Engineers Ireland

Powering Ireland:
An Electrical Energy Review

A community of creative professionals delivering sustainable solutions for society
www.engineersireland.ie

ENGINEERS IRELAND

Who we are

With over 25,000 members, Engineers Ireland is the voice of the engineering profession in Ireland. Engineers Ireland was established in 1835, making us one of the oldest and largest professional bodies in Ireland. Members come from every discipline of engineering, and they range from engineering students to fellows of the profession.

Our responsibilities

- Promote knowledge of engineering
- Establish and maintain standards of professional engineering and engineering education
- Provide opportunities for continuing professional development (CPD) for engineers
- Maintain standards of professional ethics and conduct
- Ensure that professional titles are granted to qualified candidates, and
- Act as the authoritative voice of the engineering profession in Ireland

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Foreword from the Director General

This report focuses on electrical energy in Ireland and achieving energy security in a manner that is consistent with our sustainability goals.

This review has an emphasis on electricity - rather than energy produced for heat and for transport use - and developing our renewable energy capacity. Electricity is vital to virtually every aspect of people's lives and to our economy and must be continuously accessible.

In this report we aim to demonstrate in someway, what Ireland needs to do to move from our current situation of being heavily dependent on imported energy to becoming much more self-sufficient and ultimately aim to become a net exporter of energy; we should also look beyond our island to the possibility of us playing a part within a European Super Grid and becoming a net exporter of sustainable energy. Delivering on these ambitions will require a combination of technical expertise, planning and political determination.

Ireland's economy depends on energy infrastructure which is secure and reliable and that will meet current and future needs. Energy is therefore an important sector, but also subject-matter, for our expert members. In 2016, our State of Ireland report, for example, focused specifically on energy. While every year presents unique challenges, last year, 2022, proved particularly difficult with the conflict in Ukraine triggering an energy crisis that threatened supply and increased costs. Weaknesses already inherent in our energy infrastructure became more apparent. The security of supply of Ireland's electricity is an imperative across the energy sector given the severe economic and social consequences that would result from a high impact event such as a total interruption of electrical supply.

While wind energy is increasingly one of the most important technologies for Ireland, and has such great potential for offshore development, it would not on its own be able to secure a reliable electrical energy supply for the country. Access to fossil fuels is still required and creating a zero-carbon future by 2050 is an engineering issue that requires serious focus to be resolved.

In December 2022, we welcomed the Government's National Climate Action Plan 2023. This national plan is the second annual update to Ireland's Climate Action Plan 2019. This 2023 plan is the first to be prepared under the Climate Action and Low Carbon Development (Amendment) Act 2021, and follows the introduction, in 2022, of economy-wide carbon budgets and sectoral emissions ceilings.

Eighty per cent of electricity must be from renewable sources by 2030. Demand for electricity continues to rise however, and with that, so are emissions. We are under pressure to act without delay. As Ireland's Climate Change Advisory Council said in December 2022, this problem has to be addressed now, "especially given the solution of renewable energy sources of wind and solar are right outside our doors."

We have an wonderful opportunity now to make a turning point towards a cleaner, domestic, more affordable and more secure energy system.

As an institution for professional engineers, it is incumbent on us to provide solutions that are comprehensible to the public and realistic but also ambitious for our policymakers to implement. I wish to thank our Policy Officer, Keelan Keogh for his work in compiling this report.

Damien Owens

Damien Owens, Chartered Engineer, FIEI, EUR ING
Director General, Engineers Ireland
March 2023

> "The security of supply of Ireland's electricity is an imperative across the energy sector given the severe economic and social consequences that would result from a high impact event such as a total interruption of electrical supply."

Executive summary

With over 25,000 members from every engineering discipline, Engineers Ireland is the voice of the engineering profession in Ireland. Our profession has played a central role in Ireland's economic and societal development and is key to its future success. As an institution, we aim to contribute positively to the decision-making process in Ireland.

As part of our policy work, we have prepared this review of electrical energy in Ireland. The report seeks to give a broad overview of Ireland's electrical infrastructure and the current level of demand versus supply for electrical energy.

The report also maps out what we need to do to meet our future requirements in a sustainable manner that will allow us to comply with our 2050 climate emission targets.

According to the SEAI, in 2021 energy use in Ireland can be broken down into three major elements, heat (42%), transport (36%) and electricity (22%).

The 2030 climate emission targets present us with a timeframe too close for any significant new infrastructural developments; the current plans that are in place may or may not achieve the 2030 goals. This report, therefore, will focus more on the electrical landscape needed for the 2050 goals of a net-zero system. We must start discussing the plans needed now to reach these goals.

The target of net zero by 2050 was first set out in the Paris Agreement, signed in 2016 and ratified by the European Union (EU). The EU has taken steps to achieve this 2050 goal through the European Energy Strategy and European Green Deal. The European Union's energy policy includes the need for a secure energy supply, sustainable energy consumption, lower fossil fuel dependence and improvements in energy efficiency.

The biggest challenge in energy which our country faces is known as the energy trilemma; we must ensure we increase *sustainability* and keep our energy *secure* and *affordable*.

In 2018, nearly half (45.5%) of the net electricity generated in the EU was from combustible fuel, and a mix of renewables accounted for 28.6%. When comparing Ireland to the EU-27 averages, Ireland used about 20% more conventional thermal power generation and, in a positive development, double the EU average of wind generation. Ireland is the 3rd most prominent user of wind energy in the EU, behind Denmark and Lithuania.[1] By 2021 Ireland had adjusted its fuel share for electricity production to 59.2% from fossil fuels and 36.4% from renewables.[2]

Ireland has significant potential to be a leader in renewable electrical energy production and a net energy exporter. Wind energy can and should be a majority stakeholder in energy production in Ireland in the future.

However, no one technology can meet all of Ireland's electrical needs. Ireland must have a diverse portfolio of sustainable energy options to ensure future energy security. Wind and solar will be significant parts of our green future.

Additionally, serious consideration must be given to the remaining conventional thermal power plants around the country needed as a backup supply, and other energy sources such as international interconnectors, biomass, and nuclear energy.

Developing energy sources in Ireland is only part of the challenge to a green future. A robust and adaptable electrical grid is needed to harness this energy to ensure electricity can be delivered efficiently where required. Linking our grid via interconnections to the UK and Europe will provide additional flexibility and allow excess electrical energy to be exported. The EU has set a target of 15% of demand to be available through interconnectors by 2030. This level of infrastructure will be required to secure Ireland's place as a leader in the proposed European Super Grid project.[3]

Ireland historically has created a sizeable low-level electrical grid. As demand for electrical energy has increased, this low-level grid is no longer fit for purpose and requires additional high-level infrastructure to support it. However, significant planning delays as well as public and political challenges have hindered the development of this infrastructure, e.g. the delay in completing the North-South Interconnector. We must develop our green energy sources and grid infrastructure. Engineers in Ireland require public and political support to achieve this potential. An ongoing and urgent dialogue is needed to inform and assure all stakeholders, including the general public and policymakers.

1 Energy, transport and environment statistics 2020 (Eurostat)
2 Energy-in-Ireland-2022.pdf (seai.ie)
3 EC Expert Group on Interconnections | Friends of Sustainable Grids (supergrid.brussels)

Key recommendations

Supply of electricity

- Ireland must identify its electrical requirements for 2050 and develop a system looking at a diverse portfolio of green energy zero-carbon sources, a broad collection of interconnections with neighbouring countries, and a robust and flexible electrical energy grid.

- Conventional thermal generation power stations have historically provided a significant proportion of our electricity supply. As we move towards 2050, most of these power stations will need to be shut down or retrofitted to burn green fuels such as green hydrogen or biomass to become carbon-neutral plants.

- Green hydrogen should first be used for difficult-to-electrify sectors. A rapid scale-up in green hydrogen production and its use is required to support electrical generation. This must be actively managed to ensure the displacement of fossil fuels, which will determine the location of hydrogen research, development and commercialisation activities in Ireland.

- We must accelerate the route to market for innovative energy solutions such as offshore wind, supported by Government policy centering on procurement, planning and execution. Ireland has the potential to become a net exporter of renewable energy and a leader in the EU Energy Strategy to ensure that secure EU-based energy production is feasible in a carbon-constrained future.

- Consideration should be given to removing the current statutory barriers to domestic nuclear power deployment. The current legal barriers inhibit robust analysis of its long-term potential. Government should therefore review the Electricity Regulation Act, 1999 (Section 18) and should amend it so nuclear energy can be discussed. Considering nuclear energy, investigating modern advanced nuclear reactors and SMR (Small Modular Reactors) designs, focusing on full benefits and drawbacks, would be beneficial. It would allow a more informed process on the potential for nuclear in the future of Ireland's electrical supply network.

Key recommendations

Energy Infrastructure

- Prioritise completing the North-South Interconnector Project and other outstanding grid development projects. The North-South Interconnector will provide an addition of a 400 kV overhead line to our grid, connecting the electricity grids of Ireland and Northern Ireland, ensuring we can transmit large amounts of electricity across the border in both directions.

- Consideration must be given to the use of hybrid grid connections. These connections allow the synergy of conventional energy generation and new renewable energy. They provide a near-term solution to adding additional capability to the grid. These must be endorsed and expanded to support additional energy sources such as wind, green hydrogen, and solar farms.

- There is limited social acceptance of investment in transmission lines. The Government must take ownership of this issue, supporting EirGrid, the state-owned company that manages and operates the transmission grid across the island of Ireland. The Government should fund additional public education campaigns on the need for increased electrical infrastructure and counter misinformation on health and environmental issues and streamline the planning process.

- The Government should support the provision of an LNG (Liquified Natural Gas) and regasification units as part of the near to medium-term solution to providing energy security for Ireland to prevent possible future disruptions to gas supply.

- The majority of smart meters in domestic properties are not being utilised to inform consumers of the best time to operate energy-intensive devices. Greater use must be made of smart meters. Consumers should be clearly informed of the best time to perform energy-intensive tasks through a traffic light system providing granular data with 15 minutes resolution.

