

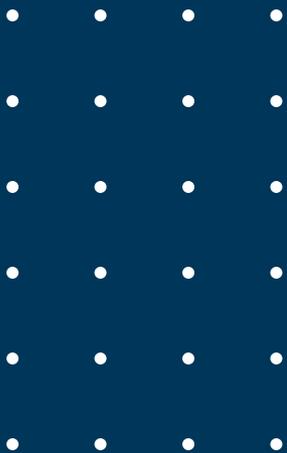


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Taighde, Idirphlé, Comhairle
Research, Dialogue, Advice

COUNCIL

No. 172 February 2026



Accelerating the Transition to a Sustainable Energy System

National Economic & Social Council

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Accelerating the Transition to a Sustainable Energy System

COUNCIL PAPER

No.172 February 2026

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Secretariat to Project

Dr Larry O'Connell, Director

Gemma O'Reilly, Policy Analyst

A full list of the NESC Secretariat can be found at
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Abbreviations

AD	Anaerobic Digestion	Mt	Megatonne
BECCS	Bioenergy with Carbon Capture and Storage	NCPC	National Competitiveness and Productivity Council
CBAM	Carbon Border Adjustment Mechanism	NESC	National Economic and Social Council
CCAC	Climate Change Advisory Council	OECD	Organisation for Economic Cooperation and Development
CCS	Carbon Capture and Storage	ORESS	Offshore Renewable Energy Support Scheme
CHP	Combined Heat and Power	PV	Photovoltaic
CO ₂	Carbon Dioxide	RED	Renewable Energy Directive
COM-B	Capacity, Opportunity, Motivation - Behaviour	RESS	Renewable Energy Support Scheme
CPPA	Corporate Power Purchase Agreement	SEAI	Sustainable Energy Authority of Ireland
CRU	Commission for Regulation of Utilities	SEM	Single Electricity Market
DAC	Direct Air Capture	SI	Statutory Instrument
DAFM	Department of Agriculture, Food and Marine	SME	Small to Medium Enterprise
DCEE	Department of Climate, Energy and Environment (from 2 June 2025)	SNSP	System Non-Synchronous Penetration
DECC	Department of Energy, Climate and Communications (up to 2 June 2025)	TCP	Technology Cooperation Programme
DETE	Department of Enterprise, Trade and Employment	TEG	Temporary Emergency Generation
DF	Demand Flexibility	ToU	Time of Use
DR	Demand Response	TWh	Terawatt (=1000 Gigawatts)
EED	Energy Efficiency Directive	UCC	University College Cork
EPA	Environmental Protection Agency	UCD	University College Dublin
ESB	Electricity Supply Board	UNESCO	United Nations Educational, Scientific and Cultural Organisation
EU	European Union	UNFCCC	United Nations Framework Convention on Climate Change
EV	Electric Vehicle	V2G	Vehicle to Grid
GAA	Gaelic Athletics Association	V2H	Vehicle to Home
GW	Gigawatts	V2L	Vehicle to Load
HVO	Hydrogenated Vegetable Oil	V2X	Vehicle to X (=everything)
IEA	International Energy Agency	VRE	Variable Renewable Electricity
IPCC	Intergovernmental Panel on Climate Change	WAM	With Additional Measures
LEU	Large Energy User	WEM	With Existing Measures
LTS	Long-term Strategy	WRI	World Resources Institute
		ZCF	Zero Carbon Fuels Executive Summary

Executive Summary

Energy is central to a functioning, healthy and thriving society, underpinning a wide range of societal and economic goals. To avoid dangerous climate change, a major energy transition is required globally and in Ireland to urgently reduce GHG emissions through ‘a substantial reduction in overall fossil fuel use, the deployment of low-emission energy sources, switching to alternative energy carriers, and energy efficiency and conservation’ (IPCC, 2022, p28). Despite many plans and strategies in place, Ireland is not on track to meet its climate and energy targets. This report, NESC’s fourth report on the energy transition, examines the energy sector in Ireland using systems thinking tools to identify approaches to accelerate the transition to a sustainable energy system.

Engagement by NESC with stakeholders has highlighted that, while there are efforts to reduce greenhouse-gas emissions, different energy outcomes are being pursued in silos. Few stakeholders or sectoral experts had a broad understanding of the transition already underway across the energy sector, nor even the optimal endpoint. When policies are not coherent, there is a risk of missing opportunities for synergies and additional benefits, slowing the transition, and undermining public support for the energy shift.

This report employs systems analysis tools and techniques to move beyond silos to integrate insights from a range of disciplines and stakeholders on the key drivers of and constraints on energy transition in Ireland. The aim is to identify systemic approaches that can most effectively drive the energy transition by designing interventions for multiple environmental, social and economic benefits in an integrated manner. The Council recommends five approaches designed to support coherence, reduce frictions, and realise the broader benefits that will cement public support for the energy transition.

Recommendation 1: Create a Cross-Government Energy Framework

To realise synergies and avoid siloed thinking, create a Cross-Government Energy Framework that addresses heat, transport and electricity together in a coherent manner, integrating existing strategies and plans for different policy objectives such as climate, energy poverty, affordability and energy security, and for different energy vectors such as electricity, gas and biofuels. The framework should aim to reduce uncertainty for energy users and investors. It should be consistent with the National Climate Objective and the Climate Action Plan but also integrate the broader social, economic and environmental objectives associated with energy, as captured in the energy doughnut (section 2.2).

Recommendation 2: Make Government Plans for Green Energy Industrial Parks More Ambitious

Some research suggests that public support for the energy transition could trickle up rather than down – in other words, that good experience locally can build support for national action. Government has already outlined plans for Green Energy Industrial Parks to act as a future end use for renewable energy, particularly offshore wind. These plans should be more ambitious, designing-in broader benefits including greater decarbonisation potential and tangible benefits

for local communities. This can include provision of local amenities, district heating extended to complementary businesses on site and to the local community, space for nature, sustainable mobility infrastructure connecting industrial parks with local communities and population centres, and durable employment opportunities.

Recommendation 3: Develop A New Focus on Energy Demand

With energy projections pointing to overall growth in energy consumption, energy demand management needs more focus as a necessary tool to meet energy and climate goals. There is a lot of policy and action on energy efficiency across households, businesses, public sector and even large energy users, but more can be achieved. Electrification will deliver energy savings, while compact growth and sustainable transport also offer scope to reduce energy demand. The Council recommends that Government initiate a study on the potential of energy demand management across different sectors to assist in meeting energy transition goals.

Recommendation 4: Increase Energy Literacy and Public Engagement

Communication efforts currently focus on promoting uptake of specific energy efficiency measures or retrofit programmes. However, a broader effort on energy literacy and public engagement is needed as one of the foundational elements for achieving behavioural change. Low levels of energy literacy are an important factor undermining efforts to develop measures such as demand response, uptake of energy efficiency grants, and even sensible cost-saving measures in the home. As part of an overall Cross-Government Framework for Energy, a strategy should be adopted to increase energy literacy across the population and to achieve effective public engagement across the transition.

Recommendation 5: Build Distributed Resilience

The energy transition must do more than cut emissions. It also has to address the needs of households and communities. Together with previous recommendations on energy poverty and affordability (Council Report No.170), the Council recommends that more focus be placed on the energy resilience of households, businesses and communities, and on their capacity to cope with power outages, particularly in isolated areas. Energy efficiency, microgeneration and retrofit support programmes should be expanded to also work towards building the resilience of households, communities and SMEs, particularly in vulnerable areas and for vulnerable households. Building resilience could also be supported through advice, grant assistance, designating local resilience hubs, and appropriate training of tradespeople.

Chapter 1: Introduction

Energy is central to a functioning, healthy and thriving society. It underpins a wide range of societal and economic goals. International commitments under the United Nations Framework Convention on Climate Change (UNFCCC) and national legislation require the avoidance of dangerous climate change by urgently reducing greenhouse-gas emissions. According to the Intergovernmental Panel on Climate Change (IPCC), this requires globally 'a substantial reduction in overall fossil fuel use, the deployment of low-emission energy sources, switching to alternative energy carriers, and energy efficiency and conservation' (IPCC, 2022, p28). In 2023, under the UNFCCC Paris Agreement, all countries called for 'tripling renewable energy capacity globally and doubling the global average annual rate of energy efficiency improvements by 2030', and 'transitioning away from fossil fuels in energy systems in a just, orderly and equitable manner, accelerating action in this critical decade, so as to achieve net zero by 2050' (UNFCCC, 2024, p5). This requires a major transition across the energy sector, both globally and in Ireland.

A large policy effort is underway to transition Ireland's energy system, including through the Climate Action Plan (DCEE, 2025a), updated annually, the Energy Poverty Action Plan (DECC, 2022), Energy Security in Ireland to 2030 (DECC, 2023a), the Future Framework for Offshore Renewable Energy (DETE, 2024), the National Hydrogen Strategy (DECC, 2023b), the National Biomethane Strategy (DECC and DAFM, 2024), the Electricity Storage Policy Framework (DECC, 2024a) and the proposed Large Energy Users Connection Policy (CRU, 2025b).

However, despite these strategies, Ireland is not on track to meet its climate and energy targets. The latest Environmental Protection Agency (EPA) projections highlight that the required transition is not occurring fast enough to meet legislated targets. Analysis by the Sustainable Energy Authority of Ireland (SEAI) shows that technological change alone will not be sufficient to meet targets in time, suggesting that consideration will need to be given to energy demand management (EPA, 2025; SEAI, 2024). Furthermore, engagement by NESC with stakeholders, as part of this research, shows that few stakeholders or sectoral experts had a broad understanding of the transition already underway across the energy sector, nor even the optimal endpoint. It is evident that different energy outcomes are being pursued in silos, and that an overly technocratic approach is often applied. This risks missing opportunities for synergies and additional benefits, creating friction that slows down the transition when diverse policies are not coherent, and undermining public support for the energy transition.

This report employs systems analysis techniques to move beyond silos and technological analyses to integrate insights from a range of disciplines and stakeholders on the key drivers of and constraints on energy transition in Ireland. The aim is to identify specific actions and approaches, or levers, that can be particularly effective across the energy transition through designing for multiple benefits to achieve environmental, social and economic objectives. The systems approach does not replace primary research and analysis but rather offers tools to organise and combine insights from such sources and across a variety of disciplines in order to obtain a coherent and cohesive understanding of the overall system. Systems analysis tools include causal loop diagrams to explore dynamic influences, participative stakeholder engagement, leverage frameworks, and examination of goals and vision. Taking a systems

approach helps identify ways to accelerate the energy transition sustainably because it aims to work with the complexity of the energy system, leveraging system dynamics to identify the most effective interventions, whether technology or behavioural change, while maintaining public support through attention to the practical needs of the public and of communities.

Drawing on systems analysis and stakeholder engagement, this report identifies ways to build rather than overwhelm current levels of support for the energy transition through new approaches to existing intervention options. The Council recommends five interventions designed to support coherence, reduce frictions, and realise the broader benefits that will cement public support for the energy transition.

1.1 Report Structure

Chapter 2 presents an overview of Ireland’s energy system, and identifies the multiple social, economic and environmental objectives that it underpins. It highlights the changes required of the energy system if it is to achieve these objectives. It explores drivers of changes to the system, including policy and technological developments, while pointing to policy gaps, complexities and technological limitations that are preventing change at the pace required.

Chapter 3 explores how a systems analysis can support navigating the complexities of the energy system to explore barriers and dynamics that can help or hinder the energy transition and identify interventions that can scale up transition. It provides a brief explanation of system dynamics, describes its features for four areas of the energy system, and identifies important interventions to accelerate energy transition in Ireland.

Chapter 4 proposes recommendations to support the acceleration of a sustainable energy transition in support of social, economic and environmental objectives.

Chapter 2: The Energy System

2.1 Introduction

This chapter presents an overview of Ireland's energy system and the multiple social, economic and environmental objectives that it underpins.

Achieving these multiple objectives requires changes across a complex system, which involves multiple stakeholders across energy generation and supply, use and distribution.

The chapter reflects changes that are already underway, driven both by policy and technological change. However, because of policy gaps and technological limitations, these changes are not happening fast enough or deeply enough.

It shows that a comprehensive approach to energy policy is lacking despite the potential synergies that arise from an integrated approach. Accelerating change may require a new approach that accounts for complexities and system dynamics to identify the most impactful way forward.

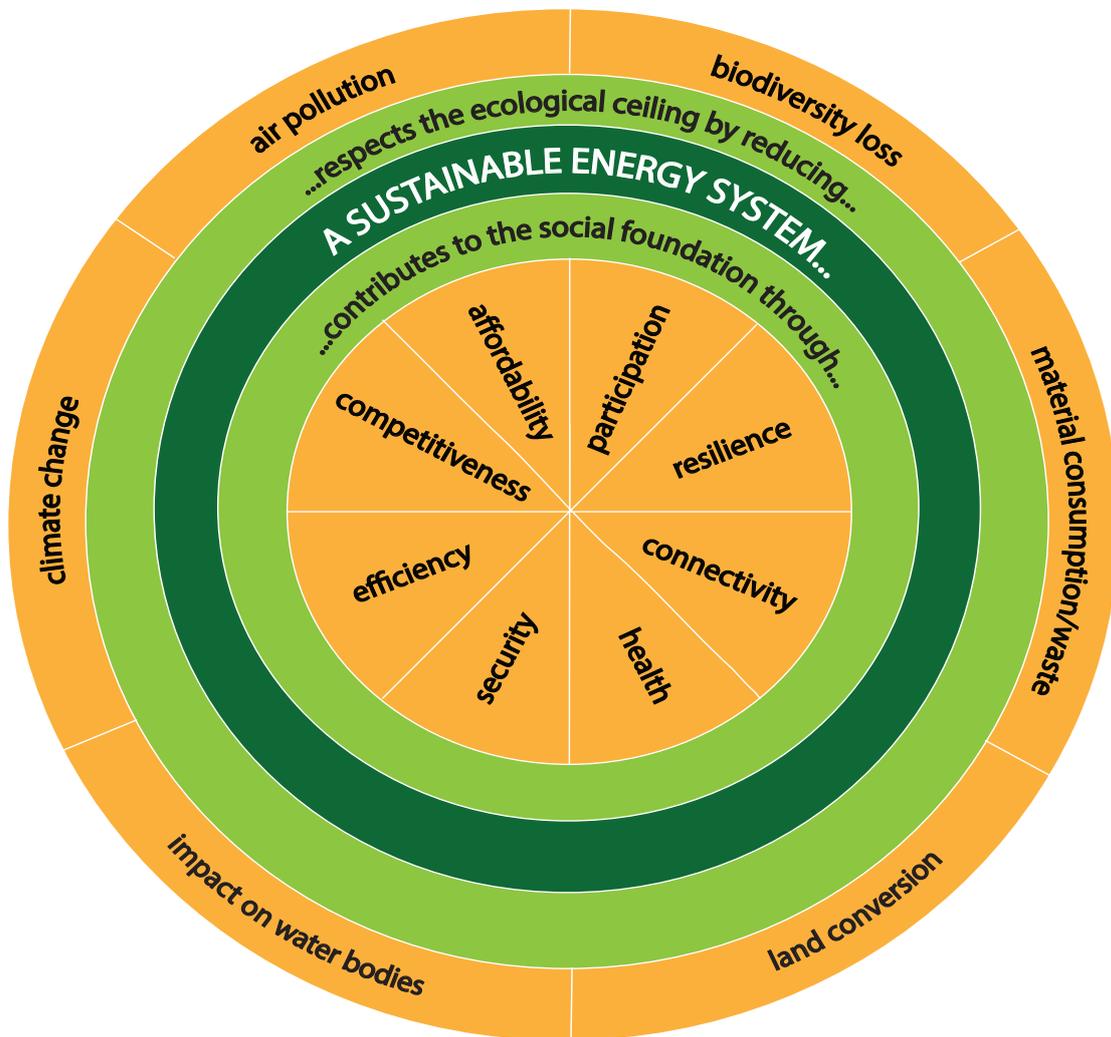
2.2 Energy is Central to Multiple Policy Objectives

Energy underpins societal and economic goals, and sustainable energy is central to meeting environmental outcomes. The interplay between social, economic and environmental objectives both drives change in the energy system (to meet targets and goals) and makes transition more complex – for example, through the potential unintended consequences of transition for vulnerable groups or economic competitiveness.

