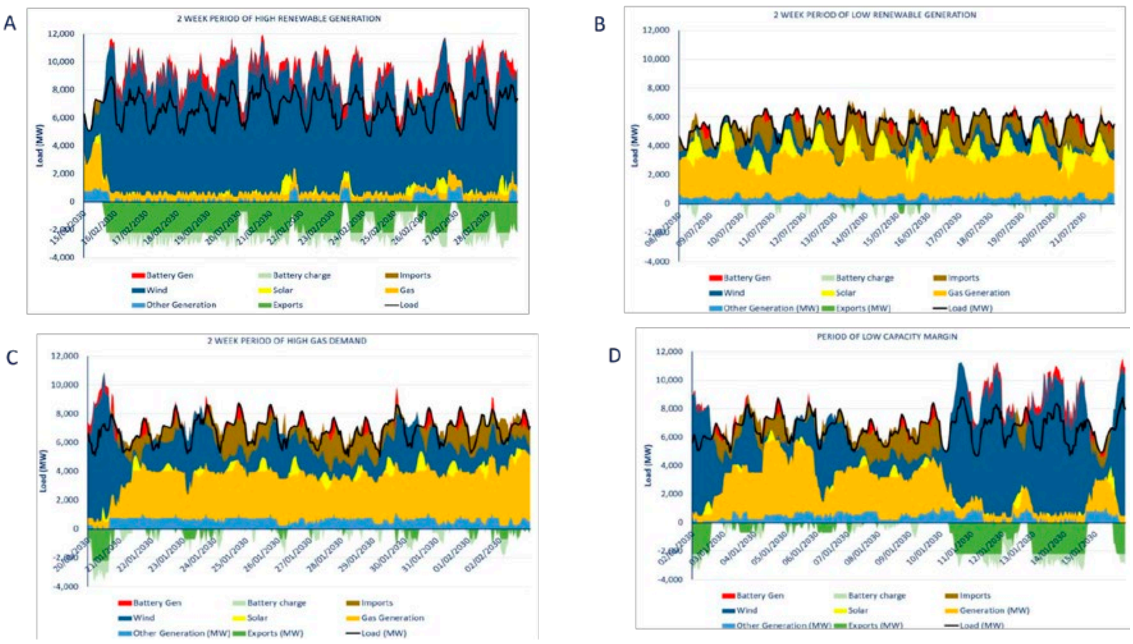
19 Our Zero e-Mission Future – EA Ireland
20 Cradden LC, McDermott F. A weather regime characterisation of Irish wind generation and electricity demand in winters 2009–11. Environmental Research Letters. 2018;13(5):054022.10.1088/1748-9326/aabd40

The Impact of Weather Patterns on Technology Choice (continued)

In the Marei analysis, 30 historical years of hourly European weather data was used to simulate the full system with a particular focus on 4 specific events all over 2-week periods: A) maximum generation of variable renewables. B) minimum generation of variable renewables. C) highest generation of dispatchable gas fleet and D) period with lowest capacity margin.

The analysis highlights how remarkably flexible the all-island system will have to be to deal with a wide and extreme variation in weather events. At times the system will produce more renewable generation (Pane A) than can be used, stored or exported, while it must also be resilient and reliable to deal with periods (Pane C) when gas, dispatchable generators and interconnectors will provide the bulk of weekly generation and demand side response units and batteries help on shorter timescales. There will also be short periods of system stress where all available dispatchable generation is called upon (Pane D) to ensure supply is met.

Figure 3: Weather Years Scenario: A) High Wind Period, B) Low Wind Period, C) High Gas Generation Period and D) Low-capacity Margin – MaREI 2020



Large-Scale Storage

A significant challenge with using electrical storage in conjunction with weather driven renewable generation is the scale required to store enough energy for a prolonged period with low weather availability.

Storage technologies such as batteries have many uses over short time scales and can provide important services to the grid, but current technologies cannot economically provide the scale of capacity to operate an electricity system on variable renewable generation alone. For example, if we consider the two-week window of low wind speeds in Pane C above, approximately 65 million Tesla Power walls (assuming 13.5kWh per unit) or 0.8775 TWh would be required to provide energy for this period.