- Gas storage will be required in the near and long-term energy landscape of Ireland. Government should work with industry to ensure gas storage is available in the near term and is prepared to align with Ireland's hydrogen strategy.

- Develop additional deep-water ports to support supply chain requirements and assembly of offshore wind projects.

1. Energy in Ireland today

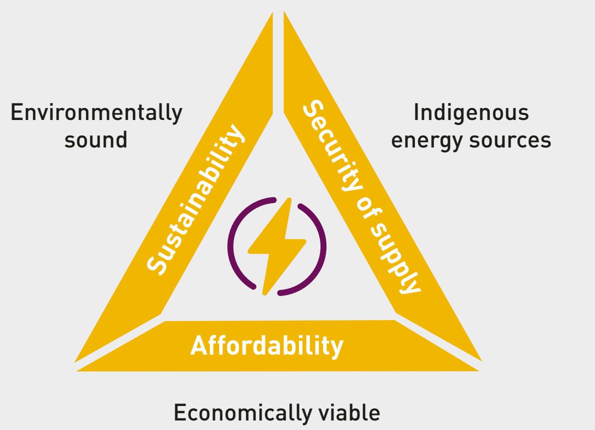
Ireland currently has an integrated energy system relying on multiple energy sources including wind, coal and gas, which provide our heat, transport and electricity requirements.

According to the SEAI, approximately 86% of Ireland's total energy was imported in 2021.

As we move towards a carbon-zero future, a reduction of imported energy will be needed, and an increase in electrification of heating and transport will be required. Relying entirely on electrical energy may not be practical in all applications (i.e. furnace applications or heavy industry) and an integrated energy system will still be required.

The biggest challenge in energy which our country faces is known as the energy trilemma; we must ensure we increase *sustainability* and keep our energy *secure* and *affordable*.

Ireland's Energy Trilemma



1.1 Electrical energy supply in Ireland

Ireland's economy depends on a secure and reliable energy infrastructure that can meet our current and future needs. With the economic success of Ireland and the large number of multinational companies based in or attracted to Ireland, the demand for secure and abundant energy has become more critical than ever. This secure energy must be provided through renewable means to support our economic growth.

According to the SEAI, in 2021 energy use in Ireland can be broken down into three major elements, heat (42%), transport (36%) and electricity (22%).

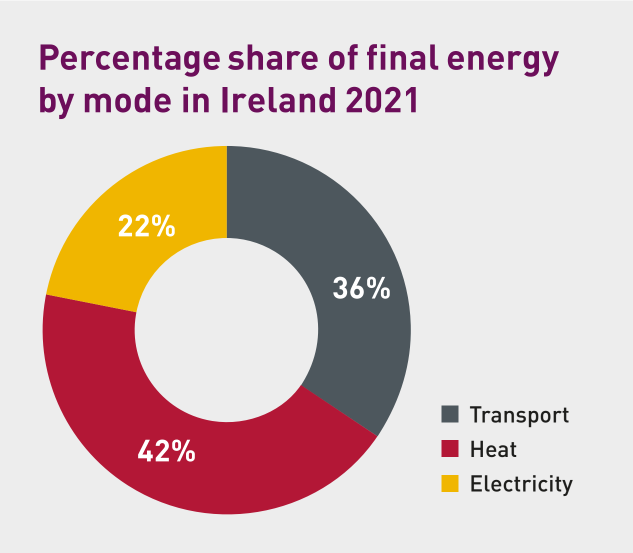
In 2020 we used approximately 12.5 Mtoe (megatonne of oil equivalent) for all our energy uses. On average, Ireland currently generates over 80%[4] of energy used from fossil fuels. Only 14% of energy is produced through renewable sources, half of which is through wind turbines.

4 Energy Use Overview | Energy Statistics in Ireland | SEAI

Electrical energy is the most diverse form of energy used in homes and businesses across Ireland and is fundamental to our modern society. In 2020 approximately 2.5Mtoe was used to meet Ireland's electrical needs of about 30.8TWh.[5] As we move to a green and an electrified economy, with increased demand in heating our homes through electrical systems like heat pumps, and the electrification of transport through electric vehicles (EVs), electricity will become the key energy system for attaining our sustainability goals.

By 2030, we will likely require between 40 – 50 TWh[6] of electricity. This requirement is likely to increase as we move towards 2050. Therefore, to be successful in our sustainability goals, we will need to source more than 80% of our electrical energy from clean sources by 2030.

5 Annual-Report-2021.pdf (eirgridgroup.com)
6 EirGrid_SONI_Ireland_Capacity_Outlook_2022-2031.pdf (eirgridgroup.com)



Energy use in Ireland 2021[7]

The most obvious and critical aspects to note about electricity is that there is currently limited battery storage of electrical energy at a grid level in Ireland. As electricity is used, it must be created in a supply and demand model. This is particularly problematic for Ireland as we are almost totally dependent on fossil fuels on days when the wind is insufficient.

In the 1920s, Ireland first aimed to become energy independent by generating 80% of its electrical needs from renewable energy, predominantly from the Ardnacrusha hydroelectric power station.

This was built to ensure Ireland could produce its electrical requirements domestically, ensuring energy security and independence from importing energy sources. As Ireland's society and population have developed, our need for electrical energy has far outpaced the ability of hydro alone to sustain us. The Ardnacrusha system still operates today but can only provide a fraction of Ireland's current electricity needs.

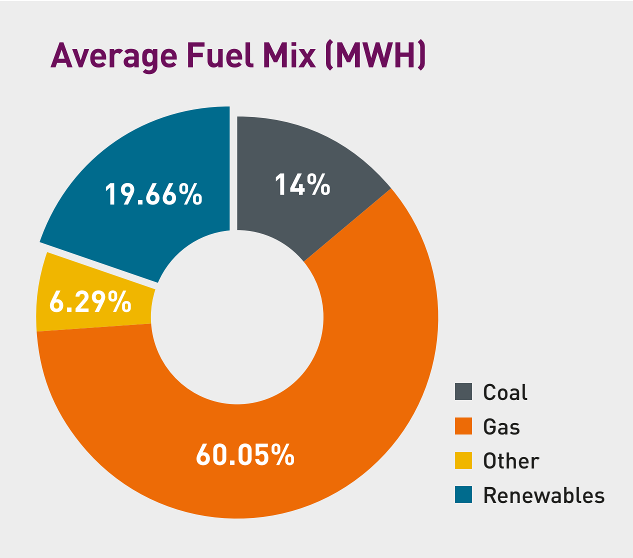
Currently, we get our electrical energy annually from a mix of sources. They are: Gas, Renewables, Peat, Oil, Coal and Others (a combination of interconnectors, hydro, and biomass). This mix varies according to weather conditions, maintenance schedules for power generators and the availability of interconnectors. For example, in the month of September 2022, which was a month of particularly low wind, the electrical grid for the island of Ireland, on average, was powered by Gas (60%), Renewables (almost 20%), Coal (14%), and Others (6%), such as interconnectors.

It is this variability in supply that highlights why a diverse portfolio of energy sources allows stable electricity to be generated and distributed around Ireland as required. Stable production systems must offset variable producers like wind and solar to ensure a consistent and stable electrical grid. When there is limited renewable energy, fast-responding dispatchable sources must be available to compensate.

Ireland, like most countries, has identified gas thermal generation as the most viable solution to this problem. Gas is fast responding low emission fossil fuel and, up until recently, a cheap and abundant fossil fuel. Gas complements the use of variable renewables to keep electrical production consistent and stable.

Ardnacrusha hydroelectric power station, Co. Clare

7 Energy Use Overview | Energy Statistics In Ireland | SEAI



Energy use in Ireland September 2022[8]

Responding to the challenges created by climate change, Ireland has committed to a climate-neutral economy by 2050 and a 51% emissions reduction by 2030 compared to 2018 levels. Thus, almost a hundred years after the completion of Ardnacrusha, Ireland will once again require at least 80% of our electrical energy to come from renewables. This time we cannot just look to hydro, but we will depend on a mix of offshore and onshore wind projects, solar farms and alternative solutions like green hydrogen and nuclear.

As we move towards 2050, the use of fossil fuels for electricity must be reduced to zero at least a decade before that date, to achieve the carbon-zero electrical production goals.

Identifying a suitable complementary electrical producing technology is a significant engineering challenge. Technologies like green hydrogen, hydro, battery storage and nuclear, have the potential to provide this dispatchable fast-responding capability, but there are significant engineering challenges, planning and political challenges to creating these technologies at scale.

In light of the current energy crisis, no country, including Ireland, can take a stable electricity supply for granted. *"The long-term impact of the war in Ukraine remains uncertain. However, this situation is being closely monitored by EirGrid and SONI"*.[9]

As Ireland's demand for electricity continues to increase, to ensure our security, a shift to domestically-produced energy is needed. Renewable energy can provide a considerable part, but a stable baseload system is required to ensure secure electricity.

> "A diverse portfolio of energy sources allows a consistent and stable electricity supply to be generated and distributed around Ireland as required."

1.2 A review of electrical infrastructure in Ireland

Ireland's electrical infrastructure was initially developed to transmit power from hydro and peat-fired stations. Later additions in the 1950s of oil and gas-fired generation stations were built to support increasing rural connectivity. This organic expansion of Ireland's electrical demand and the distributed population of the countryside resulted in Ireland creating an extensive but low-level network except for a number of 400kV lines like those connecting the Greater Dublin Area (GDA) to Moneypoint in the Shannon Estuary. This leaves Ireland's electrical infrastructure in a difficult position with limited ability to divert power around the country as demand requires it. This also limits the number of new input stations the grid can handle, which in turn hinders our ambition to create new renewable energy sources.

EirGrid, Ireland's Transmission System Operator (TSO), develops and operates the national electricity grid. EirGrid ensures power is always available when and where it is needed by forecasting the requirements across the country. The power is then delivered to the distribution network, which ESB Networks operate, and in turn, powers every electricity user in Ireland. The Republic of Ireland and Northern Ireland cooperate closely on energy matters. The all-Ireland Single Electricity Market (SEM) is one of the first in Europe[10], combining two separate jurisdictional electricity markets.