The energy transition is often characterised as being a process of decarbonisation but many more elements are involved. To be sustainable, the energy transition has to satisfy provision of basic requirements for life, society and commerce while also respecting planetary boundaries or ecological ceilings. Drawing on the doughnut economics model and visualisation (Fanning and Raworth, 2025), the energy doughnut, captured in Figure 2.1 (O'Reilly, 2026 forthcoming), shows how a sustainable energy system should contribute to the social foundation while respecting the relevant planetary boundaries or ecological ceilings.

The energy doughnut offers a clear illustration of the complex but interrelated space in which the energy transition operates. It also highlights the importance of a policy response that recognises the wide range of policy goals and targets, as well as social, economic and environmental considerations, that must be taken into account when planning the energy transition. The doughnut can therefore serve as a useful prompt to design-in synergies and co-benefits to energy transition plans and policies while avoiding or reducing wider negative impacts, where possible.

Figure 2.1: The Energy Sector Doughnut



Source: O'Reilly, 2026.

2.2.1 Environmental

Meeting climate and environmental targets is a major driver of change, including the shift towards energy efficiency and renewable energy. The Paris Agreement, under the UNFCCC, committed signatory countries, including Ireland, to limit warming to well below 2°C and to pursue efforts to limit the global temperature increase to 1.5°C (UNFCCC, 2015). The 1.5°C target is increasingly acknowledged internationally as essential to avoid dangerous climate change (UNFCCC, 2021: §16).

Towards this end, the European Union Climate Law sets a goal of achieving climate neutrality or net-zero greenhouse-gas emissions by 2050 (EU, 2021); the recast EU Energy Efficiency Directive (EED) sets an overall target for the EU's final energy consumption to reduce by 11.7 per cent by 2030 compared to the projected energy use in 2030, based on the EU Commission's reference scenario (EU, 2023a), and the EU Renewable Energy Directive (RED) sets a target for

renewable energy to account for 42.5 per cent of gross final energy consumption across the EU by 2030, covering electricity, transport and heat. (EU, 2023b).

In Ireland, the Climate Action and Low Carbon Development Act (as amended, 2021) set a national climate objective to 'transition to a climate resilient, biodiversity rich, environmentally sustainable and climate neutral economy' (Government of Ireland, 2021). Under the Act, the Government sets five-year carbon budgets.

The carbon budgets already adopted by Government under the Climate Act have been allocated across sectors to create mandatory sectoral emissions ceilings. These set a limit on the amount of emissions each sector can emit in each five-year period. The energy system is implicated in the sectoral emissions ceilings for the electricity, transport, built environment and industry sectors. For energy efficiency, the updated 'Ireland's Integrated National Energy and Climate Plan 2021-2030' calculates Ireland's share of the EU's final energy consumption target for 2030, which suggests that Ireland's total final energy demand would be capped at around 122TWh (DECC, 2024). For renewable energy, Ireland's expected national contribution to the EU target is to achieve 43 per cent across all energy.

Under the Climate Action Plan, Ireland set targets for various renewable energy or carbon-neutral technologies, including increasing the renewable electricity share to 50 per cent by 2025 and 80 per cent by 2030, an onshore wind target of 6GW by 2025 and 9GW by 2030, a solar target of up to 5GW by 2025 and 8GW by 2030, an offshore wind target of at least 5GW by 2030, and a 50-55 per cent share of carbon neutral heating in industry by 2025, rising to 70-75 per cent by 2030 (DCEE, 2025).

Beyond climate objectives, the energy transition has implications for wider environmental objectives including reducing biodiversity loss, impacts on water bodies, air pollution and material consumption. For example, Molloy et al. (2024) find that renewable energy infrastructure and crops have potentially positive impacts on biodiversity in Ireland but that large-scale adoption of renewable energy and biofuels may lead to conflicts with biodiversity, including through habitat loss, degradation and fragmentation. They find that negative impacts could be mitigated through energy demand management measures, energy efficiency and prioritising renewable energies that require less land; they further note that appropriate siting of renewable energy and associated infrastructure is critical.

Despite these targets, progress is happening too slowly. Analysis by the Environmental Protection Agency (EPA) and the Sustainable Energy Authority of Ireland (SEAI) suggests that Ireland is not on track to meet its carbon budgets (EPA, 2025; SEAI, 2024a). Under the EU Energy Efficiency Directive and the National Energy and Climate Plan, Ireland is required to make efforts to limit its final energy consumption to 122TWh by 2030, but has exceeded this level since 2004 (European Union, 2023). Final energy consumption stood at 143TWh in 2024 (SEAI, 2025a). Moreover, with respect to renewable energy targets, SEAI energy projections show that, under the favourable 'with additional measures' (WAM) scenario, Ireland is expected to fall just short of the 43 per cent target across all energy, at 42.7 per cent (SEAI, 2024a). Under the less favourable 'with existing measures' (WEM) scenario, which recognises some of the current delivery risks, Ireland would be expected to achieve a share of about 31 per cent.

2.2.2 Social

Energy plays a key role in policy objectives related to social inclusion, poverty reduction and health. For example, the Roadmap for Social Inclusion 2020-2025 includes a commitment to 'ensure that all people can live with confidence that they have access to good quality healthcare, housing, *energy* and food' [emphasis added] (DSP, 2023). The Energy Poverty Action Plan noted in 2022 that 'consumers are facing energy costs of a level never experienced before' (DECC, 2022). Johnston (2025) highlighted the impacts of energy poverty such as colder indoor air temperatures placing a 'thermal stress' on the body, affecting the immune system, cold damp accommodations aggravating respiratory and allergic conditions, negative impacts on mental health, and an inability to pay bills leading to mental stress. Recent data published by the CRU show that 298,336 households were in arrears on their electricity bills in May 2025, up from April 2025, while 183,520 households were behind on their gas bill (CRU, 2025a). Pobal (2025) found that 'households in the most disadvantaged areas are almost five times less likely to use renewable energy than those in more affluent communities'. More needs to be done to achieve social benefits in the energy transition. NESC has outlined many potential societal benefits of a just and fair energy transition, particularly for households and communities, concluding that 'further measures are required to support groups at particular risk of energy poverty' (NESC, 2025a: 80).

2.2.3 Economic

NESC has previously noted (NESC, 2025b) the importance placed on job creation and enterprise opportunities in many key Irish policy documents. Ireland is currently among the most fossil-fuel import-dependent countries in Europe. This presents several disadvantages for the Irish economy, including exposure to supply disruptions and price volatility on international markets, financial outflows, and inefficient fossil-fuel subsidies (NESC 2025c).

Competitive pricing is a key concern for exporters, foreign direct investment and the viability of small businesses. The National Competitiveness and Productivity Council (NCPC) stated in its 2024 report: 'In an intensely competitive international environment, there is a need to prioritise actions to address competitiveness issues related to energy costs, renewable energy provision, infrastructure, housing and water/wastewater' (NCPC, 2024). It noted that cost challenges for firms in recent years included energy. Household and business energy cost concerns are hard to manage in a context where over 78 per cent of Ireland's energy is imported (SEAI, 2024b). Energy efficiency represents an opportunity to reduce costs and improve competitiveness (DCEE, 2025).

Technological development is shifting the economic drivers of change in the energy sector. The Rocky Mountain Institute highlighted falling costs of 35 per cent for solar PV from November 2023 to November 2024, and the costs of batteries falling by 20 to 50 per cent in the same period (Atkinson and Gulli, 2025). Smart technologies and energy efficiency innovations also improve the ability to manage energy consumption and costs, particularly in the energy sector. NESC (2025a) outlines how new technologies and the potential for automation employing AI can support more responsive energy management by households. These effects also apply more generally to commercial and public buildings.

2.3 Change is Needed Across an Already Complex System

The diversity of current energy sources and uses points to the complexity of the energy system, which underlines the challenge in achieving coherence. This diversity creates risks of unintended consequences where interdependencies are not factored into plans, but it also opens up opportunities where synergies exist. This section outlines the main sources and uses, as well as identifying a number of features of the system that increase its complexity.

The broad energy system includes energy for space and water heating/cooling, lighting, appliances, data, processing, manufacturing, steam, cooking, transport of passengers and of goods. These are often categorised under three service headings: heat, electricity and transport. Fossil fuels accounted for about 82.7 per cent of final energy consumption across all uses in 2023, with consequences for greenhouse-gas emissions (SEAI, 2024b). The vast majority of fossil fuels are imported to Ireland (ibid.), with implications for energy security (NESC, 2025c). Energy consumed at home, at work and in transport is delivered through a series of different infrastructures and markets. There are arguably four means of energy delivery in Ireland:

- the electricity system (ranging from the ‘microgeneration’ of renewable electricity by households and small businesses to large-scale renewable and fossil-fuel based generation);
- the gas network (currently focussed on delivery of natural gas to homes, businesses and large energy users, including the electricity system);
- the fuel delivery system (consisting of petrol stations, oil and solid-fuel distribution companies for transport and heating buildings); and
- district heating systems (consisting of a heat source, such as waste heat, heat pumps or geothermal, and a piped network for distributing that heat around a locality).

Each of these sources has a variety of customers employing the energy for a variety of services: heat, electricity and transport. The following subsections describe these service demands and their current reliance on fossil fuels.

2.3.1 Heat

Heat encompasses space heating for buildings, water heating for personal use, industrial heat (required, for example, for generating steam), and demand for cooling. Buildings are currently predominantly heated by fossil fuels: natural gas-fired central heating where the network is available, and oil-fired central heating away from the gas grid. Many homes are still heated by solid fuels such as peat and coal, giving rise to emissions of around 1 Mt CO₂ and emission of air pollutants such as particulate matter and reactive gases, which affect health, wellbeing and ecosystems (SEAI, 2024b; EPA, 2024).

Electricity is also a source of heat for homes and buildings, either through relatively inefficient electric heaters, or with very high efficiency using heat pumps (qualifying as a renewable energy because of its high efficiency and its use of ambient heat). Electricity also powers cooling systems.

Commercial buildings and manufacturing processes can use oil, natural gas, woodchip biomass or electricity as heat sources.

Demand for heat can be met through a contract with a gas supplier using a national network, through a supply delivery from a fuel merchant or even through a local arrangement for peat harvesting or timber.

2.3.2 Power/Electricity

Appliances, lighting, data storage and processing, manufacturing, heat, cooling and, increasingly, transport are powered by electricity. It is delivered primarily through the national grid network but may be supplemented by local on-site generation (e.g. microgeneration in buildings).

In 2024, 42 per cent of Ireland's gross electricity supply came from natural gas, while wind provided another 32 per cent (both down on 2023). Interconnection led to import of almost 14 per cent of electricity supply in 2024 from Britain, up from just over 9 per cent in 2023 (SEAI, 2025a). More recently, and on an all-island basis, in August 2025 fossil fuels supplied 47 per cent of electricity demand, with renewable generation supply at 33.4 per cent and imports at 19.7 per cent (Green Collective, 2025).

Electricity is delivered to consumers by electric utilities (also known as electricity retail). Electricity retail suppliers buy their supply off the Single Electricity Market (SEM), the wholesale electricity market covering Ireland and Northern Ireland. Some households and businesses invest in on-site electricity generation such as solar photovoltaic panels (solar PV) and even battery storage.

Some large energy users invest in onsite back-up generation from gas or diesel or combined heat and power (CHP). On farms, electricity remains the power source for lighting and other processes such as milking and refrigeration. The tractor engine, fuelled by diesel, can be another source of power for specialised farm equipment.

2.3.3 Transport

Transport on the island of Ireland, of both people and goods, includes cars, lorries, vans, bikes, trains, scooters and walking. The primary energy sources for transport today are liquid fossil fuels, petrol and diesel.

A small but growing share is powered by electricity, mainly from the national electricity grid.

Biofuels, usually imported, are increasingly mixed into petrol and diesel at rates set by government. Some forecourts and fuel distributors also offer a pure biofuel mix (e.g. hydrogenated vegetable oil – HVO) for use in vehicles, often commercial fleets.

2.3.4 Factors Increasing Complexity of the Transition

In addition to the multiple sources and uses of energy, additional factors increase the complexity of the energy system and the complexity of transition. Factors include some features of the existing energy system as well as technological uncertainties and lack of clarity on the phase-out of fossil fuels.

Characteristics of the existing system

First, most energy consumers interact directly with multiple sources and sellers of energy – an electricity utility, potentially a gas utility, or an oil supplier (kerosene/petrol/diesel). Achieving significant changes in energy consumption levels and environmental impact (changing source, significantly changing quantity) usually incurs an upfront capital cost for a household, business or the Government. Capital costs may include retrofitting a building to increase thermal efficiency, changing boilers, installing heat pumps, upstream investment in renewables and grid upgrades, investing in sustainable modes of transport and infrastructure, or changing vehicles. When scaled up, these changes imply potential for changed relationships between agents within the energy system. Large businesses may be better resourced to manage diverse energy relationships but will often face additional complexities with respect to international trade, hedging activities, required permits and social licence to operate.

Secondly, the different energy types (electric, gas or liquid fuel and renewable or fossil) and services (electricity, heat, transport) are becoming increasingly entangled, which adds to complexity of the energy transition. Developments in one segment of the energy system influence progress in other segments. As noted above, most energy consumers already interact with multiple suppliers to meet their demand. On the supply side, the electricity system currently uses natural gas as a major source of power and is expected to remain, to some extent, dependent on gaseous fuel delivered by the gas grid in the medium term – coupling the electricity and gas systems. Electricity generation is therefore an important customer for the gas grid now and in future. The electricity system is also expected to provide a key ingredient for delivery of green hydrogen on the network. Future district heating systems could run on electricity (heat pumps) and/or some kind of zero carbon gas and/or biofuels, in addition to waste heat from other large energy users or geothermal. Fuel merchants currently selling solid and liquid fuels have the potential to distribute biofuels. These examples highlight that any transition effort in one part of the energy system needs to be sensitive to the impacts on other parts of the system.

Thirdly, matching supply and demand is a further challenge, particularly for the electricity network and to a lesser extent for gas, as systems have to cope with daily and seasonal demand peaks and troughs on networks that cannot function if demand (withdrawals from grid) do not closely match supply (injections to grid) on a minute-by-minute basis. This technical balancing act has to function while maintaining viability for suppliers through low-demand periods, and increasingly while coping with fluctuating supply from variable renewables.

Fourth, the energy transition implies a big change for the gas network and industry. Fuel switching from natural gas to biomethane and/or hydrogen and electrification in the broader economy mean a substantial change in business model, with implications for employees in the industry, for gas customers and for state assets (Khammadox *et al.*, 2025).

A final layer of complexity comes from cross-border and international trade, which was explored in detail in NESC (2025c). Ireland imports its petrol, diesel and coal supplies. Most of Ireland's gas is imported from the UK via Scotland and Northern Ireland as the domestic source of gas from Corrib is insufficient to meet demand, and diminishing. Ireland and Northern Ireland share a wholesale electricity market (SEM), while there are electricity interconnectors between the grid in the North and the South. Interconnection with Britain, and soon with France, provides a means of trade beyond the boundaries of the SEM. International trade in energy is likely to remain important in the coming decades even if volumes change. However, Brexit has introduced complications, and the imminent implementation of the carbon border adjustment mechanism (CBAM) will also have an impact (see NESC, 2025c).

Uncertainty on the future of fossil fuels and CCS

Uncertainty on the future of fossil fuels and carbon capture and storage (CCS) increases the complexity of transition. CCS is a technological approach to capturing carbon dioxide (e.g. from smokestacks coming from electricity generation or industrial units) and then transporting that carbon dioxide to a site of long-term storage (e.g. depleted oil or gas field). When applied to fossil-fuel combustion, it can reduce their potential carbon dioxide emissions by up to 90 per cent in well-designed systems, when operated efficiently. However, an analysis by the World Resources Institute (WRI) in 2025 found: 'There are not many examples to date of its successful application, and several high-profile projects have been abandoned or shuttered' (Lebling *et al.*, 2025).

The Long-term Strategy on Greenhouse Gas Emissions Reductions 2024 suggests that negative emissions or carbon dioxide removals will be required for Ireland to reach net zero in 2050 and to maintain it beyond then (DECC, 2024c). This is based on research by the IPCC, which found that '[r]eaching net zero GHG emissions primarily requires deep reductions in CO₂, methane, and other GHG emissions, and implies net negative CO₂ emissions' (IPCC, 2023, p19). The IPCC further found, in its 2023 Synthesis Report, that global 'pathways that limit warming to 1.5 °C ... reach net zero CO₂ in the early 2050s, followed by net negative CO₂ emissions' (*ibid.*: 20). This places further demands on capacity for storage of carbon dioxide.