In a recent report by the Royal Society[21] they concluded that the potential for wind and solar generation in GB exceeds projected future electricity demand but that it must be supported by large-scale storage or other forms of flexible supply when the sun doesn't shine, and the wind doesn't blow. If surplus wind and solar supply is harvested and stored, energy security is improved. They determined that the cost of large-scale storage compares favourably with the cost of low-carbon alternatives.

Large-scale electricity storage systems are characterised by:

- the size and cost of the storage facility,
- the cost and rate of converting energy to the form in which it is stored,
- the cost and rate at which stored energy is converted back to electricity, and
- the conversion efficiencies and leakage.

The Royal Society study reaches the conclusion that wind, and solar supply vary by large amounts over time scales of decades. In an electricity system largely supplied from those sources, there will therefore be a need to store large amounts of energy. The large-scale of the storage that will be needed in the net zero era must be considered when designing a decarbonised electricity system.

The results from this study, which modelled future GB demand (10 times the projected Irish demand) found a requirement to deliver a storage of between 76TWh and 85TWh or in an Irish scenario (10 times smaller) 7.6TWh to 8.5TWh . A recent ESB[22] report puts the quantum of Hydrogen storage at 6-10 TWh with an additional 4GW of offshore wind above current ambition to generate the volume of hydrogen in storage needed for stress events.

21 Royal Society Large-Scale Electricity Storage – Royal Society 2024
22 ESB Net Zero 2040 Pathway Report 2024

Large-Scale Storage

Security of Supply	[Green]	▶ If surplus wind and solar supply is harvested and stored, energy security is improved.
Investment Market Signals	[Red]	▶ Radical new investment framework needed to unlock development of multiple annual energy storage projects to include targets for large-scale renewable energy storage, accelerated licensing process and commercial incentives.
Carbon	[Green]	▶ An array of storage technologies at various durations, will be required to support the transformation of the electricity system as the level of renewable penetration increases.

As part of the EAI's contribution to the dialogue on the future pathways for the power system, the following report card on the maturity of post 2030 technologies in an Irish context are provided to assist in the development of policy that support the sector meeting its decarbonisation targets.

Table 4: EAI Report Card on Post-2030 Technologies

	Security of Supply	Investment Framework	Carbon Reduction
Inter-connection	[Red]	[Amber]	[Amber]
Storage (Short- to medium-term)	[Amber]	[Red]	[Green]
Storage (Large-scale)	[Green]	[Red]	[Green]
CCUS + DG[23]	[Green]	[Red]	[Green]
Renewable Gases + DG	[Green]	[Red]	[Green]
-VE Emission Technologies + DG	[Green]	[Red]	[Green]

23 DG – Dispatchable Generation

Investment Frameworks for Technologies Post-2030

Investors in low carbon flexible generation will be dependent on revenue streams over long asset lives. During this time prices, regulations and government policy will change in unpredictable ways.

Investors will have to take a view on the future cost of buying energy, the selling price, the optimum timing of sales, and the behaviour of competitors.

Finding effective pricing arrangements will become increasingly important as i) the complexities of managing low carbon systems grow, and ii) scheduling and dispatch decisions increasingly relate to complex operating regimes, such as those required with storage, rather than simple merit order ranking.

This is the subject of the EAI Paper Investment Framework for Decarbonised Dispatchable Generation. This paper recommends the following actions that can be taken to ensure that we achieve a cost-effective transition to a decarbonised electricity sector:

Policy Recommendations

Early and significant investment in grid infrastructure

To remove constraints.

Plan for a steady stream of projects and auctions

Supported by policy and Government.

Accelerate the electrification of new loads,

Particularly in switching from high-carbon fossil fuel to maximise the benefit of renewable generation for emissions reduction.

Support renewables following smart electrification

To allow new loads to offset fossil fuel use and provide balancing services to the Grid.

Complete a cost benefit analysis of potential decarbonisation technology options

That fully cost the value of security of supply and carbon reduction to identify which technologies are best suited to the all-island power system.

Develop the required policy to support Investment in, and development of required decarbonisation technologies

Such as multi annual large-scale energy storage projects.

Assess the role of the State and State Agencies in the context of Procuring, operating, licensing and market participation of the technologies of the future.

Examine options to decarbonise dispatchable generation beyond 2030 to ensure investment and action in a timely manner.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