Our electrical energy infrastructure is rapidly becoming insufficient and will become more problematic as we approach 2050 with the increasing addition of variable power inputs from non-synchronous power supplies, like wind and solar. This will create system stability issues in our supply. While there has been a recent focus on electricity supply and electricity demand, it is vital that the public and our policymakers fully understand that electricity distribution via our grid infrastructure and the correct balancing of loads is also essential. New infrastructure takes time to develop to meet demand; and infrastructure projects in Ireland often take a number of years to complete.

8 EirGrid Group plc - Smart Grid Dashboard
9 EirGrid_SONI_Ireland_Capacity_Outlook_2022-2031.pdf (eirgridgroup.com)

10 2019-01-02_ireland-s-energy-transition-challenges-and-opportunities_en.pdf (oireachtas.ie)

Ireland's grid requires considerable investment. EirGrid and ESB Networks have executed excellent work through the use of new materials and technology and smarter balancing of loads to maximise the utility of our existing grid infrastructure. Ireland requires however, a significant expansion of its grid infrastructure to meet the challenge of efficiently distributing electricity from where it is generated to where it is needed. We need more substations, more pylons and, where practical and feasible, more underground cables.

Infrastructure projects have been proposed for various needs since the 1990s but have experienced considerable delays, mainly due to public and political opinion, often as a result of misinformation. This results in an average of 14 years from proposal to operation for new electrical infrastructure.[11] The longest example is the 55km electrical line from Flagford in Roscommon to Srananagh in Sligo. This line initially had an engineering project duration of four years to complete, but instead, it took 20 years. The North-South Interconnector is another essential piece of infrastructure that will significantly aid the distribution and balancing of loads, which has also faced considerable delays. The project is critical to improving the efficient operation of the Single Electricity Market (SEM) and increasing the security of the electricity supply.

The planning and execution of additional Ireland-UK interconnectors and the Celtic interconnector, which will be the first connection of Ireland's grid to continental Europe are welcome. Our ambition should be to move, not just from an all-Island perspective, but to see ourselves as part of the proposed European Super Grid. Interconnectors and increased connectivity allow for more export of renewable energy and provide greater network inertia. This infrastructure enables the potential for innovative, smart energy models with an energy excess to be created in Ireland and exported to the UK and Europe.

It is important to note that single interconnectors and their accompanying substations or converter stations require maintenance and cannot always supply continuous service.

1.2.1 Ancillary infrastructure

There are other infrastructural gaps, which, if left unfilled, could impact on Ireland's ability to meet our electrical energy requirements. Currently, we are limited to how much we can expand onshore wind generation due to the requirement that wind farms cannot be built within 500 metres of a domestic dwelling.

Despite our relatively low population density, we are now paying an additional price for poor planning of many once-off housing applications in remote areas, resulting in a large web of low-level electrical cables and limited available space and electrical capacity for new energy sources.

Our planning laws therefore must change to focus on the development of small community districts.

Ireland's offshore wind resource will be a major part of the mix as we increase our generation from renewable sources to meet demand. A difficulty for Ireland is that we will require deep water ports to facilitate the supply chain and assembly of floating platforms. Currently, ports like Shannon Foynes Port are in a position to take on this role on Ireland's west coast.

While Ireland seeks to move away from fossil fuels, we are still heavily reliant on gas. The Kinsale field has long since been decommissioned, and the Corrib field is projected to be exhausted by the early 2030s. We import 70% of our gas. Our lack of storage capability exacerbates our vulnerability to restrictions in the flow of gas. While other countries in Europe have sought to bolster their gas reserves since the conflict broke out in Ukraine in 2022, Ireland is not in a position to respond in the same manner. Ideally, our members believe we should have 15% of our annual demand in reserve. Currently we have no storage. While we clearly need to focus on renewables, gas will remain part of our energy mix in the near term. Also, gas infrastructure built now will not be redundant, as the same infrastructure can be adapted for use with green hydrogen or biomethane and work with our increasing renewable output. The 2022 Government consultation on Developing a Hydrogen Strategy for Ireland as part of the Climate Action Plan 2021 is welcome but a hydrogen strategy is overdue. The key recommendations from the consultation must be acted on and resourced.

Part of the near-medium-term solution to addressing Ireland's gas shortfall could be the provision of LNG (Liquified Natural Gas) terminals as proposed in the Shannon estuary. Ireland is one of the few countries in Europe not to possess such terminals, and this has added to our vulnerability, an issue that the SEAI raised in 2016.[12]

> “EirGrid and ESB Networks have executed excellent work to maximise the utility of our existing grid, but the reality now is that Ireland requires a significant expansion of its grid infrastructure.”

11 The Future of Electricity Transmission in Ireland – iae

12 https://www.seai.ie/publications/Energy-Security-in-Ireland-2015.pdf

1.3 Electricity production in the EU

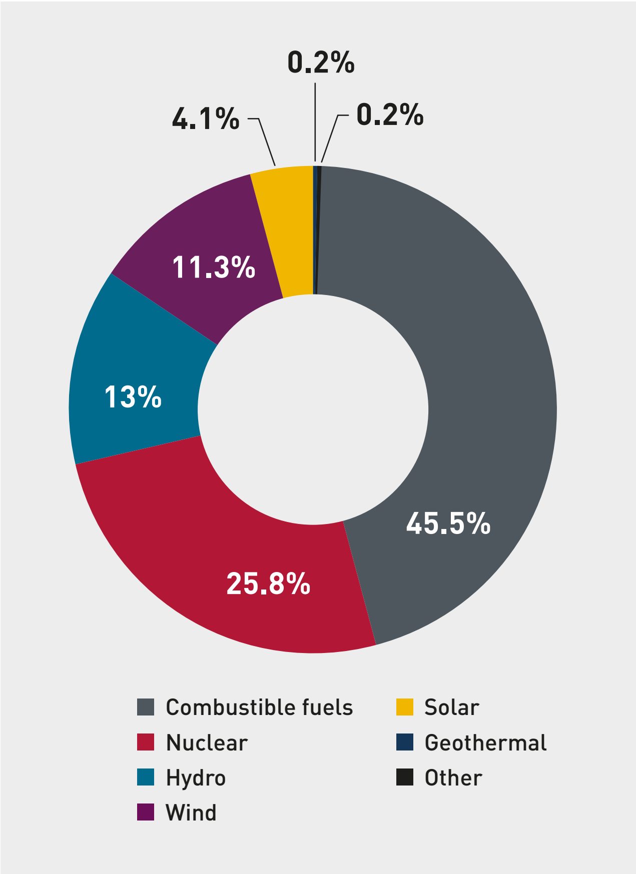
In 2018 close to half (45.5 %) of the net electricity generated in the EU came from combustible fuels (such as natural gas, coal and oil), while a quarter (25.8 %) came from nuclear power stations, with the remaining being a mix of renewable sources.[13]

Countries like Ireland, with a non-existent nuclear industry, rely on a higher percentage of combustible fuels or interconnections with neighbouring countries for electrical energy. Ireland is one of seven member states with a carbon intensity higher than the EU average (Those countries are as follows: Czechia, Malta, Bulgaria, the Netherlands, Germany, Ireland and Romania).[14]

With the invasion of Ukraine by Russia in 2022 and the subsequent EU sanctions on imports from Russia, the access to the necessary fossil fuels for electricity production has been challenging. Ireland is at the end of a long European supply chain for its fossil fuels and is at risk of further cost increases.

The EU wishes to achieve a target of 15% electricity supply to be provided via interconnection between member countries by 2030.[15] With the UK outside the bloc, the EU and Ireland will require an increase in interconnector capability to the continental EU to achieve this target.

Interconnectors will facilitate a diverse source of electricity generation, which means more competition in the market and potentially cheaper electricity for consumers across the EU. A Super Grid can potentially increase renewable energy use across Europe; wind energy from Ireland can be exported to Spain when it is cloudy and when there is no wind, solar energy from the continent can be imported into Ireland. Achieving a Super Grid of this scale in Europe would need new superconducting technology to be developed to ensure the required cables can be placed subsea or underground when passing urban areas.



The EU's Net electricity generation, EU-27, 2018

13 Energy, transport and environmental statistics 2020 (Eurostat)
14 Greenhouse gas emission intensity of electricity generation in Europe (europa.eu)

15 Electricity interconnection targets (europa.eu)

2. Future of electricity in Ireland

No one technology solution can meet all of Ireland's electrical needs. While wind energy is increasingly one of the most important technologies for Ireland and has a potential for further development, it would not, on its own, be able to provide a secure reliable electrical supply for the country.

Ireland must identify its electrical requirements for 2050 and develop a system looking at a diverse portfolio of green energy zero-carbon sources, a broad collection of interconnections with neighbouring countries, and a robust and flexible electrical energy grid. We must also focus more on reducing wastage and flattening out the peaks and troughs in our energy consumption through public education. We must look at all aspects of Ireland's electrical future to ensure energy security by 2050 and beyond.

2.1 Ireland's electrical requirements

To ensure Ireland has a suitable and robust energy system, we must first clearly understand what is required to achieve our carbon-zero goals by 2050. Engineers Ireland believes Ireland must meet the following minimum energy requirements by 2050:

1. Electrical energy must be the dominant energy used in Ireland, providing an 80% share in heating and transport.
2. Electrical energy must remain accessible to all properties and dwellings in Ireland.
3. The electrical transition and distribution grids must be sufficiently flexible to allow for maintenance or repair without significant risk of supply disruption.
4. Electrical energy must be used efficiently to reduce peak demand times.
5. Electrical sources must be carbon neutral.
6. Electrical sources must be able to facilitate at least 10GW peak load per day.
7. Electrical sources to back up wind and solar must be dispatchable, i.e. they can be brought on and off the grid quickly.
8. Electrical energy must be affordable.
9. Electrical energy must be reliably available.

2.2 Energy efficiency/demand reduction

The largest impact on Ireland's electrical supply and demand is how consumers interact with it. The more electricity that is used, the more supply must be generated to keep up and keep ahead of demand to ensure the system remains stable.