Carbon capture and storage only results in negative emissions or removals where the carbon dioxide is captured from the burning of biofuels (Bioenergy with Carbon Capture and Storage – BECCS). There are a limited number of options for creating carbon dioxide removals from the atmosphere. Nature-based approaches in Ireland include afforestation, harvested wood products and water table management of organic soils. These are proven techniques but limited at the outset by competition for land and biological limits.

Direct Air Capture (DAC) is a technology that captures carbon dioxide from the air but is at lower technology readiness level than CCS. It is energy-intensive and more expensive than CCS (IEA, 2024). The IEA estimates that *capturing* carbon dioxide from conventional power generation would cost anywhere between 50 and 100 \$/t CO₂ (IEA, 2021a). Costs of capture increase rapidly where efforts are made to capture at rates closer to 100 per cent (MIT Climate, 2021). Transport and storage of the carbon dioxide would incur further cost; estimates vary widely due to their dependence on local conditions such as the proximity of suitable storage.

Geological storage of CO₂ is currently illegal in Ireland under S.I. No.575/2011 - European Communities (Geological Storage of Carbon Dioxide) Regulations 2011 (Government of Ireland, 2011). English and English (2022) estimate carbon dioxide storage capacity in the Kinsale and Corrib gas fields as equivalent to about 40 years of emissions from the top ten point sources in Ireland.

DAC and CCS with biofuels are the two most advanced technological solutions for carbon dioxide removals, or negative emissions. Both generally rely on storage of the captured carbon dioxide. This additional demand for already expensive and possibly limited carbon dioxide transport and storage capacity would add to the costs of attempting to maintain fossil fuels in the energy system through application of CCS.

Given the need to achieve negative emissions, the limited capacity in Ireland for storage of CO₂, and the additional costs of applying CCS, the costs of maintaining fossil fuels in the energy system are likely to be prohibitive, particularly for heat and power, and lighter modes of transport where alternatives exist (cars, vans, buses, etc). Furthermore, continued use of fossil fuels would most likely mean continued importation of fossil fuels, which was identified in Ireland's Energy Security Strategy (2023) as presenting challenges to Ireland's energy security (DECC, 2023a).

Being clear about the key steps and ultimately phasing out of fossil fuels in Ireland is important to guide infrastructure investment choices and to increase investor confidence in the short to medium term, because any infrastructure investment now will generally have an asset life up to and beyond 2050. Mistaken paths could be costly.

These complexities and uncertainties underline the challenge of transitioning the energy system. Despite the complexity, there are also potential synergies that an integrated approach to transition could leverage.

2.4 Opportunities for Synergies to Meet Multiple Objectives

Bearing in mind the multiple objectives illustrated in the energy doughnut, approaches for energy transition in one area can have potential synergies supporting the achievement of other objectives in the doughnut. For example, Box 2.1 describes the deployment of electric vehicles (EVs) as an example of how EV technology could support the achievement of multiple objectives, including decreasing greenhouse-gas emissions, increasing household resilience during periods of disruption, and helping to manage power on the grid. District heating is another example of potential cross-energy-sector synergies. District heating can create expanded opportunities for efficiencies in the Irish energy system, reducing the overall cost of decarbonisation. Using efficient thermal storage, district heating can reduce peak demand by availing of cheap night-time electricity, or renewable electricity when abundant, to generate heat, then store it and deliver it to homes and buildings when it is needed (IEA, 2021b). District heating can also make it economic to make use of deep geothermal energy, which in Ireland is not feasible for individual buildings.¹

¹ Geothermal energy, drawing heat from the centre of the earth, is different to ground heat used in ground-source heat pumps. In the latter case, the ground is effectively a bank of ambient heat from the sun.

Box 2.1: Electric Vehicle Benefits for Household and Grid Resilience

Electric vehicles offer the opportunity to shift electricity demand consumption by the owners of those vehicles. Owners are already encouraged, through special 'time of use' (ToU) tariffs, to charge their vehicles overnight. However, further opportunities are emerging, known collectively as Vehicle to X (=everything) – V2X. The average electric vehicle has battery capacity that is typically more than double that of residential powerbank batteries.

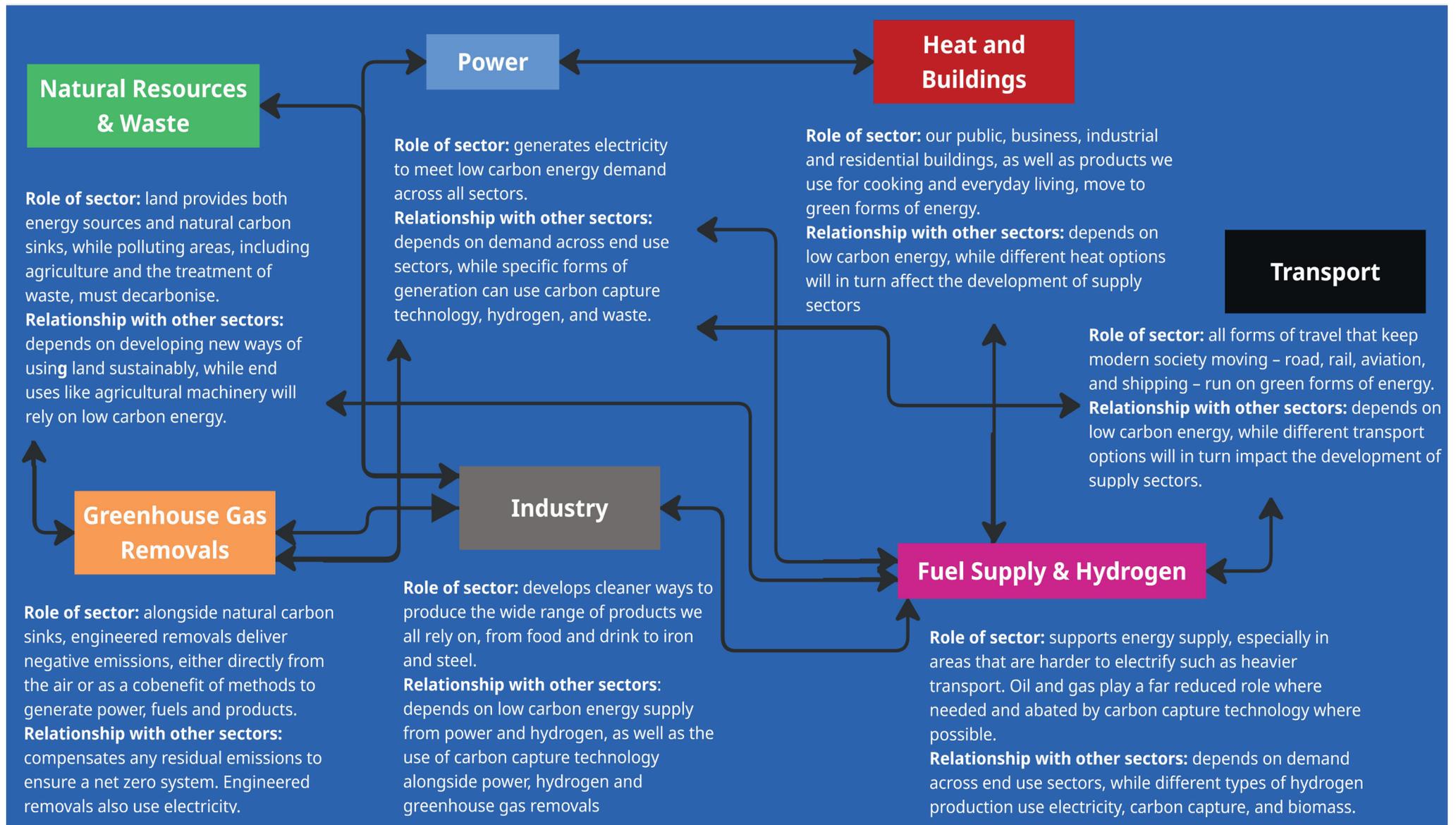
Vehicle to Load (V2L) offers consumers the chance to access the stored electricity to run or power specific *devices*, for example in the event of a blackout. Many but not all electric vehicles are capable of this two-way flow of electricity. An additional cable is generally required.

Vehicle to House (V2H) allows consumers to plug their vehicle directly into their building so that lights and electricity sockets in the building are operational, so long as the battery has sufficient charge. This requires a bi-directional charger, and an isolation switch in the home. These are not technologically difficult or costly but could have liability implications. V2H offers the opportunity for great resilience in isolated homes during a blackout. According to anecdotal evidence, some households in Ireland took advantage of this capability during or after Storm Éowyn. Most EV charger companies in Ireland offer uni-directional EV chargers only.

Vehicle to Grid (V2G) offers the opportunity to send power from an EV battery to the national grid. This can help dampen peak electricity prices by delivering power from the vehicle to the grid at times of high demand and take from the grid at times of high supply. Scaled up, V2G could even in future offer system services for the management of power on the grid (smartEn and DNV, 2023).

Looking across the energy system, the UK Net Zero Strategy of 2021 highlighted the potential for interconnectedness across strategies for different parts of the energy system, and illustrated how strategies and technologies deployed in one sector may have wider impacts and assist the transition in other areas (Figure 2.2 recreates the infographic) (HM Government, 2021). These opportunities for synergies are not currently being used in Ireland.

Figure 2.2: UK Net Zero Strategy: Build Back Greener: the role of each sector in the future net zero system (UK Government, 2021)



Source: UK Government, 2021.

2.5 A More Integrated Approach is Needed for Ireland's Energy Transition

The Climate Action and Low Carbon Development Act defines the national objective of a 'climate neutral economy' to mean 'a sustainable economy and society where greenhouse gas emissions are balanced or exceeded by the removal of greenhouse gases' (Government of Ireland, 2021). While this is a clear objective for the country as a whole, it does little to build common understanding of what long-term action will be required in individual sectors such as energy. The Irish Climate Change Assessment, Volume 4 noted in 2023 that 'Ireland's current policy direction predominantly emphasises technology transitions, rather than wider systemic transformations and shifts in development pathways'. (Moriarty *et al.*, 2023: 4).

NESC engagement with stakeholders as part of this project showed that few stakeholders or sectoral experts had a broad understanding of the transition already underway across the energy sector, nor even of the optimal endpoint. It seemed that different parts of the energy transition were being pursued in silos. In light of the dependencies between different parts of the energy transition, this presents challenges for policy and for public confidence and acceptance. The National Climate Objective and Government policy statements are good starting points in the Irish context but are not explicit on the future for the energy sector.

One specific example of lack of integration is the lack of clarity on the desired long-term endpoint for fossil-fuel consumption in Ireland. This lack of clarity can hinder long-term planning in a sector where decisions and investments today are likely to affect emissions and the costs of reducing emissions for decades to come. Under the first Global Stocktake of the UNFCCC Paris Agreement in Dubai, 2023, countries recognised the need for 'transitioning away from fossil fuels in energy systems in a just, orderly and equitable manner' (UNFCCC, 2024: §28).

The Long-term Strategy (LTS, 2024) acknowledges that expectations of how to meet the national climate objective might change over time but nevertheless states:

We know with certainty, however, that reaching climate neutrality will require Ireland's carbon dioxide emissions from fossil fuel energy use in power generation, heating, industry, and transport to reduce to effectively zero.

(DECC, 2024c:18)

The heat and power/electricity sectors have technological options to become zero-carbon without fossil fuels. Electricity has renewable electricity, batteries and zero-carbon gases like green hydrogen or biofuels. The heat sector can employ heat pumps at domestic and industrial scales, district heating and green hydrogen for the very highest temperature heat demand. The LTS 2024 points to an indicative pathway whereby emissions from electricity, transport, the built environment and industry are, each on their own, zero-emission, or potentially even below zero emissions in the case of the electricity and industry sectors. Below-zero emissions may be required from the electricity and industry sectors because 'it is likely unavoidable that some emissions will remain from production in the agriculture sector, [and any] remaining greenhouse gases will require balancing by sufficient levels of carbon dioxide removals to maintain an annual balance of emissions and removals from 2050 onwards' (DECC, 2024c:18). If energy is to become zero-emission, it requires either the use of a technological option like carbon capture and storage coupled with fossil fuels, or the elimination of fossil fuels from the system.

If the energy system is to become net-negative, it requires carbon capture and storage to be coupled with biofuels or direct air capture. Uncertainty regarding this choice reduces investor confidence across all options.

One example of siloed thinking relates to resilience in the energy system and its users. The draft Electricity and Gas Networks Climate Change Sectoral Adaptation Plan, prepared under the 2024 National Adaptation Framework, notes increasing risks to the electricity and gas networks (EGN) sector due to climate change. It states that 'impacts cascading from the EGN sector' include transport and health where 'loss of power can ... create wider health and safety hazards for members of the public' (DCEE, 2025c:103). The draft plan catalogues very comprehensively the hazards, vulnerabilities and risks to the networks and the plans and risk-mitigation strategies in place. However, the scope of the plan does not encompass the vulnerabilities and risks to households, nor is it clear that any plan addresses household vulnerabilities and risks due to climate change, or options to increase household resilience. The Climate Change Advisory Council advised, 'Increased emphasis is also required in the forthcoming Electricity and Gas Networks Sectoral Adaptation Plan on initiatives to increase the resilience of homes, business and community centres to extreme weather events through greater self-generation of electricity and backup based on sustainable and diversified energy sources' (CCAC, 2025a:8). NESC (2025a) noted a Personal and Community Resilience Booklet produced by Monaghan County Council, the Health Service Executive and An Garda Síochána (see Figure 2.3) that could operate as a template for other councils (Monaghan County Council *et al.*, 2025). A more strategic and proactive approach to supporting household resilience should be possible, employing features of the energy transition such as EVs (as outlined in Box 2.1) and microgeneration.

Communities also have a role that could be further facilitated to increase local resilience. GAA clubs have acted as support to communities – for example, in the aftermath of Storm Éowyn, providing hot drinks and meals and phone charging points to local communities when the power was out for prolonged periods (McCurry, 2025). GAA clubs and other public and community buildings such as schools have received grants for solar PV installations (SEAI, 2025b). These are not yet linked to local resilience strategies, which is a missed opportunity for integrating across objectives.

Figure 2.3: Personal and Community Resilience Booklet

Preparation for: Power Outage:

- If pre-warned ensure phones and devices are fully charged before outage.
- Have a power bank as a back-up and ensure it is charged ahead of time.
- Select low battery mode and avoid video calls or streaming during power outages.
- Have contact numbers for any vulnerable neighbours so you can check on them during and after the outage.
- Avoid the use of candles, have a battery-operated torch/ light/ candle.
- Have an alternative fuel to electric for heating and cooking.

Precautions for using alternatives to electricity:

- Portable generators can pose fire & carbon monoxide risks. Always operate outdoors, 7m from all buildings, store fuel outside and allow generator to cool before re-fueling.
- If stoves / fireplaces haven't been in use recently ensure chimneys have been checked and cleared of any blockages prior to use.
- If using a gas hob for cooking, leave windows slightly ajar.
- Use portable gas heating appliances in accordance with manufacturer's instructions.
- Ensure you have a carbon monoxide detector in rooms where appliances are located. In the event of a carbon monoxide alarm activation, follow the advice on Page 6 of this booklet.

It's important to report a power outage on the ESB's 'PowerCheck' website or call 1800 372 999 - Have your MPRN ready.

Source: Monaghan County Council *et al.* (2025).

Chapter 3: Leverage Points in the Irish Energy System

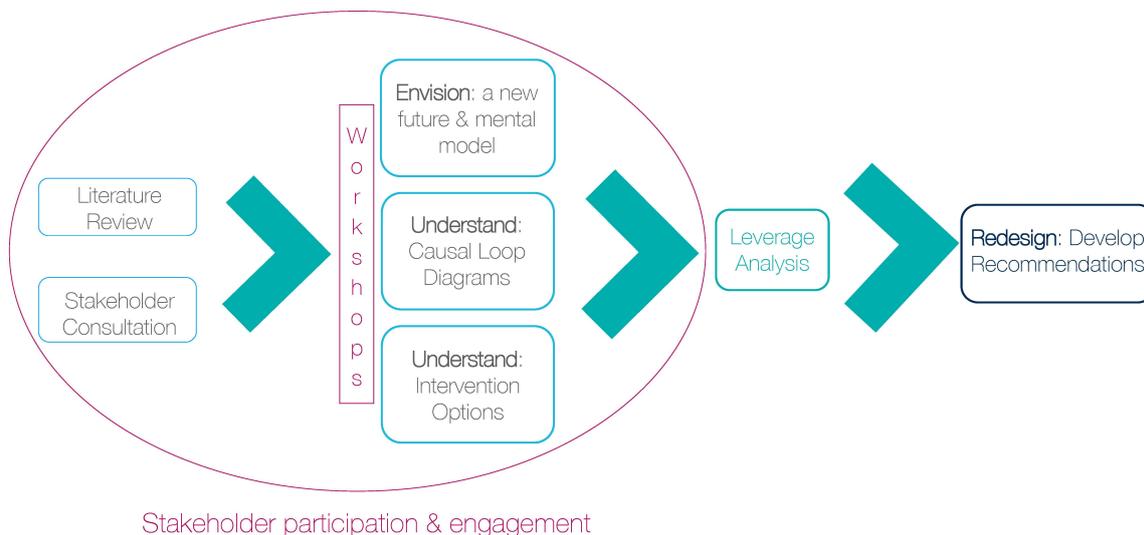
3.1 Introduction

This report employs systems analysis techniques to integrate insights from a range of disciplines and various stakeholders on the key drivers for and constraints on energy transition in Ireland. The methodology applied, as illustrated in Figure 3.1, is built on a three-step process – envision, understand and redesign – that was created by the OECD for development of transformative climate strategies (OECD, 2025a). The systems approach does not replace primary research and analysis but rather offers tools to organise and combine insights from such sources and across a variety of disciplines so as to offer a coherent and cohesive understanding of the overall system.

This chapter first outlines the concepts of systems dynamics and working with leverage points.

Secondly, it draws on systems analysis conducted for four key zero-carbon energy technology categories (variable renewable electricity, wind and solar; heat pumps; zero-carbon fuels; and district heating) and identifies leverage points that could support accelerating the energy transition in Ireland.

Figure 3.1: The systems methodology applied in this analysis



Source: O'Reilly, 2026.

3.2 Systems Analysis

A systems analysis approach can engage with the complexity of the energy system to help identify leverage points that work with the dynamics of the system to support more impactful change. Parkinson *et al.* (2025) advocate for ‘integrating behavioural science with systems approaches (including systems thinking and approaches to complex adaptive systems) as a more effective approach to resolving complex societal issues, such as public health, sustainability, and social equity’. Box 3.1 discusses the intersection of systems analysis and behavioural science.

Systems thinking aims to understand how the various parts of a system respond to a change in any individual part. Complex systems are more than the sum of their parts because the relationship between disparate parts is a key driver of outcomes. Sharpe *et al.* (2025) state:

Navigating the transition successfully requires an awareness of its dynamics. Change is often non-linear; cause and effect are disproportionate; system interactions can be complex and unpredictable. As a result, interventions can achieve much more or much less, than their intended outcomes. These dynamics can be understood in terms of feedback loops.

(Sharpe *et al.*, 2025. p4)

Sometimes a system responds in a way that amplifies the effect of the initial change. These *reinforcing* feedback loops can be recognised colloquially as virtuous circles or vicious circles, cascading impacts, runaway change, exponential growth or collapse, etc. Sometimes a system responds in a way that absorbs and balances the effect of the initial change. These are balancing feedback loops and can be recognised colloquially as equilibria, balance, bottlenecks, resistance to change, ‘stuck in a rut’, ‘catch 22s’, etc. Causal loop diagrams are a practical tool to help identify the feedback loops at play in a system. They also help to understand the drivers of transition in a way that combines insights across disciplines; for example, combining insights on institutions or behaviour with economic or technical insights.

Meadows (1999) proposed a framework to identify influential places to intervene in a system which she called leverage points. The aim was to find places where ‘a small shift in one thing can produce big changes in everything’. This approach has been taken on board across systems thinking practice, including in the UK’s ‘An introductory systems thinking toolkit for civil servants’ (Government Office for Science, 2023) which states that ‘points of leverage allow you to achieve the greatest amount of change at lowest cost and risk’. The OECD Transformational Change for Net Zero methodological framework also employs leverage point analysis to redesign systems (OECD, 2022). Writing for the World Economic Forum, Spitz (2023) noted that, ‘if we are to address our world’s most critical challenges, our responses need to be applied to high leverage points, where small interventions can result in large changes throughout the entire system’ (Spitz, 2023). Parkinson *et al.* (2025) highlight a key lesson: ‘not to fixate on where the problem appears to arise but seek to understand what the factors are that maintain the equilibrium’ or the existing persistent outcomes.

The leverage points framework suggests a categorisation of interventions along a scale of influence or ability to change a system, running from the least to most powerful. Figure 3.2 shows a representation of the leverage points scale based on a figure from OECD (2022). Interventions that address 'events' are 'end of pipe' policies that seek to manage the outcomes of the existing system, which might include, in transport for example, widening a road to cope with congestion or, in the case of health, expanding casualty departments to cope with road accidents. These are sometimes illustrated as interventions at the tip of an iceberg. Interventions at the level of coping with events may be necessary but do not have power to change the drivers of the system and therefore have a low potential for transformation.

Interventions that address patterns are those that look to strengthen or weaken system relationships, but do not fundamentally change them. These have a moderate level of transformative potential and may include increasing or decreasing resources to different parts of a system. It is particularly applicable where there is a desire to accelerate a virtuous circle. An example would be investment in public transport that increases services or makes it more attractive. However, the impact of intervention at this level can be limited by the counteracting influence of structures and mindsets.

Interventions that address structures have high transformative potential. They are interventions that seek to change the rules of a system, to change the criteria of success or to fundamentally change the relationship between parts of the system – i.e. to 'change the rules of the game'. This can include disrupting vicious circles and dismantling constraints. In the transport sphere, road space reallocation from cars to sustainable transport modes is an example of an intervention that disrupts the dynamic of ongoing congestion (e.g. from induced demand) by rebalancing the relative attractiveness of transport modes, thereby reducing congestion.

Interventions that address the mindsets underlying a system are also classed as high-leverage. They can establish and mainstream a new goal for the system and change unconscious attitudes and biases in the system that underlie existing behaviours. This notably includes changing the mindsets and attitudes of policymakers and decision-makers as well as of the general public. For example, in the transport system this could include shifting goals from mobility to access and communication efforts challenging the car-centric paradigm (OECD, 2022).

Box 3.1: Behavioural Change in Systems Thinking

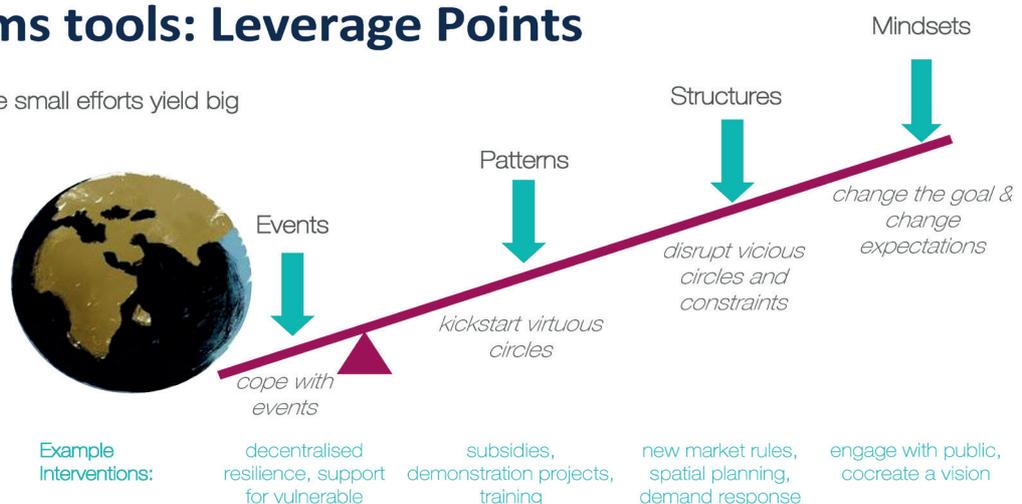
In its 2022 Irish case study, the OECD defined the systems thinking approach to behaviour as follows: ‘Individual preferences and patterns of behaviour largely result from the system structure in which they are embedded (e.g. car-dependent systems) and the mental models (e.g. car-centric thinking) that have shaped such structure. Government policies have been fundamental to shaping current systems and have also had a major influence on prevalent mental models. They will also be fundamental moving forward: with the right policies, systems could be deliberately redesigned to promote and facilitate other choices and trigger large-scale behavioural change which is otherwise unlikely’ (OECD, 2022: 13). This is consistent with widely used models from behavioural science such as the Capability Approach (Moore-Cherry *et al.*, 2022), and the COM-B model, which sees ‘behaviour as arising from people’s motivation (attitudes, habits, etc), capabilities (psychological and physical abilities) and the opportunities (physical and social factors) to act’ (Mitev *et al.*, 2023: 6).

These concepts clarify that, while internal factors such as knowledge and attitude can change, such changes are not a sufficient condition for behaviour change, which can face many other barriers, giving rise to the often observed ‘value-action’ gap or ‘attitude-behaviour gap’ (*ibid*). This suggests that a multifaceted approach to behaviour change is required. ‘For instance, a health intervention might enhance capability by providing education..., create opportunities by making healthy options more accessible..., and boost motivation through persuasive messaging that is tailored to the target audience as well as appealing to both emotional and rational aspects.’

Figure 3.2: A summarised schematic of the leverage points framework, adapted from OECD (2022), with example interventions

Systems tools: Leverage Points

Finding where small efforts yield big results



Source: O’Reilly, 2026 and OECD, 2022

Energy 'events'

Coping with events does not, on its own, have systemic leverage but is necessary for sustainable and just transitions. When a technical failing or inadequacy arises or when vulnerable users are adversely affected, remedies have to be found at short notice. For example, procurement of Temporary Emergency Generation (TEG) was a measure undertaken by the CRU to address supply shortfall concerns until further enduring power generation supply could be connected later this decade (ESB, 2025). At the micro-level, purchase of diesel generators was a measure undertaken by many households in light of their experience of prolonged power outage after Storm Éowyn. Anecdotal reports suggest that households are ready to invest in their own resilience (see section 3.4.1). This readiness should be linked to the broader energy transition effort.

While ensuring that provision of service is maintained and that vulnerable households are protected, it is also important to move beyond those interventions towards interventions that have the power to improve social, environmental and economic outcomes and tackle the root causes of failings or shortcomings.

Energy 'patterns'

Interventions that anticipate and respond to observed patterns and trends can include, for example, provision of subsidies for renewable electricity or a fuel allowance in winter. These do not fundamentally change the system; if the subsidy or allowance is removed, the effect vanishes. Nevertheless, such responses are important because they help vulnerable users and address immediate needs.

More influential interventions in this category include efforts that kickstart or 'supercharge' existing virtuous circles. This particularly applies to the technologies that have not reached a critical mass yet in Ireland such as heat pumps, district heating and zero-carbon fuels (though each is at a different level of technology readiness). Subsidies, building awareness and training, demonstration projects and enabling environments for commercial supply contracts can all be influential in accelerating or initiating the desirable dynamics of accelerating technology deployment. But this will only deliver results if counteracting constraining dynamics, such as bottlenecks or escalating costs, are also addressed. This is why it is important to move further up the lever to look at interventions that address structures; scaling down vicious circles or pushing past constraints is resource-intensive and success is uncertain.

Energy 'structures'

Interventions that address structures seek to disrupt vicious circles, holding patterns or constraints. For example, in electricity, a mismatch between supply and demand over time and geography, leading to greater costs, underlies many of the dynamics that constrain renewable energy deployment. Local and public understanding and acceptance of energy development also underlie many dynamics that constrain deployment of Variable Renewable Electricity (VRE) in the electricity sector. Structural interventions could include addressing the mismatch over time through demand response and over geography through spatial planning to release

constraining dynamics. New regulation, incentives and market structures will ultimately be required to deliver the transition.

The constraining dynamics of supply-chain bottlenecks can be undermined through EU level efforts to improve the global policy environment, increase capacity, and/or coordinate purchasing.

Path dependencies in deployment of various zero-carbon energy technologies, which act as reinforcing feedback loops, could lead to suboptimal levels of deployment of some technologies from a society perspective. Uncertainties about competing energy solutions can lead to higher capital costs and hesitation to invest. While competitiveness is beneficial, providing increased certainty on which are the applicable zero-carbon technologies for different uses could increase policy certainty for investors and encourage less mature technologies to take their appropriate space in the transition over time.

Structural interventions that transform relationships between producers and consumers in the energy system could include deep retrofits of buildings and microgeneration, both of which can substantially, and with lasting impact, change the relationship of the consumer to the energy system (as described in NESCS, 2025c). Initiatives like energy sharing can also play a role in opening up connections between wider energy policy and practice and efforts to reduce energy poverty (*ibid*).

Building on NESCS's recommendations (NESCS, 2025b), changing market rules or pricing structures to provide new incentives, whether for specific actions, timing or locations, could also be considered as structural interventions. Developing a coherent plan for the whole energy sector that outlines respective roles for different technologies, behavioural and institutional change and outline timeframes for these, could also act to change relationships across the system, moving from perceived conflict or competition to the development of synergies and coherent strategies.

Energy 'mindsets'

In management theory, it is often said that 'culture eats strategy for breakfast'.² Similarly, achieving system change is not possible without also achieving a change in mindsets or 'mental models', the 'unquestioned, often implicit and unconscious, assumptions through which humans understand the world. They ... influence the targets they set, the actions they take and the types of systems they create' (OECD, 2022, p24). Mindsets include the goal underlying a system; Meadows (1999) notes that people often don't recognise the higher-level goal of the system in which they act. Parkinson *et al.* (2025) note that 'changing the way people think about and perceive the system can lead to transformative change in actors within the system. Similarly, adjusting either the rules or the goals of the system, or what the system is striving to achieve, can significantly impact its [the system's] behaviour and outcomes'. Without understanding the mindsets at the root of the observed patterns of behaviour and outcomes, policy makers' ability to design truly transformative approaches is limited (*ibid*).

The attitudes and beliefs of policymakers and actors in the public system are also important as influential agents within a system. The OECD (2025b) noted in its systems analysis of transport in Catalonia: ‘Systems change can be achieved via the collective action of multiple actors, strategizing together to “pull” a system in a different direction than where it is currently headed. To imagine “what could be”, policymakers need to first believe that systems change is possible, and that systems can function radically differently to current systems, and lead to more desirable patterns of behaviours and results. Ingrained – and often unquestioned – ideas may limit decision makers’ vision or imagination of what is possible, thus limiting public policy scope’ (OECD, 2025b: 113).

The OECD suggests, as the first step in its transformative systems methodology: ‘envision the goal(s) and the patterns of behaviours that a properly functioning system would foster, and challenge ingrained mental models underlying poorly functioning systems’ (OECD, 2025b). Engagement with stakeholders, especially through participative processes, helps uncover mental models and can help challenge them. Challenging mental models and attempting to shift them needs to be based on broad agreement with stakeholders on the overall goal. Therefore, clarifying the goal, elaborating a vision and ensuring these are shared with stakeholders are crucial steps to shifting mental models.

In the course of this research, the energy doughnut (see Chapter 2) was used to define the parameters that a sustainable energy transition and future energy system should respect. It was a useful communication tool that was integrated in participative exercises with stakeholders on an energy vision. Going forward, the graphic representation can be useful for future policy initiatives focussed on stakeholder and public communication and engagement on energy system transition.

3.3 Irish Energy System Dynamics

NESC engaged with stakeholders and used systems analysis tools to explore deployment of heat pumps, district heating, variable renewable electricity (wind and solar) and zero-carbon fuels, as well as exploring attitudes to energy and energy demand management overall. The selection of these areas was informed by 2024 analysis by UCC and SEAI, which identified the five key action areas that represent 90 per cent of the emissions savings by 2030 proposed in the Climate Action Plan (UCC and SEAI, 2024).

Causal loop diagrams were developed for each of the four technology types through consideration of the literature, insights from early stakeholder engagement and input from Prof. Birgit Kopainsky and Aidan Sliwkowski from the University of Bergen. These causal loop diagrams were explored with stakeholders and experts at two workshops, co-designed with and facilitated by Prof. Kopainsky, in November 2024 and April 2025, and intervention points were discussed and identified. A detailed description of the workshop design, causal loop diagrams, feedback loops and dynamics can be found in O’Reilly (2026 forthcoming).