> "The potential of smart meters and thermostats is underutilised. Proper legal and financial frameworks are needed to optimise their capabilities."

Large energy users such as data centres, offices and factories need to be managed to reduce load and spread-out peak timings.

Switching off non-essential electricity demand is now important, and the best way to reduce electricity demand is to switch off unused devices.

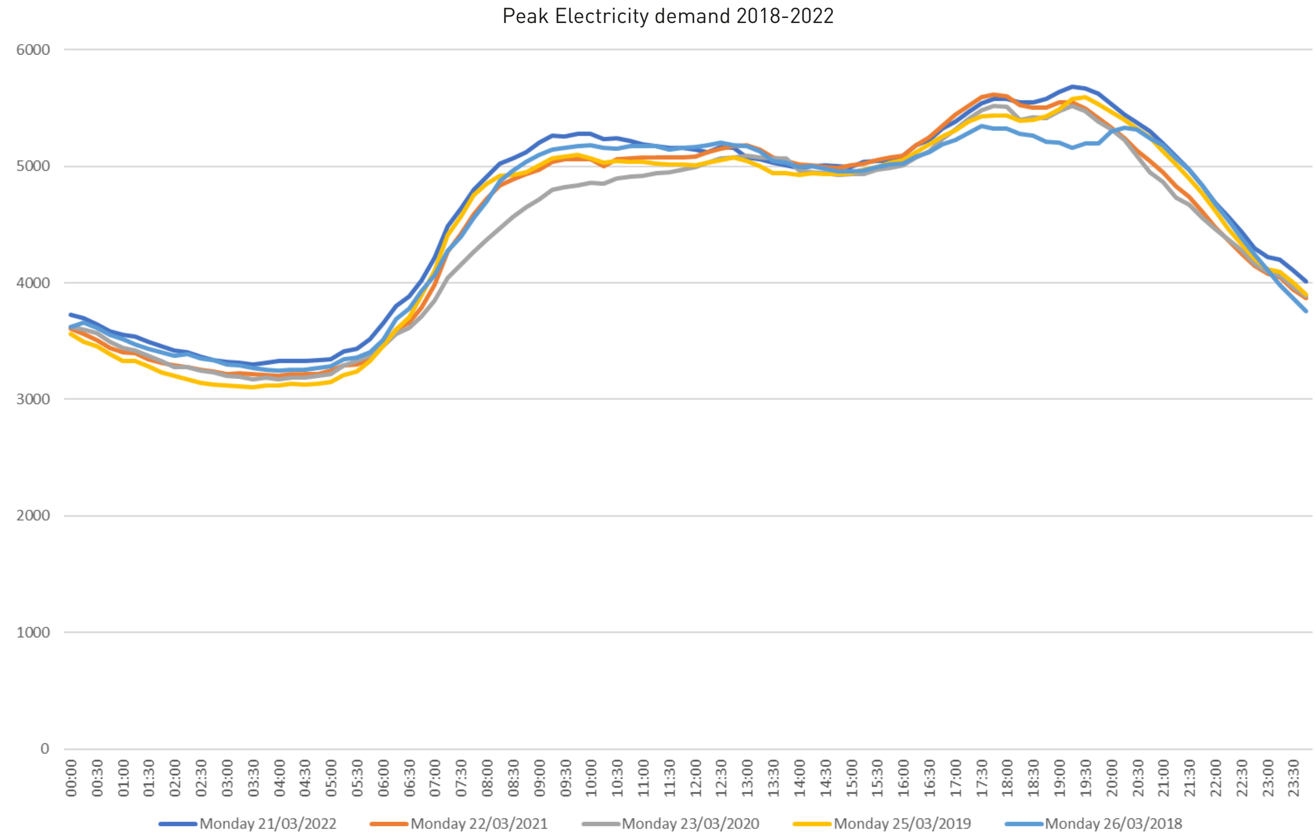
Energy efficiency opportunities can be identified using automation, machine learning and AI to analyse large data sets for users. This data can be gathered from smart meters and used to ensure peak loads are spread out and reduced.

Smart energy traffic light tools exist[16] but are not widely used, which can highlight to people the optimum time to use excess renewable energy. This traffic light tool promotes electricity use when there is abundant renewable energy, thus cheap and available. Utilising electricity in this way can have a financial benefit for customers through lower costs, as well as providing environmental benefits by using zero-carbon electricity. As we move towards a zero-carbon future, efficiently managing electricity will greatly impact the required production capacity.

The potential of smart meters and thermostats is underutilised. While these provide the basis for a smart grid with distribution flexibility, proper legal and financial frameworks are needed to optimise their capabilities. Through financial incentives, suppliers can influence consumer behaviour. Providing granular data with 15 minutes resolution to consumers will highlight financial impacts, and individuals can make decisions to lower or increase their usage appropriately.

EirGrid provides data on peak electrical usage on the national grid. This data shows that the peak electricity used is about 6GW in a day and occurs between 17:00 and 21:00.

16 Energy management and real time grid emission information - EnergyElephant



System information EirGrid[17]

There is also a noticeable lower peak between 8:00 and 10:00 of 5GW. There is a significant decrease during the night, but it still requires 3GW throughout the night. The peaks of this demand could be reduced through efficient energy management and offsetting times for different industries for operations.

The Covid-19 pandemic was expected to cause a major change to peak electrical demand. But reviewing data taken before and after Covid-19 in the same weeks, shows minimal variation in Ireland's peak demand. On 23/03/2020, the day of the first lockdown, there was a slight reduction in demand for the first peak between 7:00 and 12:00. However, electrical demand returned to normal the following year.

Recommendations

- Utilising tariffs to incentivise improved management of electrical usage to reduce peak and lower the curve of the energy usage.
- Greater use must be made of smart meters. Informing consumers of the best time to perform energy-intensive tasks through a traffic light system which provides granular data with 15 minutes resolution, would be a positive development. The majority of smart meters in domestic properties are not being utilised to inform consumers of the best time to operate energy-intensive devices.

> "Our electricity system must have a secure domestic focus."

2.3 Production of electricity

Ireland currently has various means of producing electrical energy. The majority of means depend on conventional thermal generation, burning coal and gas. However, there is a growing proportion generated by wind and solar. Ireland's current strategy for electricity system decarbonisation is focused primarily on a rapid increase in wind (onshore and offshore) capacity and some significant solar deployment.

To reach a reliable carbon-neutral electricity production system by 2050, this increase in wind and solar availability will need to be coupled with new zero-carbon technologies to provide baseline energy of dispatchable power. Interconnections with neighbouring countries will also be vital but the system must have a secure domestic focus.

2.3.1 Conventional thermal generation

Conventional thermal generation is currently a large provider of electrical energy, with eight stations[18] in Ireland. These generators burn a fossil fuel, typically gas, which either boils water, forcing steam through steam turbines or using a gas turbine combined cycle, which burns gas in a gas turbine and uses the exhaust heat to create steam and power a steam turbine increasing the overall efficiency.

17 System Information (eirgridgroup.com)

18 Annual-Report-2021.pdf (eirgridgroup.com)

These turbines then produce electrical energy, which is transmitted onto the grid.

These conventional generators take time to reach temperatures where they can produce suitable power. Some systems can take up to eight hours to reach sufficient temperature from a cold restart. This is because of the thickness of the boiler walls, found mostly in coal and oil plants.

Gas-powered combined cycle turbine systems can achieve temperatures in approximately two hours. These generators typically have high efficiency when converting chemical energy to electrical and are referred to as fast reacting dispatchable power plants.

The forthcoming decommissioning of some existing conventional dispatchable power plants causes concern for energy security in Ireland. EirGrid's Capacity Outlook 2022-2031[19] provides a comprehensive list and timetable of plants/units expected to close /retire in the immediate future. These plant closures may reduce the diversity of secondary fuels in the electricity generation sector. Delays in deploying new dispatchable generation plants are clearly a key ongoing risk in electricity supply security.

Advantages

- Conventional thermal generation could support Ireland's heat and transport electrification potentially alone.
- Conventional thermal generation can operate on shift near continuously 24/7, depending on the plant design.

Disadvantages

- Current conventional thermal generation is predominantly fossil fuel-based. Most of the current fuel sources cannot be carbon neutral. The exceptions are those that are viable to do so and that can change coal or peat steam turbines to biomass and gas turbines to green hydrogen.
- Slow starting power generation systems like solid fuel thermal generators, are difficult to marry with wind generation, as they cannot be brought online in a timeframe that can match weather models.

Recommendations

- Conventional thermal power generation has historically provided a significant proportion of our electricity supply. As we move towards 2050, most of these power stations will need to be shut down or retrofitted to burn green fuels such as hydrogen or biomass to become carbon-neutral plants.
- Government objective for 2000-4000MW of fast-starting dispatchable gas-fired generation capacity should be expedited, and this additional generation capacity should be hydrogen-ready.

"Delays in deploying new dispatchable generation plants are clearly a key ongoing risk in electricity supply security."

Dublin Bay

19 EirGrid_SONI_Ireland_Capacity_Outlook_2022-2031.pdf (eirgridgroup.com)

2.3.1.1 Hydrogen

Green hydrogen will play a major role in decarbonising hard-to-electrify sectors, such as the production processes of basic chemicals, steel production, and heavy transport vehicles.[20] Green hydrogen can potentially be used as a replacement for natural gas in open cycle thermal plants or large-scale hydrogen fuel cells providing dispatchable electricity generation.

Green hydrogen should first be used for difficult-to-electrify sectors such as road freight and high-temperature industry. Utilising it for electrical production is challenging due to the scale of hydrogen required to power a national grid.

The production and use of green hydrogen as an alternative clean energy fuel must be considered an essential element in our future energy system. The application of hydrogen gas as energy storage in Ireland has excellent potential as a replacement for natural gas. Hydrogen-ready open cycle gas turbines have many environmental, security and economic benefits. Gas turbines provide fast-start, flexible, dispatchable back-up generating capacity with supports systems with high penetrations of intermittent renewables.