3.3.1 Variable Renewable Electricity

Variable renewable electricity (VRE) generation from wind and solar is a key technology for Ireland's energy transition. Ireland has one of the highest rates of integration of variable renewables (system non-synchronous penetration – SNSP) globally and is at the forefront of engineering knowledge and skills for grid management (Colaluze, 2025).

Causal loop diagram analysis uncovers some of the fundamental dynamics setting the pace of change. For example, beneficial reinforcing feedback loops that policy interventions could seek to enhance include: progress on VRE deployment encouraging greater ambition (Reinforcing loop 1 – R1), energy cost reductions due to VRE increasing public support (R2) and demand response leading to cost reductions which encourages more demand response (R3). Examples of balancing feedback loops that policy interventions might seek to disrupt include: where increased deployment of VRE leads to a fall in wholesale electricity price, which, in the absence of subsidies or Corporate Power Purchase Agreements (CPPAs), undermines further investment (Balancing loop 1 – B1); where increased investment in VRE leads to more planning and development at local level, which can reduce local support for further deployment (B3); and where increased deployment of VRE leads to grid congestion which, through additional infrastructure requirements, adds to electricity costs, thus reducing ambition for further deployment (B2).

To accelerate VRE deployment, strategic interventions are needed to disrupt the dynamics constraining deployment. Table 3.1 summarises the feedback loops and how they operate, while Figure 3.3 and Figure 3.4 illustrate how the feedback loops are interconnected for variable renewables and electricity demand response respectively. For example, government support schemes such as the Renewable Energy Support Scheme (RESS) and the Offshore Renewable Energy Support Scheme (ORESS) already partially address price cannibalisation (balancing feedback loop B1), but an intervention to more fundamentally disrupt this would be demand response and energy storage, which could buffer the fall in wholesale prices when VRE production is high. Similarly, grid congestion, whereby increased VRE employment increases the need for grid investment, which increases the cost of electricity, thus reducing public support and undermining further investment (balancing feedback loop B2) needs attention. One 'pattern level' intervention could be alternative sources of finance to reduce the impact on bills, but a more structural intervention could be reducing the need for grid investment through closer proximity of VRE and areas of high demand, energy storage and deployment of private wires.

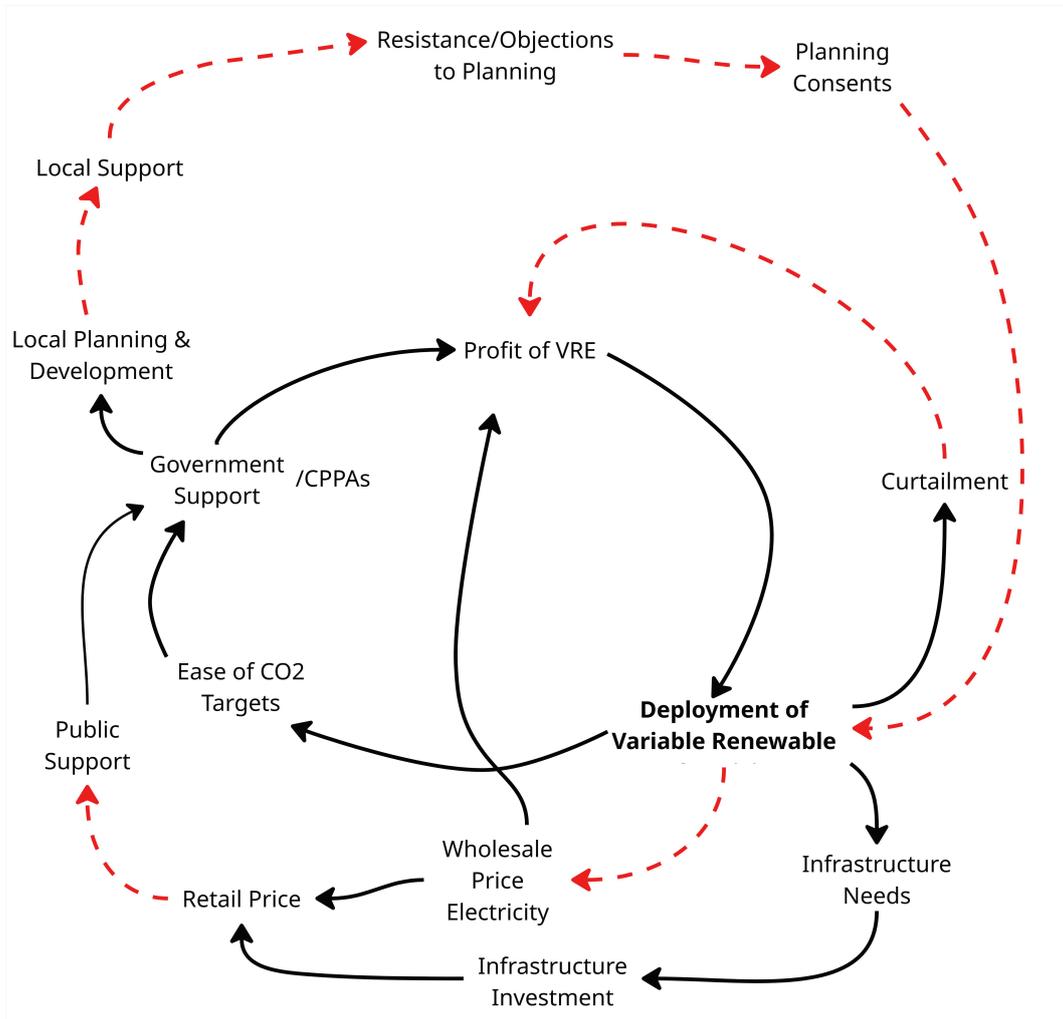
Table 3.1: Summary of feedback loops for variable renewable electricity

Variable Renewable Electricity (VRE)			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R1	Progress Feeds Ambition <i>(reinforcing feedback loop)</i>	Greater deployment of VRE encourages more climate ambition, which supports more deployment via government subsidies and Corporate Power Purchase Agreements (CPPAs).	This reinforcing loop is already in effect, but deployment is constrained by other factors. This dynamic could be supported by facilitating greater uptake of CPPAs, but it will also be important to look at addressing or removing other constraining (balancing) feedback loops (as below).
B1	Price Cannibalisation <i>(balancing feedback loop)</i>	In the absence of subsidies or CPPAs, increased deployment leads to fall in wholesale price of electricity, undermining further investment.	This balancing feedback loop is already partially addressed by government support schemes such as RESS and ORESS. Support for CPPAs is another countermeasure. More fundamentally, demand response and energy storage can buffer the fall in wholesale prices when VRE production is high. A high leverage point could be to develop (with the EU) new electricity market structures for high VRE penetrations.
R2	Public Support for Renewable Energy <i>(reinforcing feedback loop)</i>	Cost reductions due to VRE increase public support, which supports more ambition and investment.	This reinforcing feedback loop is already in effect in the desired direction but is being dominated by other counteracting and constraining feedback loops. Most leverage is achieved here by addressing the other constraints.
B2	Grid Congestion <i>(balancing feedback loop)</i>	Increased VRE deployment increases need for grid investment, which increases cost of electricity, reducing public support, undermining further investment in VRE.	This constraining feedback loop needs to be addressed through efforts to mitigate its effect or to fundamentally disrupt the process. Mitigating the effect could be achieved through identifying alternative sources of finance to reduce the impact on bills (or taxes). The feedback could be disrupted by reducing the need for grid investment due to VRE deployment. Locating VRE closer (in network terms) to areas of high energy demand would help. Energy storage can help smooth the peaks and troughs of VRE, potentially reducing grid demands. Finally, private wires, appropriately deployed, can reduce the need for public investment in the grid.

Variable Renewable Electricity (VRE)			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
B3	Local Support <i>(balancing feedback loop)</i>	Increased investment in VRE leads to more planning and development at local level which can reduce local support due to cumulative impacts (e.g. on landscape), leading to more resistance to local development.	This constraining feedback loop can be mitigated by offsetting local concerns with various benefits. It can be disrupted through fundamentally addressing local concerns about cumulative impacts and outcomes. Thus, community benefits schemes and local ownership can mitigate the effect of this feedback loop when properly designed (e.g. with inclusive approaches). The feedback loop can be disrupted through better consultation and plan-led development so that local people understand the expected outcome and impact of all development in their area over time, and the ability of the local area to manage these. Ensuring that local experience of existing installations and development processes is positive will also be important for future deployment.
B4	Curtailment <i>(balancing feedback loop)</i>	As variable RE deployment increases, everything else being equal, the level of curtailment increases which constrains further deployment efforts.	This balancing feedback loop shows how imbalances in demand and supply create profit risks for renewable developers. Further investment in the grid can help reduce this effect. It can be more fundamentally addressed if the demand and supply imbalances over time are reduced through demand response measures such as use of battery storage and behavioural incentives. It can also be addressed through addressing demand and supply imbalances spatially, including through grid investment, and also in the co-location of energy demand and supply.
R3	Demand Response Dynamics: user cost savings <i>(reinforcing feedback loop)</i>	Demand response leads to cost reductions for the user, which encourages more demand response.	This reinforcing feedback loop is not yet activated. Electricity users need to see and understand the link between demand response and cost savings. Pricing and incentives are important signals.

Variable Renewable Electricity (VRE)			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
B5	Demand Response Dynamics: diminishing returns <i>(balancing feedback loop)</i>	As the user undertakes a greater proportion of demand response or flexibility, each further unit gets harder to shift.	This balancing feedback loop is not currently a constraint as demand response levels are so low, but it will be a future consideration as the system tries to encourage greater demand response.
B6	Demand Response Dynamics: arbitrage <i>(balancing feedback loop)</i>	As demand response increases, the wholesale price differential across time will decrease which will reduce the net marginal benefits of further demand response, reducing the incentive to invest.	This feedback loop is not yet activated. Nevertheless, the uncertainty it would create in future revenue streams for energy storage would already be a consideration for any potential investors. This can be addressed by creating reliable incentives and pricing structures for energy storage that don't rely solely on profits from arbitrage.
B7	Demand Response Dynamics: Price Cannibalisation <i>(reinforcing feedback loop)</i>	As demand response increases, the price differential across time (low price when VRE production is high and vice versa) goes down, the revenue streams of VRE improve, encouraging more deployment, which acts to increase the price differential over time, which supports more demand response.	This reinforcing feedback loop is not yet activated but could be crucial to supporting more deployment of variable renewable electricity. It can be activated by offering appropriate pricing and incentives for demand response, allowing electricity users to see a net marginal benefit from their action.

Figure 3.3: Variable renewable electricity: simplified system feedback map

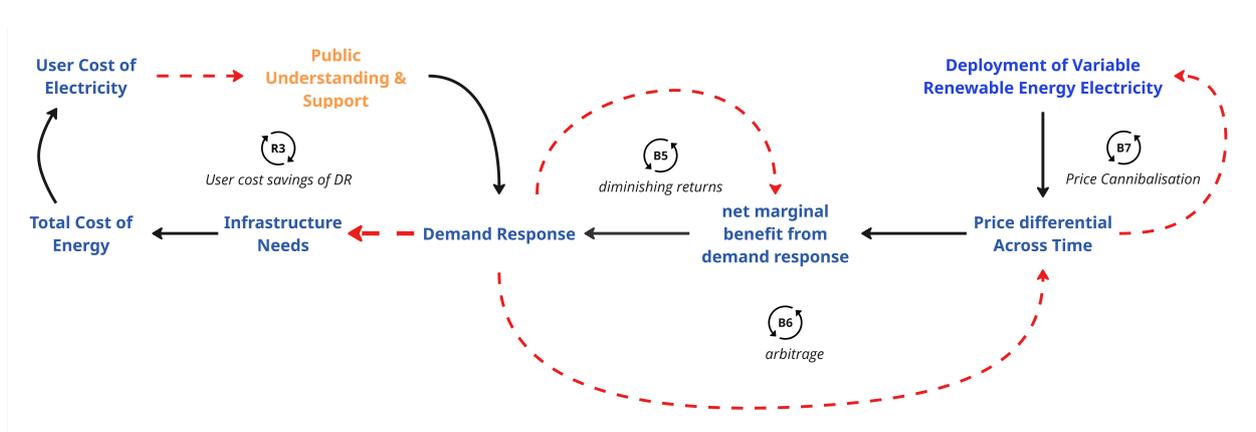


Source: O'Reilly, 2026.

Note: Solid black arrows represent relationships where the named variables move in the same direction, all else being equal – i.e. if the origin variable increases, the destination variable at the end of the arrow increases.

Red dashed arrows represent relationships where the named variables move in opposite directions, all else being equal.

Figure 3.4: Variable renewable electricity feedback loops: demand response dynamics



Source: O'Reilly, 2026.

Note: Solid black arrows represent relationships where the named variables move in the same direction, all else being equal – i.e. if the origin variable increases, the destination variable at the end of the arrow increases.

Red dashed arrows represent relationships where the named variables move in opposite directions, all else being equal.

3.3.2 Heat Pumps

SEAI identifies heat pump deployment as one of the five key actions for Ireland's energy transition (UCC and SEAI, 2024). The Climate Action Plan 2025 includes a target for 400,000 heat pumps to be deployed in existing homes (i.e. through retrofit) by 2030 (DCEE, 2025a). The European Heat Pump Association ranks Ireland fifth in Europe for heat pump deployment per 1,000 homes and attributes this to long-term stable policies (EHPA, 2025). Grants of €6,500 are available for heat pumps, and up to €10,500 for installation of a heat pump as part of a deep retrofit. Despite this, the targets remain challenging. NESC (2025a) found that progress in deployment was not happening fast enough, and upfront cost was still playing a big role.

In existing buildings, installation of a heat pump is normally carried out as part of a retrofit that improves the insulation or thermal efficiency of a building. The Council made a range of recommendations to accelerate the pace of building retrofit in households (NESC, 2025a). Other reports have pointed to the role of tax measures (e.g. in respect of capital gains tax) to enhance incentives for upgrading other buildings and to close the split incentive gap. This analysis therefore focusses on other aspects of the challenge in deployment of heat pumps.

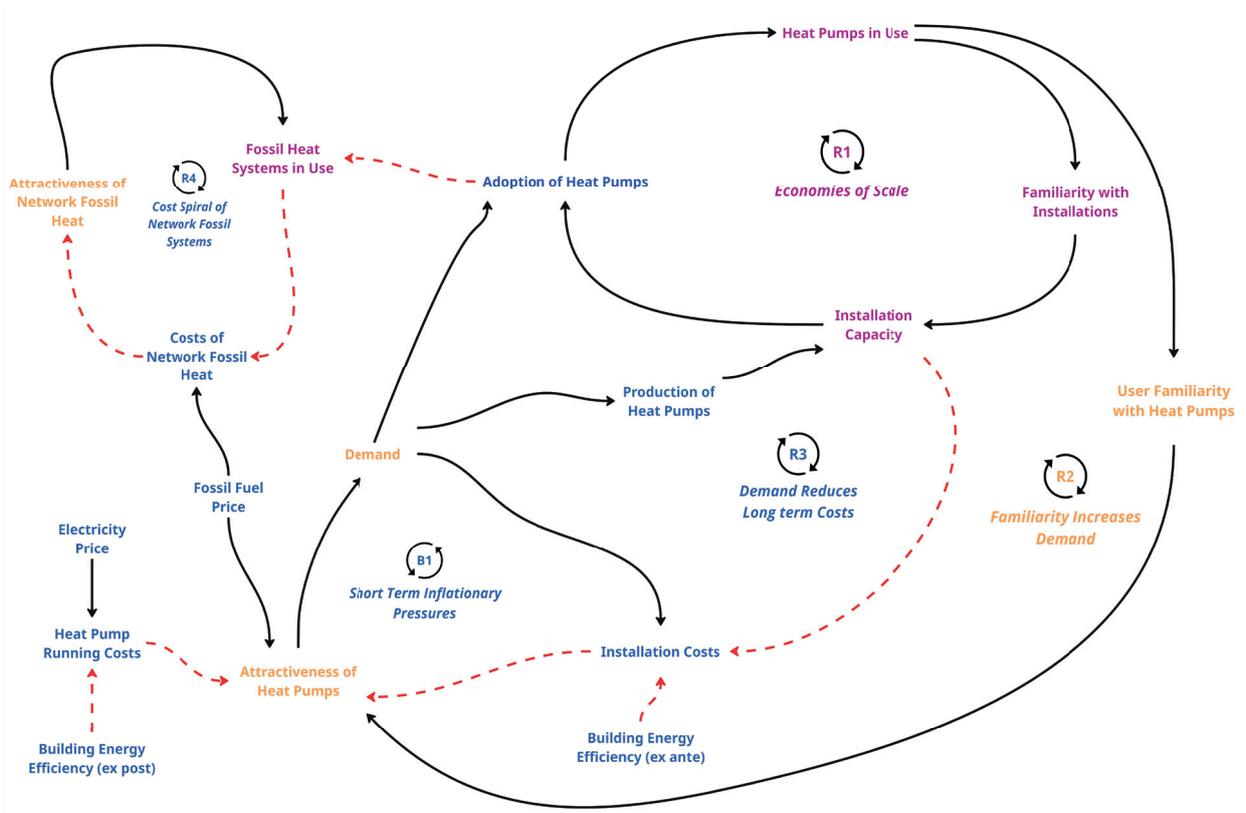
Causal loop diagram analysis uncovers a different perspective on the drivers and constraints of deployment of heat pumps. Table 3.2 summarises the feedback loops and how they operate while Figure 3.5 illustrates how the feedback loops are interconnected. To accelerate heat pump deployment, strategic interventions to unleash the reinforcing virtuous circles of technology deployment are required. For example, while the reinforcing feedback loop where greater familiarity with heat pumps increases demand (R2) is already in effect, a leverage point targeting mental modes could increase its impact; for example, through the deployment of demonstration houses and buildings, and more advice to heat pump users on appropriate usage.