Green hydrogen is currently the most feasible candidate fuel substitute for large-scale zero-carbon energy storage in Ireland, which will be essential to progressively reducing and ultimately eliminating our overall dependence on fossil fuel imports. This is not without challenges. For green hydrogen to be used as a fuel substitute, multiple technical challenges must be addressed in, large-scale green hydrogen production, large-scale hydrogen storage, transportation of hydrogen, and safety regulations. The country's new Hydrogen Strategy, which was recently open for public consultation, must be committed to the rapid scale-up of this technology to create a functioning green hydrogen market both domestically and across Europe.

20 IRENA_RE_targets_2022.pdf

Green hydrogen is produced using electricity created by renewable systems using an electrolysis process to separate liquid water into gaseous hydrogen and oxygen. The membrane technologies used in large-scale electrolysis processes are still at an early stage of development for grid-scale deployment. In the future, this process of electrolysis could allow the ability to store renewable energy in the form of green hydrogen, improving the stability of electrical grid energy and balancing wind and solar power, freeing Europe from its dependency on imported fossil fuels.[21] The electrolysis process will require significant electrical energy. Therefore, the increased availability of offshore wind could potentially provide this energy. To date, there are no large-scale green hydrogen production systems in the world, as most hydrogen demand is met through the use of grey hydrogen, which is created from natural gas.

Hydrogen can be stored in a gaseous state in depleted natural gas fields or in salt caverns, where suitable geological salt deposits are identified. This geology is limited within the Republic of Ireland, but there are potential salt deposits in the Irish sea. There is also significant salt deposit geology in Northern Ireland (in the Islandmagee area), with an existing commercial project proposed to develop gas storage facilities (initially for methane but with planned repurposing to hydrogen). Another option is storing gas in depleted natural gas fields, such as Kinsale.

As an alternative, green hydrogen could be stored in liquid form. In a liquefied form, green hydrogen potentially can be stored similarly to liquefied natural gas (LNG). Though this would be challenging to achieve the required cryogenic temperatures. The developers of the proposed Shannon LNG site have said the technology can be transitioned to hydrogen gas in the future and connect to offshore renewable developments.[22] However there is limited independent evidence to support this.

The main advantage of hydrogen gas is its ability to be utilised with existing gas infrastructure. This could initially involve blended hydrogen and later with modifications, to pure hydrogen. Such a change in the composition of gaseous fuel is not new. In the 1980s, Ireland shifted its grid gas use from 'town gas', a hydrogen hydrocarbon blend of up to 60% hydrogen, to natural gas. The reintroduction of hydrogen by blending with natural gas is an important transitional step: and repurposing pipelines to transport pure hydrogen should be pursued as rapidly as possible. Existing gas turbines can be retrofitted, and/or existing power plants can be re-powered with hydrogen capable of running on hydrogen blends of less than 100% purity. Green hydrogen can be delivered to power plants via multiple supply chains, including compressed hydrogen, liquid hydrogen and via organic carriers such as ammonia or methanol.

21 https://ec.europa.eu/research-and-innovation/en/horizon-magazine/hydrogen-could-help-secure-europes-energy-supply-bert-de-colvenaer a

22 Shannon LNG site developers in discussion with renewable energy companies – The Irish Times

Blending hydrogen 20% by volume (7% by energy content) with bio-methane and fossil methane though costly may be an option to connect hydrogen supply with demand in the near term using existing methane infrastructure, but all unabated fossil methane use must be phased out as rapidly as possible. The EU has already created a union-wide hydrogen strategy, with Germany having a clear demand for imported green hydrogen. The IEA (the International Energy Agency) proposed in their Future of Hydrogen Report 2019[23] that a useful option to promote hydrogen in the near term may be to "Build on existing infrastructure, such as millions of kilometres of natural gas pipelines. Introducing clean hydrogen to replace just 5% of the volume of countries' natural gas supplies would significantly boost demand for hydrogen."

The most recent phase of the HyDeploy[24] project presented a pilot UK deployment lasting 11 months to over 668 homes which successfully blended up to 20% hydrogen (by volume) into an existing public natural gas network. Customers continued to use their gas supply and appliances as usual. Current gas appliances are designed to operate with a blend of up to 23% hydrogen. In this pilot, no changes were required to gas appliances, including boilers, cookers and fires, or pipework. Blended gas must be carefully monitored when used in turbines to ensure a consistent mix of fuel. When used in thermal generation processes, it may be better to blend the gas onsite as tested in Hynet in Carrington, UK.[25]

The Institute of Engineering and Technology (IET) created a report in June 2019 titled 'Transitioning to hydrogen'[26], containing input from experts from a cross-professional engineering institution's working group, including IGEM[27], IChemE[28] and IMechE[29], which assessed the engineering risks and uncertainties and concluded;

> *"There is no reason why repurposing the gas network to hydrogen cannot be achieved".*

On 15 December 2021, the European Commission adopted a legislative proposal to recast the 2009 EU Gas Regulation[30] as part of the hydrogen and decarbonised gas markets package. This reflects the EU's growing climate ambitions, outlined in the European Green Deal and its 'Fit for 55' package.

Gas and electricity grids in the EU are a supply chain connecting supply to customer demand. The EU has enormous potential to connect green hydrogen suppliers to green hydrogen users in all sectors connected to the gas grid - heat, electricity and transport.

As society moves to an electrified model, hydrogen gas will have increased significance as a fuel. If we plan and execute well, Ireland can become a significant exporter of green hydrogen and other derivative fuels to the rest of the EU and beyond.

Advantages

- Green hydrogen blends of up to 7%, by energy content can be added to the gas network with minimal change to existing gas infrastructure and operation.
- Green hydrogen can be burned in conventional gas thermal generation plants.
- Green hydrogen can provide a carbon-zero dispatchable electricity source.

Disadvantages

- Hydrogen production using large-scale electrolysers has not been demonstrated.
- Electrolysis process will require high capital, creating high costs of hydrogen.
- Hydrogen is the smallest atom on the periodic table, making it hard to contain.
- Hydrogen supply and demand are both currently low. The entire market will need to be reimagined and built up rapidly.
- Hydrogen is very flammable as a gas, requiring a very low-energy spark in order to ignite.

Recommendations

- A rapid scale-up in green hydrogen production and its use is required to support electrical generation. This must be actively managed to ensure the displacement of fossil fuel, which will determine the location of hydrogen research, development and commercialisation activities in Ireland.
- We should investigate and identify suitable gas thermal generator plants to run on hydrogen gas and create a development plan to get these power plants to 100% hydrogen.
- Blending hydrogen (up to 7% by energy content) with bio-methane and fossil methane though costly may be an option to connect hydrogen supply with demand in the near term using existing methane infrastructure, but all unabated fossil methane use must be phased out as rapidly as possible. Carbon budget constraints likely mean this should be before 2035.

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23 The Future of Hydrogen – Analysis - IEA
24 https://hydeploy.co.uk/
25 About HyNet - Hynet North West
26 https://www.theiet.org/impact-society/sectors/energy/energy-news/transitioning-to-hydrogen-assessing-the-engineering-risks-and-uncertainties/
27 Institute of Gas Engineers and Managers
28 Institute of Chemical Engineers
29 Institute of Mechanical Engineers
30 https://ec.europa.eu/commission/presscorner/detail/en/IP_21_6682

2.3.1.2 Biomass energy

Biomass energy uses seasonal sources of fuel, which grow quickly, capturing carbon and then releasing the carbon in a closed fuel cycle when burned. In the process of growing the fuel for biomass, habitats are created for wildlife, increasing biodiversity. This use of biomass is also a means of capturing and storing solar energy for use in the winter months. The burning of biomass is done in a modified thermal generation process, where biomass material is processed into pellets and fed into a furnace, which is used to heat water.

Biomass is very similar to conventional thermal generation plants, in that it burns solid fuel. It relies on the generation of monocultural crops to be generated and processed and to be declared by law to be zero-carbon. There is particular risk arising around the use and availability of biomass fuel that complies with the proposed sustainability criteria in the Renewable Energy Directive. The recent European Parliament vote on the text of the Renewable Energy Directive includes a cap on the use of woody biomass to count towards renewable energy production, and some restrictions on its use in power generation. The potential of increased competition for non-woody biomass, and possible import dependence, raise specific security of supply risks.

Advantages

- Biomass fuel is a low-cost affordable fuel.
- The process of burning biomass creates a closed-loop carbon cycle. However, the loop may take decades to close.
- Biomass enables the storage of solar energy through bioengineering.
- Biomass can be a dispatchable electricity generation process.

Disadvantages

- Biomass is currently classed as a zero-carbon technology by the EU, but this designation could be reviewed and changed.
- The generation of biomass to create fuel, takes away from land that could be used for other crops.To meet demand, biomass may need to be imported, which will impact carbon offset and cost of fuel.

Recommendations

- Biomass has the potential as a substitute fuel for solid fossil fuel thermal generator stations. Potential stations can be identified and investigated for changing fuel.
- With the capital cost of creating a new thermal powerplant and the risk that its zero-carbon class may change, it is not recommended that biomass is developed as a fuel for large-scale electric power generation stations.

2.3.2 Offshore wind energy in Ireland

Offshore wind energy has enormous potential in Ireland, particularly off the west coast, where there is potentially up to ten times the area for energy production compared to Ireland's landmass.

The clear value of this potential can be seen in the Government's recent commitment to increase the target of offshore wind energy from 5GW to 7GW by 2030. Our Government has ambitions to export up to 30GW[31] to the UK and EU, of which wind energy will be a significant aspect. Ireland currently has only one active offshore wind farm off the coast of County Wicklow capable of providing 25MW.

With Ireland's position on the edge of the Atlantic, a near-constant wind is generated on the west coast of the country. Ireland's continental shelf extends up to 500 nautical miles out into the Atlantic. The RV Celtic Explorer, a multi-purpose research vessel operated by the Marine Institute in Galway, is currently mapping the entire seabed.