Table 3.2: Summary of feedback loops for heat pump deployment

Heat pumps			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R1	Economies of Scale <i>(reinforcing feedback loop)</i>	Increased deployment of heat pumps increases familiarity with installation which increases installation capacity which supports increased deployment of heat pumps.	This reinforcing feedback loop or virtuous circle is already in action with the number of one-stop shops and heat pump installers having grown considerably in the last three years. It can be further accelerated by continued investment in training for installers and by providing confidence in the long-term market prospects through clear and stable public policy and more advertising of the benefits.
R2	Familiarity Increases Demand <i>(reinforcing feedback loop)</i>	More heat pumps in use leads to public familiarity with heat pumps which increases the attractiveness of heat pumps, increasing demand.	This reinforcing feedback loop is in effect but familiarity with heat pumps is still relatively low. Some owners' lack of knowledge on how to operate heat pumps leads to poor performance, which can disrupt this effect. Demonstration houses and buildings and more advice for heat pump users on how to appropriately run their heat pump would accelerate this virtuous circle.
R3	Demand Reduces Long-term Costs <i>(reinforcing feedback loop)</i>	A global as well as local phenomenon, an increase in demand for heat pumps leads, over time, to greater production or a scaled-up supply chain of heat pumps which reduces their upfront cost.	This virtuous circle is particularly effective at the global level. Robust climate policy in the EU would support increased demand for heat pumps that can lead to economies of scale.
B1	Short-term Inflationary Pressures <i>(balancing feedback loop)</i>	An increase in demand for heat pumps while capacity or supply chains are fixed can lead to short-term inflationary pressures, which reduce demand.	It is important to ensure that installation capacity at local level stays apace with demand. Where global supply constraints exist, Ireland can be a relatively small player and therefore coordination with other EU member states could offer advantages.

Heat pumps			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R4	Cost Spiral of Network Fossils <i>(reinforcing feedback loop)</i>	The adoption of heat pumps implies a movement away from fossil heat systems, leading to reversed economies of scale for networked fossil fuels which leads to higher costs for consumers and more incentive to switch away.	Network feedback loops are reinforcing. The more people join, the more it is advantageous for others to join; conversely, the more people that leave, the less advantageous it is for others to join or even stay. This feedback loop supports greater incentives to switch to heat pumps, but it is important to safeguard the wellbeing of remaining customers on the gas grid and facilitate them to join the energy transition.
Not shown	Fossil Fuel Costs <i>(balancing feedback loop)</i>	This loop (not shown in Fig. 3.5) describes a global effect whereby, in the short term, reduced demand for fossil fuels leads to a fall in price of the fossil fuel which supports continued use of fossil fuel.	The difference in heating costs between heat pumps and fossil oil or gas alternatives is a key determinant of willingness to switch to heat pumps. The upfront costs of heat pumps are greater and therefore savings on the running costs – determined by the price spread between electricity and oil or gas – are crucial to heat pump deployment. In this regard, a carbon tax is helpful, and removal of fossil-fuel subsidies. Electricity prices also need to be managed.

Figure 3.5: Simplified heat pump feedback map



Source: O'Reilly, 2026.

Note: Solid black arrows represent relationships where the named variables move in the same direction, all else being equal – i.e. if the origin variable increases, the destination variable at the end of the arrow increases. Red dashed arrows represent relationships where the named variables move in opposite directions, all else being equal.

3.3.3 Zero-Carbon Fuels

Zero-carbon fuels (ZCF) such as biofuels and green hydrogen are not anticipated to provide the bulk of energy services in the future energy system, but are expected to play a crucial role in supporting transition of 'hard to electrify' sectors and to offer long-term energy storage capacity to provide backup for variable renewables electricity (NESC, 2025c; Khammadoov et al., 2025). Ireland's use to date of ZCF has been focussed on the biofuel obligation in transport. While this has been a useful interim measure to reduce accounted greenhouse-gas emissions, it raises questions on global sustainability and may not enhance energy security. This analysis therefore focusses on deployment of domestically produced zero-carbon fuels such as biogas and green hydrogen.

Causal loop diagram analysis uncovers some of the fundamental dynamics setting the pace of change. To accelerate appropriate ZCF deployment, strategic interventions are needed to kickstart the virtuous circles of deployment in appropriate use cases (reinforcing feedback loop R1). Taking a longer-term view, an increase in deployment of ZCF could lead to economies of scale, which reduce the scale of electrification in the Irish economy, demonstrating the need

to disrupt this reinforcing feedback loop (R4) to avoid unhelpful path dependencies. A plan-led approach that actively guides the appropriate role of ZCF is important for reducing this policy risk. Table 3.3 summarises the feedback loops and how they operate while Figure 3.6 illustrates how the feedback loops are interconnected.

Table 3.3: Summary of feedback loops for zero-carbon fuels deployment

Zero-Carbon Fuels (ZCF)			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R1	Economies of Scale <i>(reinforcing feedback loop)</i>	As more ZCF are deployed, the costs of production and price fall, which increases demand, leading to more production.	Costs of ZCF will not fall without first initiating and scaling up deployment. Initiating pilots and demonstration projects is an important first step.
R2	Track Record Reduces Risk <i>(reinforcing feedback loop)</i>	Deployment creates a track record, which improves investor confidence, lowering the cost of finance, which supports more deployment.	Offering some kind of financial support will also be key to overcoming the high initial costs. For green hydrogen, scale-up is also required at global level to achieve cost reductions, so pursuit of supportive action at an EU level is important.
R3	Secure Demand Supports Deployment <i>(reinforcing feedback loop)</i>	If offtake agreements go up, deployment of ZCF goes up which leads to economies of scale, leading to price reductions which support more offtake agreements.	Without a route to market, revenue streams with or without government support are uncertain because supports are typically and appropriately only given where renewables are actually consumed. Offtake agreements, where a customer promises or is obliged to purchase the ZCF reduces revenue uncertainty which reduces financial costs. The forthcoming Renewable Heat Obligation will play a role here (DCEE, 2025). Thus, intervention can be achieved at a sectoral or individual level. GNI could agree to inject up to x per cent of ZCF into its grid, thus creating a guaranteed revenue stream which could act as the basis for subsidy or financial support. Or a thermal plant could contract or be obliged to inject up to y per cent or convert to ZCF capability. This could have the added benefit of providing useful back-up for renewable electricity. Greater investment in or subsidisation of upgrades to the gas grid and/or thermal plant to absorb or convert to ZCF would also activate this reinforcing feedback loop.

Zero-Carbon Fuels (ZCF)			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R4	Path Dependencies <i>(reinforcing feedback loop)</i>	An increase in deployment of ZCF could lead to economies of scale which reduce the scale of electrification in the Irish economy, which lead to greater and more secure demands for ZCF.	This reinforcing feedback loop demonstrates the need to determine and guide where deployment of ZCF is most strategic from a whole-of-society / economy perspective. For many applications, electrification is more economical, especially over time. But path dependency effects could lead to a suboptimal level of electrification or deployment of ZCF where it is uneconomic. Already guiding ZCF towards those sectors and sub-sectors where it is most appropriate in the long term would reduce costs of transition. Increasing certainty by actively assigning ZCF its role in the energy transition could act to reduce policy risk (and therefore finance costs) both for ZCF and electrification options, reducing overall costs of transition.
n/a	Links to other Technology Transitions	As ZCF can be an alternative to VRE, district heating and heat pumps, the feedback loops in deployment of those technologies' affects ZCF and vice versa. ZCF could be a potential feedstock for district heating, offering another route for dependencies across technologies.	The links to deployment of other technologies emphasises the importance of offering a clear vision, which can clarify the respective roles of different actors and technologies in the energy transition, while remaining open to respond to new technological and other developments.

3.3.4 District Heating

SEAI identified district heating (DH) as a cost-effective technology for transition of the heat sector in Ireland where concentration of heat demand is sufficient, e.g. generally in more urban areas. District heating has been successful in other jurisdictions but Ireland has limited familiarity with district heating either in the residential and SME or larger public and commercial settings.

Causal loop diagram analysis, drawing on a Dutch study (Gürsan *et al.*, 2024), illustrates that beneficial system dynamics could apply if strategic interventions initiated the virtuous circles of technology deployment. A significant reinforcing feedback loop is that awareness of the benefits of district heating is a precondition to its deployment (R1). This underlines the importance of interventions to build broad-based awareness of its potential and proven track record, such as through demonstration projects and awareness initiatives, especially where district heating can bring benefits to households and the commercial sector. Table 3.4 summarises the feedback loops and how they operate while Figure 3.7 illustrates how the feedback loops are interconnected.

Table 3.4: Summary of feedback loops for district heating deployment

District Heating			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R1	Awareness as a Precondition <i>(reinforcing feedback loop)</i>	District heating is already an effective and efficient part of low-carbon heating in many jurisdictions, but awareness is too low to see the technology take off in Ireland.	Economies of scale feedback loops cannot be activated without awareness of the potential and proven track record of district heating for solutions in the residential and business sectors. Building broad-based awareness requires demonstration projects, particularly where those projects can demonstrate their capacity to meet household or commercial heat demands.
R2	Demand for Gas Grid <i>(reinforcing feedback loop)</i>	Customers for district heating will often be transitioning away from networked gas supply, leading to dis-economies of scale for natural gas and potential deterioration of the network in the absence of other measures.	It is important to monitor this reinforcing feedback loop for the effects it can have on wellbeing (or viability) of those customers remaining connected to the gas grid and for the business model of the remaining gas supply. Customers should be facilitated to switch to low-cost and zero-carbon heat solutions, and a new business model for gas supply needs to be planned and enabled.

District Heating			
Loop no.	Feedback Loop Name	Summary	Leverage Points/Transition Enablers
R3	District Heating Economies of Scale <i>(reinforcing feedback loop)</i>	As the relative attractiveness of DH increases, it attracts more subscribers, which allows DH to offer a more affordable price, which supports further expansion of subscribers.	If some familiarity is established, the attractiveness of DH should lead to increased subscribers or potential subscribers. 'Anchor tenant' subscribers who have a high heat demand can offer a quick route to building economies of scale that support greater affordability and attractiveness. Therefore, building awareness in the business community about the potential advantages of DH could build support for development and offer confidence for investment.
R4	Utility Cost Spiral <i>(reinforcing feedback loop)</i>	Applying the dynamics of R3 in reverse, the decreased attractiveness of gas systems leads to a fall in customers, which increases the cost of service for the remaining customers, leading to more departures.	The gas grid will be reshaped by the energy transition, and a new business model will have to develop. This points to the need to integrate the planning for the future of the gas system with other energy transition plans.
B5	Energy Poverty <i>(balancing feedback loop)</i>	Following the utility spiral described above, where customers are leaving the gas grid, the consequent price increases push more vulnerable households into energy poverty and reduce their disposable income so that the costs of switching supplier are hard to meet.	Specific supports to poorer households can facilitate changing heat supply. It would also be important in any DH scheme to keep initial connection charges as low as possible to encourage a broad take-up.
R5	Economies of Scope <i>(reinforcing feedback loop)</i>	As a DH network grows, it can invest in more heat sources. This diversification can offer opportunity for cost savings.	DH schemes should be encouraged to grow to sufficient scale to diversify heat sources. This would have benefits beyond the DH system, where DH could potentially supply great levels of demand response in the electricity system and also be a reliable customer for zero-carbon fuels.

3.4 Cross-cutting Interventions

Analysis across the four areas of VRE, heat pumps, ZCF and district heating identified a range of potential interventions to work with system dynamics to accelerate transition. Two cross-cutting interventions are notable: attitudes to energy and energy demand.

3.4.1 Energy Mindsets and Attitudes

Systems analysis research suggests that changing mental models (e.g. by changing system goals) can be a necessary and high-leverage intervention point to achieve transition, although it is not usually a sufficient condition for change (see section 3.2). Attitudes to energy and energy transition appear across the four technology types considered in section 3.3, including awareness of the benefits of technologies such as district heating and heat pumps, and public attitudes to and acceptability of renewable energy or ZCF infrastructure. While a 2023 survey found that a large majority in Ireland support development of renewable energy infrastructure such as pylons in their local area (O'Mahony et al., 2024), NESC (2025a) presented findings that 'most people do not regularly think about energy use, and international surveys show limited knowledge of how energy is consumed', with 'a public gap in understanding the scale of infrastructure required' in the energy transition.

To uncover, explore and challenge mental models and mindsets (as described in section 3.4.1), a NESC Energy Systems workshop, held in November 2024, guided a diverse group of stakeholders through an exercise to envision Ireland's future energy system. The results are summarised in the appendix to this report and the proceedings are described in more detail in O'Reilly (2026, forthcoming). Public support for the energy transition and how to achieve it was a key theme of discussion. Stakeholders observed that people generally have little awareness of energy in their life until something goes wrong and that this means support for necessary infrastructure and changes is hard to achieve. Another stakeholder noted that 'a successful energy transition requires a highly engaged society that does not exist in this form right now'. One participant in a NESC roundtable on Energy Demand Management in May 2025 observed that 'people in general don't make many conscious decisions about energy use'. The mindset among the public appears to include an expectation that the energy system does not require their active participation, that it is largely invisible and that energy will always be 'on tap'.

Santillán and Cedano (2023) note that 'the change in energy systems [the energy transition] will require a well-informed and participatory citizenship, who understands the importance of transitions and can be part of the decisions when investing in infrastructure, encouraging a low-carbon matrix through public policies, and of course being able to participate first-hand as trained human resources' (Santillán and Cedano, 2023). A review of 'Unintended Consequences' (Rotmann et al., 2025:142) for the IEA task force, 'Users TCP', focusing on 'hard to reach energy users' found that 'lack of knowledge or low energy literacy' can be one reason that 'energy users choose to remain hidden', pointing to the importance of energy literacy in achieving social outcomes in energy.

In its definition of literacy, UNESCO emphasised: 'Literacy involves a continuum of learning in enabling individuals to achieve their goals, to develop their knowledge and potential, and to participate fully in their community and wider society' (UNESCO, 2003). This suggests that more is required than communication about specific programmes and recommended policy options. A broader base of knowledge about the energy system today and the requirements for transition could empower decision-makers, households and communities to make decisions that support their own goals as part of a multipronged effort of behavioural change.

Current communication efforts on energy tend to be focussed on promoting retrofits or other energy efficiency programmes. While these efforts are still important, more is needed to enable people to be effective participants in any future stakeholder engagement processes. In essence, there is a need to more comprehensively address a lower rung of Arnstein's participation ladder, 'informing', before we can achieve the higher rungs of effective and genuine participation in the energy transition (Arnstein, 1969). This is coherent with capability approaches whereby the agency of people to follow goals that they value is respected and capacitated, while other conversion factors or barriers to action such as personal circumstances, environmental factors and social factors remain part of the multipronged approach (Moore-Cherry *et al.*, 2022). It is also consistent with the COM-B framework (Mitev *et al.*, 2023). Energy policy interventions focussed on increasing knowledge of the energy system and familiarity with the potential and benefits of technologies (e.g., for increasing resilience) that will play a role in the energy transition were an important common intervention identified across the four technologies considered in this analysis.