31 20201203-final-iwea-building-offshore-wind-report.pdf (windenergyireland.com)

The "Infomar" project is expected to be completed in 2026[32] and will make Ireland one of the first countries in the world to have fully mapped its entire seabed area. Ireland can use this data to create a vast offshore wind energy infrastructure. Government has set a 7 GW wind energy goal and to make it a majority stakeholder in energy production in Ireland. We have potential to surpass that value if we can harness the energy.

Modern offshore wind turbine designs are capable of generating 15MW per turbine on average and must be positioned three times the rotor diameter away from each other. 20MW is believed to be possible by the end of the decade. An extensive network of cables must be created to connect the turbines and make landfall at a suitable location where the electricity can be connected to the grid.

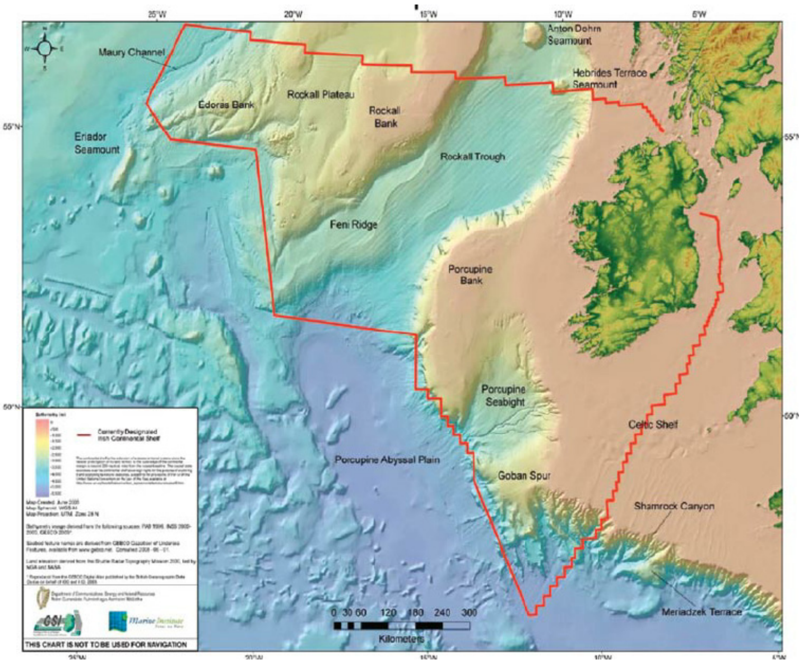
The connection between lines from offshore wind and the mainland in a location that can accommodate the lines and transmit the energy onto the grid is challenging. Connecting directly to the grid or utilising hybrid connections must be considered.

Hybrid grid connections are defined as single grid connections that facilitate the connection of an existing thermal generation plant and a proposed offshore wind project. These hybrid grid connections are essential to accelerate new energy sources to the grid. Maximising our existing assets in the near term is preferable. These hybrid connections allow new offshore projects to utilise existing cables in Ireland and accelerate the grid's carbon budget reduction. They will also facilitate the decommissioning of older thermal generation plants, as the connection can be shifted to a straight replacement over time.

Hybrid connections ensure near-term energy security. If there is insufficient wind for the supply and demand, some thermal generation plants can meet the demand. With modern wind forecasting able to predict accurate wind levels three hours in advance, there is enough time to engage gas turbine plants from a cold start. This infrastructure is available now and would lower the project's costs, benefiting consumers.

There are two ways of securing wind turbines at sea. One is a fixed foundation for the superstructure, and the other is Floating Offshore Wind Technology (FOWT). The fixed foundation normally involves a piled foundation, with subsea cables connecting the turbines to a transformer. This installation can be expensive and is limited to shallow waters of 60m.

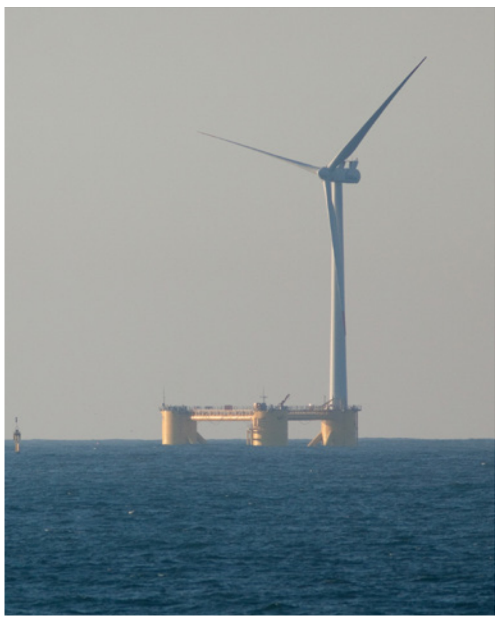
FOWT, as the name suggests, means that the wind turbines are mounted on platforms which float on the surface of the waves or are semi-submerged. FOWT is a developing technology but has the potential to be deployed into much deeper waters at lower costs once the initial capital cost of setting up the technology is done.



Irish continental shelf. Source: Department of Communications, Energy and Natural Resources, Geological Survey of Ireland and The Marine Institute.

The platforms are moored in place through drag anchors or single-point moorings. Offshore winds tend to flow at higher speeds than those onshore, thus allowing turbines to produce more economical power. With FOWT, the turbines can be mounted further out to sea, reducing the visible impact from the coastline and making them more acceptable to coastal communities. This will require specialist port facilities and support infrastructure.

Even with offshore generation, one of the biggest issues with wind electricity is the variable nature of its production. Power production will increase and decrease, depending on the weather conditions.



Floating Offshore wind turbine

32 Ireland poised to be first in the world to map its entire seabed – The Irish Times

Advantages

- Produces low-cost affordable energy.
- Directly produces electrical energy.
- Zero-carbon electricity production (excluding carbon expended in manufacture).
- High potential for electricity creation due to abundant space.

Disadvantages

- Electricity production is not dispatchable.
- Electricity production is based on wind availability.
- Landfall infrastructure must be developed to support offshore installations.

Recommendations

- Ireland has the potential to become a net exporter of renewable energy, and to become a leader in the EU Energy Strategy, to ensure that secure EU-based energy production is feasible in a carbon-constrained future. We must accelerate the route to market for innovative energy solutions such as offshore wind with support from Government policy around procurement, planning and execution.
- Develop hybrid grid connections to provide a near term solution to adding additional capability to the grid using the existing underused infrastructure.
- Support innovative solutions in the development of floating offshore wind turbine platforms, to position Ireland in taking a leading role in developing this technology.
- Coastal communities, industry and our Government must all work together to build and agree on new installations of offshore wind.

2.3.3 Onshore wind energy

Ireland currently has the 3rd largest percentage of onshore wind turbines in the EU, following Denmark and Lithuania. Ireland has approximately 5500 MW[33] of onshore wind energy capacity currently across the island as the majority source of wind energy. There are targets to increase this to ~8 GW by 2030.[34] Action 102 of the CAP 2021 has been created to ensure a supportive spatial planning framework for onshore renewable electricity generation development.[35]

Over the last three decades, wind turbine technology has advanced in terms of scale, output, reliability and sophistication. Wind energy is competitive economically. There are several companies engaged in project development, both Irish and international. The Government has put in place the 'Renewable Energy Support Scheme' (RESS) to create a stable route to market for new generation capacity whilst still stimulating competition and value for money.

Nevertheless, achieving a further 3-4 GW of installed capacity by 2030 represents a significant challenge. This includes the technical challenge of strengthening the grid to accommodate further non-synchronous generation, but also the planning and societal challenge of finding room for more wind farms. Among the solutions required to meet the challenge include:

- Innovative approaches to co-location of energy generation and energy demand, for example, energy parks, data centres and other industries with high energy demand.

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33 Facts & Stats (windenergyireland.com)
34 gov.ie - Climate Action Plan 2021 (www.gov.ie)
35 gov.ie - Climate Action Plan 2021 (www.gov.ie)

- Advancing our ability to integrate the electricity system with the gas network – for example using green hydrogen – to create more flexibility and resilience.
- Developing more energy storage capacity, and more interconnection with international grids.
- Exploring new possibilities for delivering wind farms closer to existing populations and energy users, as opposed to remote peatland sites.

Plans are currently in place to meet this goal and are likely to be achieved in the 2030s.

Onshore wind energy is limited in potential due to challenges. These challenges include finding suitable locations to install turbines which are geographically suitable with strong winds. The locations need to be acceptable to local communities as they will be visible, and also compliant with planning restrictions limiting them to a distance no less than 500 metres from a domestic dwelling.

Advantages

- Familiar, safe and low-risk technology – proven in the Irish context.
- Produces low-cost affordable energy.
- Zero-carbon energy production.

Disadvantages

- Electricity production is not dispatchable.
- Electricity production is based on wind availability.
- Continues to meet local opposition, although acceptance levels are high amongst wider public.
- Further electricity grid development is required.

Recommendations

- Onshore wind energy should continue to grow, but the majority of investment in wind should be focused on offshore wind.
- Onshore wind energy will be essential in meeting 2030 targets for decarbonisation.
- Embrace fresh approaches to land use, energy parks, energy storage and energy systems integration in order to maximise benefits.

> “Onshore wind energy should continue to grow, but the majority of investment in wind should be focused on offshore wind.”

2.3.4 Solar

There are two types of technologies which generate electricity from light, and these are solar photovoltaics (PV) and concentrated solar power (CSP).

CSP uses solar furnace principles of focusing sunlight to a specific point to drive a generator. This technology requires high levels of sunshine year-round.

Solar PV technologies are therefore best suited for use in Ireland's climate. Ireland has similar solar energy as other European nations such as the Netherlands, UK and Germany. Solar PV is the most common solar technology worldwide. The PV panels use semiconductor technology to generate electricity directly from exposure to visible light. On a clear day in Ireland, it is expected that one square meter of PV panel will generate approximately 150W of electrical power. An average house installation can have 20 square meters generating about 3 kW of electrical energy on a good day.

Large-scale ground-mounted solar farms currently are not prevalent in Ireland with the first one becoming operational in 2022 in Co. Wicklow.[36] These solar farms use PV panels secured to the ground of multiple hectares of land. Many of these solar farms are planned and will need to be brought online to provide the targeted 8GW of solar energy by 2030.[37]

Solar 16 PV panels installed on a domestic home

36 https://www.rte.ie/news/ireland/2022/0429/1295115-solar-farm/

37 Climate Action Plan 2023

Installed household PVs are low profile and can be installed on existing roofs. The panels perform best on south-facing roofs.

In Germany's domestic model, large-scale domestic installations have created energy that is used locally to heat homes. This has resulted in a large decrease in demand for energy from the predominantly gas-powered grid of Germany. Ireland could potentially gain a large amount of energy from PV installations in private homes and all social housing.

In relation to Solar PV, the Government must fast track the implementation of the National Retrofit Plan, increasing the number of One Stop Shops, and simplify paperwork needed to access SEAI energy upgrade grants. Funding must be ensured to cater for increase in demand for retrofits and upgrades. One Stop Shops must future proof the system beyond the immediate needs of a properties' generation requirements and install sufficient extra capability to ensure high near-term returns and future capability.

Using locally produced energy has benefits but creates challenges with the existing electrical grid structure and will require careful balancing of the grid with stable production systems or compensators. The Government needs to support the installation of solar capture systems at a local level and create infrastructure improvements to utilise the energy most effectively. Potentially using solar energy to create a local community district heating system, could provide a useful means of absorbing excess energy. This can be done in a similar system to how Amazon Web Services (AWS) use excess heat energy to provide district heating for the Tallaght area in Dublin.[38]

Advantages

- Solar energy is converted directly to electrical energy.
- Electrical energy is generated passively from exposure to direct light.

Disadvantages

- Peak electricity production occurs in the middle of the day, not peak demand.
- No electricity is produced at night.
- Maintenance of multiple small local systems can be more time-consuming than one maintenance of one large electrical station.
- Winter months system produces less electricity.

Recommendations

- Government must fast track the implementation of the National Retrofit Plan, increasing the number of One Stop Shops, and simplify paperwork needed to access SEAI energy upgrade grants.

2.3.5 Nuclear energy

Nuclear energy in Ireland is not a new concept and we currently import it. Nuclear power offers a potential solution to the challenge of creating a reliable zero-carbon energy source. In 1968 there was a reactor proposed for Carnsore Point in County Wexford. This proposal engendered a significant anti-nuclear movement in public opinion in the 1970s, leading to the prevention of nuclear reactors being built in Ireland. This was set in law in Electricity Regulation Act, 1999 (Section 18)[39] which states *"an order under this section shall not provide for the use of nuclear fission for the generation of electricity",* preventing fission from being used to generate electricity in Ireland in perpetuity.

Nuclear energy has been a safe generator of secure electricity for over 60 years and in more than 30 countries.[40] France is one of the heaviest users of nuclear energy and has one the lowest carbon emissions from its energy industry due to its level of nuclear. Nuclear is the only commercially available energy production system that has zero emissions with 60 years of operating at a national scale. Wind and solar energy are the most established alternatives, but both have issues of instability and weather reliance as previously mentioned.

"Nuclear power offers a potential solution to the challenge of creating a reliable zero-carbon energy source."

38 Tallaght buildings to be heated using excess energy from Amazon data centre – The Irish Times

39 Electricity Regulation Act, 1999, Section 18 (irishstatutebook.ie)

40 Nuclear energy development in Ireland

Technology like hydrogen, biomass, and battery storage have potential but are all new technologies and do not yet have the proven ability to work at scale. A suitable baseload of dispatchable electrical energy is needed. In Ireland, the current system for this is predominantly gas conventional thermal generation units, which are undesirable because of their use of fossil fuel and in the increasing cost of gas.

There has been no change in nuclear policy at Governmental level, but in 2022 and 2023 there has been more discussion in the media about the topic. Nuclear technology should be considered as part of the discussions on achieving our carbon goals and reducing our reliance on gas. The technology has developed significantly over the past 50 years, particularly in the field of Small Modular Reactors (SMR) technology.

Traditionally, nuclear energy projects have been developed by state agencies due to the complexity, large size, and capital investment of such projects. SMRs are designed to be a more compact device, which has a simple design at a comparatively low cost. An SMR is constructed by a manufacturer who delivers the reactor to a site and installs it to the grid. This gets energy on the grid quickly and ensures standardisation of the reactor design.

Nuclear will not be the sole solution to our energy crisis, but ignoring the technology entirely would limit engineering options.

Advantages

- Dispatchable source of electrical energy.
- Nuclear fuel is very affordable.
- Electrical energy can be generated 24/7.
- Nuclear is a zero-carbon electricity generation system.

Disadvantages

- Public perception of nuclear energy is negative due to past events. Nuclear energy can also be confused with nuclear weapon programmes.
- Processing nuclear waste is a complicated process and must be considered from the start.
- There is no existing nuclear experience in Ireland. Significant training would be required to both staff and monitor a nuclear industry.
- Legislation and monitoring of nuclear facilities will be complex and require significant resourcing in parallel to the production of a nuclear facility.

Recommendations

- Consideration should be given to removing the current statutory barriers to domestic nuclear power deployment. The current legal barriers inhibit robust analysis of its long-term potential. Government should review the Electricity Regulation Act, 1999 (Section 18) and should amend it so nuclear energy can be discussed.
- Considering nuclear energy, investigating modern advanced nuclear reactors and SMR (Small Modular Reactors) designs, focusing on full benefits and drawbacks, would be beneficial. It would allow a more informed process on the potential for nuclear in the future of Ireland's electrical supply network.

2.4 Infrastructure

Electricity production is clearly essential in terms of our supply and demand model for electrical energy, but it is only one factor in meeting our requirements. Even if we had an infinite supply of electricity we would still need adequate infrastructure to distribute that energy to the areas where it is needed. As Ireland develops more energy sources with more distributed networks due to the positional requirements of renewables like wind and solar, Ireland's electrical infrastructure must evolve to accommodate these power sources.

2.4.1 Improving our energy storage and grid infrastructure

Ireland's electrical grid operates very close to its capacity limit. With the recent energy crisis created by the conflict in Ukraine, access to gas has threatened the successful operation of baseline conventional thermal gas powerplants. Ireland has an integrated electrical infrastructure of fuel storage and electrical distribution. Ireland must continue its drive to move towards renewable sources for our electricity supply, but this requires flexibility both in our supply and in our ability to deliver that power across the country.

Ireland's fuel storage is currently constrained. No large-scale gas storage facilities are available and only limited coal stocks. As we move towards a zero-carbon future, there should be no need for coal storage, and large-scale gas storage can be used for future green hydrogen storage. Gas storage could be done for example, in underground salt caverns or in the form of a compressed liquid.

The liquefied natural gas (LNG) storage facility proposed in the Shannon estuary could prove to be a crucial part of Ireland's gas infrastructure in the coming years, with the intention for it to be converted and used with hydrogen gas storage. The Government should work with industry to investigate LNG storage to ensure gas energy security in the near term, but with a clear plan for converting the infrastructure to hydrogen gas when green hydrogen is available.

Energy storage is critical to Ireland's energy security as we increase our reliance on variable non-synchronous renewable power supplies like wind and solar. As we reduce our emissions, we will need storage systems in the TWh range. To date, discussion of deployment of such very long-duration storage has generally assumed that it can be largely deferred to the post-2030 planning horizon. However, given the recent adoption of such challenging, statutorily binding national GHG budgets (with constituent sectoral ceilings), these plans now need to be urgently accelerated. Behind the Meter (BtM) Battery Storage may be one of the most practical options going forward. However, there are no grid-level battery storage systems available and to achieve TWh levels of storage, hydro, green hydrogen, and methane will be needed.

Ireland's electrical distribution grid was created and developed by ESB since 1927. Ireland has an extensive low-level grid in the countryside to meet the requirements of the dispersed population and has some high-voltage cables to connect to the greater Dublin area. The capacity of the nationwide electrical network does not have existing spare capacity for supporting both increases in offshore wind to onshore or distributing power around the country. This has created a national electrical grid that is susceptible to outages due to maintenance and repair. The electrical grid has also become a bottleneck to adding new power generation systems into the grid.

EirGrid's 'Shaping our Electricity Future' report[41] provides a valuable roadmap to 2030. It also links to the duration of the Phase 2 delivery to develop our offshore potential effectively. We must think in decades, out to 2050 and beyond. With additional gigawatt power sources, long-term planning for supporting infrastructure is required, along with near-term solutions, such as hybrid grid connections.

Increases in substations are needed to accommodate additional wind and solar installations. Consumer-produced solar energy can cause issues with the existing grid. Adjusting the grid with more substations to manage electrical energy at a local level, will ensure energy efficiency can be increased with the generated solar energy.

This could be done as transferred electricity or as heated water for distribution in local communities.

Additionally, more high-voltage lines are needed in Ireland to ensure energy transmission can happen as needed. Large-scale investment in new transmission capacity will be needed to connect new-generation systems efficiently.

As we move away from fossil fuels which provide network inertia due to the mass of spinning turbines, and towards renewables which have little to no inertia, there will be a need to create this inertia to ensure the stability of the network.The development of the Moneypoint's Synchronous Condenser "flywheel" is a critical component of Ireland's future to ensure stable energy production. But this inertia is only short-lived; if there are long delays in renewable energy input, Ireland will need to import electricity through interconnectors or use turbines in conventional thermal generators or nuclear plants.

Investment in national electrical infrastructure is essential to achieve our renewable energy ambition. Ireland has a high potential for innovation in energy management, floating offshore wind generation, and green hydrogen production. We have the potential to be a leader in green energy in Europe and become a net exporter of green energy to support the REPowerEU Plan[42] but only if we have suitable infrastructure and physical connections to the EU.

> "We must think in decades, out to 2050 and beyond."

41 https://www.eirgridgroup.com/site-files/library/EirGrid/Shaping_Our_Electricity_Future_Roadmap.pdf

42 REPowerEU: affordable, secure and sustainable energy for Europe | European Commission (europa.eu)

Advantages

- Electrical grid improvements will ensure that we can bypass areas for maintenance and repair.
- Grid improvements can handle peak demand for areas beyond the Greater Dublin Area.