A positive and tangible vision to help the public understand the changes they can expect in their lives and the associated benefits is important to deliver support for the energy transition and to underpin coherence. Stakeholders voiced great appetite for an articulated vision of the future for energy in Ireland which could motivate and pull forward the transition. It can also help motivate and inspire innovation and openness to change for those working in policy and decision-making systems. Co-created visions can be even more powerful as they foster real ownership of the transition. As part of the first Energy Systems workshop held in 2024, NESC co-created a 2050 Vision for Energy with stakeholders that offers an elaborated vision of what life and business could look like when the energy transition is complete, for households, urban areas, rural areas, business parks and utilities. This stakeholder exercise informed the subsequent research and recommendations in this report. A summary of the vision is contained in the appendix, while further details on the workshop and visioning exercise are available in O'Reilly (2026, forthcoming).

Box 3.2: Storm Éowyn

The fallout from Storm Éowyn left many rural electricity customers much more aware of their energy dependence. Many homes were left without electricity supply for days and even weeks. Many households responded by purchasing petrol or diesel generators for use during power outages.

Improved resilience to the impacts of climate change should be a benefit of transition but NESC 2025c noted ‘a concern among households with how resilient their energy source is in the face of extreme weather events’. After Storm Éowyn, 768,000 premises were left without power and it took 19 days to restore all connections (CCAC, 2025b). Some of the rural energy communities consulted for NESC (2025a) were upset about their lack of resilience to winter storms and felt ignored. They noted that ‘everybody is putting in stoves and buying [diesel] generators’ in response to their experience with Storm Éowyn. Media reported on the use of generators in the storm aftermath; a Leitrim resident was quoted as saying: ‘You go to the petrol station and you have people in front of you and all they’re doing is filling up canisters and bottles for petrol for generators... Our generator costs €20 a day to run and all I get from it is a couple of lights’ (Osborne, 2025). Local press in Roscommon reported that a generator supplier had been ‘inundated with people contacting them from all over the country, particularly in rural areas in the west, to purchase generators’ (O’Donoghue, 2025). The supplier said: ‘I’ve never heard anyone give out about the price of it, the people that are giving out are the people that are in the dark and have no generator... I think people would spend €100 a day on petrol if they thought they [would have] power’ (ibid.). Understandable efforts by individual households to improve their resilience to storms are leading to worse environmental outcomes and inefficient solutions, with generators requiring regular maintenance to stay functional. It is difficult for the public to reconcile experience of storm-related outages with messages on the need to electrify. Measures and solutions are required to better manage resilience to such events. New solutions are required.

NESC (2025a) has already noted the power of energy communities and microgeneration to change attitudes towards energy and build support for the energy transition. Bringing the potential benefits of the energy transition into focus through a reframed and elaborated tangible vision of life and business after a successful transition could help engage the public and stakeholders. Increasing the public’s understanding of the current and future energy system through better communication and engagement, capacitating individuals to make changes, and addressing issues that matter to households and businesses will be crucial to deliver the transition.

A further mindset or paradigm shift identified through workshops with stakeholders relates to the skillsets, knowledge base or broader considerations required to achieve a sustainable transition of the energy system. The importance of the spatial dimension of a sustainable energy system was highlighted as a necessary shift in thinking, including the strategic location and siting of energy supply and demand connections, which stakeholders agreed was a neglected feature in current approaches. In the absence of strategic spatial planning, network and grid

operators, and consequently the entire energy system, are in a position of responding to events, with the consequences apparent in feedback loops, as explored in section 3.3.1.

3.4.2 Energy Demand Management

SEAI National Energy Projections indicate that existing and projected energy efficiency gains to 2030 will be balanced by increases in energy demand due to macroeconomic growth, transport energy growth and the addition of new large energy users (LEUs) to the Irish system, leading to an overall increase in final energy consumed by 2030 (SEAI, 2024a). The analysis suggests that technological change, or deployment of the key technologies, will not be sufficient for Ireland to achieve its climate or energy targets. More focus needs to be given to energy demand management and the extent to which it can and should be used in the Irish context. NESC convened an Energy Demand Management Roundtable, held across two dates in May 2025 with a small group of varied stakeholders, to consider energy demand management's role in the energy transition.³

Views and evidence vary on how abundant renewable energy will be in 2050 and beyond, when the energy transition is complete, but the evidence is clear that zero-carbon energy will *not* be abundant in the short term or during the transition phase. The question then arises: what is the best use of Ireland's limited energy resources (grid capacity, renewables, security, carbon budget allocation), and for whom, in that interim period during the transition phase?

Good energy (renewables), necessary energy use and well-timed energy use should be encouraged and/or supported, while bad energy (fossil fuels), wasteful energy use and poorly timed energy use should be discouraged. Appropriate location of new energy supply and demand connections to grids should also be encouraged. However, the mechanisms and incentives to achieve this do not exist in the current system.

While the 'value' of some energy uses remains open to debate, it is clear that a considerable quantity of energy is wasted. Addressing wasted energy should be the first priority of energy demand management. Many of the least efficient homes are using high-emissions fuels such as solid fuels, peat or coal, which not only are very carbon-intensive but also bad for indoor and outdoor air quality, with implications for the health of those households and the broader population. Oil-burning homes, concentrated in small towns and rural areas, would be the next most carbon-intensive on a like-for-like basis. Supports would be most effective if targeted first at both the most inefficient carbon-intensive homes and the homes of the most vulnerable. Compact growth and sustainable mobility should also be recognised as significant potential contributors to the energy transition through reducing demand for energy.

Uncontrolled expansion of overall energy consumption, at least in the short to medium term, cannot be reconciled with environmental objectives. However, an expansion of *electricity* consumption due to electrification of heat and transport leads to many efficiency gains that can reduce overall energy consumption so long as rebound effects are avoided.

New areas of energy consumption such as AI services could greatly increase overall energy consumption. This area needs to be watched closely globally and especially in Ireland, as promised efficiency gains due to AI will be distributed globally among service users while the attendant implications of increased energy consumption by data processors will be concentrated in the location of data centres. Research by Daly (2024) found that, between 2017 and 2023, all additional wind energy generation in Ireland was absorbed by data centres. At a minimum, the efficiency of data centres and AI models should be a key objective internationally. Domestically, at a minimum, new LEUs should maximise their support for the broader energy transition (e.g. through provision of system services or zero-carbon demand response) and be complementary to the local energy transition by bringing tangible and demonstrable benefits to local communities and the economy while addressing environmental concerns.

In its sectoral adaptation plan in 2019, the sector noted that ‘the Distribution System only needs reinforcement when the loads on it exceed its peak capacity... This means that where peak capacity is to be exceeded there is a choice between adding Network reinforcement or changing when the peak loads are used’ (DECC, 2019). Shifting peak loads or shifting portions of electricity demand to reduce peak loads or to follow variations in renewable energy production is also known as demand response. Section 3.3.1 of this report illustrated the role that demand response can make in reducing costs and easing constraints in the electricity system. Demand response can be achieved through behaviour change, smart energy management systems and/or energy storage technologies such as batteries or thermal. The Commission for the Regulation of Utilities (CRU) National Energy Demand Strategy focusses on: smart services and dynamic tariffs to deliver flexibility from domestic and smaller business customers; increasing the potential for demand response from larger users and storage installations by providing efficient market signals and mechanisms; and requirements for flexibility from new LEU connections (CRU, 2024). The Climate Change Advisory Council in 2025 noted that ‘the lack of dynamic and hybrid [electricity] contracts limits consumers’ ability to adjust their energy usage to periods of higher renewable generation, and correspondingly lower prices, restricting their participation in the energy transition’ (CCAC, 2025a). The NESC Council (2025a) recently found that ‘households could make energy and cost savings using dynamic tariffs and these should be introduced as soon as possible... with support for those who need it to manage their energy demand’. This further emphasises the need for energy literacy to enable full participation in the energy transition.

3.5 Conclusions

The application of systems thinking tools to the Irish energy system yields a number of insights on specific interventions to accelerate transition in VRE, heat pumps, ZCF and district heating. It also underscores the importance of two cross-cutting areas: attitudes to energy and considering energy demand management.

Drawing on this analysis, the following chapter outlines Council recommendations for accelerating transition in the energy system.

Chapter 4: How to Achieve Transition Goals

4.1 Introduction

Drawing on the results of the systems analysis and stakeholder participation, the Council has developed five recommendations to advance the energy transition sustainably. These recommendations are designed to cover high-leverage intervention points, as described in section 3.2, including system structures and mental models. They are also designed to bring multiple benefits across the energy doughnut, contributing to the social foundation while respecting planetary boundaries, aiming at environmental benefits where possible.

4.2 Recommendation 1: Create a Cross-Government Energy Framework

Create a Cross-Government Energy Framework that addresses heat, transport and electricity together in a coherent manner, integrating existing strategies and plans for different policy objectives such as energy poverty and energy security and for different energy vectors such as electricity, gas and biofuels. The framework should aim to reduce uncertainty across energy users and investors. It should be consistent with the National Climate Objective and the Climate Action Plan but also integrate aims regarding the other social, economic and environmental objectives faced by energy (as summarised in the energy doughnut, section 2.2).

NESC has already recommended developing a plan for electricity as well as a long-term national plan for strategic clean energy reserves based on zero-carbon fuels (NESC, 2025a, 2025b). This report recommends that this ambition be expanded to address the whole energy transition and the roles of different parts and layers of Government in its delivery. The annual Climate Action Plan contains a lot of information on energy commitments in respect of reducing greenhouse-gas emissions. However, an overarching Cross-Government Energy Framework that is consistent with the Climate Action Plan is needed to resolve the disparate objectives and constraints placed on the energy sector and its transition to a future sustainable system.

Without a unifying framework for the energy transition, opportunities are being missed, some elements are 'falling between stools', and frictions are being created between the multiple diverse pathways to a zero-carbon future by different subsectors in the energy transition. This confusion of approaches leads to uncertainty among investors, increasing costs. It also reduces support among the public as contradictory messages lead to loss of confidence.

The Council recommends that a Cross-Government Energy Framework be developed that includes the following elements.

The framework should build off a vision co-created with a wide range of stakeholders, for a successful future energy system that is independent of fossil fuels. A review of international research suggests that carbon capture technologies will be expensive and will be required in future to produce negative emissions, rendering continued fossil-fuel use uneconomic in most cases.

The framework should address social, environmental and economic objectives and constraints, as summarised in the energy doughnut. It should cover heat, electricity and transport and the interdependencies between them. It should cover electricity and gas networks and fuel delivery systems, each advancing towards zero-carbon, albeit at different rates. Areas where interdependencies, trade-offs and synergies exist should receive particular attention in the framework.

The framework should address technological solutions as well as energy efficiency, demand management and behavioural solutions, and outline the expected role for each, with accelerated timelines for implementation. The complementarities and interdependencies between energy solutions at micro (household, SME), meso (community/regional) and macro (national/transmission grid) scales need to be given due attention, with integrated approaches to realise the potential co-benefits and minimise frictions. While achieving consistency with the Climate Action Plan, the framework should also be consistent with economic and industrial policy and the National Planning Framework.

The framework should contain a strong spatial element as this presents a major opportunity to reduce grid development costs, which are a big risk for energy affordability and competitiveness. Building on this, more signals and/or incentives should be offered to inform the location of new energy supply and demand. While some mechanisms such as Use of System Charges (already in place) and the forthcoming Regional Renewable Energy Strategies, required under the revised National Planning Framework (Government of Ireland, 2025) can guide locational choices, a framework could assist a cohesive spatially plan-led approach that addresses both new supply and demand. Electricity and gas grid operators should be given a legal direction from the CRU to prioritise connections. Such prioritisation should be based on guidance from Government which could be provided through the Cross-Government Energy Framework. In the context of trying to speed up transition and to progress in other areas such as housing, the ability to prioritise connections is essential.

The Cross-Government Framework should reflect challenges and opportunities shared with Northern Ireland in respect of energy markets, interconnection, transmission infrastructure and achieving greater economies of scale.

The framework would benefit from integrating systems approaches to its development and implementation, in particular through adaptive approaches and engagement with stakeholders. It should:

- be a 'living document' that responds to new developments and evidence to continually refine Ireland's approach to the energy transition;
- encourage innovation and enable sandboxing and trialling of new approaches and interventions;
- include robust monitoring, including indicators for progress in implementation, and tracking of progress and outcomes in respect of each of the segments of the energy doughnut; and
- incorporate continuous stakeholder feedback and engagement.

Stakeholder engagement should also be encouraged, particularly in formats that encourage shared conversations and insights.

4.3 Recommendation 2: Make Government Plans for Green Energy Industrial Parks More Ambitious

Plans outlined in 'Powering Prosperity – Ireland's Offshore Wind Industrial Strategy' for Green Energy Industrial Parks to act as a future end use for renewable energy, particularly offshore wind, should be more ambitious so as to design-in greater decarbonisation potential and tangible benefits for local communities.

The Government is already exploring co-location of large energy users with renewable electricity. 'Powering Prosperity – Ireland's Offshore Wind Industrial Strategy' outlines initial measures to promote the co-location of offshore renewable energy with demand, especially by developing Green Energy Industrial Parks, with a view to developing future end uses for excess renewable energy (DETE, 2024). As outlined in NESC 2025b and NESC 2025c, such plans create benefits for offshore developers in the form of more certain profits, and benefits for the owners of large energy users in assisting sustainable delivery of their services. It also delivers benefits to the Government (and society at a macro level) by generating tax revenue. However, as currently envisaged, the benefits for the local community are potentially limited to temporary construction jobs and the community benefit fund. The decarbonisation benefits are also centred on renewable electricity. These plans need to be more ambitious.

Green Energy Industrial Parks should include not just renewable electricity as envisaged but also district heating infrastructure to take advantage of waste heat for commercial use. The parks should be located where complementary businesses support each other's decarbonisation through acting as reliable buyers for renewable electricity, renewable and waste heat and potentially zero-carbon fuels so that electricity and heat decarbonisation efforts are integrated. Electric and thermal energy storage as well as zero-carbon fuels could allow the parks to offer demand response services to the energy system.

The parks should be designed to 'give back' to their hosting communities through greater and ongoing employment opportunities and other economic benefits such as supply of low-cost district heating and/or renewable electricity to the local community and link to local resilience efforts as per Recommendation 5. The Green Energy Industrial Park will not only have the advantage of co-location with significant renewable energy sources, but it will also benefit from solar panels on all its buildings in line with the EU Energy Performance in Buildings Directive which mandates suitable solar energy installations, if technically suitable and economically and functionally feasible on all new non-residential buildings with useful floor area larger than 250 square metres by 31st December 2026. With a diversity of renewable energy sources, the parks located in more rural areas would be well placed to operate as community power-banks to support resilience in the event of extreme weather events.

Such parks, appropriately located in line with compact growth objectives, should create or enhance critical mass to support viable local sustainable transport services such as local links routes, bike paths, etc. They should include landscaping and building features that support biodiversity, with an area set aside for nature, and public access, with features appropriate to the needs and natural features of the local area such as native trees, meadow grass, wildlife pond and nest boxes (e.g. for swifts, whose numbers are falling).

Sites should be chosen in consultation with the regional assemblies, SEAI, the IDA and Enterprise Ireland as well as the electricity and gas transmission and distribution system operators, regional stakeholders and communities. Government should allocate funding to prepare the sites with appropriately scaled energy, transport and communications infrastructure, including district energy networks. The parks should be international showcases for a sustainable future and, at a minimum, bring demonstrable and obvious benefits to the local community.

Adopting this approach to Green Energy Industrial Parks would help unlock and accelerate the energy transition while also delivering social, economic and environmental benefits for local communities. System dynamic analysis (outlined in section 3.3.1) suggests that local support is crucial to unlocking deployment of variable renewable electricity. Some research suggests that social licence for the energy transition could trickle up rather than down – in other words, that good experience locally can build support for national action (Lesser *et al.*, 2023). In this way, Green Energy Industrial Parks that integrate appropriately with local communities, bringing a diversity of benefits, will support the national effort.

System dynamic analysis also suggested that visible, large-scale pilots would be crucial to unlock progress in district heating and zero-carbon fuels, two technologies (of different readiness levels) that are relatively unfamiliar in Ireland. The parks could act as a substantial demonstration site for district heating. It was found that a pilot project delivering heat to the residential and commercial sector would be very effective to build support and confidence in that technology. Similarly, some of the Green Energy Industrial Parks could act as a reliable buyer and a demonstration site for zero-carbon fuels for use-cases that are hard to electrify.