Disadvantages

- Electrical infrastructure can be hard to gain local support. It will require significant political approval and understanding to increase the existing infrastructure.

Recommendations

- Gas storage will be required in the near and long-term energy landscape of Ireland. Government should work with industry to ensure gas storage is available in the near term and is prepared to align with Ireland's hydrogen strategy.
- Energy storage is critical to Ireland's energy security. As we increase our reliance on variable non-synchronous renewable power supplies, we will need storage systems in the TWh range.
- Behind the Meter (BtM) Battery Storage may be one of the most practical options going forward to achieve energy storage and should be accelerated now to reach our 2030 and 2050 goals.
- Offshore wind is one area where progress must be made. If Ireland maximised its full potential for renewable energy, it could and should aim to become a net exporter of electricity. To maximise the full wind potential, significant infrastructure would be needed to connect wind turbines in the west to interconnectors in the east.
- There is limited social acceptance of investment in transmission lines. The Government must take ownership of this issue, supporting EirGrid, the state-owned company that manages and operates the transmission grid across the island of Ireland. The Government should fund additional public education campaigns on the need for increased electrical infrastructure, and to counter misinformation on health and environmental issues and improve the planning process.
- Hybrid grid connections allow synergy of conventional energy generation and new renewable energy. They provide a near-term solution to adding additional capability to the grid. These must be endorsed and expanded to support additional energy sources such as onshore wind, green hydrogen, and solar farms.
- Develop additional deep-water ports to support supply chain requirements and assembly of offshore wind projects.
- The Government should support the provision of LNG (Liquified Natural Gas) and regasification units as part of the near to medium-term solution to providing energy security for Ireland to prevent possible future disruptions to gas supply.

2.4.2 Interconnectors

Interconnectors are high-voltage electrical connections linking one country to another. Ireland's peripheral location at the edge of Europe isolates it from the more comprehensive European grid. Ireland currently has two operational interconnectors, and both connect to the UK mainland through the East-West Interconnector (500MW) and the Moyle Interconnector (500MW).

Ireland envisages it can export up to 30GW of energy to other countries by 2050. This will be challenging with the current interconnector capacity of a combined 1GW to the UK. Two further interconnection projects are planned, the Celtic Interconnector (700MW) to France and the GreenLink Interconnector (500MW) to the UK. It is envisaged that these interconnections are likely to have more export capacity than import.

Ireland must expand its portfolio of energy sources and interconnectors with a focus on direct links to the EU. We must create connections in the GW range to the EU to ensure a robust electrical system can operate to position Ireland as a net exporter of green energy. The EU envisages greater electrical interconnection between member states in a Super Grid. Ireland could be an essential part of the Super Grid both as a producer of green wind energy with the vast potential of energy from the west coast, and as a leader in integrating electrical grids with the experience gained from managing the north and south electrical grids. Superconductor technology would be essential to such a Super Grid for both land and subsea electrical transmission. The Republic of Ireland and Northern Ireland cooperate closely on energy matters.

The North-South Interconnector has been under development for more than a decade and has faced significant planning issues; it has recently been approved in Northern Ireland, and in the Republic of Ireland after much discussion. Due to its economic, environmental and societal benefits, the North South Interconnector has received strong backing from Government and industry but has remained undelivered with no major progress updates in the past two years.[43]

Advantages

- Increased interconnections allow more energy producers to interact with the Irish market reducing costs to the consumer.
- Interconnectors can supply energy when renewable energy production is low.
- They can export energy when excess renewable energy is available.

Disadvantages

- Interconnectors require a good connection to Irish power stations and Irish consumers. This creates a need for high-voltage land infrastructure to connect to the grid. This infrastructure can impact an area's hinterland and face public opposition.

Recommendations

- Prioritise completing existing interconnectors like the North-South interconnector project and other outstanding grid development projects.
- A detailed study is needed to identify the correct level of interconnections between Ireland and the EU and UK to support Ireland's future energy needs.

43 What's Happening Now? (eirgridgroup.com)

3. Summary of Recommendations

No one technology will be the answer to Ireland's electrical energy production requirements. Each technology has advantages and disadvantages. Identifying the most appropriate balance of systems is an engineering challenge that can be solved.

Energy efficiency/demand reduction

- Utilising tariffs to incentivise improved management of electrical usage to reduce peak and lower the curve of the energy usage.
- Greater use must be made of smart meters. Informing consumers of the best time to perform energy-intensive tasks through a traffic light system which provides granular data with 15 minutes resolution, would be a positive development. The majority of smart meters in domestic properties are not being utilised to inform consumers of the best time to operate energy-intensive devices.

Conventional thermal generation

- Conventional thermal power generation has historically provided a significant proportion of our electricity supply. As we move towards 2050, most of these power stations will need to be shut down or retrofitted to burn green fuels such as hydrogen or biomass to become carbon-neutral plants.
- Government objective for 2000-4000MW of fast-starting dispatchable gas-fired generation capacity should be expedited, and this additional generation capacity should be hydrogen-ready.

Hydrogen

- A rapid scale-up in green hydrogen production and its use is required to support electrical generation. This must be actively managed to ensure the displacement of fossil fuel, which will determine the location of hydrogen research, development and commercialisation activities in Ireland.
- We should investigate and identify suitable gas thermal generator plants to run on hydrogen gas and create a development plan to get these power plants to 100% hydrogen.
- Blending hydrogen (up to 7% by energy content) with bio-methane and fossil methane though costly may be an option to connect hydrogen supply with demand in the near term using existing methane infrastructure, but all unabated fossil methane use must be phased out as rapidly as possible. Carbon budget constraints likely mean this should be before 2035.

Biomass

- Biomass has the potential as a substitute fuel for solid fossil fuel thermal generator stations. Potential stations can be identified and investigated for changing fuel.
- With the capital cost of creating a new thermal powerplant and the risk that its zero-carbon class may change, it is not recommended that biomass is developed as a fuel for large-scale electric power generation stations.

Offshore wind energy in Ireland

- Ireland has the potential to become a net exporter of renewable energy, and to become a leader in the EU Energy Strategy, to ensure that secure EU-based energy production is feasible in a carbon-constrained future. We must accelerate the route to market for innovative energy solutions such as offshore wind with support from Government policy around procurement, planning and execution.
- Develop hybrid grid connections to provide a near term solution to adding additional capability to the grid using the existing underused infrastructure.
- Support innovative solutions in the development of floating offshore wind turbine platforms, to position Ireland in taking a leading role in developing this technology.
- Coastal communities, industry and our Government must all work together to build and agree on new installations of offshore wind.

Onshore wind energy

- Onshore wind energy should continue to grow, but the majority of investment in wind should be focused on offshore wind.
- Onshore wind energy will be essential in meeting 2030 targets for decarbonisation.
- Embrace fresh approaches to land use, energy parks, energy storage and energy systems integration in order to maximise benefits.

Solar

- Government must fast track the implementation of the National Retrofit Plan, increasing the number of One Stop Shops, and simplify paperwork needed to access SEAI energy upgrade grants.

Nuclear energy

- Consideration should be given to removing the current statutory barriers to domestic nuclear power deployment. The current legal barriers inhibit robust analysis of its long-term potential. Government should review the Electricity Regulation Act, 1999 (Section 18) and should amend it so nuclear energy can be discussed.
- Considering nuclear energy, investigating modern advanced nuclear reactors and SMR (Small Modular Reactors) designs, focusing on full benefits and drawbacks, would be beneficial. It would allow a more informed process on the potential for nuclear in the future of Ireland's electrical supply network.

Improving our energy storage and infrastructure

- Gas storage will be required in the near and long-term energy landscape of Ireland. Government should work with industry to ensure gas storage is available in the near term and is prepared to align with Ireland's hydrogen strategy.
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Interconnectors

- Prioritise completing existing interconnectors like the North-South interconnector project and other outstanding grid development projects.
- A detailed study is needed to identify the correct level of interconnections between Ireland and the EU and UK to support Ireland's future energy needs.

Contributing members

Engineers Ireland relies on the expertise of our members to create informed policy work. We want to thank all members and others who have contributed to the production of this report.

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4. Glossary

Acronym/Abbreviation	Term	Explanation
AC	Alternating Current	A form of electric current
AWS		Amazon Web Services
CPD	Continuing Professional Development	Process of lifelong learning and structured learning to remain up to date in developing engineering fields.
CSP	Concentrated Solar Power	Focuses solar energy to a point using mirrors; the heat can then be used to do work.
DSO		Distribution System Operator
ESB		Electricity Supply Board
EU		European Union
EVs		Electric Vehicles
FOWT	Floating Offshore Wind Technology	Wind turbine infrastructure, with connected substations and electrical links, mounted on floating platforms moored off the coast.
FSRU	Floating Storage and Regasification Units	A special type of ship for the transportation of LNG
GDA		Greater Dublin Area
GW	Gigawatt	Unit of Energy
GWh	Gigawatt Hour	Unit of Energy
IC	Interconnector	Electrical links, facilities and equipment connecting one country's transmission network to another.
IEA		International Energy Agency
kW	Kilowatt	Unit of energy Kilowatt = 1000 watts
LNG	Liquefied Natural Gas	A process of storing natural gas under pressure as a liquid
Mtoe	Megaton of oil equivalent	Unit of energy
MW	Megawatt	Unit of energy 1 megawatt = 1000 kilowatts = 106 joules / second
PV	Photovoltaics	Technology allowing the creation of electrical energy from exposure to light
SEAI		Sustainable Energy Authority of Ireland
SEM	Single Electricity Market	The electrical market on the island of Ireland covers both the North of Ireland and the Republic of Ireland.
SMR	Small Modular Reactor	Small nuclear reactor based on the concept of standardised units that can be deployed as needed to create a powerplant
TSO		Transmission System Operator
TWh	Terawatt Hour	Unit of energy 1 terawatt hour = 1000000000 kilowatt hours = 3.6 x 1015 joules

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