Existing places of business, including business parks, should not be neglected. There are 41 decarbonisation zones identified by local authorities around Ireland, covering urban, semi-urban and rural areas. Many of these zones include commercial activities and they offer a vehicle to trial new approaches to decarbonisation. Efforts to deploy district heating across Ireland should consider the potential for retrofitting existing business parks and businesses to be customers for district heating or even sources of waste heat for local schemes. The Energy Performance of Buildings Directive requires existing non-residential buildings with useful floor area larger than 500 square metres to deploy suitable solar energy installations, if technically suitable and economically functionally feasible, when they undergo major renovations or an action that requires an administrative permit, roof works or when they install new technical building systems, by 31st December 2027. Existing places of business, including business parks around the country, could be encouraged and supported to get ahead of the directive's requirements, and decarbonise, improve energy efficiency and link up with local energy resilience efforts, as per Recommendation 5.

4.4 Recommendation 3: Develop a New Focus on Energy Demand

Initiate a study on the potential of energy demand management to assist in meeting energy transition goals.

NESC has noted that ‘both energy efficiency and energy sufficiency measures are needed to achieve the EU’s energy and climate goals’ (NESC, 2025a, p48). With energy projections by SEAI pointing to an overall growth in energy consumption, energy demand management needs more focus as a necessary tool to meet energy and climate goals (SEAI, 2024a). A lot is happening on energy efficiency across households, businesses, the public sector and even large energy users, but more can be done. Electrification will deliver energy savings, while compact growth and sustainable transport also have potential to reduce energy demand.

The Council recommends that the potential requirement for energy demand management, including what is possible and what is desirable from different sectors, be explored to inform the transition pathway. This should consider the potential for energy efficiency measures, electrification and spatial planning to reduce overall energy demand. It should consider behavioural and systemic approaches to energy demand management, their feasibility and potential. The report should also provide an updated assessment of the potential for and costs of zero-carbon energy demand response across existing and anticipated future energy demands, including household, business, public and large energy user demands.

4.5 Recommendation 4: Increase Energy Literacy and Public Engagement

As part of an overall Cross-Government Framework for Energy, a strategy should be adopted to increase energy literacy across the population and achieve effective public engagement across the transition.

Communication efforts currently focus on uptake of specific energy efficiency measures or retrofit programmes. However, a broader effort on energy literacy and public engagement is needed as one of the foundational elements for seeking behaviour change. Low levels of energy literacy are an important factor undermining efforts to develop measures such as demand response, uptake of energy efficiency grants, and even sensible cost-saving measures in the home. Stakeholders consulted by NESC over the course of this research observed that ‘people in general don’t make many conscious decisions about energy use’ and that ‘a successful energy transition requires a highly engaged society that does not exist in this form right now’. However, as noted by Santillán *et al.* (2023) the energy transition ‘will require a well-informed and participatory citizenship’. A review commissioned by an IEA taskforce (Rotmann *et al.*, 2025) found that ‘lack of knowledge or low energy literacy’ can be a barrier to behaviour change and that ‘we need to improve energy literacy across the population in order to ensure there is enough knowledge of how the energy system works, and how transitioning it will benefit them in various ways’ and that ‘this is particularly relevant with newer and sometimes complex DR

[demand response] and DF [demand flexibility] programmes and tariffs'. Capacity to act can also constrain behaviour change. This means that energy literacy requires a multi-faceted approach, and that energy literacy alone is only one part of a wider effort to enable effective participation in the energy transition. That wider effort must address the factors that shape behaviour – capacity, opportunity and motivation (the COM-B model).

Energy literacy is essential for households to make the best energy choices for themselves, whether by investing in retrofit measures, energy storage options or an EV charger, or for day-to-day choices (such as responding to price signals for electricity consumption). Without energy literacy, households are liable to make choices that lead to extra costs, which undermine support for energy transition. The risks of not building public energy literacy are that misinformation would gain an easier footing under such conditions. In this context it is notable that the 2025 Eurobarometer poll found that more than half of Irish respondents thought that 'it is difficult to differentiate between reliable information and disinformation about climate change on social media' (European Union, 2025) while an assessment of climate communication challenges and needs carried out by University College Dublin (UCD) found that 'countering misinformation and disinformation around climate change and emissions reductions remains a significant challenge across all sectors, as does the need for more nuanced and expert media coverage' (Pender *et al.*, 2025).

The Council recommends that, as part of an overall Cross-Government Framework for Energy, a strategy should be adopted to increase energy literacy across the population and achieve effective public engagement across the transition. Current communication efforts should be expanded to support public energy literacy, raising energy understanding and widening public participation. The energy doughnut could be used as a tool to support energy literacy that covers not just the broad technological realities and potentials, but also the social, economic and environmental dimensions.

For communication and engagement, Pender *et al.* (2025) highlight the need to 'identify the different potential audiences within a sector and the most appropriate message for each, ... to better communicate the co-benefits of emissions-reduction actions... [and] to highlight positive stories and engage trusted messengers'. High-profile demonstration projects, such as Green Energy Industrial Parks (see Recommendation 3) have the potential to be a positive story, and to increase energy transition awareness and literacy among the public. Similar effects have also been noted for deployment of household microgeneration and deep retrofit. Therefore, the educational benefit of existing transition measures should also be harnessed as part of the energy literacy effort. Media campaigns, social media, documentary programming, local library initiatives and school curricula could all play a role in reaching different parts of the population, building a foundation for effective participation in the energy transition and future energy system.

'Change requires trust, consensus, and shared goals' (Parkinson *et al.*, 2025). Effective public engagement must be designed into the energy transition and the Cross-Government Energy Framework. Parkinson *et al.* (2025) note that 'by involving stakeholders and their narratives, it is possible to unearth places of tension within the system' which can help identify areas of potential high leverage. Continuous engagement with stakeholders combined with an iterative

approach to planning and policy design, such as recommended above for a Cross-Government Energy Framework, would help ensure that interventions remain responsive both to changing conditions in the energy system and to the needs of stakeholders.

4.6 Recommendation 5: Build Distributed Resilience

Energy efficiency, microgeneration and retrofit support programmes should be expanded to also work towards building the resilience of households, communities and SMEs, particularly in vulnerable areas and for vulnerable households. Building resilience could be supported through advice, grant assistance, designating local resilience hubs, and appropriate training of tradespeople.

Improved resilience to the impacts of climate change should be a benefit of transition but NESC 2025a noted 'a concern among households with how resilient their energy source is in the face of extreme weather events' such as Storm Éowyn. Some of the rural energy communities consulted for NESC 2025a were upset about their lack of resilience to winter storms and felt ignored. In the aftermath of Storm Éowyn, local press in affected areas reported high demand for diesel generators. Understandable efforts by individual households to improve their resilience to storms are leading to worse environmental outcomes and inefficient solutions.

The draft sectoral adaptation plan in the energy sector sets out a vision for the sector as 'a resilient electricity and gas networks sector that adapts to climate change, while delivering safe, secure, and affordable energy for future generations'. Similar to the 2019 plan, the draft plan states that 'emergency plans involve the restoration of supply and effective communications with customers and key stakeholders' (DCEE, 2025c). This is appropriate for grid and network managers but is an insufficient intervention for the energy system as a whole. NESC found that 'energy resilience includes a focus on alternative power and heat supplies during power outages but also on the capacities of households and communities to stay well and safe' (NESC, 2025a: 55).

The Council recommends greater focus on the energy resilience of households, businesses and communities, and on their capacity to cope with power outages. No electricity grid will ever be 100 per cent storm-resilient and efforts to achieve that would be costly. NESC 2025a highlighted that, in Sweden, 'it is expected that households will have the capacity to cope for 72 hours without external help'. The Government is currently developing a 'Be Winter Ready' campaign to inform people what to do if electricity is cut, water lost or phone connections disrupted (O'Keeffe, 2025). This is a welcome development but more ambition is needed. Agencies that are currently tasked with supporting business and households in their energy transition should design and deliver storm resilience measures and support, including for off-grid solutions in the event of power outages such as micro-generation coupled with energy storage (including EVs with V2X capability) and isolation switches. This is a key area where a Cross-Government Energy Framework could add value so that efforts at retrofit connect with efforts for resilience which also connect with efforts to electrify transport. In light of Storm

Éowyn, storm resilience could be a strong selling point for energy retrofits and EVs, particularly in more rural and exposed areas.

Public and/or community buildings and/or local business parks that receive grants or subsidies for microgeneration could also be part of adaptation plans to support resilience in their local area. They could be equipped to provide charging facilities in the event of prolonged power outages.

Designating and achieving an optimum balance here between investment in decentralised resilience versus investment in grid resilience could lead to better outcomes in extreme events and potentially reduce overall system costs. The potential for system cost savings needs further research.

By explicitly linking energy transition efforts to increased resilience to events such as extreme weather, the transition can connect to the immediate concerns of the public, whether households or businesses, particularly in rural areas.

Appendix

In November 2024, NESC convened an Energy Systems participative workshop with a variety of invited stakeholders, co-facilitated by Prof. Birgit Kopainsky, University of Bergen. One outcome of the workshop was a vision, co-created between NESC and stakeholders, of what a sustainable energy system could look like after a successful transition. Details on the workshop are available in O'Reilly (2026, forthcoming). The following text describes the co-created vision.

The Vision

Ireland has achieved a zero-carbon energy system with no fossil fuels in use. It achieved its energy transformation not only through a just transition but also through enhancing wellbeing while respecting planetary boundaries and supporting a thriving natural world. Energy deprivation is a thing of the past. Households and businesses, rural and urban areas, and the energy utilities all played their role and continue to support a sustainable energy system.

Households in 2050

The 2050 household is energy-efficient and situated in a sustainable community that benefits from a range of renewable energy sources such as wind and solar, with district heating and/or biofuels depending on the local area energy plan. Good planning reduces energy demand and improves air quality through reduced transport demand, active travel, and local green space that filters remaining air pollution and mitigates any urban heat island effects in summer. Demand flexibility is delivered through automation and programming to respond to varied price signals. Households maintain control over their own energy use. Vulnerable people are protected via minimum-energy entitlement, graduated pricing schemes or reduced pricing for vulnerable groups. There is greater awareness of energy and a focus on energy education in schools. The local community has an important role in co-developing and helping to deliver aspects of the local area energy plan, for example through energy cooperatives, energy sharing or community-owned energy suppliers.

Rural Areas in 2050

The 2050 vision for rural areas emphasises the importance of agriculture and food production and of social as well as economic benefits. These benefits were important to build community support for the energy transition. The envisioned rural landscape is a mosaic in which agriculture remains dominant, renewable energy infrastructure is visible, and dedicated spaces for biodiversity are integrated throughout. The rural community benefits from a range of renewable energies, including anaerobic digestion, onshore wind and solar. Solar is mainly situated on domestic and farm buildings as well as integrated with sheep grazing; only some land is dedicated solely to solar farms. Anaerobic digestion, with inputs supplied by farmers and local households, delivers a range of local economic opportunities such as energy, refined fuels, novel proteins and fertiliser. There is a mix of large and small AD plants, in a hub and spoke model, with some transport of materials across local areas replacing historic transport of fossil fuels. There is more sustainable mobility in rural areas, with more active travel and sustainably fuelled/powered

tractors and vehicles. Rural areas have more resilient infrastructure and they benefit from the energy infrastructure they host. Local benefits of the energy transition include energy self-sufficiency, export to grid, ownership opportunity, and district heating for villages.

Urban Areas in 2050

Energy is super-abundant. Rooftop solar is common. All state-owned public buildings have solar panels and most households practice some form of microgeneration. Buildings are energy-efficient, with heat pumps and district heating playing a role in less and more dense localities respectively. Households and public buildings have improved energy storage options, reducing their dependence on the grid and supporting flexible demand. The gas network remains but with decarbonised supply. Green hydrogen is available as a back-up energy supply. Localised electricity microgrids enable neighbourhoods to share energy and operate independently of larger utility networks during disruptions.

Smart grids are equipped with digital technologies to manage real-time energy flows, ensuring reliability despite variable sources, and supporting two-way, instantaneous communication between households and utilities. Households have access (e.g. through smart phones) to AI-powered energy management systems that provide recommendations on pricing, energy usage and export. The internet of things gives users the option to automate demand response to price and grid signals. Utilities shift their business model to provide energy as a service packages or customised energy plans. Options include: energy management systems and apps, general maintenance, solar PV, heat pumps, and energy efficiency upgrades.

A basic energy guarantee provides a certain quantity of energy per person for free. Older and vulnerable people have a higher basic energy guarantee level, covering most of their energy needs. Utilities and government focus on ensuring that clean energy and advanced technologies are accessible to all households.

Good planning has delivered a streetscape that is child-friendly, with biodiverse green space, that reduces travel demand, including through work from home policies, and supports the safety, convenience and comfort of sustainable travel. Infrastructure also incorporates biodiverse greenery. Roadside energy stations or parks act as charging hubs and sustainable fuel suppliers. Public transport is electrified. Health is supported through cleaner urban air, the elimination of mould in buildings, green space and more walking and cycling.

Business Parks in 2050

The state-of-the-art zero-carbon business park in 2050 is based on somewhat centralised planning that chooses locations and tenant types for each business park strategically to optimise the co-location benefits of energy demand and supply. The key elements of successful zero-carbon business parks are: access to affordable and renewable energy/ electricity; energy storage; connectivity in terms of transportation including good road networks and transportation links as well as access to ports and railways; connectivity in information technology; integration with the local community; and circularity.

Some business parks could work around a large energy user (LEU) anchor tenant such as a cement plant or alumina refinery along with other complementary industries such as hydrogen electrolyzers with good access to port and rail infrastructure in the region. Large-scale data centres could co-locate with these to benefit from hydrogen back-up supply. Bioenergy with carbon capture and storage delivering negative emissions and linking with AD plants in the locality, and with infrastructure for using and transporting the captured carbon, is another specialised option for a zero-carbon business park. More often, dotted around the country, smaller business parks, more typical of the scale that exists today, are focussed on food/dairy processing, biotech and pharma industries supported by biomethane and AD in the locality. In all cases, business parks are supported by the local community because of the benefits they bring, including job creation, space for nature and biodiversity, and the use of waste heat to support a district heating network for hospitals, schools, nursing homes, etc and high-density urban residential areas in the vicinity

Utilities in 2050

In 2050, the energy system has good energy storage and a strong renewables economy primarily based on offshore wind. There is green dispatchable generation, with green hydrogen as a potential source. Ireland's energy system is interconnected with the EU.

Long-term integrated planning for energy adopts a system-wide approach across sectors and energy vectors. An all-island energy strategy ensures coherence and allows for greater economies of scale. Dispersed energy generation necessitates planning with a strong spatial aspect that aims to co-locate demand and supply. Energy system efficiency is supported by development of economic sectors that offer responsive flexible demand, buying energy when it is abundant and reducing energy consumption when it is not. These responsive industries are able to develop quickly with public support because they offer tangible benefits to local communities and/or the country (e.g. quality job creation).

EU support was important in the success of the transition and continues to be important to the sector. A massive programme of energy network development and upgrade, particularly in electricity, was supported by the EU. Bulk procurement was used to secure components and materials, using a model developed for vaccines purchases during the COVID crisis. EU-backed green bonds help leverage private funding.

Financial instruments include carbon taxes, providing companies with confidence to invest, and government support such as government-backed green bonds and first-loss guarantees. Ireland leverages partnerships with like-minded countries and the diaspora to attract new industries and new customers through a rewards-based system.

As zero-carbon technology and the energy sector continue to evolve, the sandbox approach, pioneered in the Electricity Storage Policy Framework of 2024, is broadened to test a greater range of innovative technologies and solutions.

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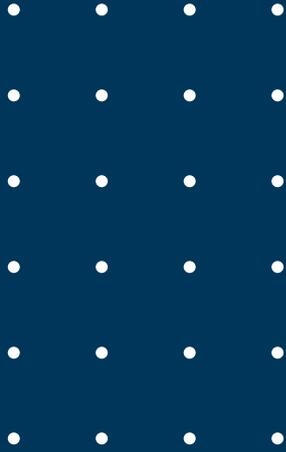
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National Economic & Social Council

Parnell Square, Dublin 1, D01 E7C1

+353 1 814 6300 info@nesc.ie

www.nesc.ie